GROUSE NEWS

Newsletter of the Grouse Group *of the*
IUCN-SSC Galliformes Specialist Group

Galliformes Specialist Group

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Chair Grouse Group within the IUCN-SSC Galliformes Specialist Group

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Contents

From the Editor 4
From the Chair 5
News from the Galliformes Specialist Group 7
News from the Grouse Group
Conservation News
Conserving the lesser prairie-chicken 9

Research Reports
Annual variation in breeding success in boreal forest grouse: Four decades of monitoring reveals bottom-up drivers to be more important than predation 10
Twenty-five years of monitoring the occurrence of hazel grouse (*Bonasa bonasia*) in the canton of Neuchâtel, Switzerland 11
The past, present, and future of the Siberian Grouse (*Falcipennis falcipennis*) under glacial oscillations and global warming 16
Genomic analysis revealed differentiation between Chinese grouse and Hazel grouse in demographic history and the introgression and adaptive population in genes controlling epigenetic variation 18

Forum 22

Conferences
Participants Flock to the First Annual Kansas Lek Treks Prairie-Chicken Festival! 23
The 15th International Grouse Symposium Białystok, Poland in 2023 23
8th International Galliformes Symposium Taman Safari, Prigen, Java, Indonesia – 9-13 October 2023 24
Practical Conservation for Scottish Grouse Species Conference to be held on Friday 5th May 2023 at Balhousie Castle, Pert 24
The 34th Biennial (mostly) Meeting of the Prairie Grouse Technical Council, October 3-6, 2022, Lewistown, Montana 25
Sage and Columbian Sharp-tailed Grouse Workshop 45
The Wildlife Society 63

New Books
Ecology and Conservation of Mountain Birds 92
The Future of the Red-legged Partridge, Science, Hunting and Conservation 93

Recent grouse literature 94

Researchers and their Best Friend Assistants
The Calm, the Chaos, and the Reward: All in the Day of a Pointing Dog 100

Snippets
Spatial ecology of ptarmigan 102
Grouse on Stamps 102

From the Editors

Grouse News started as a printed version in March 1991. The first issue to be published electronically was issue 24 in December 2002. This change to electronically publishing made it much more easy both distribution and contact with subscribers. Also from issue 1 to 23 you had to pay for the subscription for Grouse News to cover the costs of printing and others. From the electronic publishing started with issue 24 there was no longer necessary to pay for subscribing.

The primary function of Grouse News is still to give people the possibility to publish short interim papers, which the big peer-reviewed journals would usually reject. In this way it was hoped that hypotheses and new techniques could be described to colleagues in the Grouse world without precluding eventual publication of a completed study elsewhere. Research articles, conservation news, small notes of what you are doing, suggestions and ideas are welcome. News about status and conservation of grouse species in your country is very important. Also new subscribers of Grouse news are encouraged to write a short note on what they are doing to inform the rest of us, or you may write an article of your research or other.

In this issue you will find info about annual variation in breeding success in boreal forest grouse based on four decades of monitoring, and an article on twenty-five years of monitoring the occurrence of hazel grouse. Also two articles from China, one on the past, present, and future of the Siberian Grouse under glacial oscillations and global warming and one dealing with genomic analysis revealed differentiation between Chinese grouse and Hazel grouse. Abstracts from the 34th Biennial Meeting of the Prairie Grouse Technical Council, October 3-6, 2022, Lewistown, Montana are published and a note on the coming second annual Kansas lek treks Prairie-Chicken festival 13-16 April, 2023. The 15th International Grouse Symposium was first planned to be held on September 12-16, 2021 in Poland and hosted by University of Białystok (UoB). Because of the COVID-19 in 2021 and the Russian invasion of Ukraine in 2022 the Conference Committee, in consultation with other responsible persons has decided to postpone the conference by one year to 2023. If the situation in Ukraine does not improve, an alternate site for the IGS might be considered. Also information on 8th International Galliformes Symposium Taman Safari, Prigen, Java, Indonesia – 9-13 October 2023, and Practical Conservation for Scottish Grouse Species Conference to be held on Friday 5th May 2023 at Balhousie Castle is found, Pert. A coming publication in early 2023 of a global reference volume on high mountain bird ecology and conservation is found under new books. Although not a grouse, a book on The Future of the Red-legged Partridge, Science, Hunting and Conservation is published. Under Researchers and their Best Friend Assistants an article on The Calm, the Chaos, and the Reward: All in the Day of a Pointing Dog. A note on spatial ecology of ptarmigan and Grouse on Stamps is under snippets. And Don Wolfe has made a long list of recent literature on grouse.

The new web page on Galliformes (https://galliformes.org/) is not yet up and operating.

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From the Chair

The final decision to federally list the northern distinct population segment (DPS) of lesser prairie-chicken (*Tympanuchus pallidicinctus*) as "Threatened" and the southern DPS as "Endangered" was published in the Federal Register of the U.S. government on 25 November 2022. To the casual observer this might appear as though it was a simple process, determined primarily by biological considerations, and little else. A careful review of the history of this decision shows that it was anything but simple.

The Biodiversity Legal Foundation was the first group to petition the U.S. Fish and Wildlife Service (USFWS) to list the lesser prairie-chicken (LPC) as a threatened species in October 1995. The USFWS responded in July 1997 by stating "that the petition presents substantial information indicating that listing the species as threatened may be warranted." In June 1998 the USFWS determined that the LPC was "warranted [for listing] but precluded by other higher priority actions".

For the next 10 years the LPC remained a "candidate" for federal listing, but the USFWS was under pressure from conservation groups upset about the lack of action. The USFWS increased the threat level (which increased the priority) and in June 2012 they published a proposed rule to list the LPC as threatened. After rule modifications and multiple comment periods, the USFWS finalized the decision to list in April 2014.

In most situations, this would have been the final word except for future changes in status (up or down) or designation of critical habitat. However, in this case the Permian Basin Petroleum Association and 4 counties in New Mexico filed a lawsuit challenging the rule. In September 2015 the U.S. District Court for West Texas vacated the rule. The USFWS responded by removing the LPC from the list of endangered and threatened wildlife in July 2016.

The ink was barely dry on the previous decision when, in September 2016, the WildEarth Guardians, Center for Biological Diversity, and Defenders of Wildlife petitioned the USFWS to list the LPC as an endangered species. They also recommended reclassification of the LPC by three distinct population segments (DPSs – DPSs have their own set of rules). By November the USFWS had already decided that the petition had merit.

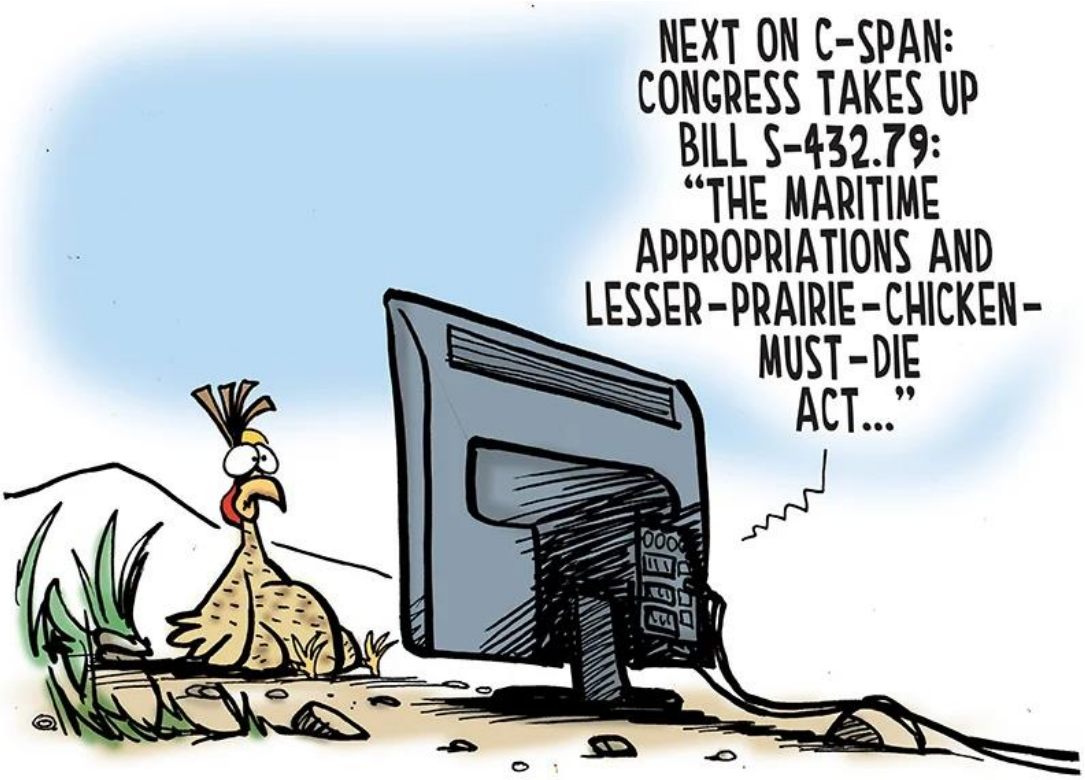
The lack of a proposed rule in the next 3 years brought the conservation groups back to court. As per court settlement, the USFWS proposed to reclassify the LPC as two DPSs (not the recommended 3 DPSs); the southern DPS in the shinnery oak (*Quercus havardii*) ecoregion and the northern DPS in the sand sagebrush (*Artemisia filifolia*), mixed grass, and short grass/CRP ecoregions. They also proposed listing the southern DPS as "Endangered" and the northern DPS as "Threatened". The final rule I mentioned at the beginning of this column codified this decision.

The 'threat' of a listing decision brought many individuals, groups, and government agencies together to discuss and negotiate data collection/interpretation and conservation actions. The USFWS has many conservation tools available including Candidate Conservation Agreements with Assurances (CCAAs), Habitat Conservation Plans (HCPs), and Safe Harbor Agreements. Some of these tools (especially CCAAs and HCPs) have already been used for the LPC.

The collaborative effort peaked with publication of "The Lesser Prairie-Chicken Range-wide Conservation Plan" in 2013. Since this plan was published many LPC efforts have been anything but collaborative. There were numerous lawsuits filed by both industry and conservation groups. Some were upset that the conservation actions were not sufficient to benefit LPC. Others were upset that the LPC was federally listed despite development of a rangewide conservation plan.

One reason for this conflict is that the groups do not agree on a purpose, even when it is clearly stated. For example, when the Kansas Natural Resource Coalition (KNRC – not what most people would consider a conservation group) challenged the USFWS application of the "Policy for Evaluation of Conservation Efforts when Making Listing Decisions" (PECE policy), they implied that the purpose of the 2013 rangewide conservation plan was to prevent federal listing of the LPC. The actual purpose stated in the plan was "to develop a conservation strategy for the species that identifies, coordinates, and commits to the implementation of an effort that ensures the improvement and long-term persistence into the foreseeable future (50 years) for the LPC throughout its current or expanded range." In theory, achievement of the stated purpose would preclude the need for federal listing, but the two purposes are clearly not identical. The KNRC case was rejected by the 10th Circuit Court of Appeals in August 2020 and the Supreme Court of the United States declined to review the decision in June 2021.

Some of these lawsuits are reflected in the approach by lawmakers to weaken the 1973 Endangered Species Act (ESA). A preferred approach lately is to attach riders to federal budgets that limit spending on specific USFWS activities such as listing. For example, between 2014 and the present there has been a rider to the federal budget limiting the Secretary of the Interior (oversees USFWS) from writing or issuing a rule related to the ESA for greater sage-grouse (*Centrocercus urophasianus*). The same approach has been tried for LPC.



The illustration was provided by Chris OBrion for an article titled "Seven Ways Congress Is Trying To Destroy The Endangered Species Act" first published by Maggie Caldwell online (https://earthjustice.org/features/political-animals) on 23 April 2015 and updated on 21 January 2016.

The ESA has clearly benefitted conservation activities for LPC during the last quarter century. It is doubtful that private landowners, conservation groups, government agencies, and energy companies would have worked together to develop the 2013 plan without pressure from the ESA. The same is true for all the signed CCAAs and HCPs. The question is, now that the LPC is federally listed, will conservation activities be adversely impacted? The logical answer should be no. The reason for the CCAAs in the first place was so landowners would have assurances that their management would not be adversely impacted if the species should be listed. However, when politics is involved in conservation, logic may not matter.

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NEWS FROM GALLIFORMES SPECIALIST GROUP

In most places we are now pretty much post-covid in operations so the GSG is getting ramped up again in a number of different ways. Website is redone, but not quite deployed. The Species Survival Commission is fixing their membership pages to make it much easier for members and SGs to keep up with it. The SSC Director has been upgrading all aspects of their technology and communications to reduce filters for flow of information. Early in 2023 they will be launching a "One Stop Page" for specialist group members to more easily navigate SSC and on to the IUCN pages.

Upcoming reminder that the postponed 8th International Pheasant Symposium will be held in Indonesia 9-13 October 2023. Please contact Barbara at WPA for details. office@pheasant.org.uk I have participated in most of the previous symposia, and although the focus tends to be pheasants and Asia, usually there is a broad range of papers on other Galliformes and good participation by Asian and South Asian Galliformes biologists.

Please remember the SG is useful for flowing through requests to SSC when support for conservation efforts are needed to help inform governments and others. We have helped a number of NGOs around the world make their case for conservation efforts on various Galliformes species.

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NEWS FROM GROUSE GROUP

CONSERVATION NEWS

Conserving the lesser prairie-chicken
U.S. Fish & Wildlife Service, USFWS, 17 November

The U.S. Fish and Wildlife Service today is announcing our decision to list two Distinct Population Segments (DPS) of the lesser prairie-chicken under the Endangered Species Act. The Southern DPS is being listed as endangered and the Northern DPS is being listed as threatened with a 4(d) rule under the Endangered Species Act. The 4(d) rule tailors protections for the species.

This decision was made after reviewing the best available scientific and commercial information regarding past, present and future threats, ongoing conservation efforts and more than 30,000 public comments received during the public comment period and two virtual public hearings.

For more information: www.fws.gov/lpc.

RESEARCH REPORTS

Annual variation in breeding success in boreal forest grouse: Four decades of monitoring reveals bottom-up drivers to be more important than predation

Per Wegge, Robert Moss and Jørund Rolstad

Abstract

Knowledge of the temporal variation in reproductive success and its key driving factors is crucial in predicting animal population persistence. Few studies have examined the effects of a range of explanatory factors operating simultaneously on the same population over a long period. Based on 41 years of monitoring (1979–2019), we tested prevailing hypotheses about drivers of annual variation in breeding success in two sympatric species of boreal forest grouse—the capercaillie (*Tetrao urogallus*) and the black grouse (*T. tetrix*)—in a 45 km^2 boreal forest landscape. From counts in early August, we measured breeding success (chicks/hen) along with potential determining factors. We formulated five main hypotheses on causes of variation (hen condition, chick weather, chick food, predation, demographic characteristics) and derived 13 associated explanatory variables for analysis. We first tested the five hypotheses separately and then used model selection (AICc) to rank the best predictive models irrespective of hypotheses. Lastly, we used path analysis to illuminate potential causal relationships. Barring demographic characteristics, all hypotheses were supported, most strongly for chick food and predation. Among predictor variables, chick food (insect larvae and bilberry fruit crops), vole and fox abundances, the winter-NAO index, and temperature after hatching, had the strongest effect sizes in both species. Precipitation after hatching had no detectable effect. Model selection indicated bottom-up factors to be more important than predation, but confounding complicated interpretation. Path analysis suggested that the high explanatory power of bilberry fruiting was due not only to its direct positive effect on chick food quality but also to an indirect positive effect on vole abundance, which buffers predation. The two components of breeding success—proportion of hens with broods and number of chicks per brood—were uncorrelated, the former having the strongest effect. The two components had different ecological correlates that often varied asynchronously, resulting in overall breeding success fluctuating around low to moderate levels. Our study highlights the complexity of key explanatory drivers and the importance of considering multiple hypotheses of breeding success. Although chick food appeared to equal or surpass predation in explaining the annual variation in breeding success, predation may still be the overall limiting factor. Comparative and experimental studies of confounded variables (bilberry fruiting, voles, and larvae) are needed to disentangle causes of variation in breeding success of boreal forest grouse.

Keywords: bird breeding success, boreal forest, grouse, hypothesis testing, information theory, NAO, path analysis, *Tetrao*

Wegge, P., Moss, R., & Rolstad, J. (2022). Annual variation in breeding success in boreal forest grouse: Four decades of monitoring reveals bottom-up drivers to be more important than predation. Ecology and Evolution, 12, e9327. https://doi.org/10.1002/ece3.9327.

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Comments

Our article attempts to disentangle biological, possibly causal, relationships between annual breeding success and a rather large data set of potentially explanatory variables. Although some relationships stood out as expected (i.e. the importance of insect larvae and warm weather), confounding among other variables shadowed clear results (e.g. the role of bilberry and vole cycles), reminding us that conventional statistical analyses may not always produce unbiased information.

Per Wegge and Jørund Rolstad

Twenty-five years of monitoring the occurrence of hazel grouse (*Bonasa bonasia*) in the canton of Neuchâtel, Switzerland.

Jean-Lou Zimmermann

Introduction

The hazel grouse (*Bonasa bonasia*), a grouse species difficult to observe and detect, is listed on the Red List of Breeding Birds - Threatened Species in Switzerland (2021) and a priority for targeted conservation. It locally coexists with the Capercaillie (*Tetrao urogallus*). The favorite habitats are the wooded pastures of fir-beech woods (*Abieti-Fagetum*) in the Haut-Jura of Neuchâtel, provided that there is a mosaic of grassy, bushy and arborescent environments rich in wild fruit trees. After twenty-five years of observations in this region for the purpose of protection, we thought it is worth to present the evolution of this work.

Monitoring objectives

Conservation programs have emerged in favor of the Capercaillie in the Jura, but it seems their implementation was too late to reverse the negative trend of the relict population. Concerning the hazel grouse, likely due to its secretive behavior, the bird remains the great forgotten among grouse species. The hazel grouse is monogamous and their habit differ from other tetraonids, especially during display. As males do not gather on a lekking ground, it is difficult to carry out effective counts. Searching for indices like feces or feathers allows confirming the presence of the species on a site, but it is expensive to count the individuals by this means.

Among the most relevant approaches for the detection, the census, or ethology studies as well, acoustic monitoring reveals a very interesting potential. This method applies fine to the hazel grouse as its song is very characteristic and easily individualized, each male producing a very distinct sound signature on the sonograms.

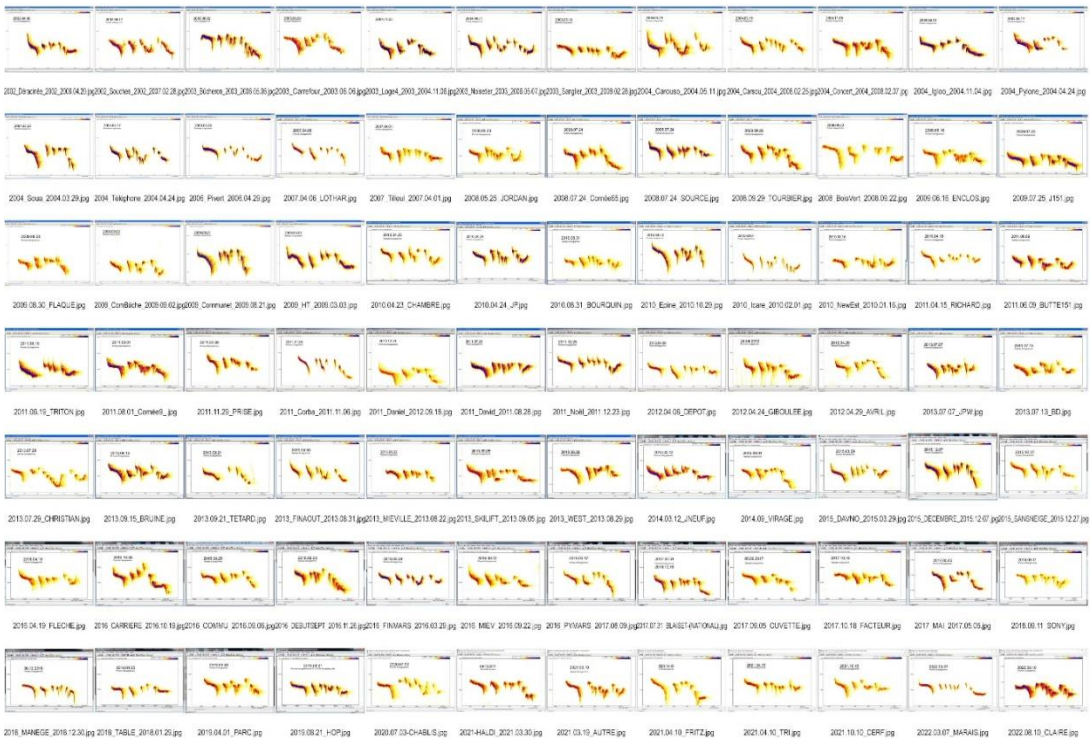


Figure 1: Sonagrams of some Hazel grouse recorded in the Jura (Canton of Neuchâtel, -Switzerland). Males of this grouse species may be easily differentiated by their vocal signature. A bioacoustics survey, carried out from 2001 to 2021 (21 years), enabled to identify 400 different males in the canton of Neuchâtel.

Development of the working method

From 2001, the first surveys were initially based on instantaneous recordings of singing males of hazel grouse in the field. From 2014 onwards, this was completed by using several automatic recorders. This approach is currently being developed on a larger scale with a large number of automatic recorders, without, however, restricting the direct recordings of singing males in the field. The latter provides important additional information about both space use and habitat quality.

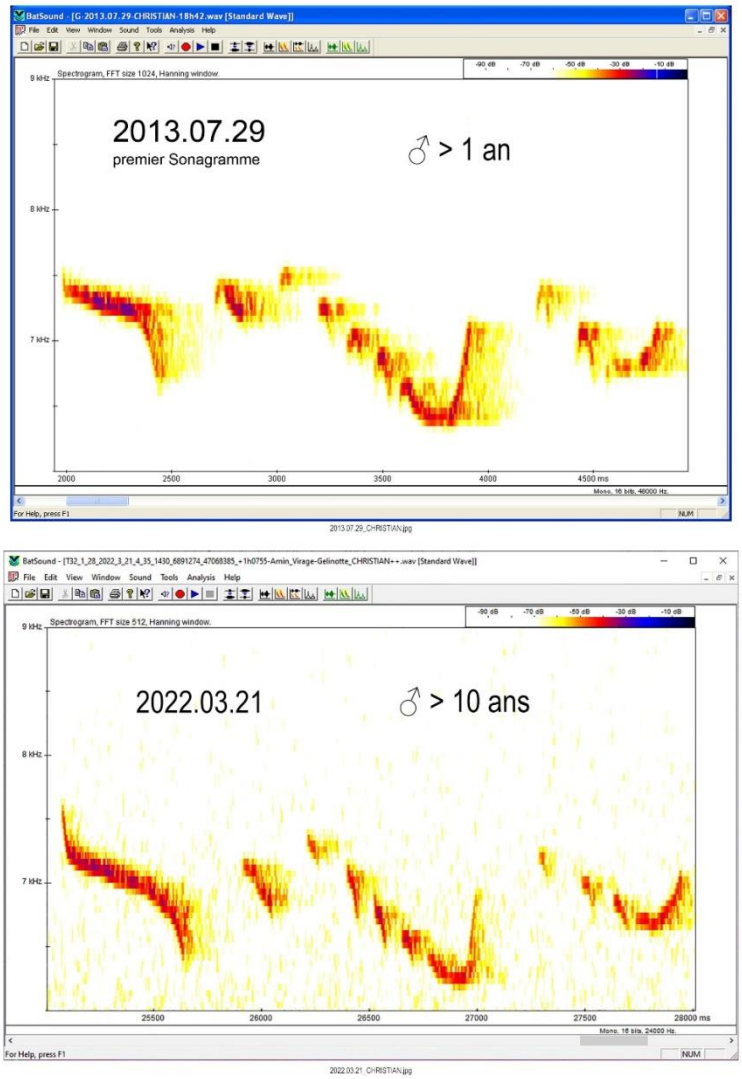


Figure 2: Sonograms of the same hazel grouse male recorded over a 10-year period.

Some results

This bioacoustics program, carried out from 2001 to 2021 (21 years), has enabled to identify 400 different males in the canton of Neuchâtel, a cumulative number to which we can add a quarter to two thirds of females, the sex ratio being unbalanced to females in this species. Field monitoring allowed collecting more than 8,500 signs of presence with GPS coordinates for each of them (roosting places, perches, droppings, tracks, snow burrows, songs).

Method

The detection and the monitoring of populations by bioacoustics using automatic recorders allows to collect many and diverse observations with a minimum of human disturbance in the field and a relatively moderate hourly cost. The loggers are placed in the forest after being programmed to switch on and off automatically (for example at dawn and dusk). Occasionally, the gear may be redeployed to other sites. With automatic recorders, songs are spontaneous which means there is neither external influence nor human disturbance, the individuals singing according to their specific temporal rhythm. The most favorable periods for the singing of hazel grouse are highlighted and it can be seen that almost all the ten-day periods considered include display activity.

The survey is therefore efficient, particularly in spring and autumn. The temporal distribution of recorded contacts is somewhat skewed, as the recorders were only programmed for two periods (dawn and dusk). Throughout the 21 years of monitoring by live recordings, the observation is that the hazel grouse can also sing at any time of the day, however in a less systematic way.

Interest of the method

This technique for monitoring populations has the advantage of being easily reproducible and objective. It constitutes, with the simultaneous establishment of a bioacoustics register, a key solution for the detection and monitoring of the species, which can be used for instance, to test the relevance of the measures carried out for the preservation or restoration of habitats.

It should be noted that during the formation or strengthening of pairs in the spring, the female sometimes responds with a song just after the end of that of the male with whom she is paired. Hence this also allows detecting and confirming the presence of a certain number of pairs.

Age of grouse and effects of disturbances

The study allowed us to confirm the lifespan of a bird tracked for 11 years using bioacoustics, which appears to be a record. To date, the maximum reported lifespan from a ringing bird was in Europe 7 years and 3 months (Source Euring). Several hazel grouse found in particularly favorable areas have lived for 8 to 10 years. Another male followed for 7 years remained in an area of 8.7 ha all his life!

It has also been noticed that when an individual leaves his usual home range, for example following habitat changes resulting from woodcutting, or by the arrival of a new, more aggressive bird, he will not survive for a long time.

Ce mâle de Gélinotte des bois est âgé au minimum de 11 ans, record de longévite en milieu naturel pour l'espèce. C'est la bioacoustique qui a rendu possible ce suivi à long terme. La trace graphique de son chant (le sonagramme) est à l'image d'une empreinte digitale, en quelque sorte une carte d'identité.

This male of hazel grouse is at least 11 years old. This longevity, never recorded into the wild, has been evaluated using bioacoustics. The sonogram represents the bird's vocal signature, a sort of identity card.

Perspectives from the use of bioacoustics

The potential of bioacoustics monitoring using automatic recorders is the way to be developed for this very secretive species. Generating no human disturbance, this inexpensive method in hours/person makes it possible, among other things, to survey numerous sites simultaneously, and/or to shed light on the dynamics of the population, on the replacement of individuals on a site, etc.

Adequate (appropriate) habitat

Given the species-specific requirements for forest habitats, the hazel grouse is a key species for conservation of the forest biodiversity. A homogenization of the habitat should be avoided; it should ideally consist of a mosaic of different forest structures, both horizontally and vertically, including micro-clearings, herbaceous and shrub layers. The presence of conifers with low branches touching the ground is essential, especially for "safety". To guarantee the trophic requirements of hazel grouse, the presence of thickets of wild fruit trees such as hazelnuts, hawthorns, mountain ashes, willows, raspberries, and blueberries is a crucial point. Whether the food resource is in buds, catkins, fruits or seeds of different woody species, the hazel grouse exploits the most abundant at the moment and the richest in nutrients. Unlike other grouse species, it never feeds on resinous needles.

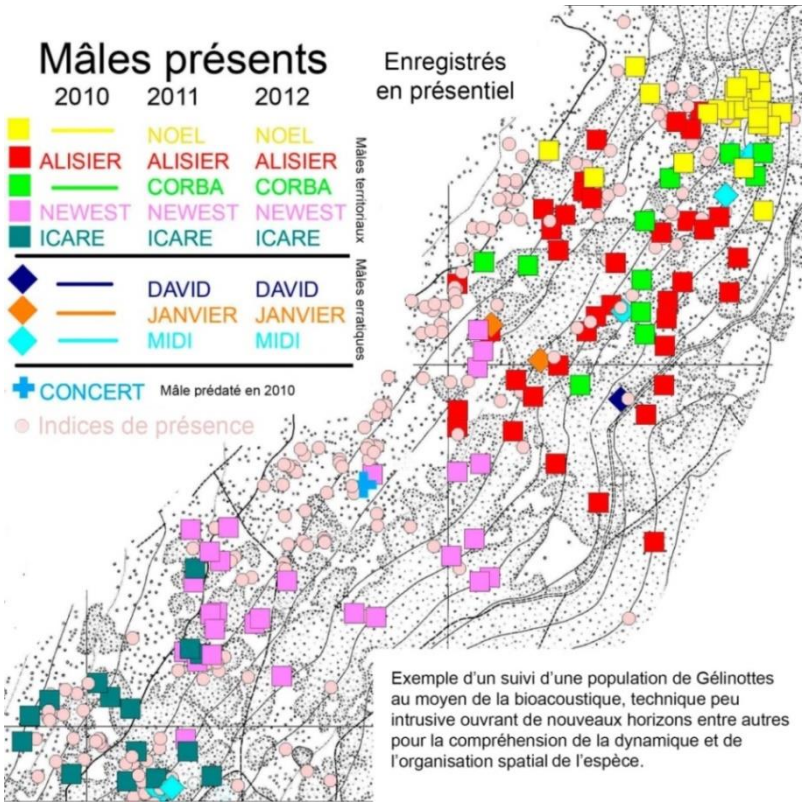
Suggestions for appropriate forestry measures

It should be remembered that assessing how any changes in forestry structure can benefit to target species requires patience and modesty. The forest time is not agricultural time! What is counted in months for agriculture is like decades for the forest environment. In addition, the whole forest is not logged in one year, but sector by sector, which further lengthens the potential impacts.

The relevance of the habitat management of a species is far from obvious and requires follow-up to see if the desired effect has been achieved. It is very important to plan for corridors for grouse to migrate between small populations in order to guarantee gene flow. Wind farms may also be a problem!
Given that the life expectancy of the hazel grouse is about ten years, and his sedentary behavior, the bird can live in a habitat which is degrading. On the other hand, it is very likely that once degraded this environment will no longer be recolonized, in particular by a new female.

Where are the responsibilities?

In the chain of stakeholders in forest management (politicians, professionals, owners, etc.), it is essential that all are informed and committed to the process. A significant mixing of those responsible can be observed in a few years on the same forest. The measures discussed and planned in the mid-term must therefore be able to transit efficiently and assuredly to new staff at all levels.



An example of hazel grouse monitoring by the mean of bioacoustics. this non-invasive method is quite well adapted for studying the population dynamic and the spatial distribution of birds. The figure shows the result of a bioacoustics monitoring over a 3-year period during which the male NOEL has been detected in 2011 and 2012, the male ALISIER in 2010, 2011 and in 2012, etc…

In addition, the subsidies allocated must be fully allocated to the defined goals and not to minor measures because the financial windfall is ultimately used to support the balance of more general accounts that have little connection with biodiversity objectives. Strict control carried out by an independent staff with the power of denunciation, competent in terms of the needs of the target species, is very important.

Timber skidding techniques may cause irreparable damages to the forest ground. This is compensated for by changing and expanding these activities, and also increasing their number. As a result, we see a multiplication of the network of services, which have crisscrossed the forest environments exponentially in recent years, often without consideration other than profit.

It is no longer possible to find quiet areas unless you break up this network and that becomes a dream. Another utopian vision: that of bans of using these welcoming services, whatever their status (skid trail, forest track, etc.), whether on foot, on horseback, on a mountain bike or "new" means of transport. These prohibitions are illusory measures because they are neither accepted nor respected by the population and even less controlled by the authority.

Future of the species

The hazel grouse has had a heavy population decline in France, but also in a major part of Europe. In view of what is currently happening in forests and wooded pastures in the Swiss Jura, we may say that we are not escaping this regression either.

Faced with the urgency of the situation and in view of what happened to the Capercaillie, everything must be done quickly for the conservation of the hazel grouse. The woodcock (*Scolopax rusticola*) is another species of breeding bird in great danger in our Neuchâtel Jura, and pooling appropriate protection measures with those that also concern this species would be important. The same bioacoustics study is carried out in parallel on the woodcock (see references). Let's hope it's not already too late. As a reminder: for more than twenty years we have been talking about the need of reducing disturbance but nothing has yet been acted... except for the disappearance of the capercaillie!

Acknowledgement

I have made most of the observations, recordings and the whole technical approach (groping and evolving, type of microphone, recorder, preamplifier, etc.) allowing the recordings, but also its financing.

Thank you to the Sorbus association and particularly to Blaise Mulhauser, to whom I have regularly transmitted a great deal of information from my fieldwork. He was kind enough to publish them on different occasions (see bibliography).

Many thanks to Serge Santiago for help in the field and who has very good knowledge of the forest grouse, and who kindly review the entire manuscript and made relevant suggestions.

Thanks also to Pierre-André Taillard for the development of an algorithm allowing to quickly extracting the contacts of the target species among the long recorded sequences... Previously, however, I extracted sequences from my "old-fashioned" automatic recordings in quickly and visually searching for interesting tracks with the Audacity software, before having access to Pierre-André's algorithm, constantly improving with the aim of achieving efficiency for future work. My thanks also go to Marcel S. Jacquat for his proofreading and his formatting proposals.

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Jean-Lou Zimmermann, Naturalist Circle of the Neuchâtel Mountains, La Chaux-de-Fonds. jean-lou.zimmermann@net2000.ch.

The past, present, and future of the Siberian Grouse (*Falcipennis falcipennis*) under glacial oscillations and global warming.

Wen-Dong Xie and Yue-Hua Sun

Global climate change has a significant effect on species especially in subarctic areas. During the last three million years, the earth has experienced glacial oscillations. During glacial periods, species were forced to survive in ice free refugia and disperse deglacial. With different adaptability and dispersal ability, different species respond differently to the climate change and, eventually, formed unique geographical patterns. With the accelerating human development, the global climate is undergoing rapid warming, with exert great influence on different species.

In this study, by assessing the potential distribution of Siberian Grouse (*Falcipennis falcipennis*), we used Global Circular Models and Representative Concentration Pathways to model their pattern of range changes during glacial oscillations and the potential impact of present global warming.

Figure 1. Siberian Grouse in Russia (From Siegfried Klaus).

The Siberian Grouse is endemic to a restricted range in far eastern Russia (Klaus and Andreev, 2003; Ludwig and Konovalenko, 2012). Its distribution range and population size are declining and it is listed as near threatened (NT) on the Red List of the International Union for Conservation of Nature (IUCN; latest assessment in 2016), due to forest fires and logging in the dense conifer forest that the grouse prefer (BirdLife International, 2017). Recent studies concluded that the Siberian Grouse is extinct in China, as there have been no records of its occurrence there for more than 35 years, as documented in National Red Data Books of China and Russia (Zheng and Wang, 1998; Klaus and Andreev, 2003).

To attempt to clarify these questions and determine how the Siberian Grouse's restricted distribution range was formed, we used the species distribution modeling method, applying models of climate change to the Pleistocene, and a repeated cold and warm loop, due to the “expansion and contraction” pattern of the glacial and interglacial period (Dong et al., 2017), particularly in three historical periods, Last interglacial, the Last Glacial Maximum and Mid-Holocene. We simulated the shifting of the grouse's potential historical distributions and applied different scenarios of future climate change in 2050 and 2070 to evaluate the impact of global warming (Wang and Overgaard, 2007).

Figure 2. Siberian Grouse in Russia (From Siegfried Klaus).

The Total Suitability Zone ($P \geq 0.33$) of Siberian Grouse is about 243,000 km2 and the Maximum Suitability Zone ($P \geq 0.66$) is 36,000 km2 and is confined to the Russian Far East. The Siberian Grouse feeds exclusively on spruce needles, mainly Ajan Spruce, in winter, and young needles of Dahurian Larch in May (Klaus and Andreev, 2003). Although it also feeds on moss, forbs, grass, ants, and other insects, Ajan Spruce and Dahurian Larch are the crucial food sources and these two plants are also restricted to northeastern Asia, which is similar to the Siberian Grouse's occupied range.

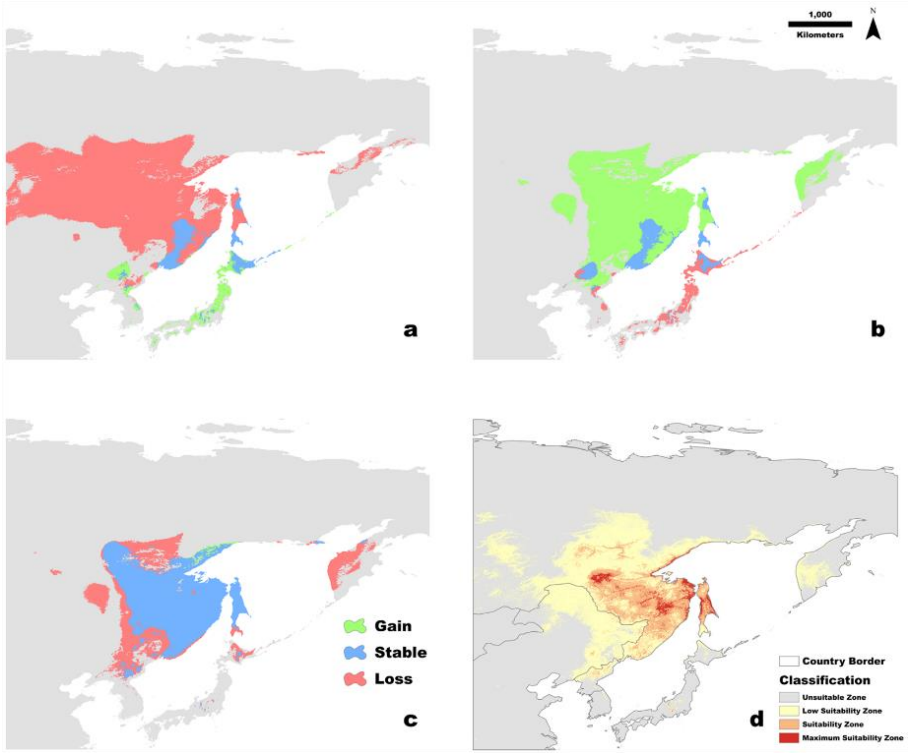

Figure 3. The binary distribution change of Siberian Grouse in the simple climate model between LIG-LGM (A), LGM-MID (B) and MID-CUR (C). Loss of habitat is shown in red, stable habitat in blue, and newly gained range in green. The current potential distribution of Siberian Grouse in the full model is shown in the reclassified map (D) (Unsuitable zone ($P < 0.05$), Low suitability zone ($0.05 \leq P < 0.33$), Suitability zone ($0.33 \leq P < 0.66$) and Maximum suitability zone ($P \leq 0.66$)).

Potential habitat modeling suggested that annual precipitation, annual mean temperature, and the distance from lakes are the most explanatory variables for the current distribution of Siberian Grouse. The distribution center moved to the southeast during the Last Glacial Maximum and spread back to the northwest after the ice melted and temperatures rose.

