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Annotated Bibliography of Scientific Research on Gunnison Sage-Grouse Published from January 2005 to September 2022

Open-File Report 2023–1079

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

Cover. Gunnison sage-grouse habitat in the Gunnison Basin, eastern Colorado. Photograph by Kathy Broadhead, Bureau of Land Management.

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U.S. Geological Survey, Reston, Virginia: 2023

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Suggested citation:
Maxwell, L.M., Teige, E.C., Jordan, S.E., Rutherford, T.K., Samuel, E.M., Selby, L.B., Foster, A.C., Kleist, N.J., and Carter, S.K., 2023, Annotated bibliography of scientific research on Gunnison sage-grouse published from January 2005 to September 2022: U.S. Geological Survey Open-File Report 2023–1079, 52 p., https://doi.org/10.3133/ofr20231079.

ISSN 2331-1258 (online)

Acknowledgments

Funding for this work was provided by the Bureau of Land Management (BLM). We are appreciative of the input and guidance of Travis Haby (BLM), Patricia Deibert (BLM), and Leah Waldner (BLM). We are very grateful to Whit Blair (U.S. Fish and Wildlife Service), Kathy Griffin (Colorado Parks and Wildlife), Nathan Seward (Colorado Parks and Wildlife), and Taylor Applewhite (BLM) for providing independent peer review of the report and the summaries it contains. We thank the many authors of publications summarized within this annotated bibliography for providing input on the draft product summaries, including Cameron Aldridge (U.S. Geological Survey [USGS]), William Baker (University of Wyoming), Brian Cade (USGS), Todd Castoe (University of Texas at Arlington), Amy Davis (USDA-APHIS), Brian Gerber (Colorado State University), Robert Gibson (University of Nebraska–Lincoln), Seth Harju (Heron Ecological), Corrine Knapp (University of Wyoming), Sarah Lupis (SWCA Environmental Consultants), Alexa McKerrow (USGS), Terry Messmer, Phoebe Prather (Utah State University), Mindy Rice (U.S. Fish and Wildlife Service), Joanne Saher (Colorado State University), Ilse Storch (University of Freiburg), Daniel Walsh (USGS), Michael Wisdom (USDA Forest Service), and Shawna Zimmerman (USGS).

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)

Abbreviations

APHIS	Animal and Plant Health Inspection Service
BLM	Bureau of Land Management
CC	climate cluster
DNA	deoxyribonucleic acid
EPA	U.S. Environmental Protection Agency
FWS	U.S. Fish and Wildlife Service
GUSG	Gunnison sage-grouse
MZ	management zone
SNP	single nucleotide polymorphism
spp.	several species of
ssp.	subspecies
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

Species Names

[ssp., subspecies; spp., several species of]

Common name	Scientific name
big sagebrush	*Artemisia tridentata* Nuttall
Burmese python	*Python bivittatus bivittatus* Kuhl
burro	*Equus africanus* Heuglin and Fitzinger
California condor	*Gymnogyps californianus* Shaw
Clark's nutcracker	*Nucifraga columbiana* Wilson
common raven	*Corvus corax* Linnaeus
domestic chicken	*Gallus gallus* Linnaeus
Galliformes	Phasianidae Temminck
golden eagle	*Aquila chrysaetos* Linnaeus
greater prairie-chicken	*Tympanuchus cupido* Linnaeus
greater sage-grouse	*Centrocercus urophasianus* Bonaparte
greater sandhill crane	*Antigone canadensis tabida* Peters
grouse family	Phasianidae
Gunnison sage-grouse	*Centrocercus minimus* Young, C. Braun, Oyler-McCance, Hupp & Quinn
least tern	*Sternula antillarum* R. Lesson
lesser prairie-chicken	*Tympanuchus pallidicinctus* Ridgway
marbled murrelet	*Brachyramphus marmoratus* J.F. Gmelin
Mojave Desert tortoise	*Gopherus agassizii* Cooper
mountain big sagebrush	*Artemisia tridentata* ssp. *vaseyana* (Rydb.) Beetle
piñon pine	*Pinus edulis* Engelmann
piping plover	*Charadrius melodus* Ord
prairie grouse	*Tympanuchus* spp. Gloger
pygmy rabbit	*Brachylagus idahoensis* Merriam
rough-legged hawk	*Buteo lagopus* Pontoppidan
sagebrush	*Artemisia* spp. Linnaeus
sage-grouse	*Centrocercus* spp. Swainson
sand sagebrush	*Artemisia filifolia* Torrey
serviceberry	*Amelanchier* Medik.
sharp-tailed grouse	*Tympanuchus phasianellus* Linnaeus
western snowy plover	*Charadrius nivosus nivosus* Cassin
Utah juniper	*Juniperus osteosperma* (Torr.) Little
wild horse	*Equus ferus* Boddaert
Wyoming big sagebrush	*Artemisia tridentata* ssp. *wyomingensis* Beetle and Young

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By Logan M. Maxwell,[1] Elisabeth C. Teige,[1] Samuel E. Jordan,[2] Tait K. Rutherford,[2] Ella M. Samuel,[2] Lea B. Selby,[1] Alison C. Foster,[2] Nathan J. Kleist,[2] and Sarah K. Carter[2]

Abstract

Integrating recent scientific knowledge into management decisions supports effective natural resource management and can lead to better resource outcomes. However, finding and accessing scientific knowledge can be time consuming and costly. To assist in this process, the U.S. Geological Survey is creating a series of annotated bibliographies on topics of management concern for western lands. Previously published reports introduced a methodology for preparing annotated bibliographies to facilitate the integration of recent, peer-reviewed science into resource management decisions. Therefore, relevant text from those efforts is reproduced here to frame the presentation. *Centrocercus minimus* (Gunnison sage-grouse; hereafter GUSG) has been a focus of scientific investigation since the early 2000s. The U.S. Fish and Wildlife Service listed GUSG as threatened under the Endangered Species Act in 2014 because of declining populations and increasing habitat loss. The U.S. Fish and Wildlife Service, Bureau of Land Management, and Colorado Parks and Wildlife have sought to increase the conservation of this species by adapting management and recovery plans to reduce threats and increase population resiliency. GUSG are studied less than the closely related *Centrocercus urophasianus* (greater sage-grouse); however, research efforts have recently increased to understand the life history, genetics, and habitat suitability of this sagebrush-obligate species. We compiled and summarized peer-reviewed journal articles, data products, and formal technical reports (such as U.S. Department of Agriculture Forest Service General Technical Reports and U.S. Geological Survey Open-File Reports) on GUSG, published between January 2005 and September 2022. We first systematically searched three reference databases and three government databases using the following search phrases: “Gunnison sage-grouse” or “lesser sage-grouse” or “Gunnison grouse” or “Gunnison sage grouse” or “lesser sage grouse” or “*Centrocercus minimus*.” We refined the initial list of products by removing (1) duplicates, (2) publications that were not published as research, data products, or scientific review articles in peer-reviewed journals or as formal technical reports, and (3) products that did not have GUSG as a research focus or products that did not present new data or findings about GUSG. We summarized each product using a consistent structure (background, objectives, methods, location, findings, and implications) and identified the management topics (for example, population estimates or targets, habitat, and management efforts) addressed by each product. We also noted which publications included new geospatial data. The review process for this annotated bibliography included two initial internal colleague reviews of each summary, requesting input on each summary from an author of the original publication, and a formal peer review. Our initial searches resulted in 80 total products, of which 63 met our criteria for inclusion of which 53 were products that had not been summarized before. Across products summarized in the annotated bibliography, broad-scale habitat characteristics; population estimates or targets; behavior or demographics; and genetics were the most commonly addressed management topics. The bibliographies are available on the Science for Resource Managers tool (https://apps.usgs.gov/science-for-resource-managers) and are searchable by topic, location, and year, and the search tool includes links to each original publication. The studies compiled and summarized in this annotated bibliography may inform planning and management actions that seek to maintain and restore sagebrush landscapes and GUSG populations across the GUSG range.

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Introduction

Reviewing the best available science relevant to land management decisions and resource planning efforts is an important part of decision-making processes, helping to ensure that proposed resource management actions and decisions are as effective as possible in meeting their stated goals (Sullivan and others, 2006; Esch and others, 2018; Su and others, 2021). However, the number of scientific publications, the restrictive access to many publications and publication databases, and the time needed to perform a comprehensive search for the best available science on any given species or topic can hinder the ability of resource managers to access and consider this science in their decisions. To facilitate the integration of science into decision making on western lands, the U.S. Geological Survey (USGS) initiated a program of work to compile and summarize recent peer-reviewed scientific literature on a series of resources and topics of management concern.