The total area range of Siberian Grouse experienced a dramatic loss during the Last Glacial Maximum. Global warming is presently forcing the Siberian Grouse to migrate northward with a contraction of its range. There is an urgent need to protect its habitat, because little of its Maximum Sustainable Zone is protected, although there are some large reserves in that area.

The reintroduction of Siberian Grouse by human effort and more prioritized protection on the specific species of spruce, that this grouse feed on, will be a necessary or alternative measure to bring Siberian Grouse back into China, for it will be difficult to expect the grouse to spread back itself, considering the Siberian Grouse's northward shifting trend in the future and declining potential range in China.

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Genomic analysis revealed differentiation between Chinese grouse and Hazel grouse in demographic history and the introgression and adaptive population in genes controlling epigenetic variation

Kai Song and Yue-Hua Sun

Background

The Quaternary had worldwide consequences in forming the contemporary diversity of many populations, species and communities, which is characterized by marked climatic oscillations between glacial and interglacial periods. The origin and evolution of biodiversity in mountainous areas are highly dependent on historical orogenesis and associated climatic changes. Here we use whole genome sequences obtained from individuals belonging to a pair of boreal forest dwelling sibling grouse species: the Chinese Grouse *Tetrastes sewerzowi* and Hazel Grouse *T. bonasia* to infer their demographic histories and relate the inferred changes to known past climatic geological events and their climatic impacts. The Chinese Grouse is an endemic species inhabiting high mountain coniferous forests in central China. The Hazel Grouse is the sibling species of Chinese Grouse and occurs within the temperate, boreal, and subarctic biogeographical zones of the Northern Hemisphere.

A male Chinese Grouse at Taohe National Nature Reserve, Zhuoni County, Gansu Province, in July 2022, (taken by Sun Yue-Hua)

We used whole genome resequencing data to estimate the divergence time and used a pairwise sequentially Markovian coalescent (PSMC) modeling to reconstruct the ancestral demographic trends in both species. We used a multiple sequentially Markovian coalescent (MSMC) model to estimate the effective population size of both species in more recent time. Combined with glacial event data, we aim at understanding the effects of past climatic changes on past distribution changes of Chinese Grouse via Species Distribution Modelling (SDM). The combination of SDM and population genomics also provides new insights to understand the impact of past climatic changes on population dynamics.

Finally, to investigate the genetic basis for local adaptation, we examined nuclear genomic diversity in this pair of sibling bird species across their contemporary distribution while controlling for population structure within and between species. At the continental scale, we evaluated and compared genetic diversity, population structure, and introgression in populations and genes under divergent selection between the two taxa.

Results

We estimated the divergence time of Chinese Grouse and Hazel Grouse to 1.76 (0.46–3.37) MYA. The demographic history of different populations in these two sibling species was reconstructed (Figure 1), and showed that peaks and bottlenecks of effective population size occurred at different times for the two species. The northern Qilian population of Chinese Grouse became separated from the rest of the species residing in the south approximately 250,000 years ago and have since then showed consistently lower effective population size than the southern population (Figure 2). The Chinese Hazel Grouse population had a higher effective population size at the peak of the Last Glacial Period (approx. 300,000 years ago) than the European population. Both species have decreased recently and now have low effective population sizes.

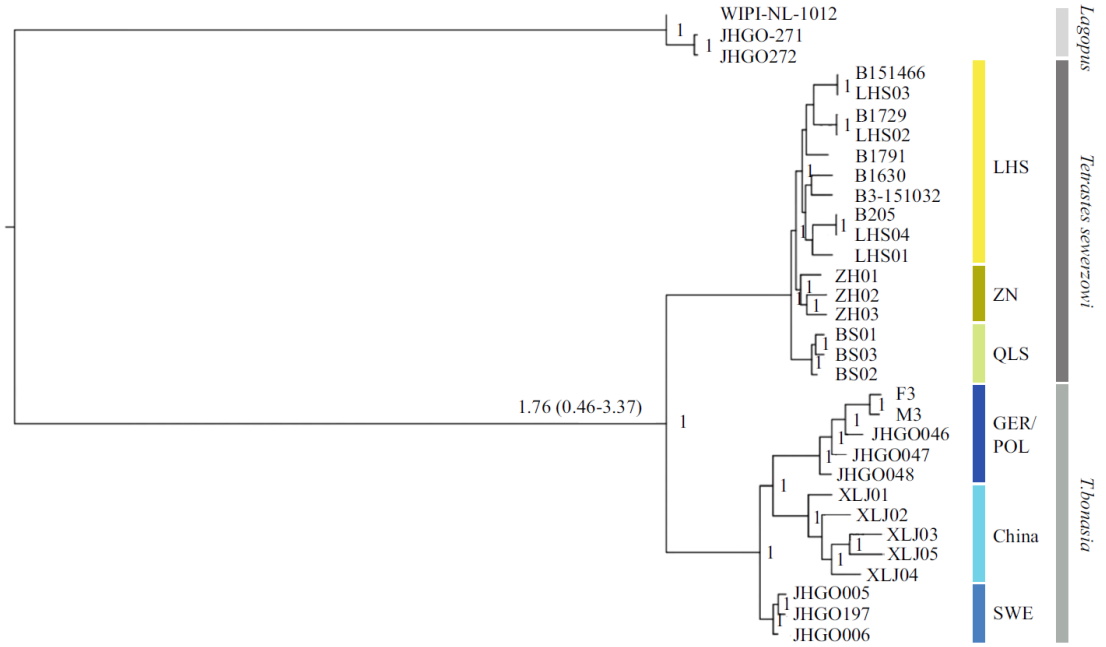

Figure 1. Phylogenetic relationships based on Bayesian analyses. The split between these sibling species is given in million years (with 95% confidence limits) from MSMC analysis. Numbers at the nodes indicate posterior probabilities.

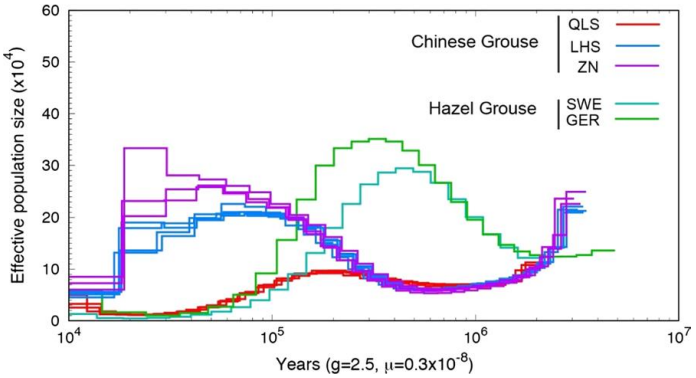

Figure 2. Historical changes in effective population size of Chinese Grouse and Hazel Grouse from PSMC analyses of whole-genome sequences. Profiles labeled SWE and GER, the European populations, (green) are from Hazel Grouse, ZN (olive), LHS (blue) and QLS (red) are from Chinese Grouse.

Analyses of the Chinese Grouse genome revealed fluctuations throughout the Pleistocene in effective population size. Populations decreased during early to middle Pleistocene but showed an expansion during late Pleistocene which was then followed by a sharp decline during the last glacial

maximum (LGM). Ecological niche modeling indicated that a suitable habitat shift between high altitude regions to low altitude regions was due to a changing climate (Figure 3). This result parallels patterns of population size change in Chinese Grouse estimated from PSMC modelling, which suggested an expansion in population size from the last interglacial period (LIG) and then a peak and a bottleneck occurring at the last glacial maximum (LGM). Furthermore, the present-day distribution of Chinese Grouse is greatly reduced and fragmented. It will likely become even more fragmented in the future since coniferous forest cover is threatened in the region of their distribution and the availability of such habitat restricts their ecological niche.

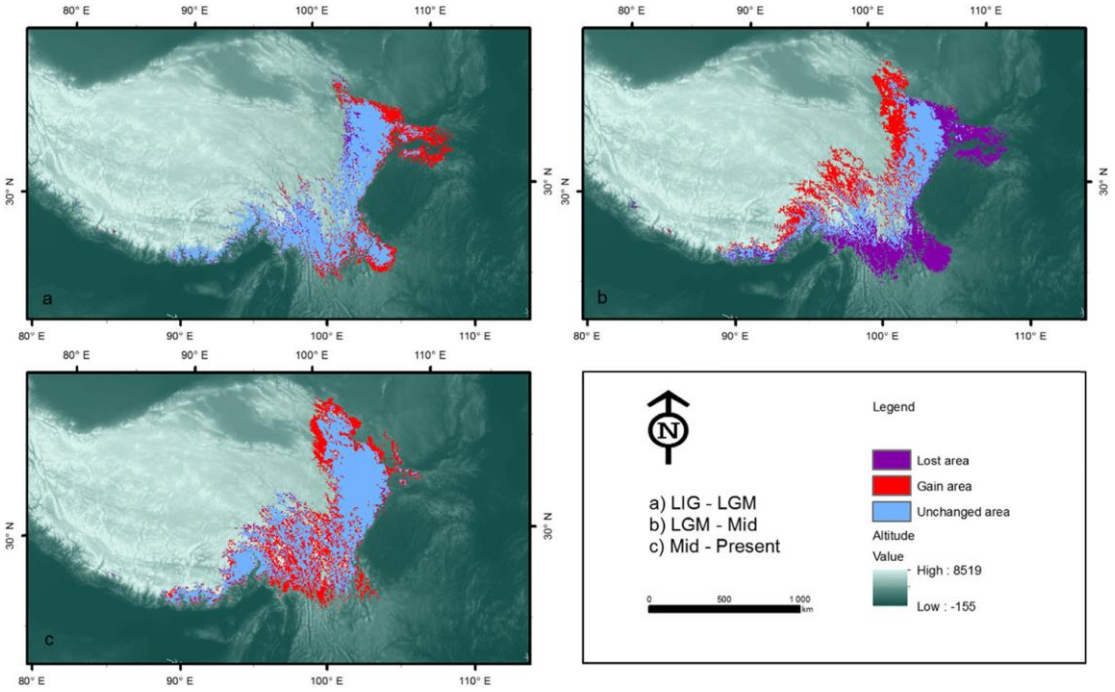

Figure 3. The change in predicted distributions of the Chinese Grouse: a from LIG to LGM; b from LGM to Mid-Holocene; c predicted from Mid-Holocene to Present-day. Map data was from WorldClim-Global Climate Data, which is free data for ecological modeling and GIS.

Through selective sweep analysis, we found evidence that Chinese Grouse inhabiting the high-altitude Qinghai-Xizang (Tibet) Plateau (QTP) have evolved adaptations to hypobaric hypoxia and high ultraviolet radiation. We also found that many genes under positive selection in the two species were related to histone modification and chromatin structure (Figure 4). Thus, differentiation between the two species may be targeted at genes involved in epigenetic regulation, suggesting a role of phenotypic plasticity in species and population differentiation. Further analysis indicated a strong population structure for each species and evidence of local adaptation in the Chinese Grouse. Analysis also identified certain regions (Sweden and Qilian Mountains) with particularly low diversity. These results suggest a role of phenotypic plasticity in differentiation among and within species, which may explain local adaptation and may have profound implications for how to preserve threatened local populations.

Conclusion

In conclusion, our analyses provided insights into divergence and demographic history of a sibling species pair both residing in cold boreal forest habitats in Eurasia and the QTP. Combined with the uplift history and reconstructed climate change during the Quaternary, our results support that cold-adapted grouse species diverged in response to changes in the distribution of palaeo-boreal forest and the formation of the Loess Plateau. Our analyses also provide insights in to how these sibling species have responded to changes in climate throughout their evolutionary history.

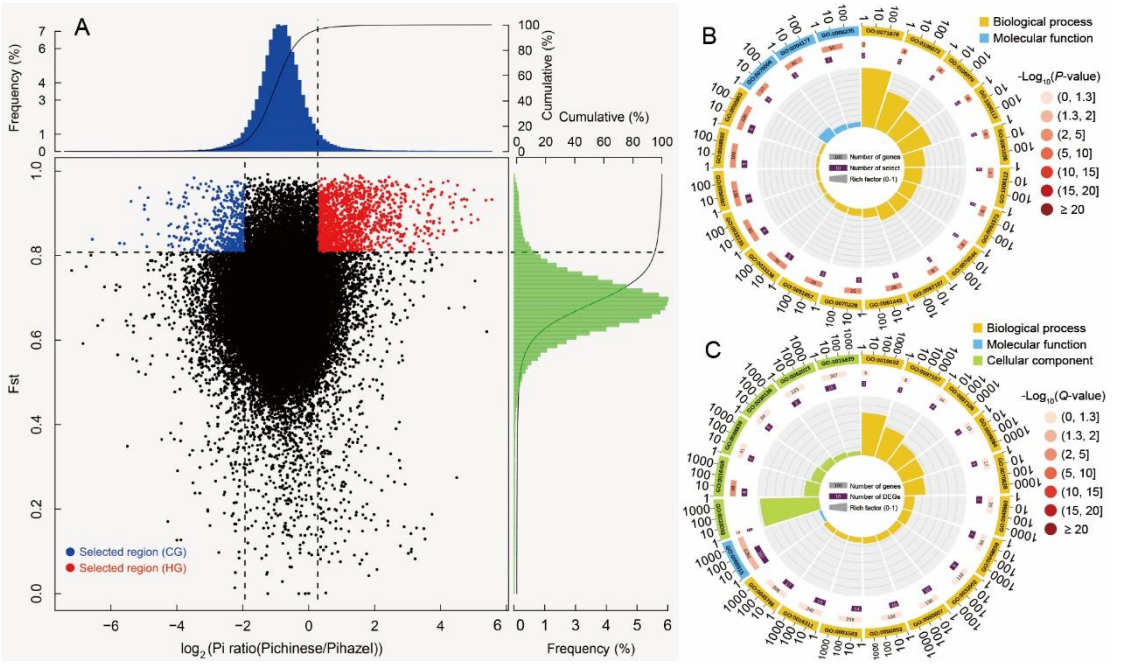

Figure 4. Analysis of genes under local adaptation. A: Genomic regions (blue points) located at top left of dashed lines are candidate positively selected regions for Chinese Grouse. Genomic regions (red points) located at top right of dashed lines are candidate positively selected regions for Hazel Grouse. B: Gene enrichment in Chinese Grouse in GO terms. C: Gene enrichment in Hazel Grouse in GO terms.

The Chinese Grouse have experienced substantial population size changes from the beginning to the LIG and reached a peak before the LGM. A sharp decrease and bottleneck occurred during the LGM, when the coniferous forests were subjected to extensive loss. The results inferred from the whole genome sequencing and species distribution models both support historical population fluctuations. The distribution of the Chinese Grouse is strongly dependent on the coniferous forest cover. To protect the fragmented coniferous forests is an essential action to protect the Chinese Grouse.

To the best of our knowledge, this is the first description of the population structure and genetic diversity of the Chinese Grouse and the first study to use whole-genome data to reveal the population structure of the Hazel Grouse. PCA and ADMIXTURE analyses showed a strong population genetic structure for both species. In the Chinese Grouse, the QLS population was clearly divergent from the other two populations, with the low genetic diversity, high pairwise FST, and high LD decay supporting its strong divergence and long-term isolation.

Original works:

Song, K., Gao, B., Halvarsson, P. et al. Demographic history and divergence of sibling grouse species inferred from whole genome sequencing reveal past effects of climate change. BMC Ecol Evo 21, 194 (2021). https://doi.org/10.1186/s12862-021-01921-7

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Song, K., Gao, B., Halvarsson, P. . et al. Conservation genomics of sibling grouse in boreal forests reveals introgression and adaptive population differentiation in genes controlling epigenetic variation. Zoological Research 43, 2 (2022). https://doi.org/10.24272/j.issn.2095-8137.2021.227

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FORUM

Welcome members and subscribers to a new section in the Grouse News. Do you have questions or topics for discussion? Here is an opportunity to bring those to a vast and growing pool of experts, many of whom have several decades of experience. When the Galliformes website (https://galliformes.org/) is back to being fully operational, such topics can be posted there, and answers and further discussion could be nearly instantaneous. We can also post those same topics and discussions in each upcoming issue of Grouse News. Below are a few such topics for starters:

1. Types of transmitters and attachment methods, pros and cons of each?
2. Translocation methods, what has worked, and what hasn't worked? Does timing or age of birds affect success?
3. Occurrence and prevalence of unusual or abnormal coloration?

CONFERENCES

Participants Flock to the First Annual Kansas Lek Treks Prairie-Chicken Festival!

Jackie Augustine

Audubon of Kansas (AOK) held its first annual Kansas Lek Treks Prairie-Chicken Festival from April 7-10, 2022 in Hays, KS. National advertising attracted 90 participants from 25 different states and one international attendee. About 25% of attendees were from Kansas. Participants saw both Lesser and Greater Prairie-Chickens during the festival on private lands in eastern Gove and western Trego Counties in Kansas, and Sharp-tailed Grouse during pre- and post-festival trips to AOK's Hutton Niobrara Ranch Wildlife Sanctuary in northern Nebraska. The banquet featured a welcome by Brad Loveless, Secretary of Kansas Department of Wildlife and Parks (KDWP), and a presentation by Nate Swick, host of American Birding podcast. Field trips to Cheyenne Bottoms Wildlife Area, Quivira National Wildlife Refuge, Smoky Valley Ranch, Castle Rock, and Monument Rocks were also offered. Funding was obtained through registration fees, a Kansas Department of Tourism grant, and sponsorships from KDWP and The Nature Conservancy in Kansas. Additional partners included the Sternberg Museum of Natural History, Kansas Wetlands Education Center, and 'Boomer' the prairie-chicken mascot from the Missouri Department of Conservation. Next year's festival will be held Apr 13-16, 2023. Volunteers are needed and conservation partners are welcome. More information can be found at https://www.kansaslektreks.org/ or contacting Jackie Augustine at 785-537-4385 or jackie@audubonofkansas.org.

The 15th International Grouse Symposium Białystok, Poland in 2023

We remain committed to organize the event in Białystok, as planned. We set Sept. 11-15 as the dates of the IGS. We will open registration in a due course. For more information please visit the IGS15 webpage www.igs2022.uwb.edu.pl. For enquires please contact the members of the Local Organizing Committee of the 15th IGS: Dr. Aneta Książek (anetak@uwb.edu.pl) and Dorota Ławreszuk (dorota.lawreszuk@bialystok.lasy.gov.pl).

8th International Galliformes Symposium Taman Safari, Prigen, Java, Indonesia – 9-13 October 2023

The World Pheasant Association (WPA) will hold a symposium on the conservation and sustainable management of all species of Galliformes (megapodes, cracids, guineafowl, quails, turkeys, grouse and pheasants), with a special emphasis on threatened species and their habitats. This meeting is the successor to the 7th International Galliformes Symposium held in Vietnam in September 2019. It will be jointly organised by WPA and our Indonesian partner organisation, Taman Safari Prigen. The objective is to hold a major gathering of all those with an interest in Galliformes and the conservation of these birds and their habitats. Invited and contributed oral presentations, posters with short talks, discussion seminars and technical workshops may fit any of the following topics: • Ecology and conservation of the species and their habitats in Indonesia and in other range states around the world. Habitat degradation, fragmentation, climate change, forest management and genomics are cutting edge topics. • Ecological studies of threatened species. • Implementing and monitoring management actions and protected areas. • Conservation breeding of rare species, management, welfare in captivity. • Genetics and taxonomy. • Techniques: - Designing and carrying out field projects - Analysing and communicating results - Managing captive populations - Developing, implementing and monitoring recovery programmes.

Email to Barbara Ingman at office@pheasant.org.uk. Full registration details including costs and supporting information will be posted on the WPA Website (www.pheasant.org.uk) as they become available.

Practical Conservation for Scottish Grouse Species Conference to be held on Friday 5th May 2023 at Balhousie Castle, Perth.

WPA has joined forces with the Game and Wildlife Conservation Trust to hold a Conference entitled "Practical Conservation for Scottish Grouse Species" at Balhousie Castle on Friday 5th May 2023. This will discuss the threat of extinction of the Capercaillie and the threats facing Ptarmigan, Black and Red Grouse. For more info see https://www.pheasant.org.uk/grouseconferencemay2023.aspx.
To register interest, please contact office@pheasant.org.uk

The 34th Biennial (mostly) Meeting of the Prairie Grouse Technical Council, October 3-6, 2022, Lewistown, Montana

Lance McNew

Dear Prairie Grousers: After 31 years, welcome back to Montana! Montana is truly a grouser's dream – it's home to healthy populations of sharp-tailed grouse and greater sage-grouse, as well as four species of mountain grouse. For non-purists, Montana also provides habitat for four other species of non-grouse upland game birds. The MSU Wildlife Habitat Ecology Lab, Department of Animal & Range Sciences, Montana Agricultural Experiment Station, and Montana Extension are honored to host the 34th PGTC. Yep, we've got great mountains, but we hope you will take some time to explore Montana's more underrated natural wonders while you are here – its vast intact prairies and rural communities.

On behalf of the PGTC Board and Conference Planning Committee, thanks for coming.

Lance McNew, lance.mcnew@montana.edu.

ORAL PRESENTATION ABSTRACTS

(LISTED ALPHABETICALLY BY AUTHOR)

PARTICIPANTS FLOCK TO KANSAS LEK TREKS PRAIRIE-CHICKEN FESTIVAL

J.K. AUGUSTINE, Audubon of Kansas PO Box 1106 Manhattan, KS 66505-1106 785-537-4385

Audubon of Kansas (AOK) held its first annual Kansas Lek Treks Prairie-Chicken Festival from April 7-10, 2022 in Hays, KS. National advertising attracted 90 participants from 25 different states and one international attendee. About 25% of attendees were from Kansas. Participants saw both Lesser and Greater Prairie-Chickens during the festival on private lands in eastern Gove and western Trego Counties in Kansas, and Sharp-tailed Grouse during pre- and post-festival trips to AOK's Hutton Niobrara Ranch Wildlife Sanctuary in northern Nebraska. The banquet featured a welcome by Brad Loveless, Secretary of Kansas Department of Wildlife and Parks (KDWP), and a presentation by Nate Swick, host of American Birding podcast. Field trips to Cheyenne Bottoms Wildlife Area, Quivira National Wildlife Refuge, Smoky Valley Ranch, Castle Rock, and Monument Rocks were also offered. Funding was obtained through registration fees, a Kansas Department of Tourism grant, and sponsorships from KDWP and The Nature Conservancy in Kansas. Additional partners included the Sternberg Museum of Natural History, Kansas Wetlands Education Center, and 'Boomer' the prairie-chicken mascot from the Missouri Department of Conservation. Next year's festival will be held Apr 13-16, 2023. Volunteers are needed and conservation partners are welcome. More information can be found at https://www.kansaslektreks.org/.

J.K. Augustine jackie@audubonofkansas.org Audubon of Kansas PO Box 1106 Manhattan, KS 66505-1106 785-537-4385

LESSER PRAIRIE-CHICKEN STRONGHOLD DEVELOPMENT AT THE NATURE CONSERVANCY'S SMOKY VALLEY RANCH

M.R. BAIN, The Nature Conservancy, 1114 Co Rd 370, Oakley, KS 67748 mbain@tnc.org 785-269-7481

Smoky Valley Ranch is located within the shortgrass/CRP ecoregion between the Arkansas River and I-70 in western Kansas, where range wide aerial surveys indicate that well over half of all Lesser Prairie-

Chicken (LPC) now occur. Lek surveys on the Ranch suggest that the population has increased over tenfold since 2015, with 189 males surveyed this spring. We suspect the population has responded to changes in stocking rates and a rest-rotation grazing system that includes deferment. The Nature Conservancy and partners are utilizing the Ranch as an anchor property in a stronghold development pilot area of approximately 200,000-acres. One additional pilot area in the Red Hills of Kansas and Oklahoma is underway, as well as efforts in other potential strongholds. This strategy includes intense spatial focusing of additional staff capacity, test incentive payments to producers, and social science to identify and address barriers to habitat management and long-term conservation. Our goal is to create a collaborative model that can be transferred to other communities, eventually resulting in large, interconnected blocks of high-quality grasslands with long-term voluntary conservation.
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IMPACT OF GRAZING MANAGEMENT ON VITAL RATES OF GREATER SAGEGROUSE IN CENTRAL MONTANA

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D. J. MESSMER Montana Fish Wildlife and Parks, Helena, MT 59601 USA,*
M. SZCZYPINSKI Montana Fish Wildlife and Parks, Roundup, MT 59072 USA,
V. J. DREITZ University of Montana, Missoula, MT 59812 USA, and
J. GUDE Montana Fish Wildlife and Parks, Helena, MT 59601 USA

We evaluated the effects of livestock grazing on sage-grouse breeding season vital rates and whether rotational grazing systems implemented through the Natural Resources Conservation Service (NRCS) Sage Grouse Initiative (SGI) improved vital rates of greater sage-grouse in central Montana, 2011–2019. We used radio telemetry to collect data on hen survival, nest success, and chick survival. We used field measurements and remote sensing to quantify vegetation characteristics. Our results indicated generally weak or negligible effects of SGI grazing management on vegetation metrics. Likewise, nest success and chick survival were not higher during or after pastures enrolled in SGI programs. Results on hen survival are forthcoming. Although preliminary, our results suggest that annual and pasture (spatial) variation have more of an effect on sage-grouse demographics and habitat than grazing management. Our preliminary conclusions concur with other recent research indicating that preserving sagebrush habitat by keeping working ranches intact may be more important than recommending particular grazing management systems.
D.J. MESSMER David.Messmer@mt.gov O:406-444-2008 C:406-299-0884

GROUSE TRANSLOCATIONS: MOVING BROODS, POPULATION IMPACTS, AND HABITAT SELECTION IN EXPLORATORY VS. SETTLEMENT STATES

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1 Utah State University, Logan, UT
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3 North Dakota Game and Fish, Dickinson, ND
4 Idaho State University, Pocatello, ID

Past grouse translocations had little monitoring of translocated individuals. Marked translocated grouse have been plagued with low survival and productivity. We translocated female greater sage-grouse, both pre-nesting and brooding. We developed a novel method to transport and release brood females and chicks. We used a brood transport box with two compartments separated by a removable perforated divider. The female and chicks were able to stay in contact, but the brood female was unable to physically impact the chicks during transport. At the release site, the brood was transferred to a 4 x 8-foot release pen and released once normal behavior was observed. We had high survival during the translocation and release. Post-release movements were lower than pre-nesting females. Brood translocations may be useful for other grouse and gallinaceous species. We used radio-telemetry to monitor both the translocated females in the augmented population and resident females in the source population. We found no impact to the source population due to females removed for translocation. Brood translocations had the most positive impact on the augmented populations with only slight benefit coming from translocated pre-nesting females. We used GPS-PTT radios to monitor both translocated brood and prenesting female movements and habitat selection. We found that translocated grouse exhibited exploratory and settlement

behaviors and that habitat selection differed based on behavioral state. Therefore, when predicting optimal release areas, all post-release locations of translocated grouse should not necessarily be used for predictive models. Rather, habitat selected during settlement state should guide release area evaluations and habitat selected during the exploratory state should likely be censored.

RESTORATION OF SHARP-TAILED GROUSE TO WESTERN MONTANA

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Sharp-tailed grouse once ranged across Montana. Circa 2003, the last known sharp-tails disappeared from west of the Continental Divide in Montana despite a multi-year effort to supplement a declining population on the Tobacco Plains of northwest Montana and smaller attempts to reintroduce birds to the National Bison Range near Missoula. In 2019, following intensive collaborative planning by agencies, academics, stakeholders, and funders, the Montana Fish and Wildlife Commission launched a western Montana reintroduction effort. In fall 2021 the first seventy-five males were trapped in eastern Montana and released on three private ranches in western valleys. In April 2022, trapping was paused following the detection of avian influenza in the state, though not before a small number of additional males and females were translocated. Over five years, we aim to transplant up to 180 grouse annually, monitoring survival, movement, lek establishment, and reproductive success using MOTUS, VHF, and satellite tags. We are also cataloging DNA, and using both nuclear (12 microsatellite and one sexing locus) and mitochondrial (2 regions) markers to identify individuals, determine sex, parentage, reproductive success, and to track trends in genetic diversity and effective population size. In June 2022, the first successful nesting by sharp-tailed grouse in western Montana since 1991 was confirmed and was soon followed by a second in July.

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PRAIRIE TALES: THE STORY OF THE RISE AND FALL OF PRAIRIE CHICKENS IN EASTERN NORTH DAKOTA

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The greater prairie-chicken (*Tympanuchus cupido*) population in Grand Forks County, North Dakota has declined since 2005, after initial success following restoration efforts from 1992-1998. During this period, sharp-tailed grouse (*Tympanuchus phasianellus*), which co-occupy the area, have increased. We conducted annual spring lek counts (15 March to 15 May 2019 - 2022) to monitor the population trends for both prairie grouse species. Within two study blocks, we attempted to identify all leks of both species through listening surveys and then return to count the number of birds on each lek by species and sex. We counted between 24 and 38 active leks annually. We observed steady decreases in prairie chickens (only 6 male prairie chickens were observed in 2022); increases in sharp-tails; and increases in hybrid Greater prairie-chicken x sharp-tailed grouse (8/31 leks in 2022). Previously, managers assumed that hybrids were relatively rare, but we documented as many as 16 hybrids in a single year. Current trends suggest prairie chickens will not persist without active management to increase their populations.

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ABOVE GROUND BIOMASS RESPONSE TO PRESCRIBED GRAZING FOR LESSER PRAIRIE-CHICKEN HABITAT MANAGEMENT

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An Area of Critical Environmental Concern (ACEC), located in New Mexico in the Sand Shinnery Oak Prairie Ecoregion (SSOP), is managed by the Bureau of Land Management under a multi-use mandate, with emphasis on habitat management for lesser prairie-chickens (*Tympanuchus pallidicinctus*; LEPC). This includes, but is not limited to, prescribed grazing within context of best available data for LEPCs. The goal of this project is to quantify vegetation response and beef-herd health associated with prescribed grazing designed specifically to meet conservation goals for the species. We GPS-tagged cattle among different herds to quantify and compare vegetation response and cattle-specific health metrics, 2020-2022. The objective of this presentation is to quantify available above ground herbaceous biomass before, after, and one-year post-grazing within two pastures, Crowley (4014 ha) and Old Savory (3092 ha). Preliminary results suggest grazing reduce biomass from 987 kg/ha to 285 kg/ha (71% decrease) in Crowley and 759 kg/ha to 327 kg/ha (57% decrease) in before and after grazing measurements. Herbaceous biomass did not decrease one-year post-grazing from post-grazing measurements in both pastures (Crowly: 238 kg/ha; Old Savory: 288 kg/ha).
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USE OF A NEW WEB-BASED TOOL REVEALS THAT GREATER SAGE-GROUSE ARE AN UMBRELLA SPECIES FOR SHRUB STEPPE BIRD COMMUNITIES AT RANGEWIDE SCALES

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Prairie-grouse and Greater Sage-grouse are often cited as umbrella species for rangeland conservation. However, direct evidence of this is often equivocal. We created a Python-based tool to mine public databases for bird occurrence data. Our script allows users to specify the time period and geographic extent of interest. The tool will return counts of each species present, species richness, biodiversity, rarity and apply State Space Model MCMC analysis to estimate abundance, λ, and r for selected species or guilds present. We used this tool to evaluate hypotheses related to sage-grouse being an umbrella species for sage-brush areas throughout the intermountain west. We found that sage-brush areas with protections for sage-grouse had significantly higher rarity and similar levels of diversity and richness compared to sage-brush areas lacking sage-grouse protections. During this presentation we will demonstrate the utility of this tool on a selected species of prairie-grouse.
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THIS ONE IS TOO TIGHT, THIS ONE IS TOO LOOSE, WHICH ONE IS JUST RIGHT? AN EVALUATION OF RUMP-MOUNTED TELEMETRY HARNESSES USED TO MONITOR PRAIRIE GROUSE

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Monitoring of wildlife population performance as it relates to management or disturbance often relies upon handling and marking of animals. Such studies must assume that marking animals does not affect their behavior or demography. Recent advances in the miniaturization of satellite and Global Positioning Systems (GPS) has led to widespread use of this technology in prairie grouse research. Previous research has indicated potential negative effects of GPS unit mass and the rump-mounted harness attachment type. Concerning the latter, some studies have reported abrasions and irritations of the skin in and around the thighs of greater sage-grouse (*Centrocercus urophasianus*). We examined survival and retention rates of two types of harnesses fitted to sage-grouse (n = 161) across southeastern Oregon, and northwestern Nevada (2019-2021). The standard harness was one with Teflon tape that had an elastic band inserted in it. The altered harness was the standard but had plastic tubing shrink- fitted to part of the harness to reduce potential for abrasions under the thigh region. We discuss implications of harness type on grouse survival and retention of telemetry devices to achieve research objectives.
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DRONES AND MACHINE LEARNING PROMISE ADVANCEMENTS IN LEK-BASED POPULATION SURVEYS OF PRAIRIE GROUSE

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Unbiased counting of prairie and sage-grouse at leks is an annual challenge that requires substantial time and effort. Unmanned arial vehicles (a.k.a. drones) and artificial intelligence are emerging tools that may 1) increase efficiency of lek counts, 2) reduce sources of observer error, and 3) automate the creation of digital data that can be stored and used for further analysis. We compared standard lek count methods and counts collected by a drone at 23 greater sage-grouse leks in 2021 and 2022. At each lek, sage grouse were counted following standard state-wide monitoring protocols as well as a drone programmed with an autonomous flight plan and equipped with an infrared video camera. Integrating an autonomous flight plan allowed a single observer to simultaneously observe sage-grouse to ensure that the drone did not interfere with breeding behavior. We then employed two independent methods to identify and count sage grouse from each video. Birds were first counted manually by a trained observer, and then by a machine learning-based automated tool. Comparisons of counts show promise for surveys using drones and automated processes. The average difference across all observations for 2021 was less than one bird, while the average standard deviation across observations is less than four birds; counts via drone were consistently greater. Both drone (15 ± 3 min) and traditional lek counts (15 ± 5 min) took similar time to complete. However, the drone survey consists of four separate counts completed in one flight. Using just one count per flight could increase the number of leks surveyed daily. Future analyses will estimate detection probabilities for traditional and drone-based lek surveys.
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CONSERVATION PLAN FOR GREATER PRAIRIE-CHICKENS AND SHARP-TAILED GROUSE

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The Western and Midwestern Associations of Fish and Wildlife Agencies, North American Grouse Partnership and Ecosystem Management Research Institute helped coordinate 14 state wildlife agencies in the development of a conservation plan for greater prairie-chickens (GPC) and plains and prairie subspecies of sharp-tailed grouse (STG). The plan calls for expanded and coordinated grassland and shrubland conservation efforts using GPC and STG as flagship species. The objective is to maintain, improve, and restore large blocks of native grasslands and shrublands of sufficient size, arrangement, and quality to support populations of GPC and STG along with associated grassland and shrubland wildlife species. Occurrence data of both species were compiled and new estimated occupied ranges were developed. Spatial layers were compiled to help identify priority areas for targeted conservation efforts. State wildlife agencies and conservation partners including USDA, USFWS, non-profit organizations, Joint Ventures and others should cooperate to identify and refine areas where 50,000-acre blocks of high-quality habitat for GPC and STG can be managed. The current version of the plan is seeking input and engagement from partners and coordination with other on-going grassland conservation efforts to increase effective implementation of grassland conservation actions.
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NAGP'S CONSERVATION PLAN FOR LESSER PRAIRIE-CHICKENS

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Conservation actions for lesser prairie-chickens (LEPC) have failed to prevent its listing as threatened and endangered. While the Range-wide Plan for Lesser Prairie-chickens provides a solid long-term foundation for conservation, a more focused and executable conservation strategy is needed to reverse continuing declines. The North American Grouse Partnership (NAGP) reviewed the status of LEPC conservation in 2017 and developed specific recommendations for what was needed. NAGP has since developed a more

specific conservation plan for this purpose. This plan identifies a strategic system of core areas with each consisting of a 50,000 ac block of high-quality habitat. NAGP has identified potential locations for core areas with an initial effort to establish 500,000 ac of high-quality habitat. To voluntarily engage landowners to provide LEPC conservation, enhanced incentives are needed to make LEPC conservation economically advantageous. NAGP has worked with landowners to identify incentives they endorse. They include enhancements to existing conservation programs, stacking of different programs within core areas, and new sources of funding. Also needed is a new mitigation framework that will restrict impacts within core areas and then actually replace acres lost. While the price tag for this work is substantial, it is past time that restoration of Southern Great Plains prairie ecosystems receives the priority that they deserve. LEPC are the flagship species for launching a more effective conservation effort.
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GROUSE-HABITAT RELATIONSHIPS ARE DRIVEN BY MULTILEVEL MOVEMENT PROCESSES

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Sage-grouse use of landscapes are modulated by their multilevel movement processes. Understanding the relative contributions of hard-wired and environmental influences on movement processes is necessary for a comprehensive understanding of sage-grouse ecology. We equipped 86 female sage-grouse with transmitters which were programmed to record >4 locations per day. We calculated 15 movement properties across all sage-grouse phenological stages for up to 4 years per individual. We related the 15 movement properties to 24 landscape-condition variables and 7 behavior modes using a direct gradient analysis. Numerous terrain and vegetation variables were weakly associated with female sage-grouse movement properties, but no single landscape condition or class of conditions appeared to explain a dominant portion of movement-property variation. Hard-wired or learned seasonal behavior modes appeared to be more influential than managed vegetation conditions. Sage grouse can exhibit reactive responses to landscape conditions but also use the landscape as a function of high-level endogenous constraints likely due to memory mechanisms, high temporal predictability of some resources, and moderate spatial heterogeneity of resources. Management prescriptions may ignore important ecological levels such as those responsible for learned-heuristic movement and space use modes.
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RANGEWIDE GENETIC DIVERSITY OF THE GREATER PRAIRIE-CHICKEN (*TYMPANUCHUS CUPIDO*)

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Genetic diversity is important to the health of wildlife populations but is being lost for many species due to declines in the number of individuals and loss of connectivity. The Greater Prairie-Chicken (*Tympanuchus cupido*) is a lek-mating grouse whose population and range have contracted greatly since the beginning of the 20th century due to agriculture and other anthropogenic land uses. In collaboration with several state and federal agencies we collected lek feathers and tissue from across four states for use in an analysis of range-wide genetic diversity and population structure using microsatellite loci. We found that genetic diversity across the range remains high (H E =0.908 versus H O =0.827). In addition, we found moderate evidence of genetic structure linked to each state, and two distinct sub-populations in OK. Future landscape genetic analysis will link observed structure to landscape attributes to support management.
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CAPTIVE PROPAGATION OF ATTWATER'S PRAIRIE-CHICKENS FOR RELEASE INTO THE WILD: UPDATES ON PRODUCTION AND FOSTERING METHODOLOGIES

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The Sutton Avian Research Center has completed three full years of captive breeding of the Attwater's prairie-chicken. There are numerous challenges and complexities of raising these birds in captivity. Typically, the eggs are incubated artificially and chicks have been raised by humans. Hand-raised chicks commonly exhibit increased mortality at 4 to 10 days old due to inanition – a lack of nourishment and vitality. Experiments were started in 2022 to foster chicks with adult prairie-chicken hens in an attempt to increase survival rates. Methods included 1) moving artificially incubated eggs and placing them under the hens to hatch; and, 2) placing chicks ranging from newly hatched to 16 days old under hens with broods for fostering. No inanition-based mortalities were observed for foster raised chicks, and the reduction in hand raising was a labor-saving benefit. Fostering contributed to a 65% chick production increase compared to 2021.