Centrocercus minimus (Gunnison sage-grouse; hereafter GUSG) has been a focus of scientific investigation and management action for the past two decades, as the U.S. Fish and Wildlife Service (FWS) has reviewed a series of petitions to list the species under the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.). The most recent FWS listing determination of "threatened" in 2014 (FWS, 2014a) was attributed to declining GUSG populations and increasing habitat loss (Gunnison Sage-grouse Rangewide Steering Committee, 2005; Storch, 2007; FWS, 2014b). In addition, the FWS designated geographical areas as either occupied or unoccupied and included a designation of critical habitat for GUSG (FWS, 2014b). As part of this decision, the FWS carried out a Species Status Assessment (SSA) and developed a recovery plan with actionable steps to increase the survival and conservation of GUSG by improving habitat and strengthening population resiliency (FWS, 2019). The Bureau of Land Management (BLM) manages nearly half of the GUSG-occupied habitat across the range and is developing an environmental impact statement to support the recovery of GUSG populations, through enhancing both occupied and unoccupied habitat. Management actions will conserve GUSG populations and respond to changing ecological and climate conditions that affect GUSG on BLM-managed lands (BLM, 2022).

GUSG was recognized as a new species separate from *Centrocercus urophasianus* (greater sage-grouse) in 2000 and has eight geographically distinct populations remaining in southwest Colorado and southeast Utah (Young and others, 2000). The populations are identified as Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Monticello, San Miguel, Piñon Mesa, and Poncha Pass (fig. 1). The Gunnison Basin population supports most of the breeding GUSG and occupied habitat, whereas the Poncha Pass population is the smallest with the least amount of occupied habitat (FWS, 2020). GUSG rely on continuous stands of sagebrush species and mountain shrub communities for food and shelter throughout the year and rely on grasses and forbs (flowering plants) during nesting and early brood-rearing periods (Aldridge and others, 2012; Apa and others, 2021). Population declines are primarily attributed to the small population sizes, geographically isolated population structure, and loss and fragmentation of sagebrush habitat. Threats to sagebrush habitat and GUSG populations include historical livestock overgrazing, agriculture, and human activity, such as developing infrastructure and roads (Oyler-McCance and others, 2001; Gunnison Sage-grouse Rangewide Steering Committee, 2005). Many uncertainties remain in our understanding of how GUSG respond to changes in their environment, and the scientific community has continued to study GUSG to strengthen the science foundation for GUSG management and conservation. New scientific information augments existing knowledge and can help inform updates or modifications to existing plans for managing GUSG and their habitat, and it also informs strategies for alleviating threats to GUSG populations. To assist in this process, the USGS has reviewed and summarized the scientific literature published about GUSG between January 2005 and September 2022.

Although this annotated bibliography does not replace the need to read the primary literature and published products, we hope that this document will provide a valuable plain language reference for planners and managers responsible for managing GUSG populations and habitat. Each summary (and associated publication) is available on the Science for Resource Managers tool (https://apps.usgs.gov/science-for-resource-managers) and is searchable by management topic, location, and year. We also provide links to the original publications to facilitate access to primary literature sources. As such, information in this document could be maintained and periodically updated to serve as a readily accessible, up-to-date resource for managers, planners, academics, and policy makers who need a quick reference to recent peer-reviewed science and data about GUSG.

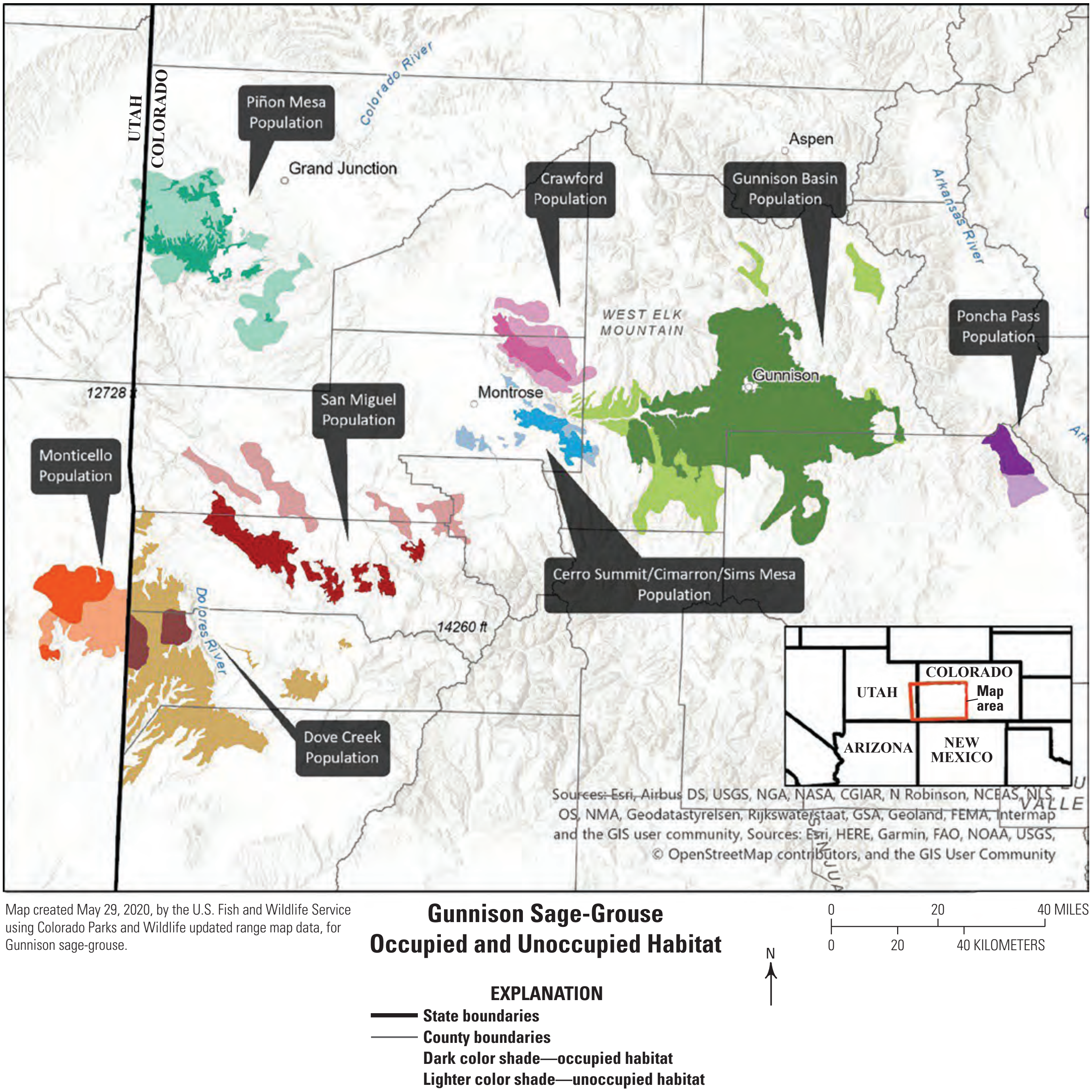

Figure 1. Distribution in 2020 of the eight *Centrocercus minimus* (Gunnison sage-grouse [GUSG]) populations in Colorado and Utah. Colors distinguish the populations. Light shading indicates likely formerly occupied areas that still contain some of the appropriate biological and physical features for GUSG. The darker colors indicate occupied habitat where breeding takes place or is known to have taken place. (Modified from U.S. Fish and Wildlife Service [FWS], 2020.)

Methods

Previous reports (Carter and others, 2020) introduced a methodology for creating annotated bibliographies to facilitate the integration of recent, peer-reviewed science into resource management decisions. This and other annotated bibliography reports (for example, Poor and others, 2021; Kleist and others, 2022) build on that method and apply it to new species and topics of management concern on lands in the western United States. Therefore, relevant text from these reports is reproduced herein to frame the presentation.

We did a systematic search of 2 citation indices (Web of Science and Scopus [accessed through the USGS Library]) and 3 Federal Government publication databases (USGS ScienceBase, USGS Publications Warehouse, and U.S. Department of Agriculture, Forest Service TreeSearch), using the search phrases "Gunnison sage-grouse" or "lesser sage-grouse" or "Gunnison grouse" or "Gunnison sage grouse" or "lesser sage grouse" or "*Centrocercus minimus*." We developed these search phrases through consultation with an interagency team of GUSG experts to help ensure our searches would capture products relevant to management of GUSG on western lands in the United States. We also limited our search to products that were published since January 2005 to better reflect the period of research focus on this species. Our final standard search of all databases was on September 2, 2022, and did not include literature published after the final search, representing an incomplete list of relevant literature. However, we opportunistically included products brought to our attention through other means after September 2, 2022 (for example, products about GUSG shared with us as part of our process of requesting input on product summaries from the original product authors). We required that all opportunistically obtained products meet the same criteria described in the following paragraph to be included in the annotated bibliography.