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UNDERSTANDING SHARP-TAILED GROUSE SUBSPECIES STATUS IN SOUTHCENTRAL WYOMING

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Sharp-tailed grouse (*Tympanuchus phasianellus*; hereafter STGR) are found in suitable grassland and shrubland habitat across northern North America. There are currently 6 extant subspecies, including Columbian (*T. p. columbianus*) and plains (*T. p. jamesii*), both of which are found in Wyoming. Within Wyoming, Columbian STGR can be found in Teton County; a second population in south-central Wyoming was historically thought to be Columbian STGR, however, recent evidence suggests otherwise. The objective of our study was to determine if south-central Wyoming STGR are Columbian, plains, or possibly a different subspecies of STGR. We collected morphological measurements and genetic samples from south-central Wyoming (unknown STGR; n = 430), eastern Wyoming (known plains STGR; n = 75), and eastern Idaho (known Columbian STGR; n = 108). Using a morphospace analysis and the Mahalanobis distance, we found that morphologically, the south-central Wyoming population was more similar to Columbian STGR than to plains STGR, though there was not much difference overall. Using a Structure analysis on microsatellite genotypes, we found that genetically, there was evidence for three groups. Additional genetic evidence suggests subpopulation structure within all sampled populations. Generally, the three identified groups represented Columbian, plains, and south-central Wyoming STGR, with some intermixing of populations. Our study suggests that Columbian and plains STGR represent separate subspecies, with the south-central Wyoming STGR not clearly fitting in with either Columbian or plains STGR.

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WHY DIDN'T THE CHICKEN CROSS THE ROAD? IMPACTS OF ENERGY DEVELOPMENT ON MOVEMENT AND SELECTION OF GREATER PRAIRIECHICKENS

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Many remaining grasslands are becoming increasingly fragmented by energy development. Structures associated with development can have important implications for wildlife populations as they may create barriers to movement or alter habitat selection. Our first objective in this study was to assess if greater prairie-chickens (*Tympanuchus cupido*), alter their movement behaviors (speed or direction of travel) or their habitat selection patterns relative to structures associated with oil and gas development using integrated step selection analysis (iSSA). Our second objective was to determine if changes in movement or selection behavior influenced the frequency at which greater prairie-chickens crossed roads or power lines. We assessed crossing rates by comparing the number of movements in observed greater prairie-chicken movement tracks that crossed these features to the number of movements that crossed these features in simulated movement tracks. Based on the iSSA analysis, we found that greater prairie-chickens avoided oil wells, power lines, and roads and altered their speed when near these structures but found little evidence for changes path tortuosity (direction of travel). Further, prairie-chickens crossed roads and power lines at lower rates than expected compared to simulated movement tracks. Consistent

avoidance of development resulted in indirect habitat loss for greater prairie-chickens, and the avoidance of linear features has the potential to reduce connectivity across the landscapes for this species.
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AN INTRODUCTION TO THE U.S. GEOLOGICAL SURVEY'S ANNOTATED BIBLIOGRAPHY OF SCIENTIFIC RESEARCH ON GREATER SAGE-GROUSE

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Multiple laws and policies require that planning and management decisions on public lands be informed by a foundation of relevant, high-quality science. However, the time and resources needed to review the high volume of science products available for some topics can make it challenging for managers to find and use. Our goal for this project was to develop annotated bibliographies that support and facilitate the use of science in public lands decision-making. We conducted a literature search of multiple databases from 2019–2022 on greater sage-grouse (*Centrocercus urophasianus*), and composed objective, unbiased summaries of products for a management audience. The annotated bibliography will be made available via a public-facing online platform where managers can search summaries by management topics and output results in a user-friendly format for easy use in environmental planning decision-making, including NEPA analyses. We have previously published annotated bibliographies for greater sage-grouse 2015–2019, ventenata (*Ventenata dubia*), and pygmy rabbits (*Brachylagus idahoensis*), and are currently working to develop an annotated bibliography on Gunnison sage-grouse (*Centrocercus minimus*).
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LINKING GREENESS (NDVI) TO LESSER PRAIRIE-CHICKEN REPRODUCTIVE HABITAT AVAILABILITY AND QUALITY

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Patterns of the Normalized Difference Vegetation Index (NDVI) have been associated with wildlife use for decades, but recent technological advances highlight its potential for identifying reproductive habitat quality over broad scales, particularly for the grassland-obligate lesser prairie-chicken (*Tympanuchus pallidicinctus*). Lesser prairie-chickens are an at-risk species that relies on healthy grassland to reproduce. We evaluated the potential of NDVI and NDVI-based phenology metrics to predict reproductive habitat selection and nest survival. Using cloud-free Landsat 8 satellite imagery, mean NDVI estimates were derived at > 70 nest locations from 2013- 2015 among two sites. Additionally, we evaluated the potential of 9 MODIS derived phenologymetrics to predict nest and brood habitat using values from 243 nest and 410 brood locations. Snapshot NDVI was not related to nest survival. However, amplitude and Maximum NDVI reliably predicted nest site and brood site selection, respectively. Nesting females selected sites with higher amplitude values and brood-rearing females selected sites with greater maximum NDVI. The selection for greater amplitude and maximum NDVI likely indicated greater food abundance and denser herbaceous cover at used locations than available. Our results suggest that NDVI phenology metrics have utility in predicting reproductive habitat within remaining grasslands.
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ACCELERATING TREE ENCROACHMENT THREATENS GROUSE HABITAT ACROSS THE U.S. GREAT PLAINS

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Tree encroachment is a growing conservation challenge for grassland biodiversity and habitat quality. In the U.S. Great Plains, tree encroachment shrinks remaining habitat for sage-grouse and prairie chickens,

which are particularly sensitive to even low abundances of trees. Applying new satellite technology, we show that the loss of grassland bird habitat to expanding tree cover is equivalent to known impacts from cropland cultivation. In total, a quarter of U.S. grasslands are being invaded by trees and grassland tree cover has increased by 50% in the last 30 years. In Montana alone, we find roughly 8.3 million acres of tree encroachment into rangelands, much of which overlaps with sage-grouse habitat and core areas. The irreversible conversion of vast expanses of southern Great Plains grasslands to woodlands is a call to action for the coalition of grassland bird communities. In the northern Great Plains, where tree cover is beginning to exhibit exponential growth, land managers must rapidly embrace a proactive and coordinated strategy to interrupt encroachment before the problem becomes insurmountable. Acting now can simultaneously achieve unified conservation goals of preserving grouse habitat and grassland connectivity, while promoting economically sustainable outcomes for working grasslands.
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FACTORS AFFECTING SURVIVAL OF ATTWATER'S PRAIRIE-CHICKEN BROODS

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Previous research identified poor survival of chicks as a primary bottleneck for recovery of the Attwater's prairie-chicken (APC). We evaluated the relative importance of 26 factors (weather and topography, habitat, plant phenology, time and site, hen characteristics) on APC brood survival to 2 weeks post-hatch (the period when chick mortality is highest) and on the number of chicks per brood at 6 weeks post-hatch (when chicks are capable of independent survival). Broods were most likely to survive to 2 weeks if they hatched between early and late May and were located within areas (1) that were treated to suppress red imported fire ants, (2) where vegetation produced intermediate values for maximum Normalized Difference Vegetation Index, and (3) that supported high invertebrate biomass. The number of chicks per brood surviving to 6 weeks post-hatch was maximized at values of the average Keetch-Byram Drought Index (during the first 0–2 weeks post-hatch) ranging from 200–400 which indicates moderately depleted soil moisture, but not severe drought. Our comprehensive analysis of factors affecting APC brood survival provides valuable information to guide management and recovery efforts for this species.
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DEMOGRAPHIC EFFECTS OF A MEGAFIRE ON LESSER PRAIRIE-CHICKENS IN THE MIXED-GRASS PRAIRIE

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Studies have documented benefits of small, prescribed fire and wildfire for lesser prairie chickens (*Tympanuchus pallidicintus*), but lesser prairie-chicken response to the scale and intensity of megafire (wildfire >40,000 ha) remains unknown. Limited available grassland habitat makes it imperative to understand if increasing megafire activity could reduce already declining lesser prairie-chicken populations. We leveraged demographic data from before (2014–2016) and after (2018–2020) a 2017 megafire in the mixed-grass prairie of Kansas, USA (Starbuck fire ~254,000 ha) and found a 67% decline in attending males on leks post-fire and a 46% decline in occupied leks. Adult female breeding season survival ($\hat{S}$) remained similar before ($\hat{S}$ = 0.63 ± 0.08 [SE]) and after the fire (0.61 ± 0.08), as did chick survival (before: 0.23 ± 0.07; after: 0.27 ± 0.11), while nest survival trended lower post-fire (before: 0.42 ± 0.06; after: 0.27 ± 0.07). Although we documented minimal effects on vital rates, reduced lesser prairie-chicken abundance and reproductive output suggest recovery may take >3 years. Increased propensity for megafire due to fire suppression, climate change, and woody encroachment may threaten lesser prairie-chicken populations.
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RELATING SAGE-GROUSE NEST SUCCESS AND AMERICAN BADGER OCCURRENCE IN SOUTH DAKOTA

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Nest success is a primary driver of sage-grouse populations, and predation is usually the leading cause of nest failure. We studied nest survival in relation to the mammalian predator community in South Dakota during 2016 and 2017. We fitted 76 female sage-grouse with VHF radio-collars and subsequently detected 71 nests. We deployed remotely triggered cameras at 48 of 71 nests (68%) to determine nest predators. Cause-specific nest failures could be determined for 12 of the 25 failed nests with cameras. American badger (*Taxidea taxus*) depredation caused 50% of known cause nest failures followed by coyote (*Canis latrans*) depredation, and abandonment. Since American badgers were the primary nest predator, we modeled their occurrence using data collected via remotely triggered camera stations located approximately 6.68 km apart (n=274). We then used presence only data (n=41) to model American badger habitat suitability. We extracted predicted probabilities of American badger presence for each nest and used in daily nest survival models. Neither the probability of American badger presence nor the presence of camera equipment explained significant variation in nest survival.
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MONTANA FISH, WILDLIFE AND PARKS HABITAT PROGRAMS FOR UPLAND GAME BIRDS

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Montana Fish, Wildlife and Parks has a long history of implementing habitat practices that benefit upland game birds on both public and private land. Since 1987, through its Upland Game Bird Enhancement Program, Habitat Montana program, Montana Sage Grouse Habitat Conservation Program and other wildlife habitat programs, Montana FWP and partners have conducted over 3,500 habitat projects. These projects protected, restored, or enhanced more than 1.8 million acres of habitat, provided over 5 million acres of hunting access, and expended over $143 million dollars to improve habitat for upland game birds and other wildlife. Practices have included nesting cover plantings, shelterbelts, grazing systems, aspen stand improvements, wetland enhancements, long-term leases of key habitats, perpetual conservation easements, and some permanent fee-title acquisitions. Most of these projects have been implemented with private landowners with a smaller number through coordination with public land managers. This discussion of program development, practices implemented, summary of key accomplishments, and future plans for the programs may provide insight to other upland game bird managers in their own implementation of habitat conservation programs.
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ORIGINS OF COLUMBIAN SHARP-TAILED GROUSE IN GRAND TETON NATIONAL PARK, WYOMING

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Sharp-tailed grouse (*Tympanuchus phasianellus*) are found throughout portions of northern North America, including the Intermountain West such as Grand Teton National Park (GTNP), Wyoming. This population was thought to be extirpated during the 1940's; during 2010, a single lek was found within GTNP (currently there are 2 known leks). Due to the reappearance of this population, the goal of our study was to determine whether the identified population was a remnant population that went undetected for 60–70 years or if individuals from the nearest population(s) repopulated the area. We collected tissue samples from road killed carcasses within the GTNP, tissue samples from hunter harvested wings in in Idaho, blood samples from Carbon County, Wyoming, and blood samples from eastern Wyoming. We used whole genome sequencing and will generate a maximum likelihood phylogenetic tree to identify the

ancestry of the GTNP population. Understanding the ancestry of this population could provide a greater understanding of mountains driving vicariance of sharp-tailed grouse populations throughout the Intermountain West, which will help us improve population level management of this species.
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INVESTIGATING THE USE OF GRAZING DISTURBANCE TO RESTORE HABITAT FOR THE LESSER-PRAIRIE CHICKEN

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Anthropogenic influences (e.g., energy production and rangeland conversion) have fragmented and degraded the lesser prairie-chicken's (*Tympanuchus pallidicinctus*, LPC) habitat range wide. This project is focused on a 320-acre parcel of land in southern Roosevelt County, New Mexico that was once used for crop and oil and gas production before being allowed to naturally revegetate with native plant species. Previous land use has left soil health in poor condition and allowed for the invasion of undesirable plant species, resulting in high measures of bare ground throughout. The objective of this study is to determine if a high intensity/short duration grazing system can be economically and ecologically feasible in a low-rainfall area, and ultimately restore the property to suitable habitat for the LPC. From 2018 through 2022, we have utilized daily paddocks to move cattle through the test plot; cattle are then moved to the control plot to graze in the landowner's traditional pattern before the property enters a 10-month period of rest. Thus far, the system has been economically feasible. Ecologically, we have found a more stable response in desirable native species on the test plot in years of low rainfall. However, we have not reduced invasive species occurrence. We plan to continue our research in the coming years to better identify quantifiable trends with climatic variability.
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LESSER PRAIRIE-CHICKEN MOVEMENTS UNDER PATCH-BURN AND ROTATIONAL GRAZING MANAGEMENT

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Understanding lesser prairie-chicken (*Tympanuchus pallidicinctus*) response to different land management practices is necessary for continued viability of the species. Both patch-burn and rotational grazing practices are used by ranchers within the lesser prairie-chickens' range, creating different grazing distributions that result in spatially varying vegetation composition and structure across the landscape. Patch-burn grazing creates a more heterogeneous landscape of vegetation composition and structure, increasing the capacity of landscapes to provide all required habitats within a smaller area than rotational grazing. These conditions could decrease daily and total movements by lesser prairie-chickens, resulting in overall higher quality habitat. We hypothesized that under patch-burn management, birds would travel less to meet their daily resource needs; thus, average daily displacements would be smaller than on rotationally grazed land. We used data from 54 individual lesser prairie-chickens fitted with satellite transmitters between 2013 and 2019 in the Red Hills region within the Mixed-Grass Prairie Ecoregion of Kansas. We compared movement metrics between adjacent patch-burn and rotationally grazed ranches in Kiowa and Comanche counties. We applied a novel Bayesian nonstationary continuous-time animal movement model to estimate the birds' movement trajectories and compute movement descriptors including average daily displacement. We found that birds spent more time on average in patch-burn than rotational treatments, and that movement metrics differed between grazing treatments. Our results provide insight on lesser prairie-chicken response to different grazing management strategies within the Mixed-Grass Prairie Ecoregion.
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SUGGESTED PREVENTATIVE MEASURES TO LIMIT OLD-WORLD BLUESTEM INVASION OF THE NORTHERN GREAT PLAINS

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Caucasian bluestem (*Bothriochloa bladhii*) and yellow bluestem (*B. ischaemum*), together called Old World bluestems (OWB), are Eurasian/African mid-grasses deliberately introduced in the Southern Great Plains (SGP) in the early 1900's. They were widely seeded in the early years of the Conservation Reserve Program in Texas, Oklahoma, and New Mexico. Both are highly invasive and capable of transforming diverse native grassland ecosystems into monocultures, greatly reducing both forage and wildlife-habitat quality. The metastatic spread of OWB within and beyond the SGP has been facilitated by mowing, haying, hay transport, vehicles, and contaminated seed mixtures. Initial OWB establishment is typically along roadsides or in areas where hay is stored or fed. Once established in pastures, OWB coverage can increase 15% per year and become nearly impossible to eliminate. OWB could soon invade the Northern Great Plains (NGP) as winters become warmer with climate change. States, federal agencies, and conservation organizations in the NGP should proactively designate OWB as noxious, establish preventative surveillance protocols, and initiate educational programs to raise awareness of this threat. Once found, OWB infestations should be immediately killed, GPS marked, and seed heads carefully removed and destroyed. Surrounding areas should be checked for additional plants. Frequent follow-up monitoring and treatment over multiple years is necessary to eliminate even small infestations. Prevention remains possible on the NGP and is the only practical option.

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NEONICOTINOID PREVALENCE IN SHARP-TAILED GROUSE AND GREATER PRAIRIE-CHICKENS ALONG AN AGRICULTURAL GRADIENT

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Neonicotinoids have been detected in many wild birds; however, few studies have attempted to quantify population-level exposure. We examined population-level exposure to 7 neonicotinoids in sharp-tailed grouse and greater prairie-chickens in Minnesota, USA. We sampled fecal pellets at leks in spring and collected livers from hunter-harvested birds in fall. Most (93%) sharp-tailed grouse and (80%) prairie-chicken fecal pellets had detectable concentrations of >1 neonicotinoid. Similarly, most (90%) sharp-tailed grouse and (76%) prairie-chicken livers had detectable concentrations of >1 neonicotinoid. Imidacloprid (IMI) and clothianidin (CLO) were most commonly detected. Spring concentrations of IMI in fecal pellets of both species increased with the proportion of a 2-km buffer in cultivation surrounding sampling locations and detections occurred along the entire gradient of cultivation intensity. Spring CLO concentrations increased with Julian date in prairie-chickens, as expected with the progression of spring planting. In contrast, neonicotinoid detections from livers were not related to the proportion of area in cultivation. Fewer crops are planted in the fall and grouse may be exposed through routes other than treated seeds. High detections, even in areas with little cultivation, likely reflect selection of cultivated fields for food, but may also indicate that exposure risk extends beyond sites of application.

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SHARP-TAILED GROUSE RESPONSES TO FALL PRESCRIBED FIRE AND MOWING

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We examined sharp-tailed grouse responses to prescribed fire and mechanical treatment in the fall during 2015-2021 in northwestern Minnesota. We surveyed sharp-tailed grouse use and measured vegetation at 16 mowing/shearing treatments, 12 prescribed burns, and also at 22 control sites. We conducted fecal pellet transects and documented sharp-tailed grouse observed 0–28 (mean 9.1) days before management, and 1 week, 1 month, 1 year, and 3 years after management. Sharp-tailed grouse use increased following prescribed fire but did not change after mowing. Increased sharp-tailed grouse use following prescribed fire was temporary. Changes in vegetation metrics were also temporary with most metrics returning to pre-treatment levels after 1 year, although shrub height at mowed sites returned more slowly and the forb response at fall prescribed fire sites persisted >3 years. We suggest that prescribed fire is more effective at

increasing sharp-tailed grouse use of sites, perhaps due to cues associated with fire that attract sharp-tailed grouse. However, mowing and shearing are important to maintain sharp-tailed grouse site use, otherwise, woody encroachment reduces sharp-tailed grouse habitat, and fall prescribed fires had no measurable effect on shrubs. Thus, prescribed fire and mowing/shearing produced different sharp-tailed grouse and vegetation responses in the fall and should be applied to meet different management goals.
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PRIVATE LANDS STEWARDSHIP IN THE FLINT HILLS ECOLOGICAL REGIONIMPLICATIONS TO GREATER PRAIRIE-CHICKENS

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Private lands dominate the prairie grouse ranges in the United States making private landowners crucial for prairie grouse conservation. In 2010, we began to implement additional tallgrass prairie stewardship practices within a large production agriculture operation. This led us to seek collaboration with colleagues experienced in tallgrass prairie management and particularly those with experience researching species of conservation concern. This collaboration resulted in research addressing management questions and almost real time integration of data into our land management. Results include an increase in plant diversity, a 3-fold increase in greater prairie chicken density, and a notable increase in other grassland birds such as Henslow's Sparrow. Further, we were able to make management changes without negatively affecting our business model. Ranch personnel and researchers remain engaged, communicate effectively, and develop adaptive management strategies during research activities. However, weather variability, market volatility, management flexibility, and the lack of confidentiality protecting mechanisms at the state level remain as challenges and barriers for private landowners who may wish to participate in conservation collaborations.
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INVASIVE ANNUAL GRASSES AND FIRE IN THE WEST: NEW INSIGHTS FROM REMOTE SENSING

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Rapidly expanding invasive annual grasses pose an urgent threat to sagebrush ecosystems of western North America where they displace keystone shrubs, alter natural fire regimes, and contribute to catastrophic wildfires. The accelerating loss and degradation of sagebrush ecosystems resulting from positive feedbacks between invasive annual grasses and fire is increasingly seen as an existential threat to sagebrush obligate wildlife such as sage-grouse. Halting this ecosystem transformation has vexed managers for decades. Using new, dynamic, remotely-sensed rangeland vegetation datasets, we track the 8-fold expansion of invasive annual grasses over the past 3 decades in the Great Basin, develop a fuels-based predictive fire forecasting tool, and refine our understanding of the relative contributions of biotic and abiotic factors in determining resistance to annual grass invasion and resilience following fire. Together, these insights will help managers target their efforts in the right places to maximize benefits to sagebrush ecosystems and sage-grouse habitat.
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LANDSCAPE-BASED EVALUATION OF HABITAT SUITABILITY FOR RIORITIZING LESSER PRAIRIE-CHICKEN CONSERVATION IN THE MIXED-GRASS PRAIRIE

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Populations of lesser prairie-chickens (*Tympanuchus pallidicinctus*, hereafter "prairie-chickens") in the mixed-grass prairie ecoregion of the southern Great Plains are projected to go extinct in the next 100 years unless targeted conservation efforts are implemented to increase the size and connectivity of subpopulations through either translocation or habitat restoration. To expand on current conservation efforts, we used ensemble approaches to identify habitat for potential prairie-chicken conservation. We developed lek-based relative habitat suitability models within the mixed-grass prairie ecoregion using both resource selection functions and Random Forest classification trees and calculated ensembled predictions of relative habitat suitability across all models. Next, we conducted a least-cost path analysis to identify potential corridors connecting potentially suitable, unoccupied habitat to current subpopulations. Ensembled predictions identified 4,526 km^2 of potential prairie-chicken habitat both occupied and unoccupied. We identified three contiguous areas of potentially suitable and unoccupied habitat (28 – 74 km^2) that could potentially harbor a self-sustaining population. However, least-cost path analyses revealed a low degree of connectivity between areas of occupied and unoccupied habitat indicating a low probability of recolonization. Our ensembled predictions should assist future reintroduction and habitat restoration plans by identifying habitat conditions that predict the presence of prairie- chicken leks in the mixed-grass prairie ecoregion.

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A DEEP DIVE INTO THE GENETIC DIVERSITY OF GREATER AND LESSER PRAIRIECHICKENS

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Landscape management and climate change have resulted in the expansion of Greater and Lesser Prairie-chicken (*Tympanuchus cupido* and *T. pallidicinctus*, respectively) ranges and created a zone of sympatry in central Kansas. Within this region, hybrid leks have been observed to occur, and hybridization between the two species is suspected. With the recent US Fish and Wildlife Service proposed listing rule for the Lesser Prairie-chicken, understanding the potential management implication of hybridization is critical. We used two types of analyses to investigate the possible implications of hybridization on the distinctiveness of Greater and Lesser Prairie chickens. Using a set of 12 rapidly evolving microsatellites we anticipate finding distinct alleles amongst the various species due to the rapid response in species to their environments. We are currently in the process of further exploring this dynamic using a whole genome sequence approach. This approach will allow us to delve more deeply into the coalescent history of the two species, to better understand the implications of hybridization on the distinctiveness of the two species.

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ASSESSMENT OF LESSER PRAIRIE-CHICKEN TRANSLOCATION THROUGH DEMOGRAPHICS, SPACE USE, AND RESOURCE SELECTION

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The Sand Sagebrush Prairie of southwestern Kansas and southeastern Colorado historically supported the largest density of Lesser prairie-chickens (*Tympanuchus pallidicinctus*), with estimates of 86,000 birds in the 1970s. By 2016, an estimated 1,479 birds remained. To supplement this population, 411 lesser prairie-chickens (204 males and 207 females) were translocated to the Cimarron (KS) and Comanche (CO) National Grasslands from 2016-2019. We equipped translocated birds with 279 VHF and 115 SAT-PTT transmitters. Nearly 23% of translocated birds died or went missing 2 weeks after release. Post dispersal, overall adult and nesting survival of translocated birds were decreased but comparable to previous estimates, however nesting survival decreased greatly in 2020. Lek counts decreased after translocation cessation by 24% in 2020 and 43% in 2021. After dispersal, translocated home range areas were similar

to those previously studied, however translocated home ranges remained large in the nonbreeding season. Translocated birds used Conservation Reserve Program (CRP) more than what was available. Overall, National Grassland use was low due to dispersal; however, primarily males used Comanche more than Cimarron. This translocation had short-term success but current results indicate uncertainty around population persistence.

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ASSESSMENT OF LESSER PRAIRIE-CHICKEN HABITAT IN THE SAND SAGEBRUSH PRAIRIE

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Populations of lesser prairie-chickens (*Tympanuchus pallidicinctus*) in the Sand Sagebrush Prairie Ecoregion of southwest Kansas and southeast Colorado, USA, have declined sharply since the mid-1980s. Decreased habitat quality and availability are believed to be the main drivers of declines; however, no broad-scale assessment of landscape change has been conducted for the ecoregion. Our objectives were to reconstruct landscape-scale change in the ecoregion since 1985, and assess changes in vegetation structure and composition relative to management goals. We assessed landcover change and calculated landscape metrics using LCMAP layers and documented presence of anthropogenic structures including oil wells and transmission lines. We also compared historical and contemporary fine-scale vegetation survey data. Vegetation land cover and tree occurrence changed little since 1990. However, oil and gas wells increased by 88% and transmission lines increased by 237%, causing functional habitat loss as a result of displacement of lesser prairie-chickens. Quality vegetation structure has declined on Comanche National Grassland since 1985. Increased anthropogenic structures and decrease in vegetation vertical structure appears to have decreased available habitat as well as the quality of existing habitat for lesser prairie-chickens.

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ATYPICAL PRIMARY MOLT PATTERNS IN GREATER SAGE-GROUSE: IMPLICATIONS FOR AGE CLASSIFICATION

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Age-specific patterns of primary molt facilitate age classification of native North American upland gamebirds, a critical step in understanding their ecology, behavior, life history, population dynamics and harvest. However, deviations from typical molt patterns can create confusing plumages that complicate age classification. We examined data from live-captured greater sage-grouse *Centrocercus urophasianus* across seven studies in five U.S. states and wings from harvested birds in Oregon and Colorado for evidence of atypical primary molt. We documented atypical replacement through primary nine during preformative molt, atypical retention of juvenile primary 10 during second prebasic molt, and atypical retention of basic outer primaries during definitive prebasic molt. Atypical primary molts were observed more often in live-captured females (3.2%, n = 561) than males (0.8%, n = 494). Many individuals with atypical primary patterns, especially females, are difficult or impossible to reliably age by plumage or morphology and may bias research and harvest data.

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LONG-TERM POPULATION MONITORING OF SHARP-TAILED GROUSE IN NORTHEASTERN BRITISH COLUMBIA, CANADA: A FOCUS ON THE EFFECT OF WEATHER

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Populations of the plains subspecies of sharp-tailed grouse occur sporadically in the natural grasslands, shrub-steppe habitats, and agricultural areas of the Peace Lowlands in northeastern British Columbia, Canada. A long-term monitoring program was established to assess sharp-tailed grouse populations in two study areas with different habitat types and land uses: (1) native grassland and shrub-steppe habitats and (2) agricultural-dominated habitats. Between 2003 and 2022, annual lek surveys were conducted to measure lek attendance and lek density. Since 2003, there has been a significant decline in both lek attendance and density. I examined the effects of seasonal weather conditions (precipitation, temperature, and snowfall) on annual lek attendance. There was a significant positive relationship between lek attendance and snowfall during the nesting and winter season in the year prior to lek surveys. There was no evidence of weather effects during the brood-rearing period on the following year's lek attendance. These results suggest weather conditions contribute to annual population fluctuations. However, changes in habitat quality and distribution across the landscape since 2003 have likely contributed to population declines. I recommend that future analyses investigate the role of habitat change and the potential interaction between weather and habitat at a local and landscape scale.
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POSTER PRESENTATION ABSTRACTS

ATTWATER'S PRAIRIE CHICKEN RELEASE SITE CHARACTERISTICS, CONSIDERATIONS, AND CONCERNS

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Recovering Attwater's prairie-chicken (APC) will require restoring large habitat expanses, and releasing APCs on them. Our objective is to present release site characteristics important to recovering APCs. Since 1996, the U.S. Fish & Wildlife Service (USFWS) has released APCs on Attwater Prairie Chicken National Wildlife Refuge (refuge) in Colorado County, TX. Beginning in 2007, USFWS partnered with The Nature Conservancy and private landowners to release APCs on private ranchlands. While populations at the release sites are not viable, APCs released at each location have successfully produced offspring, which enjoy survival rates we expect of wild APCs. We are now considering desirable future release site characteristics including habitat patch size, genetic exchange potential, resiliency, management sustainability, and incompatible land use prevention. Ideally, potential release sites would include APCprioritized habitat ownerships amidst broad, perpetually protected, privately owned, APCcompatible land uses. Endowments funding habitat management could perpetually maintain protected habitat. Distribution of several populations along the coast extending inland could provide redundancy with adequate proximity for genetic exchange and the potential for recolonization of areas within the historic range.
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USE OF WATER BIRCH BY WINTERING SHARP-TAILED GROUSE IN NORTHCENTRAL WASHINGTON

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Sharp-tailed grouse (*Tympanuchus phasianellus*) in north-central Washington depend on shrubsteppe for year-round survival, and deciduous trees and shrubs during the snowiest times of the winter. In north-central Washington these habitats have been severely impacted by habitat conversion, degradation, and wildfire. Standardized lek counts have been used to monitor breeding populations, but observations of birds during winter have been opportunistic and anecdotal. For four straight winters (15 Dec-10 Mar), starting in 2017–2018, trail cameras were used to monitor areas of water birch, a tree species which appears to be critical for grouse in Washington. Cameras were placed for a total of about 11,500 daylight hours in 50 different locations within 23 water birch sites. Grouse were observed a combined total of 128 of those observation hours. Assessment of photos provided information on diurnal use (heaviest about 1 hour after sunrise), flock size (up to 25 birds), and distribution (observations of birds in areas with no known leks). These observations have subsequently aided our management efforts.
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CLASSIFICATION OF SAGE-GROUSE MOVEMENT MODES TO ACCOUNT FOR BEHAVIOR IN HABITAT-RESPONSE RESEARCH

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Greater sage-grouse have movement modes that constantly change to promote survival and reproduction. We evaluated the use of detailed movement properties to identify modes important for behavior-specific habitat responses such as survival or resource selection. We equipped 86 female sage-grouse with GPS transmitters that were programmed to record 4 locations per day. We calculated 7 movement properties during all sage-grouse phenological stages for up to 4 years per individual. We then used the 7 movement properties and statistical clustering to identify 8 distinct movement modes. One mode clearly represented exploratory movements and another mode clearly corresponded to incubating. The 6 other modes were less distinct but interpretable based on unique timing and correspondence with environmental variables. Detailed movement data can be used to identify movement modes to improve the behavior-based structure of habitat response models. For instance, the exploratory mode can be used to filter out transit or searching forays that contaminate other behavior or phenology modes such as brooding, summer ranging, and winter ranging. Behavior mode identification could also be used to remotely sense nesting behavior if nest site visitation were not possible.
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DEVELOPING AERIAL SURVEY PROTOCOLS FOR PRAIRIE GROUSE WHERE MIXEDSPECIES LEKS OCCUR

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Aerial surveys have been proposed as an alternative to ground counts of prairie grouse. Where mixed-leks occur, using aerial infrared imagery (AIR) to determine grouse species may present challenges. Our objectives were to compare aerial versus ground counts of displaying males, females, and total grouse of greater prairie-chickens, sharp-tailed grouse, and mixed-leks. We conducted surveys in Grand Forks County, ND and Polk County, MN in April 2022. We conducted flights with fixed wing aircraft equipped with a high-resolution dual infrared/electrooptical gimbal simultaneously with ground counts. We completed 15 double counts at prairiechicken (n = 7), sharp-tail (n = 5), and mixed (n = 3) leks. The airplane conducted a blind survey to determine lek locations and compare detection rates between ground observers and thermal imagery. The airplane detected 60 birds at 6 leks. This is the first time AIR has been used to differentiate greater prairie-chickens and sharp-tail grouse, we suggest that AIR is a feasible method to conduct counts in mixed-species landscape.
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DEVELOPING METHODS FOR PRODUCING UNBIASED POPULATION ESTIMATES FOR THE "PRAIRIE GROUSE OF THE MOUNTAINS"

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Dusky grouse (*Dendragapus obscurus*) are the "prairie grouse of the mountains" (D. Dahlgren; PGTC 2019), but unlike their kin, no rigorous state-wide monitoring programs currently exist. Our objective was to evaluate sampling and analytical methods for producing annual unbiased state-wide estimates of population size. We compared point-counts vs. transect surveys, route type, and whether electronic playback increased detection. We evaluated and compared Nmixture models for point-counts and hierarchical distance sampling models for both point-counts and transect surveys. We used pilot data to obtain baseline estimates of probabilities of detection and abundance from hierarchical N-mixture and distance sampling models to inform our simulation study. We conducted simulations with different survey designs under different abundance and detection scenarios to evaluate the ability of our estimators to produce unbiased and precise abundance estimates. We found spring surveys with electronic playback had the highest probability of detection, and that surveys located along roads/trails best balanced the trade-offs between sampling effort and survey design requirements. For accurate state-wide population estimates, simulations using N-mixture models indicated that 300 point-counts with 4 repetitions or 1,700 point-counts using hierarchical distance sampling were needed. Our results will inform methods for state-wide monitoring in Montana and illustrate a process applicable for developing dusky grouse monitoring elsewhere.

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OFFSRPING OF TRANSLOCATED INDIVIDUALS DRIVE THE SUCCESSFUL REINTORODUCITON OF COLUMBIAN SHARP-TAILED GROUSE IN NEVADA AND QUANTIFYING THE IMPACTS OF TRANSLOCATION ON SOURCE POPULATIONS

S. R. MATHEWS, U.S. Geological Survey, Reno, NV 89515 and Idaho State University, Pocatello, ID 83209

Successful avian translocations blend effective translocation methodologies with animal behavior. We performed a reintroduction of Columbian Sharp-tailed Grouse (CSTG; *Tympanuchus phasianellus columbianus*) in Nevada and performed three Greater Sage-Grouse (GRSG; *Centrocercus urophasianus*) translocations (California, Utah, and North Dakota) and tested traditional (i.e. pre-nesting) and novel (i.e. brood translocations) translocation methodologies as part of ongoing conservation projects. Use of integrated population models in a Bayesian hierarchical framework revealed that CSTG chicks hatched at the release site demographically exceeded their translocated progenitors, which resulted in the successful restoration of an extirpated population. With GRSG, we tracked individuals at augmented, source, and at neighboring control sites in a Before-After-Control-Impact (BACI) design to elucidate the benefit of translocations on population growth (λ). The translocation of females with broods resulted in increases of λ by 11 – 30% over traditional translocation methods, which produced higher λ estimates than if no translocations were conducted. Both translocation methodologies resulted in small reductions of λ in source populations. Our results from CSTG translocations in Nevada indicated that chicks of translocated individuals drove the successful population restoration project, and results from our brood translocations significantly increased λ in augmented populations compared with translocation of pre-nesting females. These findings are preliminary, provided for timely science communication and are subject to change.

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THE IMPLICATIONS FOR CONSERVATION AND MANAGEMENT WHEN THREE DISTINCT GROUSE SPECIES ARE FOUND IN A SINGLE MORPHOSPACE

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The prairie-grouse species, Greater Prairie-Chicken, Lesser Prairie-Chicken, and Sharp-tailed Grouse found in the Great Plains and Intermountain West of the United States are considered unique based on distribution, physical appearance, and behavior but when they occur sympatrically have been observed to hybridize, increasing phylogenetic complexity. We employed a standard morphospace analysis, a common approach in paleontology, that uses evolutionary derived physical attributes to evaluate the uniqueness of the Bauplan of species. We used 28 morphometric features and ratios commonly applied to extant taxa to investigate the morphological distinctiveness of prairie-grouse with Northern bobwhite quail as an out-group. Ordered principal components analysis explained 80% of the variation in morphospace of each species in the analysis and identified bobwhite as having a distinct morphospace from the three prairie-grouse species. Similarly, the morphospace analysis provided weak support for Sharp-tailed grouse as occupying distinct morphospace but did not recognize a significant difference in the Bauplan of the Greater and Lesser Prairie-chickens. The principal component analyses show two morphospecies of *Tympanuchus* grouse: Sharp-tailed Grouse and the prairie-chicken, but recent co-ancestry and homoplasy should be considered before making any determinations.
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INVESTIGATING THE UTILITY OF SOIL PROPERTIES AND VEGETATION MONITORING DATA FOR SAGE-GROUSE HABITAT MANAGEMENT

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The greater sage-grouse is a species of conservation concern requiring collaborative, range-wide efforts to understand and conserve sagebrush steppe habitats. However, local variation in soil and vegetation characteristics have demonstrated a need for region specific investigation of sage-grouse nesting habitats. We investigated the utility of existing rangeland monitoring protocols for sage grouse habitat management through vegetation and soil data collected at sage-grouse nests. Local habitat inferences may be gained through identification of the relationships between sage-grouse nest success, soil properties, and vegetation data as collected by the Assessment, Inventory and Monitoring (AIM) protocol used by land managers across the sage-grouse range. Of particular interest are the soil properties that produce the vegetation associated with sage-grouse nest sites and nest shrubs in a small-scale heterogenous region of north-central Montana. Shrub morphology is important for sage-grouse nest concealment and may be an important factor influencing nest success. Shrub morphology and density may be associated with local soil properties including: soil depth, texture, pH, organic matter, electrical conductivity (EC) and sodium absorption ration (SAR). We anticipate gaining an understanding of region-specific soil and vegetation properties associated with sage-grouse nests to potentially provide local land managers the ability to utilize existing, multiple-use rangeland monitoring data for region specific sage-grouse habitat management.
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COMPARATIVE EVALUATION OF TRANSMITTERS TO INFORM PRAIRIE GROUSE MONITORING

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The Motus Wildlife Tracking System is a collaborative research network that uses automated radio telemetry arrays to record transmitter detections remotely and distribute the data to researchers through the Motus database system. While Motus technologies have successfully been utilized to track the phenology and large-scale habitat use of migrating birds via Motus towers placed strategically worldwide, they have not yet been assessed for use in evaluating finescale space use, particularly of ground-dwelling birds. Our goal is to estimate the accuracy, precision, detection rates, and effective detection distances of Motus technology relative to standard VHF radio telemetry technology. We will evaluate how these measures of performance vary in relation to environmental and topographical conditions associated with prairie grouse seasonal habitat use by deploying 100 transmitters of each type randomly across four habitat strata in areas representative of sharp-tailed grouse habitat in western Montana. Field technicians who are unaware of the transmitter locations will use handheld receivers to triangulate transmitters. Additionally, we will test detection ranges of Motus towers to stationary groundlevel targets by placing Motus transmitters at known distances and orientations from the Motus stations. Motus transmitters broadcast multiple times per minute and will be deployed during a 1- month period. We will use a GLM or GLMM to evaluate whether the measures of transmitter performance differ in relation to habitat strata for both the handheld triangulations and Motus tower detections. Our overarching objective is to assess the potential of Motus technology for evaluating space use and habitat selection of reintroduced sharp-tailed grouse in western Montana.

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IMPROVEMENTS TO WALK-IN TRAPS FOR CAPTURING PRAIRIE GROUSE ON LEKS

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For decades, various designs of walk-in traps have been used for capturing prairie grouse for relocation and telemetry studies. The basic design is a series of circular wire traps, each containing one or more funnel openings, usually attached to drift fences arranged in a large “W” manner across a prairie grouse lek. We will present some significant modifications we have developed, over the course of many years, to improve capture rate as well as detect captured birds when visibility of traps is limited. Other researchers and managers involved with the study or translocation of sage-grouse, sharp-tailed grouse, and prairie-chickens may also find these modifications advantageous, and some of these modifications may be applicable to other study species as well.

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Sage and Columbian Sharp-tailed Grouse Workshop

The Utah Division of Wildlife Resources hosted 163 participants at the Western Association of Fish and Wildlife Agencies (WAFWA) Sage and Columbian Sharp-tailed Grouse Workshop in Logan, Utah, USA during 15–18 August 2022. Although there was an attempt to hold this meeting in Bend, Oregon in 2020 and again in 2021, the Oregon Department of Fish and Wildlife ended up hosting a virtual meeting in 2021. There were 53 oral and poster presentations spread out over three days with a fieldtrip to sharp-tailed grouse (*Tympanuchus phasianellus*), dusky grouse (*Dendragapus obscurus*), and greater sage-grouse (*Centrocercus urophasianus*) habitat in northern Utah. It was the first time the group had meet in person and participants were very happy to attend. The list of presentations, including abstracts, follows.

Michael Schroeder, Chair, Grouse Group within the IUCN-SSC Galliformes SG (GSG)
Washington Department of Fish and Wildlife, P.O. Box 1077, Bridgeport, WA 98813 USA, Michael.schroeder@dfw.wa.gov.

Searching for Columbian sharp-tailed grouse leks using a UAS equipped with thermal camera; lessons learned in year one.

Atamian, M. T., and C. L. Lowe.

Abstract: We assessed viability of the DJI Mavic 2 Enterprise Advanced, a mid-cost UAS equipped with a thermal camera, to conduct Columbian sharp-tailed grouse (CSTG) lek searches in central Washington following a 127,430ac wildfire in 2020. Searches were a priority as most lek sites were abandoned within the fire perimeter. Trial flights were conducted at one remaining active lek to determine CSTG response to the UAS and thermal visibility at various altitudes (100–400ft agl). These flights confirmed thermal visibility of CSTG up to 400ft agl, but their heat signature was small (1–5 pixels). CSTG froze whenever the UAS was flying overhead regardless of altitude, but only flushed when the UAS was <150ft agl. CSTG typically resumed displaying within 30–60s if the UAS stopped and hovered. If females were present males continued to display even with the UAS moving and as low as 250ft agl. Based on trial flights we conducted lek searches at 300ft agl and 6mph, wherein we could cover up to 60ac per battery; however, coverage decreased with number of targets investigated. No CSTG were detected during the searches conducted this season. Although CSTG are detectable with thermally equipped UAS, auditory lek searches are likely more efficient at this price point.

Sage-grouse brood-rearing habitat within the Great Basin region of Nevada and California: observations and inference from multi-scale modeling of habitat selection and survival.

Brussee, B. E., P. S. Coates, S. T. O'Neil, M. C. Milligan, J. P. Severson, M. A. Ricca, S. Abele, J. D. Boone, E. M. Ammon, S. T. Mathews, S. Espinosa, S. Gardner, M. L. Casazza, and D. J. Delehanty.

Abstract: During brood-rearing, Greater sage-grouse (*Centrocercus urophasianus*; hereafter, sage-grouse) migrate from nesting habitat to heterogeneous upland meadows that hold moisture and support important food resources. Brood-rearing habitat may become fragmented with widespread habitat loss across the range due to invasion of annual grasses, conifer expansion, and anthropogenic development. We sought to understand impacts of habitat alterations on sage-grouse brood habitat as these disturbances threaten long-term productivity and population maintenance. Within a large-scale study of brood-rearing habitat across the Great Basin, increasing annual grass negated positive effects of burned areas on sage-grouse broods resulting in reduced survival when annual grass was dominant, highlighting the importance of heterogeneous vegetation communities for sage-grouse broods. Within the Bi-State Distinct Population Segment, brood-rearing sage-grouse likely face trade-offs, wherein the need to access forage resources in high elevation mesic areas may necessitate weakened avoidance of conifers, with consequences to survival. The importance of mesic resources, especially during dry years, was also evident within the Long Valley population of the Bi-State, demonstrating the implications of large-scale water manipulation within sage-brush ecosystems. Taken together, these findings shed light on the influences of landscape changes and fragmentation on sage-grouse brood-rearing habitat. Information is preliminary and provided for best timely science.

Patterns of structural connectivity in the sagebrush biome (1985–2018).

Buchholtz, E. K., J. A. Heinrichs, M. S. O'Donnell, and C. L. Aldridge.

Abstract: The sagebrush biome has been reshaped by disturbances such as fire, invasive grasses, and human development, but few analyses have assessed where connected sagebrush has been lost or spatially constrained. We used an omnidirectional circuit theory approach to classify structural connectivity patterns in the biome between 1985 and 2018. By comparing these connectivity patterns over time, we mapped trends in increasing and decreasing connectivity. Over the 32-year timespan, we found that 35% of the biome had consistently high connectivity, and 36% of the had consistently low connectivity. We also assessed connectivity patterns within and among Priority Areas for Conservation (PACs) and found that the area within PACs had on average higher connectivity than areas outside of PACs, that connectivity increased within PACs over time, and over half the available area within PACs had consistent, high connectivity between 1985 and 2020. These findings can help characterize opportunities for proactive conservation of remaining structural connectivity of sagebrush across the biome and identify degraded areas where targeted management could increase connectivity, offering benefits to sage grouse and other sagebrush-associated wildlife species.

Evaluating habitat-related and anthropogenic drivers of post-release movements for translocated greater sage-grouse (*Centrocercus urophasianus*) in the Sheeprock Mountains of central Utah.

Chelak, M. S., S. Picardi, and T. A. Messmer.

Abstract: Utilizing GPS technology in translocation programs aids in monitoring behavioral issues, such as movement and dispersal, and can help adaptively manage protocols. To prevent extirpation of a greater sage-grouse (*Centrocercus urophasianus*) population in central Utah, we translocated 146 individuals during the springs of 2016-2019 from two populations within the state. Using data from 38 translocated individuals marked with GPS transmitters, we segmented individuals' movement tracks from 2017 to 2020 into two homogeneous behavioral phases: restricted and exploratory. We then ran a seasonal movement-based habitat selection analysis with each behavioral state that included relevant habitat covariates, such as sagebrush, grass, and tree cover, as well as less commonly-used covariates, such as relative predator abundance and off-highway vehicle traffic volume, to model their effect on sage- grouse movement and habitat selection. Sage-grouse in the restricted behavioral phase selected a more favorable habitat each season than the exploratory individuals. During certain seasons, individuals in the exploratory state were more likely to select habitat with higher road density and closer to roads, lower sagebrush cover, and higher annual grass cover. These findings may inform future sage-grouse translocations in this area and provide a case study of accounting for behavior in post-release monitoring.

Effect of juniper expansion on avian abundance in aspen and sagebrush areas in southeastern Oregon.

Christensen, C. E., V. M. Schroeder, S. J. Wolfe, H. Higgins, D. D. Johnson, and J. B. Dinkins.

Abstract: Since the late 19th century, juniper (*Juniperus occidentalis*) has expanded into areas previously dominated by sagebrush (*Artemisia* spp.) and aspen (*Populus tremuloides*) plant communities, resulting in habitat loss for many avian species. Generally, in sagebrush plant communities, the abundance of shrub and ground-nesting birds decreases with juniper expansion while the abundance of cavity and tree-nesting birds increases. However, areas where sagebrush and juniper are co-dominant support greater avian diversity compared to areas where only one is dominant. The impact of juniper expansion on avian abundance in aspen plant communities is relatively unknown. We evaluated the influence of juniper expansion on avian species' abundance in sagebrush and aspen plant communities in the Steens Mountain area, Oregon. We compared avian communities in sagebrush and aspen areas across a gradient of juniper woodland succession using point count data from 2020–2022. We also compared abundance of Brewer's sparrows (*Spizella breweri*), a sagebrush-obligate songbird shown to tolerate early successional stages of juniper expansion, using data collected from autonomous recording units (ARUs) deployed from 2020–2022. These preliminary evaluations will guide land management considering multiple coexisting avian species in the sagebrush ecosystem that may require similar or conflicting habitat resources.

The effectiveness of habitat restoration and conservation actions on greater sage-grouse population dynamics within the bi-state distinct population segment.

Coates, P. S., B. G. Prochazka, C. L. Aldridge, K. E. Doherty, and J. C. Tull.

Abstract: Decades of conservation actions for restoring landscapes to pre-disturbed conditions have been carried out across sage-grouse range. Evaluating sage-grouse population response at broad-scales is challenging, primarily because of confounding effects. Within a distinct population of greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) on the border of Nevada and California, we carried out a Before-After-Control-Impact study to evaluate population responses from decades of conservation actions compiled from a newly established Conservation Efforts Database. Specifically, we used state-space models to estimate intrinsic rate of change (λ λˆ) in apparent abundance based on lek counts before and after a local conservation action (impact) relative to changes at broader scales (control), while including lag effects up to 6 years. Models estimated increased λ λˆ following several types of actions, including weed reduction, sagebrush restoration, road closure, conifer removal, meadow restoration, herd management, and fence removal. The effect size and lag effects varied among actions, and annual increase in λ λˆ was as high as ~9.0% for specific actions. Our findings assist federal and state resource management plans of restoration activities for sage-grouse population recovery. An expansion of this study is expected to cover broader extents within the sagebrush biome. Data are preliminary and provided for timely science.

Intact habitat for greater sage-grouse includes biological soil crusts.

Condon, L. A., M. C. Milligan, B. E. Brussee, S. T. O'Neil, and P. S. Coates.

Abstract: Biological soil crusts (biocrusts) are a common component of shrub-steppe ecosystems. The sagebrush steppe of the Great Basin is unique in its known disturbance history. Previous work in the region has linked disturbance to the loss of biocrusts, and resulting increases in cheatgrass, Bromus tectorum. Cheatgrass alters fire regimes, leading to increased loss of sagebrush that threatens the persistence of sagebrush obligate species, including greater sage-grouse (*Centrocercus urophasianus*). We used regional data collected by the Assessment, Inventory and Monitoring (AIM) program of the Bureau of Land Management, specifically the Landscape Monitoring Framework, in combination with long-term data on sage-grouse nests: locations and fates. We used Bayesian generalized mixed models to examine hypothesized relationships between disturbance, vegetation, biocrusts, and nesting patterns of sage-grouse. Preliminary results indicate that a combination of disturbances (fire, grazing and roads) lead to reductions in cover of biocrusts (lichens and mosses), resulting in increased cover of cheatgrass. Nest survival was negatively influenced by cheatgrass cover at coarser spatial scales. Our preliminary results suggest that the presence of biocrusts has cascading positive effects on an important breeding life stage of greater sage-grouse. These findings are preliminary, are provided for timely science communication, and are subject to change.

Using remote sensing in rangeland management: turning an abundance of spatial data into actionable information.

Creutzburg, M. K.

Abstract: The number of rangeland maps and spatial decision support tools has exploded in recent years as interest in sage-grouse and sagebrush management has climbed and technological advances have opened new doors. These spatial products offer great opportunities to incorporate data crossing broad spatial scales and long time frames into decision-making, but also present an overwhelming amount of new and ever-changing information for users to digest. This presentation will review some of the key barriers field users often encounter when trying to incorporate remotely sensed mapping into their day-to-day management applications. I will present four guiding principles for how users of rangeland maps can approach the use of remotely sensed maps, based on "Guiding principles for using satellite-derived maps in rangeland management" (Allred et al. 2021), and match these guiding principles with some considerations for map producers about how to increase the usefulness and adoption of map products by end users. This talk will also highlight examples of how the Oregon SageCon Partnership (https://sageconpartnership.com/) has developed synthesis maps that support a broader decision- making framework.

Columbian sharp-tailed grouse in northern Utah.

Dahlgren, D. K., T. Aubrey, A. Cook, and H. Talley.

Abstract: Columbian sharp-tailed grouse (CSTG) were designated as a sensitive species in Utah in 2020. The species has limited distribution in northern Utah. Populations have been declining and efforts have been made to increase lek monitoring. Volunteers have searched for unknown leks with mixed success. The UDWR has contracted fixed-wing arial surveys with infrared cameras as well. We used CSTG lek locations from Utah and southern Idaho to develop Maximum Entropy models to predict likely lek locations. We found closer proximity to sagebrush steppe habitat and cropland to be important predictors, as well as elevation within our study area. Historically, CSTG lek count protocols in Utah have paralleled sage- grouse protocols, with observers focusing on past lek locations. Sharp-tailed grouse leks can move between years. Like other prairie grouse protocols, we conducted two separate surveys, i.e., a detection and a lek flush survey. The detection survey consisted of 10-mile routes with 11 stop locations that were sampled during the lekking period. Flush surveys were then done on a different morning for leks identified along detection routes. Our two-part survey protocol resulted in higher lek counts than the historical protocol during our three lekking seasons.

Greater sage-grouse translocations – lessons learned.

Dahlgren, D. K., P. S. Coates, M. B. Meyerpeter, K. Lazenby, J. Kolar, S. Picardi, S. Mathews, S. O'Neil, and D. J. Delahanty.

Abstract: Past grouse translocations had little monitoring of translocated individuals. Marked translocated grouse have been plagued with low survival and productivity. We translocated pre-nesting and brood females. We developed a novel method to transport and release brood females and chicks. We used a brood transport box with two compartments separated by a removable perforated divider. The female and chicks were able to stay in contact, but the large female was unable to physically impact the chicks during transport. At the release site, the brood was transferred to a 4 x 8-foot release pen and released once normal behavior was observed. We had high survival during the translocation and release. Post- release movements were lower than pre-nesting females. Brood translocations may be a useful for other Gallinaceous species. We used GPS-PTT radios to monitor both translocated brood and pre- nesting female movements and habitat selection. We found that translocated grouse exhibited exploratory and settlement behaviors and that habitat selection differed based on behavioral-state. Therefore, when predicting optimal release areas, all post-release locations of translocated individuals should not be used for predictive models. Rather, habitat selected during settlement states should guide release area evaluations and habitat selected during the exploratory state should likely be censored.

Incentivizing private land conservation to expand greater sage-grouse habitat conservation and restoration.

Davee, R., E. Weidner, and E. Tyrrell.

Abstract: Oregon's Candidate Conservation Agreement with Assurances (CCAA) program for greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) uniquely implements a proactive rather than reactive approach to sage-grouse habitat conservation and restoration. Habitat loss is contributing to the decline of sage-grouse rangewide. Within Oregon, ~24% of core sage-grouse habitat is privately owned, highlighting the importance of private land conservation within Oregon's larger sage-grouse conservation strategy. Oregon's CCAAs are formal, voluntary agreements between U.S. Fish and Wildlife Service, private landowners, and locally-led conservation organizations to address the needs of sage-grouse before they become listed as endangered or threatened under the Endangered Species Act (ESA). In return for conservation measures, participating landowners are assured no additional conservation measures are required if sage-grouse are listed under the ESA. Local conservation organizations serve as bridging organizations to establish working relationships with landowners and bespoke conservation management using the best available science. Private land conservation combined with public land efforts allows for a wide-ranging approach that can better address landscape-level threats. Obtaining long-term funding and support are the forefront challenges the Oregon CCAA faces; however, ongoing collaboration by local, state, and federal agencies and ever-growing interest in Oregon's CCAA program shows promise that landscape level conservation is achievable.

Sagebrush Conservation Design: A Strategic Framework for Conservation of the Sagebrush Biome.

Doherty, K., D. M. Theobald, G. Bedrosian, C. S. Boyd, J. B. Bradford, M. Cahill, P. S. Coates, M. K. Creutzburg, M. R. Crist, S. P. Finn, A. V. Kumar, C. E. Littlefield, J. D. Maestas, K. L. Prentice, B. G. Prochazka, W. D. Sparklin, T. E. Remington, J. C. Tull, L. A. Wiechman, Z. Wurtzebach, and K. A. Zeller.

Abstract: We present the Sagebrush Conservation Design (Sagebrush CD) as a framework to strategically implement a "Defend the Core, Grow the Core" paradigm to reduce landscape threats in sagebrush ecosystems by prioritizing "cores" before more degraded landscapes for effective management and restoration. We developed the Sagebrush CD using an ecosystem- and threat-based approach that leveraged remotely sensed landcover data to produce spatially and temporally explicit maps of "Sagebrush Ecological Integrity" (SEI). We classified SEI using two primary indicators of ecological function (sagebrush and perennial grass cover) and three primary threats (invasive annual grass cover, conifer encroachment, and human modification of the landscape). Using our SEI outputs, we classified the sagebrush biome into Core Sagebrush Areas (CSAs), Growth Opportunity Areas (GOAs), and Other Rangeland Areas (ORAs). Using 2020 landcover data, we classified 33.4 million acres (14.2%) of rangelands as CSAs, 84.3 million acres (35.8%) as GOAs, and the remaining 117.7 million acres (50.0%) as ORAs. We demonstrated ecological relevance of these classifications when compared against patterns of population performance for greater sage-grouse. The positive link to sage-grouse population trends in CSAs is important as habitat management designations for this species have largely driven conservation actions across the sagebrush biome in recent decades.

Sage-grouse use of 'restored' sagebrush habitats in southern Utah.

Donnelly, B. C., and N. Frey.

Abstract: Pinyon-Juniper woodland expansion into sagebrush areas has led to the decline of sage grouse habitat. Pinyon-Juniper removal has been a leading method in restoring sage grouse habitat. The Utah Watershed Initiative has conducted multiple projects in Southern Utah with the purpose of improving habitat for sage grouse by the removal of juniper-pinyon trees. A pinyon-juniper removal project to restore sage grouse habitat in Sink valley was conducted in 2005. Between 2005 and 2009 a study was conducted to determine habitat vegetation before and after the removal of the pinyon-juniper. 15 years after the pinyon-juniper was remove similar vegetation surveys were conducted to determine habitat condition within the pinyon-juniper removal areas. Vegetation surveys were conducted in surrounding intact sagebrush stands and other managed areas for comparison. Similar vegetation surveys were conducted at grouse locations during the months of June and July for comparison. It was found that there were significant differences in the vegetation composition when comparing known grouse locations to the vegetation within the treated areas. Additionally, it was found that there were significant differences between the vegetation conditions of the treated area now than when compared to measurements taken during the initial study.

Science and decision support tools to inform sage-grouse management in response to wildfire and long-term degradation of sagebrush ecosystems.

Dwight, I. A., P. S. Coates, C. L. Roth, B. G. Prochazka, M. P. Chenaille, M. A. Ricca, C. L. Aldridge, A. P. Monroe, D. S. Pilliod, and M. B. Rigge.

Abstract: Sagebrush ecosystems of the American West are increasingly threatened by larger and more frequent wildfires that kill sagebrush and facilitate expansion of invasive annual grasses. Thwarting this accelerated grass–fire cycle is at the forefront of current national policies and understanding the chronic impacts to wildlife is crucial to planning efforts. Greater sage-grouse (*Centrocercus urophasianus*) populations have experienced ~3% annual declines range-wide since the 1960s, with precipitous losses in areas where native shrublands have transitioned to annual grasslands. Initial results of a range-wide analysis revealed the net loss of sagebrush resulting from wildfire contributed strongly to declining sage-grouse populations with some regional variability. In-depth studies of demographic processes have revealed mechanisms driving population declines. For example, sage-grouse tend to select burned areas for nesting and brood-rearing that adversely impact survival, indicating evidence of maladaptive behaviors in these environments. Information gained from these studies, including model outputs and estimated parameters, are currently being used within a multi-scale decision support framework. Tools developed from this framework can help improve the effectiveness of conservation actions focused on

reducing net sagebrush loss and identify priority areas for protection and active restoration within sagebrush ecosystems. These findings are preliminary and provided for timely science communication.

Multi-scale analysis linking population trends to surface disturbances for greater sage-grouse and mule deer in Wyoming.

Edmunds, D. R., A. P. Monroe, B. S. Robb, M. J. Holloran, M. S. O'Donnell, R. D. Inman, N. Graf, P. S. Coates, and C. L. Aldridge.

Abstract: Population-level effects of anthropogenic disturbances have been documented for a variety of species, including greater sage-grouse (*Centrocercus urophasianus*), a high conservation concern species. State wildlife agencies often manage disturbances for sage-grouse at the scale of Biologically Significant Units (BSU, e.g., Density Disturbance Calculation Tool [DDCT; Wyoming Geographic Information Sciences Center]). However, it remains unknown how effective disturbance thresholds are at conserving sage- grouse and sympatric species at scales different from the BSU. We used trend estimates to evaluate effectiveness of Wyoming thresholds for conserving two important species and investigated effects of surface disturbances. Specifically, we timestamped roads (U.S. Geological Survey) and surface disturbances (DDCT), including agriculture, energy development, fires, mines, urban development, and vegetation treatments (1986–2015) within Wyoming. We then used these spatiotemporal data and sage-grouse and mule deer (Odocoileus hemionus) count data (Wyoming Game and Fish Department) in state-space models within a Bayesian framework to estimate multi-scale, hierarchical level population trends in relation to disturbance on sage-grouse and sympatric mule deer populations. Sage-grouse population units reflected nine nested lek cluster levels while mule deer relied on herd unit boundaries and the state-wide distribution. Our analyses will enable managers to extrapolate thresholds to similar habitat conditions in the sagebrush biome.

Conservation of sage-grouse through precision management of palatable sagebrush.

Forbey, J. S., S. J. Galla, B. C. Robb, T. Trevor Caughlin, R. Liu, D. M. Delparte, G. Patricelli, J. J. Mitchell, C. Dadabay, D. Conner, A. Martwick, M. R. Fremgen, G. Frye, E. Ellsworth, D. Englestead, and J. Connelly.

Abstract: Spatial and temporal variation in the dietary quality of plants influences the behavior, physiology, and demographics of vertebrate herbivores. Abiotic stressors such as wildfires and biotic stressors such as invasive plants are changing the foodscape for herbivores in abrupt and unpredictable ways. Specifically, revegetation practices that do not restore sagebrush that is palatable to locally adapted sage-grouse populations may create "food deserts" that further threaten the health of sage-grouse. We demonstrate how approaches used in precision agriculture and personalized medicine can be translated to sage-grouse interacting with dynamic foodscapes to better manage this species. We couple advances in remote sensing, biochemistry, and modeling to identify, manage, and predict dietary interactions between sage-grouse and sagebrush. We found winter foraging fidelity by sage-grouse and that higher concentrations of crude protein and lower concentrations of secondary metabolites in plants influence diet selection and increase the number of bites on plants selected by sage-grouse. We also found that wildfires and restoration practices can disrupt geographically distinct chemotypes selected by sage- grouse. We recommend precision management practices that support matching palatable sagebrush with locally adapted sage-grouse.

Using genetic sequencing to characterize diet across space and time: applications in Columbian sharp-tailed grouse (*Tympanuchus phasianellus columbianus*).

Galla, S. J., M. A. Schroeder, D. Englestead, Z. Lockyer, E. Bartholomew, G. D. Randolph, C. E. Buchanan, J. L. Beck, and Jennifer S. Forbey.

Abstract: To successfully manage functional ecosystems, we need approaches that reveal complex multi-species interactions and provide context for conservation efforts. For grouse, conservation management largely focuses on habitat restoration and revegetation. However, restoration efforts are rarely informed by what birds are actually eating throughout their annual cycles. Here, we discuss how genetic amplicon sequencing can illuminate our understanding of diet in Columbian Sharp-tailed Grouse (*Tympanuchus phasianellus columbianus*). A database of trnL p6-loop sequences has been generated representing >500 plant species found in the Great Basin, with plant lists being developed for additional Sharp-tailed Grouse habitats. Further, fecal samples from birds have been collected for populations in the US (Washington,

Idaho) and Canada (British Columbia). We anticipate this approach will provide precise information on spatio-temporal shifts in Columbian Sharp-tailed Grouse diet, how diet changes with habitat loss (e.g., post-fire) and management (e.g., Conservation Reserve Program), and how individuals transition to new habitats during conservation translocations. Results will be integrated with similar efforts in Greater sage-grouse (*Centrocercus urophasianus*), mule deer (*Odocoileus hemionus*), and wild horses (*Equus ferus*) to identify dietary overlap between western herbivores. This information will inform more precise restoration of habitats for declining grouse species and enhance conservation outcomes.

Feed a grouse chick, cut a juniper: impacts of juniper removal on herbaceous vegetation and invertebrate diversity.

Haab, K. A., C. A. Hagen, K. H. Yates, T. S. Bowden, B. A. Endress, and S. J. DeBano.

Abstract: Sagebrush obligate species continue to be threatened by the ongoing expansion of western juniper. One such obligate is Greater sage-grouse, which rely on a diversity of native vegetation throughout their life cycle for foraging, concealment, and thermoregulation. Encroached juniper competes with vegetation for limited water and nutrients, and may have cascading effects on invertebrates and herbaceous vegetation. Forbs and terrestrial surface-dwelling invertebrates are an essential source of energy and nutrients for sage-grouse and their chicks. Our study was conducted in sagebrush steppe of the Warner Mountains in Washoe County, NV and Modoc County, CA (2020 and 2021) to assess impacts of juniper removal on herbaceous forage and invertebrate diversity. Vegetation and invertebrates were sampled via biomass collection and pitfall trapping from old cuts (completed ≤2013), mid cuts (completed 2014–2016), recent cuts (completed 2017-present), and controls (encroached juniper areas with no cuts). Mean forage quantity was significantly higher in old cuts (17.4g/m^2, SE=0.3) and significantly lower in controls (11.2g/m^2, SE=0.2). Mean invertebrate abundance was significantly higher in old cuts (64n/g, SE=1.1) and significantly lower in controls (41n/g, SE=0.6). Our results suggest that juniper cuts designed specifically for sage-grouse (i.e. low tree density) can have measurable effects on larger ecosystem services.

Save a grouse don't cut a tree, cut lots of trees!

Hagen, C. A., P. Street, T. Dungannon, K. H. Yates, and T. S. Bowden.

Abstract: Evidence is building that encroachment of juniper trees (*Juniperus* sp) into sage-grouse habitat is resulting in adverse effects to populations. However, mechanisms for how juniper encroachment is impacting sage-grouse populations is poorly understood. Because juniper is dispersing into elevations lower than it historically occurred, we hypothesized that chick survival will be lower in areas with high amounts of juniper. To test this hypothesis, we marked 59 female sage-grouse with GPS backpacks in the Warner Mountains of southern Oregon and northern Nevada, 2017–2019. We attempted to locate females visually ~10-d intervals to assess whether she had a brood and count chicks. We modeled changes in counts as a function of daily apparent chick survival (φ) and adoption of chicks hatched to other females. We modeled φ with a continuous effect of chick age, average daily juniper cover encountered, the average distance from juniper cover >4%, random effect of year, and use of juniper removal areas. We found little evidence for an effect of juniper cover or distance on φ. However, we did find evidence that φ was higher when a brood female used juniper removal areas. Our results suggest managers can remove juniper in brood rearing habitat and benefit chick survival.

Integrated rangeland fire management strategy actionable science plan completion assessment: sagebrush and sage-grouse topic.

Holloran, M. J., C. R. Anthony, M. A. Ricca, S. E. Hanser, S. L. Phillips, P. Steblein, and L. A. Wiechman.

Abstract: The Integrated Rangeland Fire Management Actionable Science Plan represented a significant, co-produced effort to identify Priority Science Needs for coordinated adaptive management of sagebrush ecosystems. A quantifiable assessment for accomplishing these Needs since the Plan's release in 2016 can help evaluate overall success, flag unresolved knowledge gaps, and prioritize new directions. We describe preliminary results from a scorecard-based assessment of Plan progress towards addressing nine Needs under the Sagebrush and Sage-Grouse Topic. We systematically searched peer-reviewed literature published between January 1, 2015 and December 31, 2020 to identify how well Next Steps for each Need were either fully addressed, partially addressed, or remained outstanding. Searches resulted in 333 science products that at least partially addressed a particular Need. The Needs most fully addressed included identifying sage-grouse movement patterns and population connectivity; biome-wide mapping

of vegetation; spatially explicit models of sage-grouse habitat suitability; and thresholds for conifer expansion threats. Poorly addressed Needs included understanding livestock and feral horse grazing effects on sage-grouse populations and habitats; thresholds for disturbance by renewable energy development; and studies of habitat relationships for sagebrush-reliant species other than sage-grouse, songbirds, and small mammals. This scorecard assessment will assist with updating the Plan along with other science strategies.

Current status and distribution of Columbian sharp-tailed grouse in Colorado – a product of recent natural and human-mediated range recolonization.

Holmes, B. E., K. Griffin, L. Miller, M. Cowardin, and B. Weinmeister.

Abstract: Columbian sharp-tailed grouse (CSTG) are one of two subspecies of sharp-tailed grouse found in Colorado and historically occurred across much of the Western Slope in suitable habitat that includes sagebrush steppe, grassland, mixed mountain shrub, and riparian communities. The historic range of CSTG in Colorado likely included 21 western counties but by the mid-1990's CSTG were known to occur in only three counties in the extreme northwest corner of the state. Since then, Colorado Parks and Wildlife (CPW) has engaged in several translocation efforts with the goal of restoring CSTG to portions of their historic range. These translocations have resulted in persistent breeding populations in three additional counties. Concurrent with these translocation projects, monitoring efforts in the core CSTG range in northwest Colorado have documented a steady increase in the known breeding distribution with the annual discovery of new lek sites. This talk will describe the distribution and decline of CSTG range in Colorado from pre-settlement times through the mid-1990's and the subsequent increase in CSTG range attributed to a combination of natural and human-mediated range recolonization. A review of recent CPW translocation projects and the significance of these efforts to CSTG range-wide conservation will also be discussed.

Beyond road density: understanding how vehicular traffic impacts sage-grouse populations in Wyoming.

Inman, R. D., M. S. O'Donnell, B. S. Robb, A. P. Monroe, D. R. Edmunds, J. A. Heinrichs, and C. L. Aldridge.

Abstract: Road networks negatively impact populations of many terrestrial species due to traffic noise, barriers to movement, and direct mortality from vehicular collisions, yet roads remain an integral component to our society. Regional inventories of road disturbances often focus on the 'where' (e.g., mapping current locations) but may neglect the 'how' (e.g., how much traffic occurs in a given area) or the 'when' (e.g., temporal changes in traffic volume). We addressed the 'how' and 'when' of road disturbances by developing estimates of yearly traffic volume and road age for over 145,000 km of highways, arterials, collectors, light duty streets, as well as graded and natural surface roads for the years 1986 – 2020 in Wyoming. We used these estimates in a multi-scale Bayesian hierarchical modeling framework to 1) assess how traffic has impacted sage-grouse population growth rates, 2) identify the spatial scales at which these effects are most evident, and 3) identify what levels of traffic result in sage-grouse population declines. Effects of traffic volume tend to be local, and areas that experienced rapid growth experienced the greatest declines in population rates of change. We demonstrate how traffic volume data can inform wildlife management by identifying thresholds for various functional road types.

Precipitation, drought, and mesic resources: drivers of sage-grouse productivity in the Great Basin.

Lundblad, C. G., C. A. Hagen, J. Patrick Donnelly, S. T. Vold, S. P. Espinosa, and A. M. Moser.

Abstract: Recruitment is a key demographic rate underlying Greater Sage-grouse (*Centrocercus urophasianus*) population dynamics. Therefore, identifying environmental drivers of variation in productivity will enable more effective habitat management for this declining species. Previous studies in the Great Basin have documented associations between precipitation, drought, and productivity and suggested that relationship may be mediated by the availability of mesic habitat resources during the late summer brood-rearing period. We used wings, derived from hunter harvest, to characterize spatiotemporal variation in sage-grouse productivity in the North American Great Basin (Oregon, Idaho, and Nevada) from 1993–2020. We used random forest regression and remotely-sensed predictor data to examine the relative importance of mesic habitat availability, the more general effect of annual precipitation, and landcover composition on sage-grouse productivity. We found the expected positive relationship between

mesic habitat availability and sage-grouse productivity, but annual precipitation explained additional variation even after accounting for mesic availability. Hence, precipitation apparently drives sage-grouse productivity via multiple mechanisms. Productivity was also reduced at low levels of annual grass invasion and conifer encroachment. Mesic habitat availability was a function of topography and mean snow water equivalent, emphasizing that snowpack is critical for maintaining the late summer mesic resources that support sage-grouse recruitment.

Using integrated population models to evaluate translocation methods: costs and benefits of translocation on augmented and source populations of greater sage-grouse (*Centrocercus urophasianus*).

Mathews, S. R., M. B. Meyerpeter, M. Chelak, K. Lazenby, P. S. Coates, D. K. Dahlgren, J. Kolar, S. Picardi, B. Prochazka, T. Messmer, and D. J. Delehanty.

Abstract: Successful avian translocations blend effective translocation methodologies with animal behavior. We performed three greater sage-grouse (*Centrocercus urophasianus*) translocations (California, Utah, and North Dakota) and tested traditional and novel methodologies as part of ongoing conservation projects. During traditional translocations, females were translocated during the spring breeding season to exploit their desire to nest following release and to reduce post-release dispersal. In novel methods, we translocated females with chicks (brood translocation) mid-summer to test for enhanced recruitment and reduced dispersal movements post release. We tracked sage-grouse at augmented, source, and at neighboring control sites in a Before-After-Control-Impact (BACI) design to elucidate the benefit of translocations on population growth (λ). We estimated the cost of translocations on λ within source populations and implemented integrated population models (IPMs) in a Bayesian framework to estimate λ and demographic rates for each population. Brood translocations increased λ by 11 – 30% over traditional translocation methods, which produced higher λ estimates than if no translocations were conducted. Both translocation methodologies resulted in small reductions of λ in source populations. Our results indicated that novel brood translocations significantly increased λ in augmented populations. These findings are preliminary, provided for timely science communication and are subject to change.

The role of emerging biotechnology in species conservation: can biotechnology help Gunnison sage-grouse?

McCance, S. J.

Abstract: Emerging biotechnologies such as bio-banking, assisted reproductive techniques (including cloning), and synthetic biology have the potential to assist with conservation efforts for species at risk of extinction. These technologies are currently being used on a variety of endangered species such as the Black-footed ferret and the California condor, as well as for the control of invasive species or pests that carry disease. Here, I explore the potential use of these emerging biotechnologies on Gunnison Sage-grouse (*Centrocercus minimus*), a threatened species with declining numbers and isolated populations. Several genetic and genomic studies on Gunnison Sage-grouse have provided insight into overall genetic diversity, connectivity among populations, and local adaptation. Such information could be used to guide the use of emerging biotechnologies such as biobanking material for future use, as well as assisted reproductive techniques and captive breeding. Here I explore the promise and pitfalls of such technologies and their potential application to the conservation of Gunnison Sage-grouse.

Linking resource selection to population performance to identify species' habitat across broad spatial scales: an example of greater sage-grouse in a distinct population segment.

Milligan, M. C., P. S. Coates, B. E. Brussee, S. T. O'Neil, S. T. Mathews, S. Espinosa, S. Gardner, and M. L. Casazza.

Abstract: Limited time and resources necessitate accurate identification of high-quality habitat for informing management decisions related to species conservation. Habitat selection is not always adaptive and mapping both selection and demographic performance for species of conservation concern, and identifying areas with either overlap or mismatch, can help guide large-scale conservation efforts. We demonstrate a quantitative approach to differentiate source and sink habitats at large spatial scales using the greater sage-grouse (*Centrocercus urophasianus*), an indicator species for sagebrush ecosystems. We evaluated both selection and survival across multiple reproductive life stages (nesting, brood-rearing) to

better understand the interplay between these two responses in the Bi-State Distinct Population Segment, a genetically distinct and geographically isolated population on the western edge of the species' range. Our approach allowed us to identify mismatches between selection and survival and trade-offs between life stages. Moving beyond designating critical habitat solely based on species occupancy or use by incorporating demographic measures facilitates management actions that are better tailored to specific scenarios, including protection of source areas that support high selection and high survival, or restoration actions focused on increasing survival in areas of high selection and low survival. Information is preliminary and provided for best timely science.

Artificial nest depredation by the common raven within various sagebrush treatments in southern Utah.

Moffett, Z. S., and S. N. Frey.

Abstract: With increases in rural and urban development throughout the American West, Common raven (*Corvus corax*) populations have been rising as anthropogenic subsidies provide both food and nesting habitat. As generalist scavengers and predators, ravens have been found to pose a severe threat to several threatened or sensitive species, including the Greater sage-grouse (*Centrocercus urophasianus*). The purpose of this research was to quantify the overall threat that ravens may pose as nest predators to sage-grouse within the Bald Hills and Panguitch Sage-grouse Management Areas (SGMAs) in southern Utah. To do this we conducted an artificial nest experiment over the course of two nesting seasons in 2021 and 2022. We constructed artificial nests using chicken eggs to compare nest depredation rates in sage-grouse habitats that have undergone various types of treatments (i.e., bullhog, hand-thin, chaining) which have altered habitat variables such as sagebrush cover and height and nest visibility. Each season, 80 artificial nests were placed under sagebrush and were monitored via trail cameras. Ravens successfully detected and depredated many artificial nests within various sagebrush treatments. The results of this research may have implications for wildlife managers throughout Utah as they continue to decide where and how to treat sage-grouse habitat.

Relevant, scale-dependent responses to sagebrush cover by sage-grouse populations across the range.

Monroe, A. P., J. A. Heinrichs, A. L. Whipple, M. S. O'Donnell, D. R. Edmunds, and C. L. Aldridge.

Abstract: Over the last half century, populations of greater sage-grouse (*Centrocercus urophasianus*) declined precipitously and there is an urgent need to understand the contribution of landscape habitat to plan for multiple land uses and avoid scale-dependent population impacts. Sagebrush cover (*Artemisia* spp.) is an important habitat component for sage-grouse, and studies of nesting and movement suggest specific scales of effect for trends in lek counts. However, scales of effect can vary with study location, response type, and environmental variable, and therefore generalizability of these scales among populations is unknown. Using a standardized, range-wide database of lek counts, we applied a scale selection approach to examine the scale of effect of sagebrush cover across the sage-grouse range and among hierarchical cluster levels. We fit state-space models to repeated counts from 6,746 leks across eight states (1996–2021) and characterized annual sagebrush cover from the RCMAP fractional component time-series product. We then compared scales of effect estimated across the study area with scales estimated within coarse- and mid-level clusters considered closed to movements by individuals. These results offer useful insights for anticipating how sage-grouse populations respond to changes in landscape features such as sagebrush cover at scales directly relevant to each population.

Understanding ecological potential and risk to inform wildlife and habitat management of the sagebrush biome: the efficacy of soil moisture.

O'Donnell, M. S., and D. J. Manier.

Abstract: Soil temperature and moisture (soil-climate) affect plant growth and microbial metabolism, providing a mechanistic link between climate and growing conditions. However, spatially explicit soil-climate estimates that can support conservation and management of sage-grouse and wildlife are lacking. We developed a framework to estimate high-resolution spatiotemporal soil moisture (monthly, annual, and seasonal) and temperature-moisture regimes. Notably, our approach allows for the substitution of data and parameters that importantly account for timing and redistribution of snowmelt, allowing for improved estimates for when and where water can infiltrate soil. For our initial study, we applied the model across the western United States using monthly climate averages (1981–2010) to understand whether soil-

climate can enhance our understanding of ecological potential and risk. We demonstrated that results correlated significantly with vegetation patterns, including sagebrush, annual herbaceous plant cover, bare ground, and fire occurrence. Because our framework has the flexibility to assess dynamic climate conditions (historical, contemporary, or projected), we can begin to improve our knowledge of changing spatiotemporal biotic patterns. These spatial resources are intended to provide tools to managers and researchers for assessing risk (invasives and fire), improving estimates of vegetation patterns, and informing prioritization of habitat management and expected restoration outcomes.