We refined the initial list of products in four ways. First, we removed duplicate items. Second, we retained only those articles with the phrase "Gunnison sage-grouse" or "*Centrocercus minimus*" present in the article title, abstract, or author-supplied keywords (when available) and in the main text of the article to ensure that the article focus was on GUSG. Third, we excluded products that were not published as research or scientific review articles in peer-reviewed journals or as formal technical reports; this exclusion helped ensure that all products presented final work that had gone through a structured peer-review process. Accordingly, we excluded editorial content (such as policy perspectives and commentaries), reports without evidence of a formal peer-review process (such as project and annual reports without a technical series or volume number and a permanent digital object identifier), conference abstracts, article preprints, articles in magazines (that did not refer to a peer-review process), articles in journals for which we could not find evidence of a comprehensive peer-review process, theses, dissertations, manuscripts not yet in press, and books, regardless of peer-review status. We also excluded reports that provided short summaries of research projects (often published when those projects were still in progress) that were intended for sharing with a broad public audience, as those research results would be published elsewhere once the studies were complete. Fourth, we excluded any remaining articles or reports that, upon review, did not have content of clear relevance to the conservation and management of GUSG. For example, we excluded articles that were primarily about another species, with GUSG mentioned only for context or comparison, often in the introduction or discussion sections. We also excluded publications that focused on or within GUSG habitat but did not present new findings about GUSG ecology. For very large publications (for example, hundreds of pages) covering multiple topics and species, we explicitly confined our summaries to GUSG and stated this in the summary itself.

Many articles presented findings on GUSG but lumped the species within a larger category, such as "sage-grouse" or "prairie grouse" and then used these terms to refer to GUSG in the title, abstract, or keywords and throughout the article. We included these articles, where they were identified or opportunistically brought to our attention, when it was clear from language within the article that GUSG was included in a lumped category. We cannot guarantee that our search process identified all of this type of product, particularly for journals which do not have keywords or for which keywords are not indexed by Web of Science or Scopus.

We parsed the final list of articles and reports among our group of scientists to develop summaries of each product. The scientist to which the publication had been assigned then read each publication, summarized its contents using a consistent structure (background, objectives, methods, location, findings, implications), and identified the management topics addressed (table 1). Location information included both the State(s) and (or) Province(s) where the study took place, depending on the information provided in the article. After geographic location, we listed the name(s) of the satellite GUSG population that the study addressed (fig. 1). For publications that also included information about *Centrocercus urophasianus* (greater sage-grouse), we listed climate cluster(s) (CC; fig. 2; designated in Coates and others, 2021) and management zone(s) (MZ; fig. 3) when possible. In one case, however, specific location information was not made clear in the article, and for that article the location is labeled as "Not specified." Scientific names were based on what authors used in original products; however, we used common names for all species within product summaries for ease of reading. If we had questions about scientific or common names, we checked with the Integrated Taxonomic Information System (https://doi.org/10.5066/F7KH0KBK). Considerable information was distilled from each publication in developing the summary. Some products addressed data and findings for several species; these summaries primarily focus on the species of interest in this or previous annotated bibliographies. Thus, although we accurately represent information from each publication, there may be additional information in the original product that was not included in our summary. The target length for summaries was 350 words or fewer. As a result, the source documents should always be consulted directly for more specific information (links to the original publication are provided for each summary whenever available). Each draft summary was reviewed by two additional scientists in the group to promote consistency and clarity between summaries and to provide an additional check on the accuracy of summaries in capturing key findings from the original publication.

Table 1. Management categories and topics assessed for each product included in the bibliography.