Dynamic spatial modeling of common raven densities and decision support tools to manage predation of greater sage-grouse nests.

O'Neil, S. T., P. S. Coates, B. E. Brussee, S. J. Dettenmaier, P. J. Jackson, S. P. Espinosa, D. J. Delehanty, and J. C. Tull.

Abstract: Widespread increases in subsidized avian predators such as common ravens (*Corvus corax*) can negatively impact species of conservation concern. Predation effects from ravens are concerning for declining greater sage-grouse (*Centrocercus urophasianus*) in western sagebrush ecosystems. We describe a Bayesian hierarchical distance sampling modeling framework to predict spatiotemporal patterns in raven density, evaluate sage-grouse nest success concurrent with fluctuating raven densities, and analytically link models of raven density to sage-grouse nest success while accounting for other environmental influences. We modeled raven density using point count survey data and environmental covariates on detection and abundance. Sage-grouse nest survival was estimated concurrently from nest fates using a Bayesian frailty model. We related raven densities directly to sage-grouse nest survival within our model using a two-stage approach. We simulated sage-grouse nest survival under current and reduced raven densities, where the difference indicated potential impact on nesting productivity. Raven density commonly exceeded >0.5 ravens km-2 and increased at lower elevations with prevalent anthropogenic land use. Sage-grouse nest survival was negatively related to raven density, also varying with topography, shrub cover, and burned areas. Results inform allocation of resources for conservation planning under rapidly changing habitat conditions. Information is preliminary and provided for best timely science.

Rebuilding sagebrush habitat: using state-transition simulations to scope post-fire habitat restoration for greater sage-grouse.

Orning, E. K., J. A. Heinrichs, and C. L. Aldridge.

Abstract: Wildfires are increasingly destroying wildlife habitat in the western U.S., and managers need ways to scope the pace and degree to which post-fire restoration can re-create habitat in dynamic landscapes. We developed a spatially explicit state-transition model (STSM) to simulate annual fires, project natural vegetation regeneration, annual grass invasion, conifer encroachment, and sagebrush revegetation. We cross-referenced resulting vegetation maps with greater sage-grouse habitat needs and evaluated trajectories of potential habitat condition for three Priority Areas of Conservation in the Great Basin. We compared outcomes among different types of revegetation actions (natural regrowth, seeding, planting), treatment durations, and treatment area sizes. In all scenarios, sagebrush cover was generally insufficient to meet sage-grouse needs for at least a decade post-fire, and the best habitat condition class declined or remained at low proportions of landscapes over the next 50 years. Under current fire patterns, the pace of habitat restoration is likely to lag behind losses and our results suggest more than sagebrush revegetation actions will likely be necessary to maintain and restore conditions that meet sage-grouse habitat needs in burned landscapes. By gauging potential benefits of restoration decisions, our approach can assist land managers with how to triage losses in long-term restoration and recovery plans.

Interactive effects of avian predator densities and habitat disturbance on sage-grouse reproductive success.

Owens, T. M., L. R. Perry, L. J. Foster, J. B. Cupples, and J. B. Dinkins.

Abstract: Wildfire is a primary threat to greater sage-grouse (*Centrocercus urophasianus*; hereafter, sage-grouse) that is exacerbated by a positive feedback cycle created by invasive annual grasses. When sage-grouse nesting areas are lost or degraded by wildfire, there may be lasting negative effects on reproductive success from slow sagebrush recovery. In addition, edge effects, such as increased predation associated with reduced screening cover, could negatively affect sage-grouse near or within burned areas. Common ravens (*Corvus corax*; hereafter, ravens) are a documented sage-grouse nest predator, and their

populations have increased in the Great Basin by 2.3% per year since 1993. We investigated the relationships between disturbance, increasing raven densities, and sage-grouse reproductive success in five Priority Areas of Conservation (PACs) in Oregon from 2018–2021. Raven densities were calculated using distance sampling from 1,308 point count surveys at 147 random locations within our study areas. To assess sage-grouse nest survival, we used a Cox proportional hazard model to evaluate survival of 147 nests from 89 marked female sage-grouse. We will present preliminary findings on sage-grouse nest survival modeled as a function of raven density, vegetation metrics, wildfire activity, topographic, and anthropogenic covariates. These results will be useful for targeting restoration and predator management activities.

Clutch size of greater sage-grouse in a north-central Utah population.

Radke, J., R. T. Larsen, B. R. McMillan, and S. L. Petersen.

Abstract: For birds, tradeoffs exist between investing in the current year's reproduction and preserving energy for future years. Consequently, clutch size varies among birds with different life history strategies. Within Galliformes, greater sage-grouse (*Centrocercus urophasianus*) have longer expected lifespans and produce smaller clutches than many birds in this order. Because clutch size influences population growth, it's important to understand drivers of variation—particularly for species of conservation concern. Sage grouse have been a focus of monitoring in Strawberry Valley, Utah, for many decades. Our objective is to estimate average clutch sizes from data collected between 1998 and 2022 and compare to clutches collected from the same area between 1930 and 1960. We hypothesize that average clutch size for sage grouse in Strawberry Valley has declined over time relative to clutches collected historically. We also predict that clutch size increased due to increases in genetic diversity following translocations of sage grouse from other populations into the Strawberry population. Preliminary results indicate a decline in clutch size over time. In addition, preliminary results suggest it is unlikely there was an increase in average clutch size after translocations of sage grouse were made. These data will help inform ongoing conservation efforts for this population.

Comparison of common ravens in Wyoming's sage-grouse core and non-core areas: assessing predator densities related to anthropogenic features.

Revekant, C. L., and J. B. Dinkins.

Abstract: Many factors have contributed to declines in greater sage-grouse (*Centrocercus urophasianus*: hereafter sage-grouse), including habitat loss and fragmentation from human development. While human development has been connected to lower sage-grouse demographic rates and their avoidance of anthropogenic features, it also provides an increased number of perch and nesting structures used by avian predators, including common ravens (*Corvus corax*: hereafter raven). Wyoming's Sage-grouse Core Areas were designed to help conserve important sage-grouse habitat by reducing development within these Core Areas. Core Areas have maintained higher sage-grouse trends compared to Non-Core Areas, which could be partially explained by reduced predation rates. During 2017–2018, we performed 2,157 avian point counts along 380 8.05-km transects throughout the Wyoming Basin. We used distance sampling analyses to evaluate what anthropogenic features influenced raven density; however, we also compared raven densities among existing Core and Non-Core Areas with sub- stratification among sage-grouse breeding habitat, areas of high relative sage-grouse abundance, and current development known to negatively influence sage-grouse. Our results indicated that agricultural lands, communication towers, roads, landfills and developed Non-Core Areas were positively related to raven density. Core Area protections in the Wyoming Basin appear to reduce predation risk on sage- grouse, thereby functioning as predator management.

Timestamping roads and other anthropogenic disturbances to inform wildlife studies in the sagebrush biome.

Robb, B. S., D. R. Edmunds, M. S. O'Donnell, R. D. Inman, A. P. Monroe, M. J. Holloran, N. Graf, and C. L. Aldridge.

Abstract: In the sagebrush biome, thresholds of surface disturbance are among the tools used to manage populations of greater sage-grouse (*Centrocercus urophasianus*). However, available data on surface disturbances often lack temporal context, which constrains the ability to study population-level responses by sage-grouse and other species to disturbance over time. We present an ongoing effort to timestamp anthropogenic disturbances in Wyoming to benefit wildlife studies within the sagebrush biome. Our

approach incorporated spatial data on roads (U.S. Geological Survey), energy development and other disturbances (Density and Disturbance Calculation Tool; Wyoming Geographic Information Science Center). To timestamp these disturbances, we merged the location of roads and energy development with available temporal data to inform the most likely year of disturbance. Our timestamped dataset (1986–2015) has over 145,000 km of roads and 28,000 km^2 of anthropogenic disturbances, including oil and gas well pads, wind turbines, mines, agriculture, fires, solar energy, urban developments, substations, and vegetation treatments (data will be published). With time series on wildlife demographics, we will use the disturbance data to assess spatially explicit habitat management thresholds for sage-grouse and mule deer (Odocoileus hemionus). Similarly, our framework for timestamping could be applied to other regions to help inform wildlife management.

A spatial synthesis of fuel breaks in the sagebrush biome in relation to wildfire, invasive annual grasses, and greater sage-grouse.

Roche, M. D., D. Joanne Saher, E. Buchholtz, M. Crist, D. Shinneman, C. Aldridge, B. Brussee, P. Coates, C. Weise, and J. Heinrichs.

Abstract: Increased wildfire frequency and annual grass invasion have altered much of the sagebrush biome, threatening the species that require these habitats. To provide staging areas to suppress fire and conserve sagebrush ecosystems, land management agencies have installed ~10,000km of fuel breaks. Fuel breaks can provide ecological benefits including fire suppression and habitat conservation, as well as costs such as proximate annual grass invasion, and fuel break effects on wildlife populations and habitats. To begin to evaluate ecological trade-offs, we synthesized spatial information associated with fuel breaks across the sagebrush biome. In comparison to the distribution of values or conditions in the sagebrush biome, locations near and within fuel breaks had higher burn probability, lower resistance to invasion and resilience to disturbance, and higher annual grass abundance. Fuel break density was also concentrated within priority Greater Sage-grouse habitats. Our analysis highlights the potential for fuel breaks to cause ecological risks in terms of invasion and impacts to sage-grouse habitats, and those risks are unequally distributed across the landscape. Additional research is needed to evaluate the balance of ecological risks and rewards of fuel break-supported fire suppression within and near sage-grouse habitats and identify the ecological contexts in which fuel breaks provide a net benefit for landscape and habitat conservation.

Interactive effects of predators, habitat, and livestock presence on sage-grouse nest success in Wyoming.

Ruth, K. A., J. D. Taylor, and J. B. Dinkins.

Abstract: Habitat loss and degradation are the predominant factors attributed to reductions and declines in greater sage-grouse (*Centrocercus urophasianus*; hereafter “sage-grouse”) distribution and abundance, but predation in some contexts also contributes to declines. Livestock grazing has been identified as a factor influencing sage-grouse habitat quality, including micro-habitat characteristics at nest sites, which may indirectly influence sage-grouse demography. However, little is known about the interactive effects of livestock presence and management, predators, and vegetative characteristics on sage-grouse vital rates. During 2019–2022, we conducted a study in Bighorn Basin, Wyoming to investigate these interactions. We hypothesized presence of cattle would influence both avian and mammalian predators with more avian and fewer mammalian predators near livestock. As part of our ongoing study, we present initial findings of potential benefits and threats of livestock operations on sage-grouse nest survival. Our evaluation of nesting survival includes a comparison of different grazing strategies, in addition to predator, livestock, and landscape-level covariates. This study will shed important information on understanding relationships between livestock and sage-grouse, including how livestock may modify habitat quality and local predator communities. Our results will help guide policy and management practices to promote healthy rangelands for both livestock and sage-grouse.

Applying threat-based land management to promote resilience in sage-grouse habitat.

Schroeder, V. M., D. D. Johnson, J. B. Cupples, D. Renner, A. M. Tyson, J. Austin, T. Barnes, C. S. Boyd, L. Foster, J. Kerby, A. Sitz, T. Svejcar, and M. Cahill.

Abstract: Sagebrush ecosystems face existential threats from invasive annual grasses and expanding conifers. Mesic areas within the sagebrush ecosystem, which support 80% of wildlife while comprising roughly 2% of the landscape, are threatened by a variety of factors that can lead to lowered water table

and loss of riparian vegetation. Land managers need to work at large spatial scales but have limited resources. A collaborative team has created frameworks to efficiently identify, discuss and address landscape-level threats in upland and mesic systems throughout the northern Great Basin. With this method, users map simplified ecological states and estimate future trend. This decision-support system directly promotes management objectives by helping users understand relevant threats to the ecosystem, become familiar with ecological states using a simplified decision tree and threat models, make management decisions and apply conservation measures, learn how to determine apparent trend and finally take the first steps in identifying management actions for each state. Millions of acres have been or will be enrolled in CCA/As, and many more will fall under mitigation projects. The framework is currently used on the upland portions of these lands in Oregon, and a beta version currently is in place for flowing mesic systems.

Optimizing conservation and restoration of imperiled sagebrush ecosystems to benefit multiple species.

Shyvers, J. E., B. C. Tarbox, C. J. Duchardt, A. P. Monroe, D. R. Edmunds, B. S. Robb, N. J. Van Lanen, E. K. Buchholtz, M. S. O'Donnell, N. D. Van Schmidt, J. A. Heinrichs, and C. L. Aldridge.

Abstract: Sagebrush ecosystems of North America continue to undergo widespread degradation due to multiple factors, including climate change and increased human development. Effective sagebrush management must consider how to best conserve and restore habitats to stem the decline of species that rely on them, especially given finite funding and other resources. To address the critical need for science-based tools that balance management priorities and guide strategic conservation efforts, we recently developed the Prioritizing Restoration of Sagebrush Ecosystems Tool (PReSET). PReSET utilizes the Prioritizr package (Program R) and integer linear programming to help maximize the efficiency and effectiveness of sagebrush restoration efforts. We expanded this spatial optimization framework to prioritize sites for both restoration and conservation actions based on customized management objectives. Our framework incorporates updated estimates of sagebrush recovery potential within disturbed habitats, novel abundance predictions for sagebrush-obligate and -associated species (including the Brewer's sparrow, sagebrush sparrow, sage thrasher, green-tailed towhee, loggerhead shrike, pygmy rabbit, mule deer, golden eagle, and greater sage-grouse), connectivity measures for sagebrush habitats, and potential changes in sagebrush cover based on future climate projections. We applied this framework within the sagebrush biome of Wyoming in the western United States to help guide ecosystem recovery efforts in the region. We will demonstrate the capabilities of the tool and provide application examples that facilitate State and Federal strategic planning efforts to conserve and restore sagebrush habitats for multiple species of conservation concern.

Demographic rates of a declining and augmented population of greater sage-grouse in Modoc County California, USA.

Sink, C. E., K. M. Dugger, C. A. Hagen, and J. Vradenburg.

Abstract: Greater sage-grouse (*Centrocercus urophasianus*) in Modoc County California are geographically isolated and have been subsidized by translocation to prevent inbreeding depression since 2005. Despite significant efforts to increase the population through translocations and habitat improvement by cutting encroaching juniper (*Juniperus occidentalis*), only a single lek remains (from 56 in the 1940s). Several large wildfires have occurred since 2017 and led to increases in invasive grasses and a decrease in shrub cover that has further degraded important nesting and brooding habitat. We estimated adult female, nest, and chick survival and assessed habitat and biotic characteristics that may influence these rates to identify limiting factors to population growth. We monitored 37 females marked with GPS PTTS, 39 nests, and 8 broods from 2019-2021. Preliminary results showed nest success across a 29 day incubation period was 29% (95% CI 17.1 – 44.8), chick survival across a 54 day period was 44% (95% CI: 0.232 to 0.833), and female adult survival across at 12 month period was 29% (95% CI 17.8 - 43.7). Our estimated vital rates were 45-55% lower than range-wide estimates, suggesting recent habitat changes caused by wildfire and invasive grasses are having a detrimental effect on adult and nest survival.

Non-native ungulates impact greater sage-grouse life history.

Street, P. A., T. L. Behnke, and J. S. Sedinger.

Abstract: There is a growing amount of evidence that feral horses and livestock are adversely impacting Greater Sage-grouse populations. Much of this evidence is inferred from correlations between public

grazing records and changes in counts of male sage-grouse attending leks. These correlations offer little insight into the mechanisms driving change in sage-grouse populations. Aside from copulation, males make little contribution to future populations and females are solely responsible for rearing and fledging new individuals. We develop an individual-female-based-population-model to investigate feral horse and livestock impacts to sage-grouse life history. We marked 871 female sage-grouse across 3 large study areas with different historic and contemporary grazing regimes to inform the model. Beginning at hatch we estimate probability of fledging, breeding propensity, nest survival, and female survival for each breeding state and derive an estimate of female population growth. Concomitantly, we modeled the spatiotemporal distribution of horses and livestock as well as the ecological impacts they had on vegetation needed by sage-grouse. We found that these impacts resulted in negative effects on recruitment of Sage-grouse, with the largest impact on chick survival to fledging. Management aimed at reducing the negative ecological impacts of non-native grazers would likely be most successful if directed towards reducing impacts on the vegetation sage-grouse consume.

Avian predator occupancy and diet at communication sites in sage-grouse habitat.

Szabo, S., J. Dinkins, S. Abele, P. Coates, J. Cupples, I. Dwight, H. McPherron, S. O'Neil, S. Webster, T. Levi, and T. S. Manager.

Abstract: Habitat fragmentation resulting from anthropogenic features can pose a threat to Greater Sage-Grouse (*Centrocercus urophasianus*; hereafter, Sage-Grouse). Studies have shown that Sage-Grouse avoid tall structures, and both transmission lines and communication towers have been linked to Sage-Grouse nest failure, lek abandonment, and extirpation. These unnatural features provide nesting and perching substrates for ravens and other avian predators of Sage-Grouse and their nests. We designed a field study to assess how the design, arrangement, and location of communication towers influence nesting and perching of avian predators within Sage-Grouse habitat. We visited over 700 communication sites in over 200 sage-grouse habitat clusters across Oregon, Idaho, Nevada, Wyoming, and California during the March-June nesting seasons in 2021 and 2022. Site visits consisted of a point count survey, measurements of available nesting substrate, inventory of avian predator nests, and collection of genetic materials for dietary analysis. Pilot data indicates that avian predators preferentially nest on large, wind-blocking antenna types, and areas of the tower structure with dense steel lattice. Site occupancy is also influenced by topographic, landcover, and land use characteristics. Preliminary diet data indicates that avian predators nesting in Sage-Grouse habitat eat a varied diet including multiple sagebrush obligate species of conservation concern.

Influence of soil moisture availability on sagebrush restoration across the sage-grouse range.

Tarbox, B. C., A. P. Monroe, M. S. O'Donnell, J. A. Heinrichs, D. S. Pilliod, M. I. Jeffries, J. L. Welty, R. S. Arkle, P. S. Coates, and C. L. Aldridge.

Abstract: The sagebrush biome increasingly experiences disturbances (e.g., wildfire) that degrade and destroy sagebrush (*Artemisia* spp.), threatening habitat for sage-grouse (*Centrocercus urophasianus* and *C. minimus*). Effective restoration is needed to counter these trends, but understanding the conditions determining when, where, and at what rate sagebrush recovery will occur is critical for prioritizing management actions across this vast landscape. We developed a framework for modeling and predicting sagebrush recovery across the biome (1987–2020) by taking advantage of multiple datasets spanning broad extents, including vegetation estimates derived from remote sensing (RCMAP and RAP), restoration practices (Land Treatment Digital Library, Conservation Efforts Database, Utah Watershed Restoration Initiative), fire (Landsat Burned Area), and soil moisture. When combined, these datasets yielded analysis-ready data to an unprecedented extent, including from 874 wildfires (>2.7 million ha) and 261 other disturbances (nearly 120,000 ha). We assessed the influence of environmental factors (e.g., soil moisture), disturbance type (e.g., wildfire, brush removal), and restoration treatment (e.g., aerial seeding, herbicide application) on trends in sagebrush cover. Our results will facilitate stewardship of sage-grouse habitat by providing spatially explicit predictions and projections of sagebrush recovery, thereby informing regional planning and on-the-ground restoration efforts (e.g., cost-effectiveness analyses and restoration prioritization tools).

An optimization approach to balance conifer removal trade-offs for sagebrush and pinyon-juniper songbirds.

Van Lanen, N. J., J. E. Shyvers, C. J. Duchardt, A. P. Monroe, and C. L. Aldridge.

Abstract: Greater sage-grouse (*Centrocercus urophasianus*) and other sagebrush-obligate songbirds benefit from conifer removal within sagebrush habitats. Unfortunately, growing evidence suggests pinyon-juniper associated species, including the declining pinyon jay (*Gymnorhinus cyanocephalus*), are likely negatively impacted by conifer removal. Thus, managers require information regarding where conifer removal can be implemented to improve sagebrush ecosystems, while maintaining important habitat for pinyon- juniper species. To address this need, we developed a Bayesian hierarchical modeling framework, using songbird abundance to assess habitat relationships. Using these models, we predicted songbird abundance given current conditions, and under a conifer removal scenario. We then calculated expected changes in songbird abundance following our simulated conifer removal treatments (hereafter, "utility") for six species: Bewick's wren (*Thryomanes bewickii*), Brewer's sparrow (*Spizella breweri*), gray flycatcher (*Empidonax wrightii*), pinyon jay, sagebrush sparrow (*Artemisiospiza nevadensis*), and sage thrasher (*Oreoscoptes montanus*). We incorporated these utilities in a linear integer programming optimization framework to identify conifer removal locations based upon single species, single ecosystem, and multi-ecosystem management paradigms to compare conservation outcomes. Using the Utah portion of Bird Conservation Region 16 as a test case, we identified locations for conifer removal treatments within greater sage-grouse habitat which maximizes sagebrush songbird abundances and minimizes decreases in pinyon-juniper songbird abundances.

Atypical primary molt patterns in greater sage-grouse: implications for age classification.

Walker, B. L., and M. A. Schroeder.

Abstract: Age-specific patterns of primary molt facilitate age classification of native North American upland gamebirds, a critical step in understanding their ecology, behavior, life history, population dynamics and harvest. However, deviations from typical molt patterns can create confusing plumages that complicate age classification. We examined data from live-captured greater sage-grouse *Centrocercus urophasianus* across seven studies in five U.S. states and wings from harvested birds in Oregon and Colorado for evidence of atypical primary molt. We documented atypical replacement through primary nine during preformative molt, atypical retention of juvenile primary 10 during second prebasic molt, and atypical retention of basic outer primaries during definitive prebasic molt. Atypical primary molts were observed more often in live-captured females (3.2%, n = 561) than males (0.8%, n = 494). Many individuals with atypical primary patterns, especially females, are difficult or impossible to reliably age by plumage or morphology and may bias research and harvest data.

Collaborative conservation: creating range-wide seasonal habitat models for greater sage-grouse.

Wann, G. T., C. L. Aldridge, M. M. McLachlan, J. L. Beck, T. S. Bowden, P. S. Coates, C. J. Conway, D. K. Dahlgren, J. B. Dinkins, A. N. Johnston, C. A. Hagen, P. D. Makela, D. E. Naugle, B. R. Noon, M. A. Schroeder, J. S. Sedinger, L. R. Waldner, B. L. Walker, and P. J. Williams.

Abstract: Wildlife populations commonly rely on habitats that vary seasonally in their characteristics. Identifying and protecting seasonal habitats is therefore an important conservation strategy to ensure populations have access to suitable habitats throughout their annual cycle. The greater sage-grouse (*Centrocercus urophasianus*) is a declining sagebrush specialist that occupies a 714,000 km^2 area in western North America, half of which is managed by the Bureau of Land Management (BLM). The BLM follows a habitat assessment framework (HAF) developed for sage-grouse to evaluate habitats at various spatial scales, including one intended to capture seasonal habitats. Seasonal habitat maps produced from a consistent set of models could help inform the HAF across BLM lands occupied by sage-grouse, but such a product is currently lacking. In 2020 we initiated a range-wide collaborative model-building project involving sage-grouse researchers from 11 states and multiple federal, state, and private entities. We compiled a range-wide location dataset that resulted in several million use locations. Here, we present the first iteration of range-wide seasonal habitat models developed for breeding, summer, and winter periods. We used Lasso regression to estimate resource selection functions used for predictive mapping. This project is ongoing, and we will discuss planned extensions to our modeling approach.

Impacts of communication towers on greater sage-grouse population demographics

Webster, S. C., S. T. O'Neil, P. S. Coates, J. Cupples, H. McPherron, S. Abele, G. Frederick, S. Szabo, and J. Dinkins..

Abstract: Communication infrastructure development, particularly tower structures, increases habitat fragmentation and provides additional nesting and perching substrates for avian predators throughout sagebrush ecosystems and has the potential to negatively impact sensitive species such as greater sage-grouse (*Centrocercus urophasianus*). However, previous research on impacts of tall structures on grouse has largely focused on electrical transmission or distribution lines. Thus, the impacts of communication towers and associated infrastructure on sage-grouse populations are not well understood. We developed a comprehensive communication tower database from multiple sources and applied a Bayesian hierarchical state-space model (SSM) to explore the impacts of communication towers on sage-grouse population demographics over multiple temporal (e.g., nadir-to-nadir population cycles) and spatial (1, 2, 4.8, 8, 12.5, and 20km) scales across a large portion of their range including Oregon, Wyoming, Nevada, and Idaho from 1996 – 2019. We found that several landcover features, including tower density and proximity to leks, were negatively associated with sage-grouse population growth over time. Model results suggested spatial variation in tower effects, suggesting that effects on local sage-grouse populations can depend on land-cover conditions and other local-scale attributes, offering potential to guide policy and siting of future tower development. These findings are preliminary, provided for timely science communication.

Decision support software to assess range-wide greater sage-grouse trends through a hierarchical population modeling framework.

Weise, C. L., P. S. Coates, B. P. Prochazka, M. S. O'Donnell, C. L. Aldridge, D. R. Edmunds, A. P. Monroe, M. A. Ricca, G. T. Wann, S. E. Hanser, L. A. Wiechman, and M. P. Chenaille.

Abstract: The range-wide hierarchical population monitoring framework released in 2021 by Coates et al. improved the reliability of greater sage-grouse (*Centrocercus urophasianus*) population estimates by accounting for temporal oscillations and spatial structure in populations and provided a Targeted Annual Warning System (TAWS) to assess when and where populations declines are out of sync with temporal and regional trends. We have developed secure, user-friendly decision support software that allows managers to interact with, query, and download spatial and temporal outputs from the range-wide hierarchical population modeling framework for straightforward application to their management goals. The easy-to-navigate interface provides users with drop-down menus and interactive maps to define their timeframe and populations of interest. The software outputs maps, figures, and tables displaying annual fluctuations in populations through time across relevant temporal and spatial scales. It also reports the populations of concern as defined by the TAWS, allowing managers to identify at a glance which populations may benefit from closer monitoring or management intervention within their management unit of interest. The centralization and accessibility of these data promote an understanding of deterministic factors that impact local sage-grouse populations and promote informed management actions. Findings are preliminary and provided for timely best science.

Seasonal habitat selection analyses for sage-grouse: a literature review.

Whipple, A. L., G. T. Wann, C. L. Aldridge, M. M. McLachlan, J. L. Beck, T. Bowden, P. S. Coates, C. J. Conway, D. K. Dahlgren, J. B. Dinkins, A. N. Johnston, C. A. Hagen, P. D. Makela, D. E. Naugle, B. R. Noon, M. A. Schroeder, J. S. Sedinger, L. Waldner, B. L. Walker, and P. J. Williams.

Abstract: Since the turn of the century, habitat selection studies have gained considerable representation in the wildlife management literature. With land-use planning revision efforts under way, reassessing information available for sage-grouse habitat selection could provide much needed insights into seasonal resource requirements and common analytical approaches used to assess habitat relationships. We used Google Scholar to conduct a literature search of seasonal habitat studies for sage-grouse, focusing on Johnson's (1980) 2nd and 3rd order scales of selection, and extracted information on types of covariates evaluated and statistical models implemented. We present our synthesis of 59 studies and bring forth the commonalities and differences among them. Of note, most studies used a resource selection function framework and generalized linear or generalized linear mixed models to evaluate selection during the breeding season (includes lekking, nest and brood-rearing), but winter, summer, and transitional periods were also modeled. We grouped model covariates into general categories to evaluate patterns in response

types and found most had mixed responses. However, the relationship between selection and sagebrush was mostly positive while topographic roughness, slope, and trees were mostly negative. Our synthesis provides an opportunity to reflect on progress and enables discussion for a unified best practice going forward.

Relationship between trends in female survival rates and male spring lek counts of greater sage-grouse in south-central Wyoming.

Widmer, A. M., M. P. Such, A. R. Ashby, N. J. Wojcik, J. W. Kehmeier, and K. A. Cummins.

Abstract: Characterization of population size and trend is central to effective species management. Survival rates of female greater sage-grouse (*Centrocercus urophasianus*) were found to strongly influence population growth rates in several studied populations. We evaluated the relationship between this influential population demographic and peak male lek attendance, the most widely used index of population size for species management. Female survivorship and peak male lek attendance were monitored concurrently for 13 years (2010 to 2022) by Power Company of Wyoming LLC in and around the Chokecherry and Sierra Madre Wind Energy Project in south-central Wyoming. These data were collected as part of a long-term and ongoing study of sage-grouse population demographics, movement, and habitat use response to wind energy development. We analyzed the correlation between female survival and peak male lek attendance considering location and lag time in lek attendance. The survival data included records from 400 hens that were tracked with GPS tags over a cumulative 428 grouse-years. The lek data included spring counts from 58 leks within the study region. Initial results indicate a positive correlation between female survival and peak male lek attendance, with a lag time in lek attendance of 2 years.

Development of a greater sage-grouse conservation area in south-central Wyoming.

Wojcik, N. J., R. J. Creaser, A. M. Widmer, J. W. Kehmeier, and K. A. Cummins.

Abstract: Power Company of Wyoming LLC (PCW) and TransWest Express LLC (TransWest) recognize the importance of providing species conservation while providing clean, renewable energy sources to the American public. To minimize and mitigate impacts to greater sage-grouse and its habitat caused by energy project developments in Wyoming, a multi-stakeholder effort between PCW, TransWest, the Overland Trail Cattle Company, Bureau of Land Management, and Wyoming Game and Fish Department has been established to protect, restore, and enhance great sage-grouse habitat. Approximately 2,100 acres of Core Population Area habitat located in south-central Wyoming have been identified for habitat enhancement. An ongoing, longterm study of greater sage-grouse habitat use and movement patterns along with innovative approaches were used to design and implement vegetation enhancement projects. Snowdrift modelling, implementation of multiple noxious weed treatment options, and revegetation strategies based on concepts of successional ecology were incorporated to facilitate enhancement success. Approximately 155 acres of enhancement projects have been implemented, including the control of 80 acres of noxious weeds and undesirable vegetation, seeding of 126 acres of native vegetation, and installation of water developments. Additional habitat enhancements are planned for future years following the monitoring and development of adaptive strategies to improve upon previously implemented projects.

Prescribed burning to restore and enhance sharp-tailed grouse habitat in northeastern British Columbia.

Woods, A. D.

Abstract: Populations of the plains subspecies of sharp-tailed grouse can be found sporadically throughout northeastern British Columbia and are likely the northwestern-most population of the subspecies across their range. Populations in northeastern British Columbia have been steadily decreasing over the past 14 years. The decline can largely be attributed to habitat loss including shifts in agricultural practices and changes in the historical fire regime. A reduced frequency of prescribed burning, and suppression of wildfires, has resulted in the encroachment of deciduous trees and tall shrubs into lek and nest habitat. To restore and enhance sharp-tailed grouse habitat, I conducted a prescribed fire treatment on two sites to reduce canopy cover and vertical structure of deciduous trees and shrubs, promote open sightlines around leks, and increase herbaceous and low shrub growth in nesting habitat around leks. On the Preston site, one-year post-treatment, deciduous trees and tall shrub cover decreased by 50%. Treatment of the second site was completed in May 2022, and preliminary results suggest a removal of

approximately 25% of shrubs (>2 m in height) one-month post-treatment. Lek attendance surveys and indicators of habitat quality measured pre- and post-treatment will be used to assess response of sharp-tailed grouse to the treatment.

Varying influence of sagebrush habitat on Gunnison sage-grouse gene flow.

Zimmerman, S. J., C. L Aldridge, M. B. Hooten, and S. J. Oyler-McCance.

Abstract: Habitat fragmentation and degradation affects an organism's ability to navigate the landscape and can lead to decreased gene flow and increased extinction risk. Understanding how landscape composition influences gene flow (i.e., connectivity) and interacts with scale is essential to conservation decision making. We used a landscape genetics approach to identify the primary landscape features affecting gene flow and to estimate the degree to which each component influences connectivity for Gunnison sage-grouse (*Centrocercus minimus*). We focused on understanding how landscape composition influences gene flow among discrete populations and among leks within the Gunnison Basin population in two separate analyses. Generally, our findings support previous assumptions that Gunnison sage-grouse range contraction is largely the result of habitat loss and degradation and that the sagebrush habitat is a primary influencer of gene flow. However, the important characteristics of the sagebrush community influencing gene flow differed across the two spatial scales. We also demonstrated the utility of these types of analyses to compare relative impact to long-term evolutionary capacity of the species from alternative conservation action scenarios.

The Wildlife Society

More than 2,000 people gathered for the annual conference of The Wildlife Society in Spokane, Washington, USA during 6–10 November 2022. Although the conference covered many wildlife topics in numerous concurrent sessions, 75 presentations (talks and posters) were on grouse or grouse-related topics (abstracts below). Greater sage-grouse (*Centrocercus urophasianus*) were mentioned the most (by far), but Gunnison sage-grouse (*C. minimus*), sharp-tailed grouse (*Tympanuchus phasianellus*), greater prairie-chicken (*T. cupido*), lesser prairie-chicken (*T. pallidicinctus*), ruffed grouse (*Bonasa umbellus*), dusky grouse (*Dendragapus obscurus*), and sooty grouse (*D. fuliginosus*) were also covered. There was a lot of excitement at the conference since that last time the conference was held in person was in 2019 in Reno, Nevada, USA.

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Toward Detecting Grazing Effects on Rangeland Vegetation from Space.

Arkle, R., M. Rigge, P. Coates, D. Pilliod, B. Prochazka, and S. Dettenmaier.

Abstract: One goal of the Nevada-based ROGER collaborative is to develop links between remote sensing products and cattle grazing data to help manage grazing within a more flexible framework, affording the ability to alter timing, intensity, and locations of cattle grazing to promote "outcome-based grazing" objectives. We used fractional vegetation cover maps (RCMAP, USGS EROS), produced on an annual basis from 1985-2020, to develop proof-of-concept weekly maps that depict vegetation cover of functional groups such as bare ground, litter, perennial herbaceous, annual herbaceous, sagebrush, and other shrub cover at a 30-m pixel size during each week of the growing season (April-October) at our Nevada test location. We also deployed GPS transmitters on a subset of cattle at our study site and used these data to develop weekly utilization distribution maps depicting herd-wide use intensity at a 30-m resolution as cattle moved throughout the growing season. We summarized these vegetation and grazing data, along with wildfire occurrence and weather data, within grazing pastures crossed by ecological sites to account for variation in site potential and response to disturbance. We have recently made advances with interactive display and exploration of these data using the graphical database interface, Tableau. This platform provides the first step towards readily accessible desktop analyses for managers to evaluate relationships between vegetation composition and structure, seasonal and annual weather patterns, and grazing pressure across ecological sites over time, and will ultimately be integrated with sage-grouse habitat management framework described by colleagues in this session.

Object-Based Classification of Invasive Annual Grasses Using Unoccupied Aerial Vehicle Imagery.

Beine, N., M. Bedford, Jr., A. Rees, H. Duncan, and G. Casady.

Abstract: An aerial view is valuable for monitoring invasive species' range, density, or percent cover. Unoccupied Aerial Vehicles (UAV's) provide a view that is not attainable from ground-level, aiding in research or management objectives. Remote sensing UAV imagery uses multiple spectral bands and can be stitched together to create a high-resolution picture, which can often identify specific plant species. In our study, we deployed a UAV in June and July of 2021 to collect multispectral imagery of a post-fire rangeland site in Lincoln County, WA. We used Pix4dmapper software to stitch images together into reflectance map orthomosaics. Orfeo Toolbox object-based classifier was used to categorize the data into different classes for each date individually and both dates combined. The primary focus of this categorization was cheatgrass (Bromus tectorum), a nonnative annual grass and a driver of wildfire. The object-based classification was compared to percent cover data, collected using Daubenmire plots in the study area, and its accuracy assessed. We identified a wide range of accuracies across the data sets, with User's accuracy generally being higher than Producer's accuracy. These results show both success and room for improvement in our classifying system and help inform future developments in the integration of novel technologies for invasive species monitoring.

Acquiring Large Scale Spatial Data for Use in Integrated Nested Laplace Approximation (INLA) Models.

Bondo, K., and W. D. Walter.

Abstract: Recent advances in development of packages and software to download large scale spatial data have come with simultaneous advances in statistical methods. Recently, integrated nested Laplace approximations (INLA) using stochastic partial differential equation (SPDE) solutions were developed to model large spatial datasets because traditional Bayesian methods were unsuitable due to slow computational times. We developed code that streamlines downloading of various sources of statewide spatial data and assigns these data to sampling locations with large extents. We provide an example in Pennsylvania, USA, to download and extract locations over several years from 2018 to 2020, within habitats occupied by ruffed grouse. We link mosquito abundance to West Nile Virus (WNV) exposure to ruffed grouse because mosquitoes are known vectors of WNV and common in woodland habitats used by grouse. Combining datasets collected in woodland habitats with surveillance datasets collected in human-dominated regions statewide, we built spatial models in R-INLA with the SPDE approach to identify variables driving risk of WNV exposure to ruffed grouse. Fitting these models over the extent of Pennsylvania, we found various habitat and climatic variables to be important predictors of risk of WNV exposure. To help inform agency personnel of the best areas to focus grouse management effort, we identified areas at the greatest risk of WNV exposure to grouse within the state. Providing user-friendly sources of code that downloads spatial data and subsequently extracts covariates for sampling locations with large extents will make large scale spatial data more available and accessible to the research community.

A Spatio-Temporal Model to Monitor Common Raven Populations in the Western United States.

Brockman, J., P. Coates, P. Jackson, J. Tull, and P. Williams.

Abstract: Common raven (*Corvus corax*) populations and ranges are increasing throughout the United States, in part due to an increase in anthropogenic subsidies across the landscape. Increased raven numbers and depredation negatively impact prey populations, including species of concern, creating a need for management of raven populations. Information regarding population growth, emigration, and immigration is required for effective population assessment and management. Although previous research has explored the relationship between anthropogenic subsidies and raven abundance and density, a better understanding of the demographic processes at a landscape scale is still needed. Population dynamics vary across space and time, making this especially difficult. The North American Breeding Bird Survey dataset provides an opportunity to model these dynamic processes at a large spatial and temporal scale. Using Breeding Bird Survey data, we employed ecological diffusion theory in a hierarchical Bayesian framework to develop a model of raven population growth and dispersal in the western United States. The model quantifies the effects of anthropogenic subsidies on these processes and illuminates the mechanisms contributing to increases in raven abundance and range expansion. Our model can also be

used to forecast changes in raven abundance, highlighting areas of future concern in addition to informing management strategies.

A Rapid Assessment Function to Estimate Common Raven Population Densities: Implications for Targeted Management.

Brussee, B., P. Coates, S. O'Neil, S, Dettenmaier, P, Jackson, K, Howe, and D, Delehanty.

Abstract: The western United States has experienced steady increases in common raven (*Corvus corax*; hereafter, raven) populations over the previous 50 years. Raven population increases likely presage heightened impacts to the reproductive efforts of some sensitive prey species. For example, negative impacts to nesting sage-grouse have been observed where raven density exceeded ~0.40 km^2, a potential ecological threshold. Therefore, monitoring changing raven densities is crucial to inform adaptive management frameworks for sensitive species. However, obtaining estimates of raven density is data- and resource-intensive. We developed a rapid protocol to assess site-level density based on the average number of ravens per survey (i.e. raven index). Specifically, we used a regression analysis to investigate the relationship between density estimates from robust distance sampling methods and the raven index, which revealed a strong correlation (R^2 = 0.86). We used this estimated relationship to create a rapid assessment function that accounts for detection probability of ravens within sagebrush ecosystems, serving as a correction factor on the raven index, and bypassing the need to conduct distance-based methodologies. Finally, using a simulation analysis of data from sites with abundant surveys and the rapid assessment function, we estimated raven density based on different numbers of surveys to help inform how many surveys are needed to achieve reliable estimates within this rapid protocol. While the more robust procedures of distance sampling are preferred, this method provides a reliable approximation for informing management when faced with sample size constraints.

Understanding Past and Present Connectivity Patterns for Habitat and Wildlife in the Sagebrush Biome.

Buchholtz, E., J. Heinrichs, M. O'Donnell, and C. Aldridge.

Abstract: Connectivity is a key component of functioning ecosystems, and there has been an increasing emphasis on management actions to maintain, restore, or increase connectivity. For restoration and management actions to be successful, it is crucial to understand how the spatial patterns of landscape connectivity may vary over time and how wildlife with different connectivity needs may be affected by such structural changes. We investigated temporal connectivity patterns for the sagebrush biome of the western United States, which has been affected by disturbances such as fire, invasive grasses, and human development. We used an omnidirectional circuit theory approach to classify structural connectivity patterns of sagebrush in the biome between 1985 and 2018. We identified regions of the sagebrush biome that indicated lost connectivity, persistent connectivity, and channelized locations of remaining connectivity among sagebrush patches. We compared sagebrush connectivity results to those of different wildlife guilds (e.g., movement modalities, sensitivity to disturbance, and reliance on sagebrush habitat) to assess the ability of analyses of connected vegetation to represent the movement connectivity needs of different kinds of wildlife. These findings could help characterize opportunities for proactive conservation of remaining sagebrush structural connectivity and identify degraded areas where targeted management could increase connectivity, benefiting multiple wildlife species.

Incorporating Climate Change Aspects into Translocation Design: A Literature Review and Helpful Resources.

Chelak, M.

Abstract: Climate change is affecting species' suitable habitats worldwide, which is estimated to continue according to climate projection models. This suitable habitat change will likely warrant the increased use of conservation translocations not only through assisted migrations outside species' historical distributions but also through the increased use of reintroductions and reinforcements within species' current distributions to prevent extinction or extirpation, respectively. Because translocation programs require significant resources (i.e., time and money) to succeed, this emphasizes the need for employing the most effective translocation design. Ultimately, the goal of translocations is the persistence of the target species or population. If the climate of a translocation release area becomes unsuitable following translocation efforts and the target population is no longer viable, this results in a failed translocation. In 2013, the International Union of Conservation of Nature Species Survival Commission updated previous versions

of their conservation translocation guidelines, which include factoring climate change into the planning phase, as it is integral to consider both the current and future abiotic and biotic factors of species' suitable habitat. This presentation will include a review of the current peer-reviewed literature using the Google Scholar search engine. I will summarize 21 publications incorporating climate change projections into the translocation design process, cover a few publicly-available tools to obtain climate projections within North America, and highlight some avenues for consideration to progress the field of conservation translocations.

Effect of Juniper Expansion and Removal on Avian Abundance in Aspen and Sagebrush Areas in Southeast Oregon

Christensen, C., V. Schroeder, S. Wolfe, H. Higgins, D. Johnson, and J. Dinkins.

Abstract: In the Great Basin, juniper (*Juniperus occidentalis*) woodlands have expanded into areas previously dominated by sagebrush (*Artemisia* spp.) plant communities since the late 19th century. This expansion has resulted in habitat loss and degradation for many avian species and in response, land managers are removing juniper from infilled areas. Generally, the abundance of shrub and ground-nesting species decreases with juniper expansion but increases in response to juniper removal. In contrast, cavity-nesting species largely benefit from juniper expansion but their abundance generally declines post-juniper removal. Juniper has also been expanding into aspen (*Populus tremuloides*) plant communities, which support a high diversity of avian species, particularly cavity-nesters, despite their relatively small spatial footprint. The impact of juniper expansion and removal on avian species in aspen plant communities is relatively unknown. Broadly, we are evaluating the impacts of juniper expansion and the short-term impacts of juniper removal on the abundance of cavity, ground, and shrub-nesting species across time in sagebrush and aspen areas in the Steens Mountain area, Oregon. We will present preliminary abundance data from a study using autonomous recording units (ARUs) in the Steens Mountain area of Oregon from 2020–2021. The placement of ARUs was stratified by sagebrush and aspen areas across a gradient of juniper expansion and removal. These preliminary evaluations will provide insights into the short-term effects of juniper removal on avian abundance and inform management agencies about the influence of juniper expansion on avian species in sagebrush and aspen plant communities.

Synthesizing the 'Designing Effective Avian Translocations' Symposium for Direct Application.

Coates, P.

Abstract: Given the rapid decline and extinction of species across the globe, conservation translocations are being increasingly implemented by researchers and managers to prevent, slow, or reverse these trends. Funding, time, and collaborative efforts dictate which translocations are prioritized; these resources must be utilized most effectively and ethically. This session, Designing Effective Avian Translocations, is intended to showcase long-term and recent research that has improved the effectiveness of conservation translocations for avian species, both in terms of design and implementation. Paramount to translocations is the need to adapt strategies within a program while learning from what has worked well or not in the past. Adaptive management is that process, and nesting it within a structured decision-making (SDM) framework enables researchers and managers to optimize the prioritization and timing of decisions. Going forward, using SDM frameworks should be the default for translocation projects. We will review critical take-aways from state-of-the-art applications of SDM in translocation science and list resources to help interested parties apply them in their programs. In addition, we will synthesize the authors' presentations on recent advancements in design, implementation, modeling, monitoring, and evaluation of conservation translocations and their practical relevance. Finally, we will review existing resources available in peer-reviewed publications, books, and groups to inform those interested in recent and foundational literature on conservation translocations. We aim to help all parties involved in performing translocations optimize and learn from their programs.

The Effectiveness of Habitat Restoration and Conservation Actions on Greater Sage-Grouse Population Dynamics Within the Bi-State Distinct Population Segment.

Coates, P., B. Prochazka, C. Aldridge, K. Doherty, and J. Tull.

Abstract: Decades of local conservation actions aimed at restoring landscapes to pre-disturbed conditions have been carried out across sagebrush ecosystems. However, evaluating wildlife response to such actions

is often met with significant challenges, primarily from stochasticity associated with broad-scale climatic patterns. Within a distinct population of greater sage-grouse (*Centrocercus urophasianus*; hereafter, sage-grouse) on the border of Nevada and California, we piloted an analytical framework that consisted of Before-After-Control-Impact study design to evaluate population responses from conservation actions compiled from a newly established Conservation Efforts Database. Specifically, we employed Bayesian state-space models to estimate intrinsic rate of change in apparent abundance (lambda) based on lek (traditional breeding grounds) counts before and after a local conservation action (impact) relative to changes at broader scales (control). We also evaluated lag effects of changes in apparent abundance up to 6 years following each action. Our models estimated increased apparent abundance following several types of actions, including weed reduction, sagebrush restoration, road closure, conifer removal, meadow restoration, herd management, and fence removal. However, the effect size and temporal patterns of these changes varied among actions. Overall, the annual increase in rate of change was as high as ~9.0% for specific actions. Our findings will assist federal and state resource management agencies to better plan restoration activities aimed at sage-grouse population recovery. An expansion of this study is expected to cover broader extents within the sagebrush biome. These data are preliminary and provided for timely science communication.

A Synthesis of Nest Predation Impacts of Common Ravens on Sensitive Avian Species.

Coates, P., W. C. Webb, S. Dettenmaier, and D. Delehanty.

Abstract: Decades of mounting scientific evidence have revealed that common raven (*Corvus corax*; raven) population numbers have been increasing across nearly all regions of their geographic range in North America. Concomitantly, numerous native species have experienced elevated rates of predation from ravens. Managers are concerned that increased raven predation of many threatened and endangered avian species in the U.S. and Canada during nesting periods may be hampering species recovery. We explored the literature to aggregate existing knowledge and evaluate the impacts of raven predation on nests of sensitive avian species. We found evidence of nest predation on 8 sensitive avian species, and suspected nest predation on 1 additional species. All species shared aspects of nesting biology that suggested they would likely be susceptible to raven nest predation. The species experiencing highest impacts were greater sage-grouse (*Centrocercus urophasianus*), snowy plover (*Charadrius nivosus nivosus*), marbled murrelet (*Brachyramphus marmoratus*), and Gunnison sage-grouse (*Centrocercus minimus*). As a case study, we present findings that describe mechanistic pathways of how increasing raven numbers affect sage-grouse incubation behavior, nest survival, and population dynamics. While increasing raven population numbers may be of high concern to managers, it is important to recognize that sensitive species investigated here are also facing multiple conservation threats simultaneously. Thus, our investigation is intended to help inform when management decisions are most necessary to mitigate the negative effects of raven predation on sensitive avian prey.

Intact Habitat for Greater Sage Grouse Includes Biological Soil Crusts

Condon, L. M. Milligan, B. Brussee, S. O'Neil, and P. Coates.

Abstract: Biological soil crusts (biocrusts) are a common component of plant communities in shrub-steppe ecosystems. The sagebrush steppe of the Great Basin is unique in its known disturbance history. Previous work in the region has linked the loss of biocrusts to disturbance and to increases in cheatgrass, Bromus tectorum. Cheatgrass is responsible for altering fire regimes, leading to increased loss of sagebrush that threatens the persistence of sagebrush obligate species such as the greater sage grouse (*Centrocercus urophasianus*). We used data collected by the Assessment, Inventory and Monitoring (AIM) program of the Bureau of Land Management, specifically the Landscape Monitoring Framework, in combination with a long-term dataset of sage-grouse nest locations and fates collected across the Great Basin. We used Bayesian generalized mixed models to examine hypothesized relationships between disturbance induced losses of biocrusts, subsequent increases in cheatgrass at multiple spatial scales and alterations to nesting patterns of sage-grouse. Preliminary results indicate that a combination of common disturbances (fire, grazing and roads) lead to reductions in cover of biocrusts (lichens and mosses), resulting in increased cover of cheatgrass. Importantly, nest survival was negatively influenced by cheatgrass cover at coarser spatial scales. Our preliminary results suggest that the presence of biocrusts has cascading positive effects on an important breeding life stage of greater sage-grouse. These findings are preliminary, are provided for timely science communication, and are subject to change.

Developing Novel Translocation Methods: Hedging for Success Based on Life History.

Dahlgren, D., K. Lazenby, M. Meyerpeter, P. Coates, M. Ricca, S. Mathews-Sanchez, S. Gardner, and D. Delehanty.

Abstract: Wildlife translocations, when evaluated, have had difficulty meeting intended objectives. Translocations of greater sage-grouse (*Centrocercus urophasianus*) have faced similar issues. Increased augmented population productivity has been a common objective of these translocation projects. However, most common are females translocated during the lekking season, just prior to nesting. Reproductive output by translocated females has been lower than average, especially the year of translocation. Post-release movements have been extreme leading to increased mortality probability and movement outside the targeted area. We developed a novel methodology that attempts to hedge against large movements and low productivity post-release. First, translocated females remained in the source population through the nesting period. Then we captured the female with her chicks and translocated the brood. At the release site, we used a soft release and the brood female and chicks moved from a carrier to an acclimation pen. Once normal brood behavior was detected, the brood was released into the augmented population. We monitored movements and survival of each brood through the brooding period. We also monitored females translocated during the lekking season into the same augmented populations, and source population females. We found that brood translocations resulted in higher productivity for translocated females and decreased movements compared to females translocated during the spring lekking season. We also found that source populations were not impacted by losing brood females and chicks, yet the augmented populations were benefited by brood translocations.

A Science-Based Management of Ravens Tool (Smart): A 3-Tiered Hierarchical Framework

Dettenmaier, S., P. Coates, C. Roth, S. Webster, S. O'Neil, K. Holcomb, J. Tull, and P. Jackson.

Abstract: Common raven (*Corvus corax*) population growth and distribution expansion across much of western North America is causing more frequent negative consequences to agriculture, human health and safety, and sensitive species. Traditional raven control efforts focused on the use of lethal removal, with little or no post-treatment monitoring. This approach has led to management plans that often fail to consider alternative management approaches, which may be more effective for achieving long-term predation management goals. We describe an adaptive management framework for addressing overabundant raven populations that explicitly incorporates peer-reviewed products. Our off-the-shelf Science-based Management of Ravens Tool (SMaRT) provides a user-friendly, web-based interface that guides managers through the steps of the framework to develop a fully customized adaptive plan for raven management. In the SMaRT interface, users can: (1) interact with existing maps of raven occupancy and density, input areas of interest or upload pre-defined polygons for target species within the Great Basin to delineate their proposed monitoring or treatment sites; (2) generate raven densities using a rapid assessment function; (3) compare site-level density to an identified ecological threshold; and (4) produce a list of potential management actions for their consideration. SMaRT supports decision-making by operationalizing literature and datasets within the field of raven management and facilitates meeting goals associated with sensitive species conservation. Findings are preliminary and provided for timely best science.

Increased Abundance of the Common Raven Within the Ranges of Greater and Gunnison Sage-Grouse: Influence of Anthropogenic Subsidies and Fire.

Dinkins, J., L. Perry, J. Beck, and J. Taylor.

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 from 1995–2014, we evaluated raven count data to describe changes in abundance and expansion into sagebrush (*Artemisia* spp.) ecosystems. We focused analyses on the seven sage-grouse Management Zones (MZs) delineated across 11 western U.S. states and 2 Canadian provinces. We assessed the effects of numerous land cover and anthropogenic features on instantaneous growth rate (r) or carrying capacity (K) 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 increased raven populations for several decades. Areas with greater transmission line density had higher r; higher K was positively related to proportion of urban land cover within 25 km and burned area within 3 km and negatively related to greater distance from landfills and proportion of forest land cover within 15 km. Ravens have capitalized on human subsidies to increase abundance and expand into sagebrush ecosystems that did not historically support high raven populations. Our findings suggest ravens have capitalized on human subsidies to increase abundance and expand into sagebrush ecosystems, which has ramifications for sensitive species in these ecosystems.

Evaluating the Greater Sage-Grouse Umbrella Using Neutral Landscape Models.

Duchardt, C., A. Monroe, C. Aldridge, D. Edmunds, and M. Holloran.

Abstract: Steep biodiversity declines in North American rangeland biodiversity prompted researchers and managers to use umbrella species as a tool to manage diverse suites of co-occurring wildlife, but efficacy of this method has been variable. Evaluation of prairie and shrubland grouse as umbrellas typically involves comparing observed overlap between umbrella and background species, but this approach does not distinguish between ubiquity and co-occurrence nor provide insight into performance of umbrellas at transitional zones between ecoregions. We demonstrate a novel application of neutral landscape models (NLMs) to test effectiveness of greater sage-grouse (*Centrocercus urophasianus*) as an umbrella species for grassland songbirds at a grassland-sagebrush ecotone. We leveraged existing spatial data representing two types of sage-grouse habitat (nesting and brood-rearing) and density and distribution for eight grassland songbird species. We applied a permutation-based hypothesis test using NLMs to determine whether overlap between background species and greater sage-grouse was greater than expected by chance. Three songbirds (western meadowlark *Sturnella neglecta*, loggerhead shrike *Lanius ludovicianus*, and lark bunting *Calamospiza melanocorys*) had greater overlap than expected with at least one type of greater sage-grouse habitat, while western kingbirds (*Tyrannus verticalis*) indicated avoidance. All positive-associated species nest in sagebrush shrubs (loggerhead shrike) or often select locations underneath small shrubs (western meadowlark, lark bunting), suggesting nesting substrate as a potential niche axis to consider when evaluating the umbrella species concept. This application of NLMs provides a more nuanced evaluation of the umbrella species concept than previous studies of observed overlap.

Estimating Shrub Height and Diameter Using Unoccupied Aerial Vehicle Imagery.

Fenske, M., M. Moore, and G. Casady.

Abstract: Determining shrub height and cover is valuable for assessing the health of shrub-steppe habitat in the Western US because many native species depend on shrubs for forage and shelter. Specifically, in Lincoln County, WA, greater sage-grouse (Centrocercus urophasianus) and sharp-tailed grouse (*Tympanuchus phasianellus*) are among these species. In September 2020, the Whitney Fire burned over 125,000 acres of sagebrush steppe south of Davenport, WA, removing much of the shrub cover. The height and cover of the shrub regrowth should be known in order to better manage and protect these bird's populations. To assess shrub height and cover across the site, an Unoccupied Aerial Vehicle (UAV) was used to capture imagery of shrub heights. The UAV was flown with one pass over a study site at 120 m altitude, and with two passes over four 30 m x 30 m plots at 45 m altitude to determine if better 3D models of shrub height are captured from lower elevation, slower flying speeds, and more passes. The software Pix4D Mapper was used to generate 3D models of the area in order to identify shrubs and estimate individual shrub heights and diameters which were compared to field data collected for a sample of shrubs in the coverage area. It is expected that more passes of slower flying speeds and lower elevation will generate better 3D models of shrub height. We do not expect post-fire shrub regrowth to be suitable for the reintroduction of the greater sage-grouse or the sharp-tailed grouse at this time.

Patterns of Sooty Grouse Occupancy and Abundance in Western Oregon.

Frey, S., L. Sanders, K. Walton, M. Cline, D. Gillies, and J. Dinkins.

Abstract: Western North American forested landscapes have been increasingly altered by logging, wildfire, and urbanization, resulting in habitat loss and alteration. Understanding species' responses aids management and conservation efforts. Adjusting hunting pressures for game species populations provides an additional management tool. Sooty grouse (*Dendragapus fuliginosus*) is a large game bird that occupies montane forests in the Pacific Northwest. The NA Breeding Bird Survey indicates population declines for this species (-1.8%/yr, 1968–2015). However, they are inadequately represented by BBS due

to sampling coverage, and low density and detectability. Advances in quantitative ecology have led to the widespread application of hierarchical models to simultaneously address both the observation and ecological processes associated with monitoring wildlife populations. From 2011–2021, we surveyed for sooty grouse at 113 sites across western Oregon representing four ecoregions: Coast Range, Klamath, East Cascades, and West Cascades. Occupancy analyses indicated that sooty grouse are more likely to occupy steep slopes and high elevations, although the elevation effect varied by ecoregion. Detection probability decreased throughout the survey season, increased with the number of stops per survey segment, and decreased with increasing temperatures. Abundance estimates varied by ecoregion, and detection was influenced by the proportion of a survey route completed. We compared trend estimates using occupancy and abundance models, and different data formats (spatial versus temporal replicates). There is evidence of population declines, particularly when using abundance models. However, trend estimates differed by analysis method and data format, with abundance models showing more declines, and space for time methods showing higher detection.

Assessing the Impact of Ancestry, Ploidy Level, Size, and Environment on Arthropod Richness for Two Subspecies of Big Sagebrush.

Friedlander, H., L. Waits, M. Garrett, L. Grossfurthner, P. Hohenlohe, and S. D. Eigenbrode.

Abstract: The sagebrush steppe ecosystem is home to over 300 arthropod species that depend on the foundation species big sagebrush (*Artemisia tridentata*). Characteristics within their sagebrush host affect the composition of arthropod communities. Subspecies of big sagebrush with differing genomes occupy diverse ecological niches. Hybridization events and variations in ploidy levels manifest as chemical, physical and phenological differences between plants, including size and secondary metabolites. Genetic variation in big sagebrush forms the basis of an extended phenotype for the community, and community structure and ecosystem processes are affected by these heritable differences. We explored the influence of ancestry and ploidy level on arthropod community richness, represented by unique arthropod morphotypes collected on plants, across natural sagebrush steppe study areas in Idaho and a common garden plot. Sites were inhabited by two big sagebrush subspecies: mountain (*A. t. vaseyana*) and Wyoming big sagebrush (*A. t. wyomingensis*) as well as potential hybrids. Diploid plants had a higher mean richness than tetraploids although the difference was not statistically significant at $p = 0.05$. *A. t. wyomingensis* had the greatest mean richness followed by potential hybrids and *A. t. vaseyana* subspecies, although again the differences were not statistically significant. The next steps in this project are to further identify arthropods to family level and feeding guild and incorporate collections data from previous years to expand our sample size. From there, the relative effects of genetic variation as well as the impacts of plant size and elevation on arthropod community attributes, including richness, diversity, evenness, and guild structure, will be analyzed.

Characterizing Soil and Leaf Microbial Communities of Big Sagebrush for Restoration.

Garrett, M., L. Grossfurthner, P. Hohenlohe, L. Waits, J. Forbey, and L. Bittleston.

Abstract: Big sagebrush (*Artemisia tridentata*), a foundation species providing critical habitat and food for more than 300 animal species, is facing anthropogenic threats and is disappearing from its western North American range. To increase viability and resilience under changing conditions, we need to understand the relationships between genetic variation in sagebrush and associated communities. Sagebrush are hosts to vast microbial assemblies responsible for a suite of functions. However, limited research has analyzed how big sagebrush genome size, allelic variation, or phytochemical expression, plus environmental factors, can influence microbial communities. The objectives of this study were to characterize the variation of associated soil and leaf microbial communities among big sagebrush genotypes and to determine the relative influence of environmental and big sagebrush genetic and phytochemical variability on associated microbial communities. Big sagebrush leaves and soil were collected in Idaho across big sagebrush ecotones with multiple subspecies. Genotyping of sagebrush followed a double-digest Restriction site Associated DNA sequencing (RADseq) approach, and microbial communities were identified through amplicon sequencing using 16S and ITS primers for bacterial and fungal taxa, respectively. We are using bacterial and fungal species composition to test for associations with sagebrush genetic and phenotypic variation. This work is among the first to apply community genetics theory to evaluate indirect genetic effects in the big sagebrush system and will guide restoration efforts by informing managers on how to better reseed areas in need. By gaining a better understanding of these relationships, we can better manage for big sagebrush resilience and ecosystem viability.

Cyclic Greater Sage-Grouse Populations Raise Challenging Questions.

Garton, E.

Abstract: Are greater sage-grouse (*Centrocercus urophasianus*) populations cyclic? Visual inspection of 30 populations and metapopulations reconstructed from lek counts suggests that 10 show regularity of population increases and decreases commonly described as cycles. I evaluated the Snake-Salmon-Beaverhead Management Zone metapopulation of Southern Idaho and Northern Nevada statistically to test for the presence of cyclic changes in abundance. This metapopulation shows a statistically significant 8–9 year cycle of population changes imposed on a 90% long-term decline in numbers from 1965 to 1993. I used annual rates of change over this 28-year period to test a series of hypotheses concerning the underlying causes of changes in this population: time lags in density dependence, drought, sunspots effects on soil moisture, cumulative fires across the sage-brush steppe and indices to jack rabbit and coyote population abundances. The best model based on 5 statistically significant predictors explained 67% of the variation in annual rates of change in sage-grouse numbers across this metapopulation and provided rough estimates of the relative magnitude of each predictor's impact. The possibility of cyclic population changes in sage-grouse raised substantial controversy recently and challenges wildlife managers and researchers in developing future management actions to recover this popular gamebird within the increasingly impacted sage-brush steppe facing increased rural development, expanding oil and gas production, impact of climate change on drought and fire regimes also impacted by invasive exotic plants.

Estimating Density of Sage Grouse at Summer Brood Rearing Habitat Using Modified Distance Sampling.

Golden, J., P. Street, J. Sedinger, and P. Williams.

Abstract: Population declines of greater sage-grouse (*Centrocercus urophasianus*) have been examined since the mid-20th century. While many factors have been attributed to sage-grouse decline, effects of habitat on population dynamics during late-season brood rearing remains understudied. Upland riparian meadows provide forbs and arthropods for juvenile sage-grouse. Females congregate at these areas during summer regardless of reproductive status. Because upland riparian meadows in the Great Basin comprise only a small percentage of the landscape, they attract a disproportionately large number of sage-grouse from the region. These congregations provide a unique opportunity to examine the effects of meadow management strategies on sage-grouse population dynamics during the late-season brood rearing period. We used modified distance sampling during nighttime trapping efforts during the summers of 2021 and 2022 to estimate sage-grouse density around five meadow sites located in northwestern Nevada. Each of the five sites were subject to different management actions including strip grazing, open grazing, non-native ungulate fences, and complete removal of non-native ungulates. To obtain density estimates for each meadow site, we fitted a distance sampling model in a Bayesian framework. We summarize the density of sage-grouse populations around each meadow site which provides the opportunity to compare management strategies and their relation to sage-grouse population dynamics during the late-season brood rearing period.

Grouse Groceries in the Sagebrush Steppe: Impacts of Juniper Removal on Herbaceous Vegetation and Invertebrate Diversity.

Haab, K., C. Hagen, K. Yates, T. Bowden, B. Endress, and S. DeBano.

Abstract: Western juniper (*Juniperus occidentalis*) has expanded by 3.6 million hectares into sagebrush (*Artemisia* spp.) ecosystems, causing degradation and loss of these habitats. Sagebrush obligate species continue to be threatened by the ongoing expansion of juniper. One such obligate is greater sage-grouse (*Centrocercus urophasianus*) which rely on a diversity of native vegetation throughout their life cycle, for foraging, concealment, and thermoregulation. Encroached juniper competes with vegetation for limited water and nutrients, and may have cascading effects on invertebrates and herbaceous vegetation. Forbs and terrestrial surface-dwelling invertebrates are an essential source of energy and nutrients for sage-grouse and their chicks. Our study was conducted in sagebrush steppe of the Warner Mountains in Washoe County, NV and Modoc County, CA (2020 and 2021) to assess impacts of juniper removal on herbaceous forage and invertebrate diversity. Vegetation and invertebrates were sampled via biomass collection and pitfall trapping from old cuts (completed ≤ 2013), mid cuts (completed 2014–2016), recent cuts (completed 2017-present), and controls (encroached juniper areas with no cuts). Mean forage quantity was significantly higher in old cuts (17.4 g/m^2, SE=0.3) and significantly lower in controls (11.2

g/m^2, SE=0.2). Forage crude protein was significantly higher in mid cuts (11.6%, SE=0.2) than in other cuts. Invertebrate abundance was significantly higher in mid cuts (1002, SE=66), old cuts (547, SE=34) and recent cuts (471, SE=38) than in controls (290, SE=15). Our results suggest that juniper cuts designed specifically for sage-grouse (i.e. low tree density) can have measurable effects on larger ecosystem services.

Isotopic Analysis Reveals Landscape Patterns in the Diet of a Subsidized Predator, the Common Raven

Harju, S., C. Olsen, J. Hess, and S. Webb.

Abstract: Anthropogenic subsidies to native predators can have cascading effects on sensitive prey populations, but the spatial mechanisms behind these effects are often unknown. We used a stable isotope mixing model to reconstruct spatially naïve assimilated diets of common raven (*Corvus corax*) chicks and then used regression analysis to investigate landscape patterns in assimilated chick diet, with particular respect to the eggs and chicks of greater sage-grouse (*Centrocercus urophasianus*). Assimilated raven diets were primarily composed of mammal carrion, followed by anthropogenic food and sage-grouse eggs and chicks. Raven diets showed landscape gradients, whereby raven chicks in nests near active greater sage-grouse breeding leks consumed a higher proportion of sage-grouse eggs, sage-grouse chicks, and insects in their diet and less mammal carrion. A majority of raven nests on anthropogenic nesting structures (78.7%) were within 5 km of the nearest sage-grouse lek. Ravens nesting in high-probability greater sage-grouse nesting habitat consumed more insects and plants and less mammal carrion. In landscapes devoid of natural raven nesting substrates, such as our study area, anthropogenic nesting substrates can 'anchor' breeding ravens nearer to greater sage-grouse leks, with concomitant increases in raven predation on greater sage-grouse nests. Curtailment of anthropogenic nesting substrates within 5 km of a sage-grouse lek may have a disproportionately positive impact on sage-grouse populations. More generally, these findings highlight that the spatial arrangement of anthropogenic subsidies can result in indirect interactions between humans and predators with direct implications for predators and prey.

Trends in Common Raven Populations Across North America Over the Past 50 Years.

Harju, S., P. Coates, S. Dettenmaier, J. Dinkins, P. Jackson, and M. Chenaille.

Abstract: Over the last half-century, common raven (*Corvus corax*; raven) populations have increased in abundance across much of North America. Ravens are generalist predators known to depredate the eggs and young of several sensitive species. We used a hierarchical Bayesian modeling approach to analyze trends of standardized raven counts from 1966 to 2018 using Breeding Bird Survey data within each Level I and II ecoregion of the United States and Canada. We also compared raven abundance within and outside the distributions of nine sensitive or endangered species. Although we found substantial evidence that raven populations have increased across North America; populations varied in growth rates and relative abundances among regions. We found 73% of Level I (11/15) and II (25/34) ecoregions demonstrated positive annual population growth rates ranging from 0.2% to 9.4%. We found higher raven abundance inside versus outside the distributions of seven of the nine sensitive species included in our analysis. Gunnison sage-grouse (*Centrocercus minimus*) had the highest discrepancy, with 293% more ravens within compared to outside of their range, followed by greater sandhill crane (*Antigone canadensis tabida*; 280%), and greater sage-grouse (*C. urophasianus*; 204%). Only two of the species, least tern (*Sternula antillarum*) and piping plover (*Charadrius melodus*), indicated lower raven abundance within relative to outside their distributions. Our findings will help wildlife resource managers identify regional trends in abundance of ravens and anticipate which sensitive species are at greatest risk from elevated raven populations.

Assessing Sagebrush-Obligate Songbird Abundance: Considerations of Landscape-Level Threats and Umbrella Species Efficacy.

Harrington, A.

Abstract: The umbrella species concept is a single-species conservation strategy built on the notion that indirect protections are provided for multiple species that occupy the same area as a single, or umbrella, species. The utility of the umbrella species concept relies on similar associations of abundance, distribution, life history requirements, and threats of umbrella and co-occurring species. Greater sage-grouse (*Centrocercus urophasianus*, hereafter "sage-grouse"), a sagebrush-obligate species, is a high-

profile umbrella species for the sagebrush ecosystem. Direct comparisons linking sagebrush-obligate songbird population performance to sage-grouse metrics are necessary to fully evaluate the utility of the umbrella species concept. From 2018–2020, we surveyed 147 random and 97 sage-grouse locations for three sagebrush-obligate songbird species approximately bi-weekly during the breeding season. Surveys were conducted May through July across 6,458 km^2 of sagebrush ecosystem in Baker and Malheur counties, Oregon. We predicted that sagebrush-obligate songbird abundance would be higher at sage-grouse use locations than locations of sagebrush habitat available to sage-grouse, and that sagebrush-obligate songbird abundance align with sage-grouse indices and distance to lek. Sage-grouse breeding habitat indices at 6.4 km performed well for predicting the abundance of sage thrasher (*Oreoscoptes montanus*) and Brewer's sparrow (*Spizella breweri*). We observed higher abundance of both sage thrasher and Brewer's sparrow in available habitat for sage-grouse relative to sage-grouse use locations, but differences were not significant. Our findings support developing literature that suggests the sage-grouse conservation umbrella may be effective at large spatial extents, but additional considerations for co-occurring species may be necessary to achieve overlapping conservation outcomes.

The Missing Element in Sage-Grouse Conservation: Restoring Depleted Understory Plant Communities.

Harris, S.

Abstract: Despite substantial collaborative efforts to conserve greater sage-grouse (*Centrocercus urophasianus*), and their critical habitats, the dramatic decline in populations over the past 50 years has yet to be arrested. The breeding population of sage grouse in Oregon was estimated to be 15,927 in 2021, the third lowest population estimate since 1980. The habitat threats of juniper encroachment, invasion of annual grasses, and altered fire regimes receive much conservation and management attention. Combined, these threats impact the habitats that grouse depend upon. However, removing or mitigating these threats does not guarantee the restoration of critical habitat elements, in particular understory plant communities. For example, the understory response following juniper removal is poorly studied. Initial studies suggest that the understory plant community will not respond to juniper treatments without subsequent seeding and restoration efforts. Forbs, perennial grasses, and forb-associated arthropods in sagebrush understories are critical for chick-rearing and reproductive success. Studies have shown that annual recruitment is directly correlated to availability of grass and forb-associated arthropods. Therefore, restoration of these important understory forb plant communities is a high priority, as they are scarce or missing in many priority sage-grouse conservation areas. Here, we present 1) a review of the role of understory forb and grass communities in sage-grouse conservation, and 2) results from the first phase of an experimental study in eastern Oregon of best practices for restoring these plant communities in sage brush steppe ecosystems.

Prairie Grouse and Wind Energy: The State of the Science.

Haukos, D., J. Lloyd, C. Aldridge, T. Allison, C. LeBeau, L. McNew, and V. Winder.

Abstract: Understanding effects of wind-energy development on prairie grouse is particularly important because these species are of high conservation concern, some are important game species, and have geographic distributions that overlap with areas of potentially high-value wind resources that may experience development pressure in coming decades. Development of other renewable energy resources currently have relatively minor effects on prairie grouse compared to wind energy. We summarized the state of the science surrounding wind energy and its effects on prairie grouse and their habitats in the United States and Canada, and identified major information gaps for assessing risk associated with future wind-energy developments and guiding future research designs for conserving prairie grouse in the face of anticipated build-out of wind energy. Direct effects of wind energy development are minor as the amount of habitat loss or degradation caused by land clearing are relatively small compared to the amount of space used by individual grouse. Indirect effects of wind energy development may be significant and primarily represented as functional habitat loss through avoidance of wind energy structures (e.g., towers, transmission lines). Avoidance behavior reduces the carrying capacity of an area in the same way as would habitat loss or degradation. Future research would benefit by using geographically extensive, replicated studies of empirically defined populations; including collection of pre-construction data, use of control sites, and designs that can estimate impact thresholds, which allows insight into changes in population growth rate, the parameter of most interest from a conservation standpoint.

Classification of Sage-Grouse Movement Modes to Account for Behavior in Habitat-Response Research.

Haynam, T., L. McNew, and M. J. Borgreen.

Abstract: Greater sage-grouse (*Centrocercus urophasianus*) use large extents of the landscape, and their movement modes are constantly changing to promote survival and reproduction. We evaluated the use of detailed movement properties to identify modes important for behavior-specific habitat responses such as survival or resource selection. We equipped 86 female sage-grouse with GPS transmitters that were programmed to record > 4 locations per day. We calculated 7 movement properties during all sage-grouse phenological stages for up to 4 years per individual. We then used the 7 movement properties and statistical clustering to identify 8 distinct movement modes. The 8 modes were most strongly organized along axes of variation corresponding to patch revisitation, patch residence time, home range area, variability in patch residence time, and variability in patch time-to-return. One mode clearly represented exploratory movements and another mode clearly corresponded to incubating. The 6 other modes were also interpretable based on associations with field-confirmed behaviors such as brooding, description of modes relative to movement properties, and spatial context such as overlap with core areas or forays away from core areas. Detailed movement data can be used to identify movement modes to improve the behavior-based structure of habitat response models. For instance, the exploratory mode can be used to filter out transit or searching forays that contaminate other behavior or phenology modes such as brooding, summer ranging, and winter ranging. Behavior mode identification could also be used to remotely sense nesting behavior if nest site visitation were not possible.

eDNA Applications for Improving Sage-Grouse Management: Detecting Nest Predators from Eggshells after Depredation Events.

Helmstetter, N., C. Conway, S. Roberts, P. Makela, J. Adams, S. A. Nerkowski, and L. Waits.

Abstract: Advancements in molecular techniques have given rise to promising and often non-invasive methods for addressing questions in wildlife research. A recent example is the ability to identify the species responsible for depredation events (i.e., predator-specific mortality) via DNA from prey remains. Nest predation is the primary cause of nest failure for many birds and habitat features at birds' nests can influence predator-specific nest mortality. However, elucidating the explicit predator once a nest has been depredated is challenging and using cameras to document explicit predators can affect nest success. We used molecular methods to identify greater sage-grouse nest predators via DNA collected from eggshells from depredated nests. Additionally, we deployed artificial nests with cameras to validate the accuracy of our method by comparing our molecular results to the species captured on cameras. We designed species-specific primers for the mitochondrial DNA cytochrome b region to amplify two common avian nest predators: ravens (325 bp) and magpies (280 bp). We used this species-specific fragment length analysis to amplify corvid DNA from our artificial nests and depredated sage-grouse nests. eDNA from eggshell fragments and swabs correctly identified the species captured on camera for 84% of our artificial nests and identified corvids from 31 real nests (sage-grouse nests). We are also testing a metabarcoding method using 12S ribosomal DNA to identify a broader range of nest predators. Our approach can be employed to aid sage-grouse management and conservation and is applicable to research interested in documenting predator-specific nest mortality for a variety other species.

A Bird's-Eye View: Developing Aerial Survey Protocols for Prairie Grouse Where Mixed Species Leks Are Observed.

Isaacson, C., C. Merriman, A. V. Jørgensen, G. Knutson, J. Kolar, C. Roy, E. Trout, B. Walker, and S. Ellis-Felege.

Abstract: Aerial surveys have been proposed as an alternative method to ground counts of prairie grouse. In locations where mixed species leks occur, it can be challenging for aerial thermal imagery to determine the species of each bird. Our objectives were to compare aerial versus ground counts of displaying males and total grouse observed on greater prairie-chickens (*Tympanuchus cupido*), sharp-tailed grouse (*Tympanuchus phasianellus*), and mixed species leks. We collected total counts classified by sex and species. We conducted surveys in Grand Forks County, ND and Polk County, MN near Glacial Ridge Wildlife Refuge in April 2022. We located leks prior to flights via ground surveys. We conducted flights with fixed wing aircraft equipped with a high-resolution dual infrared/electro-optical gimbal simultaneously with ground counts. Ground observers counted from blinds, vehicles, and using flush counts (after the plane was finished counting). We completed 15 double counts at prairie chicken (n = 7),

sharp-tail (n = 5), and mixed (n = 3) leks. The airplane survey detected both sharp-tail (n = 15) and prairie chickens (n = 17) across all leks. In addition, the airplane conducted a blind survey to determine lek locations and compare detection rates between ground observers and thermal imagery. During this 1.5-hour search more than 60 birds were detected at 6 leks. This is the first time aerial infrared has been used to differentiate greater prairie chickens and sharp-tail grouse, and it suggests that it is a feasible method to conduct lek counts on a mixed-species landscape.

Inter- and Intra-Annual Effects of Lethal Removal on Common Raven Abundance in Nevada and California, USA

Jackson, P., S. O'Neil, P. Coates, J. Brockman, J. Spencer, and P. Williams.

Abstract: Populations of common ravens (*Corvus corax*; hereafter, raven) have increased rapidly within sagebrush ecosystems over recent decades (1960s–2020). Though ravens are native to North America, their population densities have expanded to levels that negatively influence the population dynamics of other wildlife species of conservation concern, such as greater sage-grouse (*Centrocercus urophasianus*) and desert tortoise (*Gopherus agassizii*). For these reasons, lethal removal techniques, such as the application of the corvicide DRC-1339, have been approved to control raven populations under certain circumstances. Because the relative effectiveness of DRC-1339 in reducing raven densities is not thoroughly understood, we investigated its influence on raven abundance from point count survey data at control and treatment field sites using Bayesian hierarchical distance sampling and a before-after-control-impact (BACI) modeling design. We analyzed data from > 16,000 point count surveys, split into an intra-annual study design and an inter-annual design. DRC-1339 application was effective at reducing local raven densities, with a 100% probability of decline relative to control sites for both the intra- and inter-annual model designs. At treatment sites, expected counts of ravens varied but were reduced on average, whereas counts increased at control sites. Though population densities were reduced with treatments, trends indicated that sustained effort is needed to maintain densities at acceptable levels. Effectively reducing the adverse effects of overabundant raven populations will depend on a variety of targeted management actions that lower population density while also treating the cause of overabundance to reduce future carrying capacity and prevent rebounds.

Applying the Land Treatment Exploration Tool for Planning and Adaptive Management of Wildlife Habitat Restoration Actions.

Jeffries, M., and D. Pilliod.

Abstract: Each year, public land managers make decisions regarding reclamation, rehabilitation, and restoration actions that influence landscapes and ecosystems. Many of these decisions involve soil and vegetation manipulations, often known as land treatments. These treatments were historically planned on a case by case basis with decisions about implementation, methods, and operations derived from personal experience of past successes or failures. Modern adaptive management strategies strive to capture this local knowledge through time, to create a comprehensive picture of effective treatment strategies both locally and regionally. In 2017, the U.S. Geological Survey partnered with the Bureau of Land Management (BLM) to create the Land Treatment Exploration Tool to facilitate adaptive management of land treatments. The Exploration Tool taps into a wealth of information about past treatments in the Land Treatment Digital Library (LTDL), a catalog of information about all known treatments on public lands administered by the BLM in the Western United States. The Exploration Tool is designed for resource managers to use when planning land treatments. The tool provides useful summaries of environmental characteristics of planned treatment areas and facilitates adaptive management practices by comparing those characteristics to other similar treatments within a specified distance or area of interest. This presentation will provide an overview of the functionality of the tool and specifically highlight the utility for sage-grouse conservation planning.

Sound Mapping Characteristics of Ruffed Grouse Drumming Log Locations in Northern Wisconsin.

Johnson, C., A. Weisbeck, Z. Cason, E. Eldeen, A. Wallin, and B. Roberts.

Abstract: Ruffed grouse (*Bonasa umbellus*) are an important game bird of the Great Lakes region. Males perform a unique drumming display atop fallen logs to attract females and maintain their territory throughout the spring. Drumming logs may be strategically selected based on how sound propagates in that location. We will evaluate different environmental characteristics and their effect on sound travel in

northern Wisconsin as part of a UW-Stevens Point Student Chapter of The Wildlife Society undergraduate research project. Drumming log locations were identified by use of auditory point count surveys, and male ruffed grouse were captured using mirror box traps in April and May of 2021 and 2022. The locations were compared to randomly selected sites within the study area using SPreAD-GIS, a tool that models how sound travels through space based on multiple environmental factors. This information could improve knowledge about male ruffed grouse mating behaviors and influence habitat management decisions on ruffed grouse management areas.

The Tail of Two Grouse: Hybridization of Sharp-tailed Grouse and Greater Prairie Chickens in North Dakota.

Jørgensen, A. V., C. Isaacson, J. Kolar, and S. Ellis-Felege.

Abstract: The greater prairie-chicken (*Tympanuchus cupido*) population in Grand Forks County, North Dakota has declined since 2005, after initial success following restoration efforts from 1992–1998. During this period, sharp-tailed grouse (*Tympanuchus phasianellus*), which co-occupy the area, have increased. We conducted annual spring lek counts (15 March to 15 May 2019–2022) to monitor the population trends for both prairie grouse species. Within two study blocks, we attempted to identify all leks of both species through listening surveys and then return to count the number of birds on each lek by species and sex. We counted between 24 and 38 active leks and observed: steady decreases in prairie chickens (only 6 male prairie chickens were observed in the entire county in 2022); increases in sharp-tails (31/38 leks with grouse in 2021); and increases in hybrid Greater prairie-chicken x sharp-tailed grouse (5/38 leks in 2021). Previously, managers assumed that hybrids were relatively rare, but we documented as many as 12 hybrids in a single year. Current trends suggest prairie chickens will not persist without active management to increase their populations.

Rangewide Analysis of Genetic Diversity of the Greater Prairie-Chicken.

Kieleczawa, K.

Abstract: Genetic diversity is important to the health of wildlife populations but is being lost for many species due to declines in the number of individuals and loss of connectivity. The Greater Prairie-Chicken (*Tympanuchus cupido*) is a lek-mating grouse found in the central United States, but its population along with its range have contracted greatly since the beginning of the 20th century as agriculture and other anthropogenic land use fragmented its habitat. Currently it is a species of concern across its range and the focus of much conservation effort. Using environmental DNA as well as tissue samples, from the core species' range including Kansas, Oklahoma, Nebraska and South Dakota, we are analyzing genetic diversity and structure of Greater Prairie-Chicken populations. Preliminary results done at 8 microsatellite loci indicated the presence of three distinct genetic sub-populations from the sampled range. Each sub-population contained a set of private alleles and lower than expected heterozygosity. The results will be used in further landscape analysis to determine barriers that exist to gene flow and dispersal, as well as to inform management decisions, such as for potential future translocations.

Navigating Jurisdictional Constraints to Achieve Species Conservation: Mapping Greater Sage-Grouse Habitat in Utah.

Kohl, M., S. Picardi, D. Dahlgren, N. Frey, R. T. Larsen, E. Thacker, B. Allred, J. Reese, A. Cook, and T. Messmer.

Abstract: The identification and management of critical habitats is the basis for conservation of threatened and endangered species. However, identifying critical habitats for wide-ranging species is challenging when species occupy multiple jurisdictions that have competing agency directives and incongruent habitat models. If the directive challenges can be addressed, the incongruent habitat models may still be hindered by large-scale (e.g., state-wide) differences in species conservation threats or habitat quality. We provide a case study in Utah where sage-grouse populations inhabit 11 management units comprised of federal, state, and local jurisdictions as well as significant variation in habitat characteristics. This poses challenges for conservation practitioners when identifying critical habitat or prioritizing management actions across populations. To overcome this, we used Generalized Functional Response Resource Selection Models that incorporated 21 years of sage-grouse nesting data (1526 nests), five years of sage-grouse GPS tracking data (503 individuals, > 485,000 locations), and high resolution (30 x 30 m) remotely sensed annual vegetation measures (Rangeland Analysis Platform) to quantify seasonal habitat use within and across management units and years. Using this approach, we coordinated

season-specific habitat management actions that accounted for variation in sage-grouse habitat quality while accommodating jurisdictional areas, annual changes in vegetation characteristics, and state-wide habitat guidelines. This flexible approach thus provided the capacity for prioritizing management actions in spatially and temporally dynamic environments; a critical step as conservation funding becomes increasingly limited. Together, this suggests this process may be highly transferable and useful for the regional or state-wide scale management of other wide-ranging species.

Wildlife Responses to PV Solar Energy Development.

Kosciuch, K., D. Riser-Espinoza, C. Moqtaderi, M. Gerringer, K. Smith, H. Sawyer, T. Mattson, and W. Erickson.

Abstract: Despite the widespread deployment of photovoltaic (PV) solar energy in the U.S., the potential effects on wildlife are largely unstudied. PV solar does not present a vertical airspace hazard, but concerns regarding bird collisions with infrastructure have been raised. Further, the required security fence can remove habitat for larger-bodied species like ungulates. We conducted four separate studies to investigate effects of PV solar development on wildlife in the western U.S. In a summary of bird mortality across 10 sites in the southwest, we found that mortality at PV solar sites was lower than other anthropogenic sources, and most carcasses were of locally common ground-dwelling birds. In a study of the lake effect hypothesis, we found that the aquatic habitat bird community at PV solar differed from, and occurred at lower abundance than at a nearby lake, suggesting a low or minimal attraction effect. We opportunistically observed greater sage-grouse utilize habitat inside a PV solar facility in Wyoming, but GPS data collected from pronghorn showed the same facility removed critical habitat for both resident and migratory animals. Overall, our results indicate that potential effects of PV solar on wildlife vary by species and depend on the siting and design of each facility. Habitat will be lost for larger-bodied species, but PV sites may continue to provide habitat for smaller species, depending on revegetation methods.

Finding an Oasis: Identifying Thermal Refugia in the Great Basin Ecosystem.

Landry, S., D. Dahlgren, and S. Picardi.

Abstract: Landscape thermal ecology is a relatively new topic for wildlife management and is increasing in importance with the growing effects of climate change, especially in slow-growing, low resiliency ecosystems. The Great Basin Ecosystem has an arid basin and range topography, where the mountains represent ‘sky-islands’ of high-elevation habitat among a sea of sagebrush. Those ranges offer an oasis of watersheds and shaded forest canopies for wildlife to escape summer heat, so better understanding the region’s thermal landscape could benefit many of the native, montane wildlife species as increasing climate change affects usable space at those higher elevations. Thus, our objective was to identify landscape thermal refugia for various native wildlife species across the Great Basin ranges. During summer from 2019–2021, we used iButtons to measure microsite temperature ranges of 5 major vegetation types across three mountain ranges in eastern Nevada, then characterized the surrounding vegetation to quantitatively describe differing microsite characteristics. We compared observed temperatures to known physiological thermal limits of native wildlife in the region, including mammals, birds, and reptiles of varying sizes. Along with satellite-derived environmental and climate data, we estimated the best fit model that characterized thermal refugia for as many aggregated species as possible at both local and landscape scales. Finally, we predicted and mapped critical thermal refugia across the Great Basin ranges. As drought, wildfires, and other natural disasters continue to increase, this information can help identify areas of conservation need for wildlife and help guide disaster planning, prevention, and mitigation across the region.

Developing Methods for Producing Unbiased Population Estimates of Dusky Grouse.

Leipold, E. A., L. McNew, K. Banner, C. Gower, and L. Berkeley.

Abstract: No rigorous state-wide monitoring programs currently exist for dusky grouse, *Dendragapus obscurus*, an upland game species. Difficult to reach habitat and low probability of detection make monitoring dusky grouse inherently difficult. Our objective was to develop and evaluate sampling and analytical methods for producing annual unbiased statewide and regional estimates of population size, providing baseline information necessary for the development of a state-wide monitoring program. We compared point counts vs. transect surveys, route type (off-trail, trail, road), spring vs. summer surveys, and the use of electronic playback to increase detection. We evaluated and compared five analytical methods: time-to-detection model, state-space model, N-mixture model for point counts, and raw count

(naïve) and hierarchical distance sampling model for both point counts and transect surveys. We used pilot data to obtain baseline estimates of probabilities of detection and abundance from hierarchical N-mixture and distance sampling models to inform our simulation study. We conducted simulations with different survey designs under different abundance and detection scenarios to evaluate the ability of our five estimators to produce unbiased and precise abundance estimates. We found spring surveys with electronic playback had the highest probability of detection, and that surveys located along roads/trails best balanced the trade-offs between sampling effort and survey design requirements. Initial simulations using N-mixture models indicated that 300–360 point-counts with 4 repetitions were needed to produce accurate population estimates. Our results will inform methods for regional and state-wide monitoring in Montana and illustrate a process applicable for developing dusky grouse monitoring elsewhere.

Climate Sensitivity Drives Great Basin Mesic Resources and Greater Sage-Grouse Productivity.

Lundblad, C., C, Hagen, P. Donnelly, A. Moser, S. Espinosa, and S. Vold.

Abstract: Anticipating and mitigating the effects climate change will have on wildlife populations requires an improved understanding of the ways that those populations are currently adapted to climatic variation. Previous studies have established a link between precipitation, drought, and the productivity of Greater Sage-Grouse (*Centrocercus urophasianus*). We used sage-grouse production ratios, derived from harvested wing data, to characterize spatiotemporal variation in sage-grouse productivity throughout the North American Great Basin from 1993–2020. We tested the hypothesis that the relationship between climate and sage-grouse productivity is mediated through the availability of mesic habitat resources that support brood survival during late-summer. We defined mesic habitats as those with maximum NDVI >0.3 and used random forest regression and other remotely sensed explanatory data to model sage-grouse productivity as a function of mesic habitat availability, a more general effect of annual precipitation, and landcover composition. We then examined potential acute direct effects of exposure to inclement weather on sage-grouse productivity. Finally, we examined which topographic and climatic variables best predict mesic habitat availability. We found the expected positive relationship between mesic habitat availability and sage-grouse productivity, but annual precipitation explained additional variation in productivity. Hence, precipitation and drought apparently drive sage-grouse productivity via multiple mechanisms. Productivity was also reduced at even low levels of annual grass invasion and conifer encroachment. Mesic habitat availability was a function of topographic relief, mean elevation, annual mean snow water equivalent, and winter temperatures, indicating that snowpack is critical for maintaining the late summer mesic resources that support sage-grouse.

Benefits and Costs of Translocation on Augmented and Source Populations of Greater Sage-Grouse (*Centrocercus Urophasianus*): Using Integrated Population Models to Evaluate Translocation Methods.

Mathews-Sanchez, S., M. Meyerpeter, M. Chelak, K. Lazenby, P. Coates, D. Dahlgren, J. Kolar, S. Picardi, B. Prochazka, and D. Delehanty.

Abstract: Avian translocations can be ineffectual because they result in physiologic chronic stress to all translocated individuals and because birds can easily disperse from release sites following translocation. Successful avian translocations blend effective translocation methodologies with animal behavior. We performed three greater sage-grouse (*Centrocercus urophasianus*) translocations in California, Utah, and North Dakota, and tested traditional and novel translocation methodologies as part of ongoing conservation projects. During traditional translocations, females were translocated during the spring breeding season to exploit their desire to nest following release and to reduce post-release dispersal movements. In novel methods, we translocated females with chicks (brood translocation) mid-summer to test for enhanced recruitment and reduced dispersal movements post release. We tracked sage-grouse at augmented, source, and at neighboring control sites in a Before-After-Control-Impact (BACI) design to elucidate the benefit of translocations on population growth. We estimated the cost of translocations on within source populations and implemented integrated population models (IPMs) in a Bayesian framework to estimate demographic rates for each population. Brood translocations increased by 11–30% over traditional translocation methods, which produced higher estimates than if no translocations were conducted. Both translocation methodologies resulted in small reductions in source populations. Our results indicated that traditional and novel translocation methodologies reduced source populations, but novel brood translocations significantly increased augmented populations, thus providing managers with

a new tool for augmenting sage-grouse. These findings are preliminary, provided for timely science communication and are subject to change.

Hide and Don't Seek: How Broad-Scale Juniper Removal, Mesopredator Habitat Use, and Sage-Grouse Nest Site Selection Influence Depredation Risk.

McIntire, S., P. Coates, and T. Johnson.

Abstract: Expansion of western juniper (*Juniperus occidentalis*; hereafter juniper) into sagebrush (*Artemisia* spp.) steppe plant communities is a well-documented threat to greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) populations. Sage-grouse using habitats where juniper is present experience reduced nest survival, though the exact mechanisms driving this pattern remain unclear. Juniper trees potentially facilitate avian nest predators by providing extra perching opportunities. However, alternative hypotheses examining how mammalian mesopredators are associated with juniper cover have not been investigated. Risk to sage-grouse nests could be affected by broad-scale habitat use by mammalian mesopredators and microhabitat nest site characteristics that affect availability of visual and olfactory cues to predators. Removal of juniper from sagebrush communities is becoming an increasingly common method of attempting to restore and improve sagebrush habitats for sage-grouse, therefore it is critical to understand how mesopredators respond to these management efforts. We sought to establish how landscape factors, including juniper cover and mesopredator habitat use, in addition to microhabitat features at nest sites influence nest predation rates for sage-grouse. We conducted our research in southwestern Idaho where a large-scale juniper removal project began in 2019. We evaluated broad-scale habitat characteristics including proportions of juniper cover and habitat use rates by mesopredators and collected data on both visual and olfactory concealment characteristics at sage-grouse nest sites (n=91) to determine effects on predation risk for sage-grouse nests. We will provide results on sage-grouse nest success in relation to juniper removal. Results are preliminary and provided for timely best science.

The Socio-Political Implications of Wildlife Translocations: An Imbalance between Messaging, Research, and Conservation Outcomes.

McLaughlin, J., and F. Hernandez.

Abstract: The evolution of complex and vexing conservation challenges in North America has laid bare the need for proactive tools to stem the declines of wildlife species. In response, translocations have been proposed as a technique to complement ongoing management efforts; this approach has been especially relevant for Galliformes (e.g., grouse, quail). The wealth of scientific literature, publication of national translocation guidelines, and interstate movement of birds in recent years speaks to this renewed interest. Here we use quail as a case study to highlight the associated socio-politico-ecological challenges. For states with charismatic upland game birds, interest from recreational user groups, landowners, and state leaders to use translocations as a remedy for population declines is cyclic but nonetheless common and a component of the current socio-political landscape. However, the context and rationale for translocations is not always clearly defined, which can lead to disparate outcomes, sow confusion, and cause discord. The line between research and conservation efforts can become blurred, sometimes resulting in the misapplication of this tool. Notably, few acknowledge or consider the unique biological challenges or understand the regulatory framework which guides decision making. The socio-political pressure can be intensified if proper steps are not taken to redress these misconceptions. As such, the burden is on the conservation community to provide context for translocations, be explicit about project goals and the underlying rationale, and manage expectations. Absent these precursors there is a vulnerability to wanton translocation requests, undermining core conservation messages regarding the loss of suitable habitat and biodiversity.

Predicting Within Grassland Habitat Abundance for Lesser Prairie-Chickens Using Gradient Landscape and Vegetation Phenology Metrics.

Messier, A., D. Sullins, D. Haukos, and C. O'Meilia.

Abstract: Targeted conservation of the lesser prairie-chicken (*Tympanuchus pallidicinctus*), an at-risk grassland obligate, is difficult given limitations in monitoring within grassland habitat abundance at relevant spatial scales. The ability to identify broad-scale habitat abundance is critical, yet challenging to accomplish using limited field-collected measurements from brief snapshots in time. Fortunately, advancements in remote sensing make continual broad-scale efforts feasible. Our objective was to use a

Random Forest approach and nest location data from 2014 and 2015 to test the importance of landscape scale variables, such as percent grassland within 5km and density of oil wells within 2km, and 9 NDVI-based vegetation phenology metrics in predicting the abundance of lesser prairie-chicken nesting habitat in Kansas. Results showed that important variables differed between 2014 and 2015. In 2014, nest habitat abundance was best predicted by percent grassland within 5km (variable importance = 0.04), county road density within 2km (0.038), NDVI at the end of the growing season (0.02), and time integrated NDVI (0.02). In 2015, phenology variables carried more importance relative to other variables. Specifically, maximum NDVI (0.024) time integrated NDVI (0.023), amplitude (0.023), and NDVI at the start of the growing season (0.018) best predicted nest habitat abundance. Preliminary modeling efforts suggest that habitat abundance and phenology predictors may vary from year to year, potentially due to differences in precipitation. Phenology metrics and anthropogenic feature densities appear to have utility in predicting within grassland lesser prairie-chicken habitat abundance, however, important predictors may vary annually, which complicates habitat monitoring.

Free-Roaming Equids and the American Mind; the Role of Strategic Public Engagement in Achieving Healthy Herds on Healthy Rangelands.

Messmer, T.

Abstract: The human-dimension aspects of 'wild horse and burros (WHBs; free-roaming equids)' management are not well understood. Contemporary WHB policies, which include a legacy of administrative and political constraints suggest that WHBs may be valued above all other animals in contemporary U.S. society. The strength of the emotional human-horse connection surfaced in the late 1950s, when public concerns led to the passage of the Wild and Free-roaming Horse and Burros Act. The Free-roaming Equid and Ecosystem Sustainability Network (FREES) was organized in 2018 to better engage the U.S. Public in the management of free-roaming equids. FREES established a new public forum committed to facilitating open dialogue and building positive relationships to reengage all Americans in collective actions to ensure the health of free-roaming equids, western rangeland ecosystem health and sustainability, and the principles of multiple-use. FREES is administered through Utah State University Extension (https://extension.usu.edu/freesnetwork/). All FREES participants are encouraged to seek opportunities to work with others who might have different perspectives or experiences regarding the management of free-roaming equids and landscapes they inhabit. FREES success and the effectiveness of all activities, such as the working groups and Summits, require participants to recognize their personal biases, and not allow these to pervade open dialogue as we collectively seek novel approaches to the resolution of this complicated issue. FREES approach to increasing public awareness of the issues through education and outreach, has increased public knowledge and appreciation of the complexity of issues surrounding the sustainable management of free-roaming on imperiled landscapes.

Greater Sage-Grouse Selection and Survival Across Reproductive Life Stages in the Bi-State Distinct Population Segment.

Milligan, M., P. Coates, B. Brussee, S. O'Neil, S. Mathews-Sanchez, S. Espinosa, S. Gardner, and M. Casazza.

Abstract: Limited time and resources necessitate prioritizing high-quality habitats to meet specific conservation and management objectives. Because habitat selection is not always adaptive, understanding the link between habitat selection and demographic performance is critical for effective species conservation. Mapping both selection and demographic performance for species of conservation concern and identifying areas with either overlap or mismatch can help guide large-scale conservation efforts. The greater sage-grouse (*Centrocercus urophasianus*) is a sagebrush (*Artemisia* spp.) obligate and is often used as an indicator species for sagebrush ecosystems. We evaluated selection and survival across multiple reproductive life stages (nesting, brood-rearing) to better understand the interplay between these two responses in the Bi-State Distinct Population Segment, a genetically distinct and geographically isolated population on the western edge of the sage-grouse's range. Factors influencing selection and survival differed across reproductive life stages. Selection for high elevations and wet meadows or herbaceous cover increased throughout the growing season, whereas avoidance of pinyon-juniper cover decreased despite negative effects on survival. These findings suggest competing resource demands across time, with predation risk being a dominant factor early in the breeding season whereas access to forage resources becomes more important later in the summer. An improved understanding of sage-grouse habitat requirements and constraints across life stages in combination with maps of both selection and survival for each life stage can help guide large-scale conservation efforts and prioritize habitat

designations in threatened sagebrush ecosystems. These findings are preliminary, are provided for timely science communication, and are subject to change.

Artificial Nest Depredation by the Common Raven Within Various Sagebrush Treatments in Southern Utah.

Moffett, Z., and N. Frey.

Abstract: Native invasive species often flourish in habitats where novel subsidies can support surges in their populations; they become invasive as their populations grow at the detriment of other species in the system. With increases in rural and urban development throughout the American West, Common raven (*Corvus corax*) populations have been rising as anthropogenic subsidies provide both food and nesting habitat. As generalist scavengers and predators, ravens have been found to pose a severe threat to several threatened or sensitive species, including the Greater sage-grouse (*Centrocercus urophasianus*). The purpose of this research was to quantify the overall threat that ravens may pose as nest predators to sage-grouse within the Bald Hills and Panguitch Sage-grouse Management Areas (SGMAs) in southern Utah. To do this we conducted an artificial nest experiment over the course of two nesting seasons in 2021 and 2022. We constructed artificial nests using chicken eggs in order to compare nest depredation rates in sage-grouse habitats that have undergone various types of treatments (i.e., bullhog, hand-thin, chaining) which have altered habitat variables such as sagebrush cover and height and nest visibility. Each season, 80 artificial nests were placed under sagebrush and were monitored via trail cameras. Ravens successfully detected and depredated many artificial nests within various sagebrush treatments. We detected trends in raven depredation events in relation to the treatment history of the sagebrush habitats. The results of this research may have implications for wildlife managers throughout Utah as they continue to decide where and how to treat sage-grouse habitat.

Spatial Modeling of Common Raven Densities and a Decision Support Tool to Manage Predation of Sage-Grouse Nests.

O'Neil, S., P. Coates, B. Brussee, S. Dettenmaier, P. Jackson, S. Espinosa, D. Delehanty, and J. Tull. Dynamic

Abstract: Anthropogenic resource subsidization across western ecosystems has contributed to widespread increases in generalist avian predators, including common ravens (*Corvus corax*; hereafter, raven). Ravens are adept nest predators and can negatively impact multiple species of conservation concern. Predation effects from ravens are especially concerning for greater sage-grouse (*Centrocercus urophasianus*), which have experienced prolonged population decline. Our objectives were to quantify spatiotemporal patterns in raven density, evaluate sage-grouse nest success concurrent with fluctuating raven densities, and demonstrate hierarchical distance sampling models relating raven density to sage-grouse nest success while accounting for other environmental influences. We combined raven point count surveys with data from more than 900 sage-grouse nests between 2009–2019 within the Great Basin, USA. We modeled variation in raven density using hierarchical distance sampling with environmental covariates on detection and abundance, while sage-grouse nest survival was estimated concurrently using a hierarchical frailty model with covariates influencing failure risk. We related raven densities directly to sage-grouse nest survival using a two-stage approach within a Bayesian modeling environment. We simulated sage-grouse nest survival under current and reduced raven densities, where the difference indicated potential impact on nesting productivity. Raven density commonly exceeded >0.5 ravens km-2 and increased at low relative elevations with prevalent anthropogenic development and/or agriculture. Reduced sage-grouse nest survival was strongly associated with raven density and also varied with topographic ruggedness, shrub cover, and burned areas. Results inform spatially-explicit conservation planning, while our modeling framework is compatible with modern population modeling. Information is preliminary and provided for best timely science.

Using Recent Advances in State-And-Transition Simulation Modeling to Evaluate the Scope of Post-Fire Restoration Required to Recover Habitat for Greater Sage-Grouse.

Orning, E., J. Heinrichs, and C. Aldridge.

Abstract: Wildfires are increasingly destroying wildlife habitat in the western U.S., and managers need approaches to scope the pace and degree to which post-fire restoration actions can re-create habitat in dynamic landscapes. We developed a spatially explicit state-transition simulation model (STSM) that

simulates annual fires, projects natural vegetation regeneration rates, annual grass invasion, conifer encroachment, and sagebrush revegetation (planting and seeding). We cross-referenced the resulting vegetation states with sage-grouse habitat needs to evaluate habitat restoration for Greater Sage-grouse Priority Areas of Conservation within the Great Basin. We compared habitat restoration outcomes among different (a) types of revegetation actions (natural regrowth, seeding, planting), (b) durations of actions (single, multi-year), and (c) sizes of area revegetated. In all restoration scenarios, sagebrush cover was generally insufficient to meet habitat requirements for at least a decade post-fire. Considering the size and frequency of fires occurring today, the pace of habitat restoration is likely to lag behind losses of habitat, prompting decisions on where to invest in lengthy restoration activities. Return on restoration investments may be maximized in the most important wildlife habitats, where fire prevention and suppression efforts coincide, and where vegetation can more rapidly and partially recover to states that support specific wildlife needs. Our STSM framework and resulting vegetation maps can be integrated with other restoration prioritization or wildlife monitoring tools to provide information that supports land manager decisions on where to invest time, money, and effort and how to triage losses in long-term restoration plans.

Interactive Effects of Raven Densities and Habitat Disturbance on Sage-Grouse Reproductive Success.

Owens, T., J. Dinkins, L. Perry, L. Foster, and J. Cupples.

Abstract: Wildfire is a primary threat to greater sage-grouse (*Centrocercus urophasianus*; hereafter, sage-grouse), which is exacerbated by the positive feedback cycle created by invasive annual grasses. Sage-grouse exhibit high site fidelity to nesting areas. When these areas are lost or degraded by wildfire, there may be lasting negative effects on reproductive success from slow sagebrush recovery (35–100+ years). In addition, edge effects, such as increased predation with reduced screening cover, could negatively affect sage-grouse near or within burned areas. Common ravens (*Corvus corax*; hereafter, ravens) are a documented nest predator of sage-grouse, and their populations have increased in the Great Basin by 2.3% per year since 1993. We investigated the relationships between disturbance, raven densities, and sage-grouse reproductive success in five Priority Areas of Conservation (PACs) in Baker and Malheur counties Oregon from 2018–2021. Raven densities were calculated using distance sampling from 1,308 point count surveys at 147 random locations within our study areas. We assessed sage-grouse nest site selection and survival with Cox proportional hazard and resource selection models using 147 nests from 89 marked female sage-grouse. We obtained cover of annual grass, shrub, native herbaceous, and trees; fire footprints and severity; topographic; and anthropogenic covariates from remotely sensed data. Results will be presented on interactive effects of raven density and disturbance related to sage-grouse nest site selection and survival. Integration of nest selection and survival will allow us to identify source/sink areas to target restoration and predator management activities.

Big Game at a Bird's Eye View: How Aerial Infrared Opens the Door for Conservation and Management at the Landscape Scale.

Owyhee Air Research.

Abstract: Aerial Infrared (AIR) Surveys are a cost-effective, validated, and well-published survey method that utilizes the thermal signatures of wildlife to detect, identify, and quantify animals to species, sex, and often age. Specialized fixed-wing aircraft outfitted with powerful, high resolution cooled-infrared imaging sensors allow biologists to survey wildlife at the landscape scale accurately, efficiently, and safely. The high altitudes at which fixed-wing aircraft fly also allows for observation of uninterrupted and uninfluenced wildlife behavior. Additionally, the powerful zoom capabilities of high-resolution electro-optical (daylight color) sensors allow biologists to further identify and classify wildlife across a wide array of population metrics. When used in tandem, these imaging sensors provide biologists with the most powerful and accurate tools available to maximize detection and classification, while mitigating error associated with misidentification of animals across the landscape. Owyhee Air Research has been effectively conducting aerial infrared surveys for over 10 years, delivering high quality survey data for state and federal agencies, tribes, and private contractors. From Polar Bears in the frozen riverbanks of Northern Alaska, to Sage-grouse in the high desert of the Great Basin, to Elk in the hardwood forests of Pennsylvania, we have successfully surveyed multiple species over a wide range of habitats. Our team of wildlife biologists, remote-sensing specialists, data scientists, and pilots, specifically trained in natural resources aviation, are continuously unlocking new insights into wildlife research using this technology.

Raven Nest Site Selection in Sage-Grouse Habitat in Oregon.

Perry, L., J. Dinkins, T. Owens, L. Foster, J. Cupples, and J. Taylor.

Abstract: Common ravens (*Corvus corax*; hereafter ravens) inhabit multiple ecosystems throughout North America, and their populations have increased throughout the last half-century. Although infrequently found in urban areas, they utilize anthropogenic subsidies for secure perching, nesting, and roosting locations. These structures have allowed more breeding ravens to thrive in ecosystems relatively devoid of nesting structure, such as sagebrush. Constricted home ranges of nesting ravens concentrate their foraging and potentially elevates predation pressure on nearby prey. Ravens are documented predators of several sensitive species including greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse), which has undergone multiple listing petitions in the United States through the Endangered Species Act and is protected in Canada under the Species At Risk Act. Precipitous declines in sage-grouse numbers in parts of Oregon and anecdotally high raven abundance prompted evaluation of raven ecology relative to sage-grouse habitat. During 2017–2021, we monitored 235 raven nests located through systematic searches in sage-grouse habitat throughout eastern Oregon. We evaluated nest-site selection at multiple spatial scales using resource selection functions focusing on identification of landscape characteristics and access to fundamental resources requirements. We found 87 nests built on anthropogenic structures, 67 in trees, and 81 on rock substrate. Our preliminary results show a higher probability of ravens nesting closer to both sage-grouse leks and roads, and higher road densities, and in areas of lower topographic ruggedness. Nests from 2022 and additional habitat covariates will be evaluated. Understanding factors influencing nest-site selection will aide in directing management of nuisance or overabundant raven populations.

Trials and Tribulations of Raven Nest Removal as a Management Strategy to Reduce Impacts in Sage-Grouse Habitat of Oregon.

Perry, L., T. Owens, J. Cupples, L. Foster, B. S. Ratliff, J. Taylor, S. Vold, and J. Dinkins.

Abstract: Increased population sizes of common ravens (*Corvus corax*; hereafter ravens) in western North America has contributed to decline of several sensitive species, including greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse). The Baker and Cow Lakes sage-grouse populations in eastern Oregon have decreased drastically over the past 50 years, prompting state and federal agencies to mitigate factors contributing to the decline, including raven overabundance. Nesting ravens, foraging in concentrated areas close to the nest, are hypothesized to increase predation pressure on sage-grouse eggs. Long-term efficacy of methods used to reduce the impact of ravens on sage-grouse across the range is unknown; An effective and targeted management technique is therefore desired. In an effort to decrease breeding raven foraging intensity and recruitment Oregon Department of Fish and Wildlife began lethally (eggs present in nest) removing raven nests in the Baker sage-grouse Priority Area of Conservation (PAC), and Idaho Power Company non-lethally (no eggs present) removing nest structures on power lines in the Cow Lakes PAC. During 2021–2022, we monitored 129 raven nests and removed 45 in the Baker and Cow Lakes PACs. While assessment of the lethal and non-lethal nest management techniques requires more data, several interesting findings are worth noting at this time. Of the 45 nests removed to date, 18 breeding pairs renested on or close to the original nesting structure soon after removal. These behavioral observations will help refine management techniques focused on reducing raven impacts through nest manipulation, and provide insight into the feasibility of these methods.

Stakeholder Perspective? Rangeland Scientist and Former Member of the National Wild Horse and Burro Advisory Board.

Perryman, B. L.

Abstract: Several undesirable consequences can and have accrued from the overpopulation of wild horses and burros on federal public lands and other land tenures. Aside from quality and longevity of equid life, is the higher tiered concern of habitat degradation. Seasonal habitats not only support rangeland human uses such as dispersed recreation, but other ecologically significant animals as well, including big game, non-game mammals, avian species, reptiles, pollinators, and domestic livestock. Diet preference and habitat selection of wild horses and burros overlap significantly with many of the aforementioned classes of animals. In much of the Great Basin, late-summer/early-fall habits are the limiting habitat for most classes of wild animals and in some cases domestic animals. When equid populations have previously occupied these critical seasonal habitats to the extent of reducing their ability to support transient species, those individuals must migrate in search of other resources. This movement

requires additional energy expenditure for locomotion eventually reducing reproductive fitness, and also exposes some to additional predation pressure and water stress. Fertility control efforts will be a major population control tool for maintaining equid populations once they are reduced below habitat degrading levels. The National Wild Horse & Burro Advisory Board has recommended pilot projects on 2 to 4 Horse Management Areas in order to demonstrate the efficacy of contraception as a major population control method.

Effects of Livestock Grazing on Greater Sage-Grouse Habitat Selection.

Picardi, S., C. McGinty, and T. Messmer.

Abstract: Rangelands occupy 54% of continental surfaces and, in North America, they are predominantly used for livestock grazing. Wildlife species inhabiting rangelands, including greater sage-grouse (Centrocercus urophasianus), may be negatively impacted by livestock grazing. Livestock may compete with sage-grouse during the summer, when sage-grouse rely on herbaceous vegetation to rear broods. However, the evidence regarding negative effects is mixed; some even speculate that, if livestock are functionally equivalent to wild grazers (e.g., bison) who engineer vegetation dynamics during the growing season, their relationship with sage-grouse could be facilitative rather than competitive. Using GPS-tracking data for livestock and sage-grouse collected simultaneously in 2015–2016 in Rich County, Utah, we used Integrated Step Selection Analysis to test four alternative hypotheses: (H1) interference competition, i.e., the presence of livestock directly displaces sage-grouse; (H2) exploitation competition, i.e., livestock displaces sage-grouse via resource depletion; (H3) within-season facilitation, i.e., livestock extends the duration of forage availability for sage-grouse; (H4) between-season facilitation, i.e., livestock stimulates forage growth in the following season. Compared to pastures that had not been occupied by livestock in the past two years, sage-grouse were twice more likely to select for pastures where livestock had been earlier that season. Sage-grouse did not select or avoid currently occupied pastures or pastures that had been occupied in the previous year. These results are compatible with H3, indicating that grazing may create profitable conditions for sage-grouse to exploit once livestock leave a pasture. Future research should test mechanisms by which livestock may alter forage dynamics within the growing season.

Behavioral State-Dependent Habitat Selection and Implications for Animal Translocations.

Picardi, S., P. Coates, J. Kolar, S. O'Neil, S. Mathews-Sanchez, and D. Dahlgren.

Abstract: Post-release monitoring is important to inform translocation protocols in an adaptive management framework. 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. Ignoring underlying behavior may lead to the wrong conclusions regarding features that characterize suitable settlement habitat. We investigated the effect of behavioral state on habitat selection of female greater sage-grouse (*Centrocercus urophasianus*) 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, while accounting for reproductive status and seasonality. In the exploratory state, sage-grouse selected for high sagebrush cover in all seasons; during winter, they also selected for gentle slopes and avoided roads. In the 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 translocated sage-grouse adjust their habitat selection to their current internal state, initially selecting for features reminiscent of their natal habitat and later adjusting their selection to fulfill seasonal and life-history needs. Our findings indicate the need to account for behavior when estimating habitat selection to inform the choice of future release sites in translocation studies.

Improving Wildlife Habitat Management and Restoration with Planning and Decision Support Tools, Adaptive Monitoring, and Adaptive Management.

Pilliod, D., and P. Coates.

Abstract: Natural resource managers are increasingly expected to prioritize actions within managed landscapes that maximize effectiveness and efficiency. Scientists and managers are co-producing decision

support tools to meet this need and integrating these tools with adaptive monitoring and adaptive management approaches. This symposium highlights several recent decision support tools and demonstrates how they are being used effectively for wildlife habitat management, especially in sagebrush ecosystems. We set the stage for these presentations with an overview of the linkages among research, monitoring, and adaptive management in the context of wildlife management. We emphasize the importance of spatial and non-spatial data, data services, data management, and adaptive monitoring to decision support tools and the adaptive management cycle. We discuss issues of temporal scale in terms of data available to track trajectories of habitat (e.g., aspects of vegetation) through time or in response to disturbance, management, or restoration. We review issues of spatial scale in terms of data resolution (e.g., grain), heterogeneity, and extent. We then view these temporal and spatial issues through the lenses of restoration objectives, change through time analyses, and measures of recovery that support adaptive management and decision making for wildlife.

Rangeland Response to Grazing: Connecting Field and Remotely Sensed Data for a Flexible Framework.

Reintsma, K. M., M. Szczypinski, and V. Dreitz.

Abstract: Livestock grazing is the world's most common land use. Rangeland response to livestock grazing is highly variable because it is influenced by a wide variety of ecological and management factors. This study focuses on livestock grazing in a sagebrush steppe ecosystem. We use Bayesian linear mixed effect models to assess how field-based grazing metrics influence sagebrush steppe rangelands as measured by remotely sensed biomass and productivity. Environmental complexity, including plant functional groups and available moisture, are accounted for as covariates within the models. We outline our results, ideas for use of this framework in future studies, and potential implications for the management of sagebrush steppe habitat for songbird communities.

Comparison of Common Ravens in Wyoming's Sage-Grouse Core and Non-Core Areas: Assessing Predator Densities Related to Anthropogenic Features.

Revekant, C., and J. Dinkins.

Abstract: Greater sage-grouse (*Centrocercus urophasianus*: hereafter sage-grouse) abundance and distribution in North America has declined over the last century. Many factors have contributed to this decline, including habitat loss and fragmentation from human development with an associated potential for increased predation. While human development has been connected to lower sage-grouse demographic rates, it also provides an increased number of structures used by avian predators. Wyoming's Core Areas have maintained higher sage-grouse trends and numbers of birds compared to Non-Core Areas, which could be explained by reduced risk to predation in Core Areas that have lower levels of development. However, we lack a study comparing actual reduction in predation risk within and outside Core Areas. I performed 2,157 avian point counts along 380 8.05-km transects throughout the Wyoming Basin within Wyoming during the summers of 2017 and 2018. During surveys, I noted all human structures, which were added to human disturbance data from available GIS data. I conducted a distance sampling analysis with an N-mixture model to evaluate how anthropogenic features influenced raven density across the Wyoming Basin, setup as a Negative Binomial regression that simultaneously assessed detection probability. Additionally, I further categorized existing Core and Non-Core Areas boundaries based on sage-grouse breeding habitat, areas of high relative sage-grouse abundance, and actual development. Agricultural lands, communication towers, roads, and landfills were positively related to raven density, which was lower in undeveloped Core and Non-Core Areas compared to developed Non-Core Areas. These results suggest that Core Areas currently serve as effective predator management.

Bayesian Machine Learning for Movement Modeling of Lesser Prairie-Chickens.

Rieber, C., T. Hefley, and D. Haukos.

Abstract: Telemetry data can answer novel questions for wildlife managers and increase knowledge of wildlife ecology. To extract the information available in telemetry data, we must continue to improve statistical methods that enable estimation of where an animal went and how it moved, with associated measures of uncertainty. Bayesian continuous time models have been developed to estimate the true animal movement trajectory that underlies discretely recorded telemetry data, yet these models remain inaccessible and underutilized. These models allow for the estimation of derived quantities describing an

animal's movement (e.g., velocity, turn angle, length traveled), and the models' Bayesian formulation allows for quantified uncertainty on the predictions of both an animal's trajectory and associated derived quantities. However, these models do not incorporate abrupt transitions in animal movement well (e.g., an individual transitioning from sleeping to walking). To account for these transitions, we recognized a novel application of a recently developed machine learning method and incorporated it in the Bayesian continuous time modeling framework. We demonstrated this method using data from a declining grassland bird, the lesser prairie-chicken (*Tympanuchus pallidicinctus*). We estimated trajectories for 54 GPS-transmittered females over six years in the Mixed-Grass Prairie Ecoregion of Kansas, USA, and compared derived estimates for daily displacement between ranches subjected to patch-burn or rotationally grazed management practices. Our demonstrated method can be easily applied to any telemetry data to compare derived quantities (e.g., average velocity, rest time) across treatments using accessible R packages.

Decision Support Software to Optimize Outcomes of Greater Sage-Grouse Habitat Restoration Through Conifer and Wildfire Management in the Great Basin.

Roth, C., P. Coates, M. Ricca, D. Pyke, S. O'Neil, C. Aldridge, and J. Heinrichs.

Abstract: Unprecedented conservation efforts for sagebrush (*Artemisia* spp.) ecosystems across the American West have been catalyzed by risks from conifer expansion and escalated wildfire activity that reduce habitat for sagebrush obligate species such as the greater sage-grouse (*Centrocercus urophasianus*). However, restoration is challenged by spatial variation in ecosystem processes influencing resilience to disturbance and resistance to invasive species, and spatiotemporal lags between slower sagebrush recovery processes and faster demographic responses of sage-grouse to loss of habitat needed during critical life stages. Decision-support frameworks that account for these factors can help managers strategically apply restoration efforts by predicting short and long-term ecological benefits of actions. Using a multi-stage modeling approach, we extended and improved a spatially explicit decision support tool that optimizes for conifer removal and post-wildfire restoration. We quantify restoration success in terms of ecosystem resilience to disturbance (i.e., wildfire) and resistance to invasion, and include the effectiveness of restoration relative to sage-grouse habitat suitability. This tool: 1) simulates post-fire landscape and habitat loss; 2) quantifies spatial variation in vegetation recovery such as sagebrush community type, dominance, and annual grass invasion based on passive, sagebrush seeding and sagebrush seedling transplanting; and 3) incorporates predicted sage-grouse selection, use, and survival and calculates expected improvements in post-restoration habitat suitability. The tool is fully automated within a web-based application that provides a user-friendly interface. The outputs include pre- and post-restoration seasonal habitat suitability surfaces for sage-grouse and ranking of proposed restoration sites by cost-effectiveness. Findings are preliminary and provided for timely best science.

Interactive Effects of Predators, Habitat, and Livestock Presence on Sage-Grouse Nest Success in Wyoming.

Ruth, K., J. Taylor, and J. Dinkins.

Abstract: Over the last century, greater sage-grouse (*Centrocercus urophasianus*, hereafter sage-grouse) distribution and abundance in western North America have significantly reduced and declined. Habitat loss and degradation are the predominant factors attributed to these declines, but predation in some contexts also contributes to declines. Livestock grazing has been identified as a potential influence on sage-grouse habitat, which may indirectly influence sage-grouse demography. However, very little is known about the interactive effects of livestock presence and management (e.g., grazing strategies), ecosystem processes (e.g., food web dynamics), and vegetative characteristics (e.g., forage, cover) on sage-grouse vital rates. During 2019–2022 we conducted a study in Bighorn Basin, Wyoming to investigate these interactions. We hypothesized that presence of cattle influences both avian and mammalian predators with more avian and fewer mammalian predators near livestock. Subsequently, we hypothesized that lower mammalian predator abundance near livestock explains observed preliminary patterns of higher sage-grouse nest success. As part of our ongoing study, we will present initial findings of potential benefits and threats of cattle operations on sage-grouse nest survival. We present an evaluation of nest success across multiple study sites with different grazing strategies, in addition to predator, livestock, and landscape-level covariates. This study will provide an enhanced understanding of sage-grouse population dynamics associated with the presence of livestock. Understanding how livestock may or may not influence sage-grouse is essential to aid management agencies in evaluating best management practices regarding the relationship between livestock and sage-grouse in western rangelands.

Oiling Raven Eggs as a Conservation Management Action.

Sanchez, C., P. Coates, D. Delehanty, T. Shields, M. Vaughn, and S. Mathews-Sanchez.

Abstract: The common raven (*Corvus corax*; raven) is a generalist predator whose population is expanding across western North America concomitantly with the expansion of anthropogenic subsidies which they utilize for food and nesting substrate. Increases in raven presence are linked to population declines for various native prey species including greater sage-grouse (*Centrocercus urophasianus*; sage-grouse). Ravens consume sage-grouse eggs leading to lower rates of nest survival, a critical demographic factor for sage-grouse population growth. Wildlife managers seek management options for mitigating the adverse effects of raven predation where unsustainable predator-prey conflicts exist. We evaluated the method of oiling raven eggs to suppress raven reproduction and thereby improve sage-grouse nest survival (nests = 581). Raven nests (nests = 28) were successfully treated in sage-grouse breeding areas by using telescoping poles and drones equipped with remote fluid application systems (Hardshell Labs Inc., Haines, Alaska, USA). Oiling raven eggs resulted in a 94% average decrease in raven nest survival relative to controls. To evaluate the effectiveness of raven egg-oiling treatments, we applied a Before-After Control-Impact experimental design using six long-term study areas in Nevada and California over 5 years. We found an average annual increase in probability of sage-grouse nest survival of 145% (95% credible interval = 44–323%) in the treated areas relative to the controls, with an overall 99.9% probability of a positive effect of egg-oiling on sage-grouse nest survival. Results from this study are intended to inform future conservation actions. Findings are preliminary and provided for timely best science.

Optimizing Conservation and Restoration of Imperiled Sagebrush Ecosystems to Benefit Multiple Species.

Shyvers, J., B. C. Tarbox, C. Duchardt, A. Monroe, D. Edmunds, B. S. Robb, N. Van Lanen, E. Buchholtz, M. O'Donnell, J. Heinrichs, and C. Aldridge.

Abstract: Sagebrush ecosystems of North America continue to undergo widespread degradation due to multiple factors, including climate change and increased human development. Effective sagebrush management must consider how to best conserve and restore habitats to stem the decline of species that rely on them, especially given finite funding and other resources. To address the critical need for science-based tools that balance management priorities and guide strategic conservation efforts, we recently developed the Prioritizing Restoration of Sagebrush Ecosystems Tool (PReSET). PReSET utilizes the Prioritizr package (Program R) and integer linear programming to help maximize the efficiency and effectiveness of sagebrush restoration efforts. We expanded this spatial-optimization framework to prioritize sites for both restoration and conservation actions based on customized management objectives. Our framework incorporates updated estimates of sagebrush recovery potential within disturbed habitats, novel abundance predictions for sagebrush-obligate and -associated species (including the Brewer's sparrow, sagebrush sparrow, sage thrasher, green-tailed towhee, loggerhead shrike, pygmy rabbit, mule deer, golden eagle, and greater sage-grouse), connectivity measures for sagebrush habitats, and potential changes in sagebrush cover based on future climate projections. We applied this framework within the sagebrush biome of Wyoming in the western United States to help guide ecosystem recovery efforts in the region. We will demonstrate the capabilities of the tool and provide application examples that facilitate State and Federal strategic planning efforts to conserve and restore sagebrush habitats for multiple species of conservation concern.

Assessing Improvement Potential of Habitat Management Actions for the Gunnison Sage-Grouse Satellite Populations.

Shyvers, J., N. Van Schmidt, D. J. Saher, J. Heinrichs, M. O'Donnell, and C. Aldridge.

Abstract: The Gunnison sage-grouse (*Centrocercus minimus*), a species listed as threatened under the Endangered Species Act, has experienced substantial declines in range-wide abundance and distribution, primarily due to loss of habitat. It is predominantly restricted to seven populations in southwest Colorado, six of which are small, isolated satellite populations. These satellites are critical to maintaining redundancy and representation for the species and are a currently a focus of habitat improvement actions for recovery. We used existing habitat models to assess spatial variability in responses to specific restoration actions within crucial Gunnison sage-grouse habitats and generated heatmaps indicating where those actions might be best applied on the landscape to maximize effectiveness of local management plans for recovery of the species. We then assessed the utility of these resources for improving

management planning strategies by simulating restoration actions, sited with and without the use of these heatmaps, and comparing the resulting change in predicted habitat suitability. We found restoration of seemingly similar sites could yield vastly different habitat suitability outcomes for Gunnison sage-grouse across space, highlighting the complexities of local habitat-use associations and their potential influence on management outcomes. The resulting map products may serve as valuable tools for managers tasked with developing strategic habitat restoration plans that maximize returns on management investment at local scales, particularly in cases where funding and resources are limited. Our approach has the potential for broad-scale applications across a wide range of ecological systems and species for which habitat suitability models exist or could be developed.

Demographic Rates of a Declining and Augmented Population of Greater Sage-Grouse in Modoc County, California, USA.

Sink, C., C. Hagen, K. Dugger, and J. Vradenburg.

Abstract: Greater sage-grouse (*Centrocercus urophasianus*) in Modoc County California are geographically isolated and have been subsidized by translocation to prevent inbreeding depression since 2005. Despite significant efforts to increase the population through translocations and habitat improvement by cutting encroaching juniper (*Juniperus occidentalis*), only a single lek remains (from 56 in the 1940s). Several large wildfires have occurred since 2017 and led to increases in invasive grasses and a decrease in shrub cover that has further degraded important nesting and brooding habitat. We estimated adult female, nest, and chick survival and assessed habitat and biotic characteristics that may influence these rates to identify limiting factors to population growth. We monitored 37 females marked with GPS PTTS, 39 nests, and 8 broods from 2019–2021. Preliminary results showed nest success across a 29-day incubation period was 29% (95% CI 17.1–44.8), chick survival across a 54-day period was 22% (95% CI 0.9–72.3), and female adult survival across at 12-month period was 29% (95% CI 17.8–43.7). Our estimated vital rates were 45–55% lower than range-wide estimates, suggesting recent habitat changes caused by wildfire and invasive grasses are having a detrimental effect on this population across all life stages.

The Implications for Conservation and Management When Three Distinct Grouse Species Are Found in a Single Morphospace.

Stein, C., J. Lautenbach, J. Beck, and A. Gregory.

Abstract: Accurately identifying local and regional biodiversity, determining population trends, and taking actions to curb population declines and species loss are among the challenges of conservation. Applying varying species concepts to identify species is particularly problematic and can have profound impacts on how to best allocate scarce resources for species conservation. A poignant example is conserving prairie-grouse species found in the Great Plains and Intermountain West of the United States, including the Greater Prairie-Chicken (*Tympanuchus cupido*), Lesser Prairie-Chicken (*T. pallidicinctus*), and Sharp-tailed Grouse (*T. phasianellus*). These species are considered unique based on distribution, physical appearance, and behavior but when they occur sympatrically have been observed to hybridize, increasing phylogenetic complexity. We employed a standard morphospace analysis, a common approach in paleontology, that uses evolutionary derived physical attributes to evaluate the uniqueness of the Bauplan of species. We used 27 morphometric features and ratios commonly applied to extant taxa to investigate the morphological distinctiveness of prairie-grouse with Northern bobwhite quail (*Colinus virgianus*) as an out group. Ordered principal components analysis explained >80% of the variation in morphospace of each species in the analysis and identified bobwhite as having a distinct morphospace from the three prairie-grouse species. Similarly, the morphospace analysis provided weak support for Sharp-tailed grouse as occupying distinct morphospace but did not recognize a significant difference in the Bauplan of the Greater and Lesser prairie-chickens. The results indicate that the Greater and Lesser prairie-chicken are not distinct morphospecies, but recent co-ancestry and homoplasy should be considered before making a final decision.

Avian Predator Occupancy and Diet at Communication Sites in Sage-Grouse Habitat.

Szabo, S., T. Levi, P. Coates, J. Cupples, I. Dwight, G. Frederick, S. O'Neil, S. Webster, and J. Dinkins.

Abstract: Habitat fragmentation resulting from anthropogenic features can pose a threat to Greater Sage-Grouse (*Centrocercus urophasianus*; hereafter, Sage-Grouse). Studies have shown that Sage-Grouse

avoid tall structures, and both transmission lines and communication towers have been linked to Sage-Grouse nest failure, lek abandonment, and extirpation. These unnatural features provide nesting and perching substrates for ravens and other avian predators of Sage-Grouse and their nests. We designed a field study to assess how the design, arrangement, and location of communication towers influence nesting and perching of avian predators within Sage-Grouse habitat. We visited over 700 communication sites in over 200 sage-grouse habitat clusters across Oregon, Idaho, Nevada, Wyoming, and California during the March-June nesting seasons in 2021 and 2022. Site visits consisted of a point count survey, measurements of available nesting substrate, inventory of avian predator nests, and collection of genetic materials for dietary analysis. Year one data indicates that avian predators preferentially nest on large, wind-blocking antenna types, and areas of the tower structure with dense steel lattice. Site occupancy is also influenced by topographic, landcover, and land use characteristics. Preliminary diet data indicates that avian predators nesting in Sage-Grouse habitat eat a varied diet that includes many sagebrush obligate species of conservation concern.

An Optimization Approach to Balance Conifer Removal Trade-Offs for Sagebrush and Pinyon-Juniper Songbirds.

Van Lanen, N., J. Shyvers, C. Duchardt, A. Monroe, and C. Aldridge.

Abstract: Research shows greater sage-grouse (*Centrocercus urophasianus*) and other sagebrush-obligate songbird populations benefit from conifer removal within sagebrush habitats. Unfortunately, growing evidence suggests pinyon-juniper associated species, including the declining pinyon jay (*Gymnorhinus cyanocephalus*), are likely negatively impacted by conifer removal. Thus, managers require information regarding where conifer removal can be implemented to improve sagebrush ecosystems, while maintaining important habitat for pinyon-juniper species. To address this need, we developed a Bayesian hierarchical modeling framework, using songbird abundance to assess habitat relationships. These models allowed us to map predicted songbird abundance given current conditions, and under a conifer removal scenario. We then calculated expected changes in songbird abundance following our simulated conifer removal treatments (hereafter, "utility") for six species: Bewick's wren (*Thryomanes bewickii*), Brewer's sparrow (*Spizella breweri*), gray flycatcher (*Empidonax wrightii*), pinyon jay, sagebrush sparrow (*Artemisiospiza nevadensis*), and sage thrasher (*Oreoscoptes montanus*). We incorporated these utility layers into a linear integer programming optimization framework using the prioritzr package in Program R to identify locations for conifer removal based upon single species, single ecosystem, and multi-ecosystem management paradigms to compare conservation outcomes for each of our species of interest. Using the Utah portion of Bird Conservation Region 16 as a test case, we identified optimal locations for conifer removal treatments within greater sage-grouse habitat which maximizes the increases in sagebrush songbird abundances and minimizes decreases in pinyon-juniper associated songbird abundances, including the declining pinyon jay. We demonstrate the efficacy of this multi-ecosystem approach for balancing potential management trade-offs of conifer removal for non-target species.

Declining Habitat Quality and Quantity for Lesser Prairie-Chickens of the Sand Sagebrush Prairie.

Vhay, M., D. Haukos, D. Sullins, and M. Rice.

Abstract: Populations of lesser prairie-chickens (*Tympanuchus pallidicinctus*) in the Sand Sagebrush Prairie Ecoregion of southwest Kansas and southeast Colorado, USA, have declined sharply since the mid-1980s. Decreased habitat quality and availability are believed to be the main drivers of declines; however, no broad-scale assessment of landscape change has been conducted for the ecoregion. Our objectives were to reconstruct landscape-scale change in the ecoregion since 1985, and assess changes in vegetation structure and composition relative to management goals. We assessed landcover change and calculated landscape metrics using LCMAP layers and documented presence of anthropogenic structures including oil wells and transmission lines. We also compared historical and contemporary fine-scale vegetation survey data. Vegetation land cover and tree occurrence changed little since 1990. However, oil and gas wells increased by 88% and transmission line segments increased by 237%, causing functional habitat loss as a result of displacement of lesser prairie-chickens. Quality vegetation structure and frequency of desirable plant species on public lands have declined since the late 1980s. Increased anthropogenic structures and decrease in vegetation vertical structure appears to have decreased available habitat as well as the quality of existing habitat.

Who Gives a Hoot? Developing Methods to Assess Sooty Grouse Population Trends in Western Oregon.

Walton, K., S. Frey, L. Sanders, M. Cline, D. Gillies, and J. Dinkins.

Abstract: Sooty grouse (*Dendragapus fuliginosus*) populations are thought to be declining throughout their range; however, there is very little research documenting the extent of this decline or factors contributing to it. Previously established Breeding Bird Survey protocols and Oregon Department of Fish and Wildlife (ODFW) survey protocols for upland game bird species are ineffective for detecting sooty grouse population trends due to timing of surveys and low encounter rates. ODFW and Oregon State University (OSU) have worked together to develop a reliable index of sooty grouse populations in western Oregon using spring-time surveys of hooting males. The resulting protocol, adopted in 2011, consists of 3-minute auditory surveys conducted at half-mile intervals along established survey routes in three regions of western Oregon (Coast Range, western Cascades, and Klamath), with a goal of at least 300 auditory surveys per region. In 2020, we initiated an update of this protocol to quantify and incorporate variation in detection probability, facilitate evaluation of population trends, and identify environmental factors influencing population trends. We addressed these topics by conducting repeated surveys of established routes throughout the hooting season and deploying a network of acoustic recorders across elevational and latitudinal gradients to assess detection probabilities and daily and seasonal timing of hooting. Ultimately, these data will allow us to evaluate the influence of climatic conditions, habitat characteristics, and forest management practices on sooty grouse populations. Understanding these factors will allow us to effectively manage for a healthy and persistent sooty grouse population into the future.

Spatial Modeling of Common Raven Density and Occurrence Helps Guide Landscape Management Within Great Basin Sagebrush Ecosystems.

Webster, S., S. O'Neil, B. Brussee, P. Jackson, D. Delehanty, and P. Coates.

Abstract: Common ravens (*Corvus corax*) are a highly adaptable nest predator of several avian species, including species of conservation concern. However, individual differences in raven movement patterns, particularly territoriality of breeding birds and transiency of nonbreeding birds, are thought to influence the frequency and efficacy of nest predation. As such, predicting where on the landscape territorial resident and non-territorial transient birds may be found is of increasing importance to managers and conservationists. We used existing spatially explicit predictions of raven occurrence and density in the Great Basin region of the U.S. to explore whether the relationship between the two parameters would allow us to differentiate areas likely occupied by higher concentrations of resident as opposed to transient ravens. We used model residuals from a generalized linear regression of the two parameters to generate a spatially-explicit map product of different categories of expected occurrence and density associated with predicted concentrations of resident and transient ravens. We evaluated map accuracy using independently collected observed raven group sizes and GPS locations of resident and transient individuals. The map performed moderately well for both evaluation approaches, giving us confidence that it allows for broad inference about spatial variation in predation risk from ravens. Using the map as a spatially explicit decision support tool, managers can improve the efficacy of raven management efforts for improved survival and reproductive success of native species within the Great Basin. Findings are preliminary and provided for timely best science.

Modeling the Distributions of Climate-Sensitive Vertebrates to Inform Future Management Strategies.

Wilson, E., and N. Carter.

Abstract: Climate change and habitat loss are recognized as important drivers of shifts in wildlife species' geographic distributions. While often considered independently, there is considerable interaction between these drivers, and understanding how they contribute to range shifts can predict future species assemblages and inform effective management. We combined multiple sources of occurrence data, including harvest and citizen-science data, then used hierarchical Bayesian spatial models to determine habitat and climatic associations for four climate-sensitive vertebrate species [American marten (*Martes americana*), snowshoe hare (*Lepus americanus*), ruffed grouse (*Bonasa umbellus*) and moose (*Alces alces*)] in northern Michigan. We used biomass of at-risk forest types to represent habitat, and used temperature and winter habitat indices to represent climate. Marten were associated with multiple forest types (upland spruce-fir, jack pine/red pine, lowland conifer and northern hardwoods), hares with lowland

conifer and aspen-birch, grouse with lowland riparian hardwood, and moose with no specific forest types. Species differed in their response to climatic drivers with moose, hares and marten positively associated with cooler annual temperatures, and grouse negatively associated with warmer summer temperatures. Contrary to expectations, temperature variables outperformed winter habitat indices. Model performance varied greatly between species, as did predicted distributions along the southern edge of the Northwoods region. As multiple species were associated with lowland conifer habitats, potential exists for efficient prioritization of habitat management. Future analyses will forecast predicted distributions of vulnerable species under climate change and forest management scenarios and evaluate how habitat manipulation may buffer impacts of climate change on forest communities.

Species-Specific Effects of Conifer Removal on Sagebrush Songbirds.

Zarri, E., and T. Martin.

Abstract: In western North America, conifers are encroaching into sagebrush habitats, contributing to habitat loss and degradation for sagebrush associated species. Conifer removal has become a common restoration technique and is often implemented to improve habitat quality for Greater Sage-Grouse. Tree removal facilitates increases in sage-grouse populations through increased survival and reproduction. Other sagebrush-associated species are assumed to benefit similarly, but these assumptions are rarely tested. This study investigates the impacts of conifer removal on the density, reproductive success, and habitat selection of sagebrush songbirds, including sagebrush-obligate, sagebrush-associated, and generalist species. Removal of conifers could result in ecological traps for some species due to high spillover nest predation in conifer removal areas adjacent to dense conifer forests. We monitored nests, mapped territories, and quantified vegetation at nest and territory scales for eight songbird species between conifer removal and control areas in montane sagebrush habitat in southwest Montana. Sagebrush-obligate species including Brewer's Sparrow and Sage Thrasher have densities and nest success in conifer removal areas. Sagebrush-associated and generalist species show mixed responses. Vesper Sparrows have higher densities in removal areas, whereas Green-tailed Towhees, Dark-eyed Juncos, and Chipping Sparrows have higher densities where conifers remain. White-crowned Sparrows and American Robins do not show strong responses to conifer removal. We conclude that conifer removal is likely beneficial for sagebrush-obligate songbirds, but impacts to other declining species, such as Green-tailed Towhees should be considered when making management decisions.

NEW BOOKS

Coming in early 2023

Ecology and Conservation of Mountain Birds

Dan Chamberlain, Aleksi Lehikoinen and Kathy Martin, editors

Ecology, Biodiversity and Conservation Series, Cambridge University Press

We announce the coming publication in early 2023 of a global reference volume on high mountain bird ecology and conservation. The ten chapters in our multi-author book focus on avian ecology and research at and above the treeline ecotone with an emphasis on the alpine zone. The book begins with our working definition of 'mountains', global estimates of mountain habitats, an introduction to mountain bird communities and their habitats including the many adaptations that birds employ to live in high mountains. Several chapters summarize what we know about avian ecology in the alpine and nival zones (the highest elevation habitats) and the treeline ecotone in temperate and topical habitats. Two chapters review mountain bird population trends across Europe and North America, and approaches to large large-scale modelling for mountain bird ecology and conservation. There is extensive treatment of potential threats to mountain bird populations, particularly climate change and human disturbance, assessing the evidence of likely impacts and conservation actions required to minimize those impacts and improve prospects for the future. The book concludes with a 'roadmap' to guide mountain bird research over the next decades that involves improving population monitoring programs, increasing our ecological knowledge of mountain species, identifying the key drivers of their distributions and population trends, and providing an assessment of their resilience to environmental change.

Mountains are globally important for biodiversity and endemism as mountain regions cover one quarter of the earth's terrestrial surface, but contain nearly half of its biodiversity hot-spots. The high mountains host many charismatic and highly sought-after species such as giant hummingbird and glacier finch in the Andes, white-tailed ptarmigan in North America, white-winged snowfinch in the European Alps, grandala in Asia, scarlet-tufted sunbird in Africa, or rosy finches in the Holarctic. Many of you will be familiar with the research on mountain grouse, but you might be surprised to learn that at least 1,310 species of birds breed above the treeline, with additional species expected to be discovered in future, especially in the global south. This tally represents 12% of the 10,933 species currently recognized by the International Ornithological Committee (Gill et al. 2022). In some areas, high mountains support up to 40% of the local species pools with often extensive avian use year-round. About 25% of birds breeding above the treeline are alpine specialists, and 75% of birds breeding there live across a range of elevations.

Mountain biodiversity is threatened by growing pressure caused by human activities, especially climate change, that imperil many key ecosystem services provided by mountain habitats. Increasingly, mountains are providing climate and habitat refugia for open-country species that were formerly widespread, but are now declining in the lowlands due to increasingly intensive anthropogenic activities at low elevations. Despite escalating threats, mountain biodiversity is poorly studied compared to many lowland habitats. Thus, conducting further ecological and biodiversity conservation research for mountain ecosystems is a high priority. Overall, mountains support disproportionately high biodiversity, birds in high mountain are sensitive to habitat degradation, and alpine birds can be useful sentinels of environmental change. Our hope is that despite the climate change threats, mountain ecosystems may, with appropriate management, become more important centres for bird conservation in a changing climate than they are at present.

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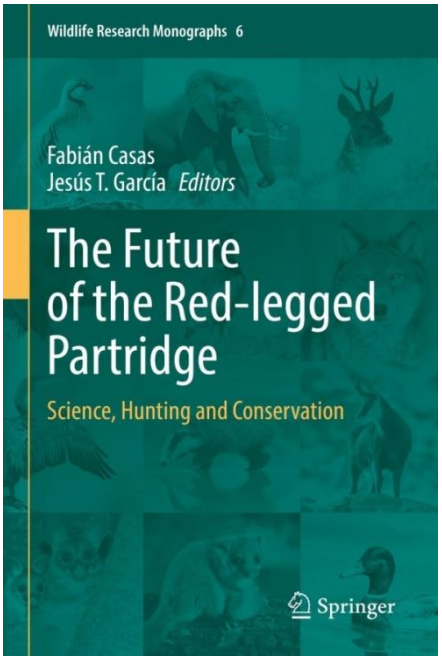
The Future of the Red-legged Partridge

Science, Hunting and Conservation

Fabián Casas and Jesús T. García, editors



There has been a recent upsurge of red-legged partridge research in most countries where the species is distributed, but no comprehensive review of that fresh and relevant multidisciplinary and international knowledge is available. In fact, this is probably the first scientific book on this important species, apart from Dick Potts' excellent works on British-introduced population, or ONCFS's (Office Nationale de la Chasse et le Faune Sauvage, France) older technical reports. This is in strong contrast with a plethora of literature in hunting magazines or non-academic books, not often precise, realistic, or well informed. Thus, the book fills a great bibliography gap that could have important social impact. The common thread of the book is the prominent role a species like this may play for research, from basic physiological or ecological knowledge to socio-economics of hunting and the rural world. The general framework of the book [I1] is the important role that hunting and game management may play in both rural economies and biodiversity conservation, with the partridge as flag species, and also in identifying the "dark drift" that industrial, incorrectly deployed management, or hunting vision may have on both sustainability of resources and nature conservation at large. The final aim of the book is identifying the best future scenario, both for partridge hunters and managers as well as the general public.

This book is part of the book series: Wildlife Research Monographs (WIREMO, volume 6)
 Published: 03 September 2022.

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RESEARCHERS AND THEIR BEST FRIEND ASSISTANTS

The Calm, the Chaos, and the Reward: All in the Day of a Pointing Dog

Kade Lazenby,

For just a moment, the world stands still; the crisp fall air fills my stressed lungs as I gasp for air, and the world is right. Three dogs are stacked in the magical pose that we call a point. I am positive there is a covey within sight of my lead dog and two in training a short distance behind. After cautiously walking to the dogs all at once, chaos ensues; 3 to the right, 5 to the left, 2 right over my head! When it is all over, I shoot both barrels, and I have three dogs looking at me with that same look I would get from my mother when I didn't reach her expectation. Lucky for me, their disgust doesn't last as long as my mother's, and they will return to the hunt momentarily.

As a hunter, moments like these are what we live for, hopefully with a heavier bag after the chaos is over. Until I was working on my undergrad at Utah State University, I thought this was the only function these wonderful creatures could complete. In Wildlife techniques class, I learned that pointing dogs are frequently used in research and that at USU, a professor was currently using dogs to locate dusky grouse (*Dendragapus obscurus*).

I have had the continued opportunity to help many bird dogs develop their natural abilities. Through countless hours we train these wonderful creatures to use naturally selected traits for our benefit. Due to their amazing loyalty, even after our shortcomings, they still work for us as though we are providing the service to them.

As a boy, I would sit on a barrel and watch my father continually praise the dogs for standing still. I would help position pigeons in locations where young dogs could locate them and spend all my free time exercising the dogs. I loved training from a young age and would spend my Saturday mornings watching *Hunting with Hank* or George Bird Evans training videos. I moved on to jump on any opportunity to learn from any trainer that would take the time to teach me anything new. After high school, I was introduced to the world of versatile hunting dogs, "the ones that could do it all," and started working for another trainer that taught me how to train for the North American Versatile Hunting Dog Association trials. Since then, I have had the opportunity to train many dogs for others and a few for myself, and I constantly enjoy the prospect of helping a new dog owner into the lifestyle that owning a working dog offers. I am intrigued by different dog breeds and training styles and continue to develop as a trainer.

Beginning in 2016, I started working for Skyler Farnsworth, one of Dr. David Dahlgren's graduate students. We used pointing dogs to locate and capture dusky grouse in Logan canyon. Through this opportunity, I convinced Dr. Dahlgren that I was a good candidate, and I moved on to complete my master's project studying greater sage-grouse (*Centrocercus urophasianus*) translocations.

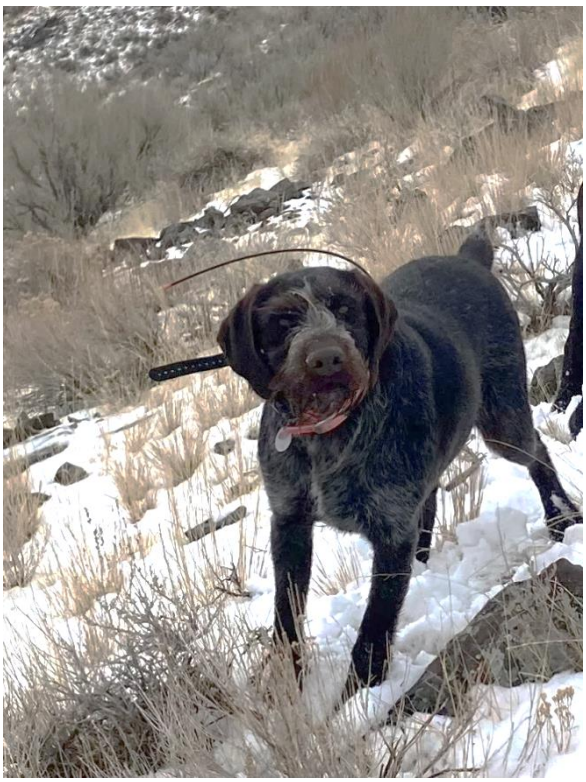


*Figure 1: LuLu, German Wirehaired Pointer, pointing chukars (*Alectoris chukar*) in Eastern Utah*

Due to declining sage-grouse populations in North Dakota, managers determined that translocations were the best tool to ensure that sage grouse persist in these fringe populations. The inherent issues with translocations are the post-translocation movements and the lack of recruitment caused by mortality and failure to produce offspring. The objective of our project was to increase recruitment using novel translocation methodologies. USGS, USU, and others developed alternate translocation methods, but it was my job to keep track of individual birds in the augmented population in North Dakota and source population in Wyoming.

Although we fitted all captured birds with a VHF or GPS transmitter, detecting translocated individuals or their offspring was often challenging. When we could not locate birds with transmitters, we would use the pointing dogs to locate birds. My dog LuLu (Lu), a German Wirehaired Pointer, and I spent many hours searching for broods and translocated individuals in the augmented population. The undetectable individuals often were mortalities, but that didn't stop the dog from locating the collars.

Although Lu's presence was a daily occurrence on the short-grass prairies of North Dakota for those two field seasons, there were instances when her presence was imperative. A particular example is after a brood translocation, we had a brood hen and four of her chicks disappear. After a flight and no detection, Lu, a technician, and I went to where we last saw the brood. We were intent on finding the transmitters with the receiver, but Lu had other ideas. I was hiking to the highest point to hear one of the transmitters hopefully, and Lu went on point. As I walked over to her, it was apparent that there were no birds within the vicinity of where she was pointing, but I kicked the bush for good measure and told her to move on. After an hour, she moved back and pointed to the same bush. This time my technician walked to her, noticed freshly disturbed soil next to the bush, and found all four chicks stashed by a weasel buried in the ground for later consumption. Without the dog, this discovery would still remain unknown to me.

Figure [2]: LuLu, German Wirehaired Pointer, pointing a translocated sage-grouse brood in North Dakota. (The sage-grouse hen is located just beneath the center of the picture)

Post graduate school, I have had the opportunity to work with multiple state agencies, where I have been able to use my dogs in multiple species surveys. Even though there is no gunshot at the climax of chaos, the dogs seem to know as the birds fly over the horizon that they have not only pushed through evolutionary selection as expert bird locators but also completed their part in our partnership. For the opportunity to train, hunt, and work, and the magic that is present within these magnificent creatures, I will always be grateful.

Kade Lazenby, MS, Habitat/ Impact Analysis Biologist, Utah Division of Wildlife Resources, klazenby@utah.gov.

SNIPPETS

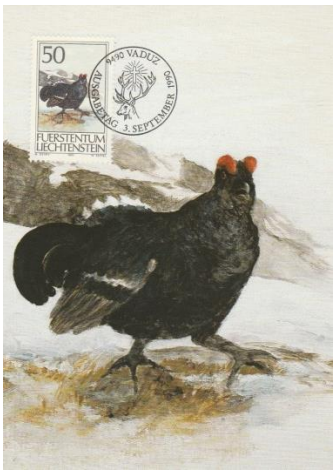
Spatial ecology of ptarmigan

Jasmin Dawson is an MSc student at Memorial University of Newfoundland studying spatial ecology of ptarmigan in Nunatsiavut. Her research project will examine ptarmigan habitat selection and spatial ecology in a landscape where weather patterns, climate, and vegetation composition are shifting due to climate change. Using remote satellite collars, ptarmigan will be tracked to determine the regions they use during the breeding season and the extent of their migration, and integrated step selection models will be used to analyze ptarmigan habitat selection and movement. Additionally, she aims to project forecasted habitat availability under climate change to predict future ptarmigan habitat use and movement in Nunatsiavut. The goals of her research are to identify current and potential ptarmigan breeding and wintering grounds, describe patterns of movement and migration, and assess potential future effects of climate change on these factors.

Jasmin Dawson, Memorial University of Newfoundland, jpdawson@mun.ca.

Grouse on Stamps

In spring 2020 Ladislav Paule asked if we should present stamps with capercaillie and black grouse. In issue 59 of Grouse News we introduced this and presented 10 stamps. Now we have got more pictures and also of other grouse species. Please see issue 59 for more information. We continue the presentation of grouse on stamps started in issue 59. You may also contact Ladislav Paule, Zvolen, Slovakia, paule@tuzvo.sk.

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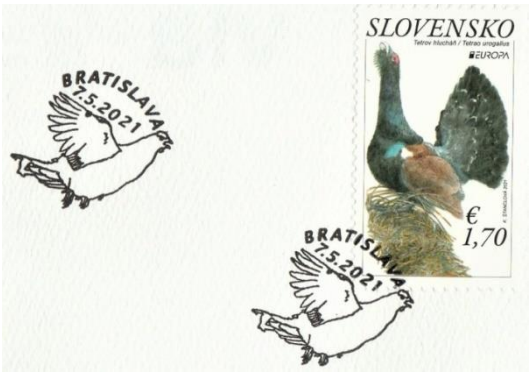
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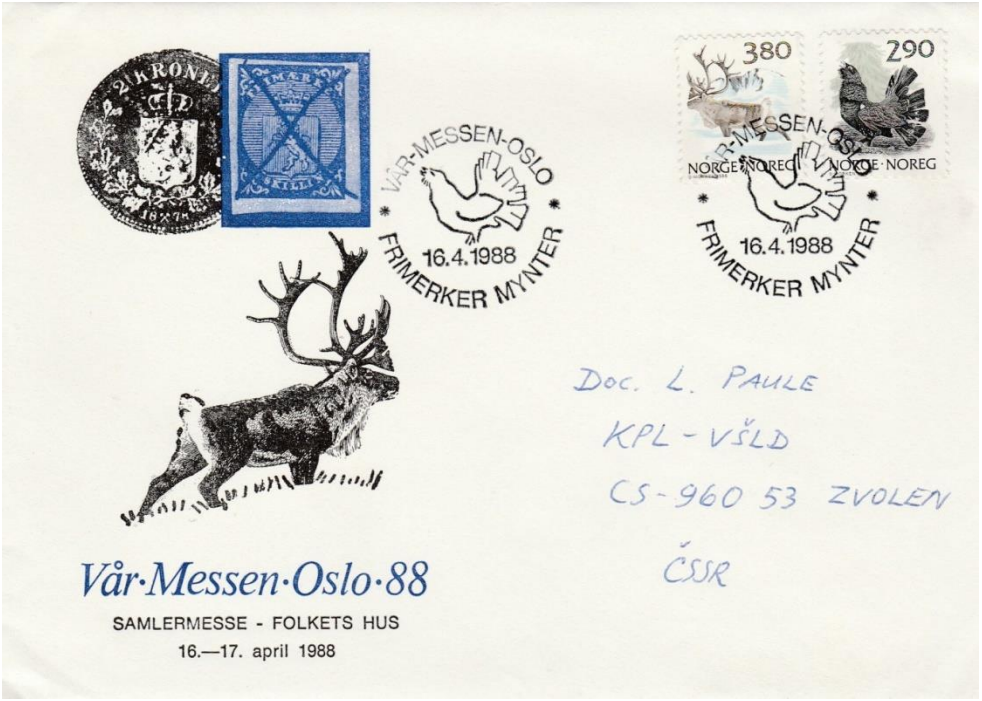
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