Management topic	Definition
Management category—Species and population characteristics	
Survival	Study quantified survival rates for plant or animal species, often in relation to environmental conditions. For plants, this includes quantification of seed longevity and viability.
Behavior or demographics	Study measured or modeled aspects of behavior or demographics for plant or animal species (for example, seasonal movements, seeds per plant, seed mass, seed germination rate, vegetative reproduction, reproductive success, vital rates).
Population estimates or targets	Study estimated or modeled plant or animal species population numbers, trends, dynamics, assessment methods, or responses to the environment.
Captive breeding	Study developed methods for or evaluated the success of species captive breeding efforts. For plant species, this could include greenhouse breeding. Where this topic applies, “Location” refers to that of the wild population, not the breeding facility.
Translocation	Study developed methods for or evaluated the success of plant or animal species translocation efforts.
Genetics	Study used genetic evidence to investigate plant or animal species biology (for example, population structure, connectivity, behavior).
Dispersal, spread, vectors, and pathways	Study addressed species dispersal abilities, invasiveness, or factors impacting spread.
Other: Species and population characteristics	Study focused on another aspect of species biology or ecology not listed elsewhere.
Management category—Habitat	
Broad-scale habitat characteristics	Study addressed landscape-level habitat characteristics (for example, size, number, or connectivity of habitat patches, characteristics of linkage areas, effects of landscape context on habitat quality, availability or use of seasonal habitats), usually across large areas.
Site-scale habitat characteristics	Study addressed habitat characteristics at the local level (for example, nest sites or brood-rearing areas for wildlife species), typically based on field measurement of vegetation or soils.
Habitat selection	Study analyzed habitat characteristics used by species, typically based on a combination of habitat characterization and telemetry or direct observations of individuals.
Habitat restoration or reclamation	Study addressed methods for habitat restoration or the responses of species habitat, individuals, or populations to habitat reclamation or restoration efforts.
Management category—Anthropogenic and ecological disturbances	
Effect distances or spatial scale	Study addressed the spatial scale or distance effects of ecological or anthropogenic features on the species (for example, estimated distance that species may be displaced by or respond to a disturbance or environmental feature).
Hunting/collectors	Study addressed the effect of hunting, harvesting, collecting, or taking (sensu Endangered Species Act of 1973 as amended, 16 USC §1532(19)) by other methods on species populations or demographics.
Recreation	Study addressed the relationship between recreation infrastructure (such as trails) or activities and species habitat, populations, or individuals.
Predators or predator control	Study addressed predator or consumer populations, the effects of predators or consumers on the species, or the effects of predator control on the species.
Fire	Study addressed the relationship between fire and the species or their habitat, including wildfire, wildland fire management, fire suppression, flame lengths, prescribed fire, controlled burn, and the use of fire for vegetation or weed management.

Table 1. Management categories and topics assessed for each product included in the bibliography.—Continued

Management topic	Definition
Management category—Anthropogenic and ecological disturbances—Continued	
Fuels and fuels management	Study addressed the relationship between fuels management and the species or their habitat, including fuel types, fuel loading, fuel models, and fuels treatments.
Fuel breaks	Study addressed the relationship between fuel breaks (sometimes referred to as fire breaks, ground strips, or green strips) and the species or their habitat.
Nonnative invasive plants	Study addressed nonnative invasive plants or the effects of nonnative invasive plants (or efforts to control those species) on the species or its habitat.
Sagebrush removal	Study addressed the relationship between intentional sagebrush removal treatments and the species or its habitat.
Conifer expansion	Study quantified the relationship between conifer expansion and the species or its habitat.
Grazing/herbivory	Study addressed the relationship between herbivory (wild or domestic) and species habitat, populations, or individuals, including consideration of grazing as a tool for vegetation or weed management.
Fences	Study assessed the relationship between fences and species persistence, survival, or behavior.
Other range management structures	Study addressed the relationship between other range improvement structures (for example, water developments, mineral licks) and species habitat, predators, or individuals.
Energy development	Study quantified effects of energy development on species habitat, populations, or individuals.
Mining	Study quantified effects of mining on species habitat, populations, or individuals.
Exurban development	Study addressed effects of exurban development on species habitat, populations, or individuals.
Infrastructure	Study addressed effects of various other infrastructure elements (for example, roads, pipelines, powerlines, cell towers) on species habitat, predators, populations, or individuals.
Agriculture	Study addressed effects of agriculture and agricultural conversion on species habitat, populations, or individuals.
Weather and climate patterns	Study addressed the effects of weather or climate patterns (for example, amounts or patterns of temperature or precipitation within a growing season, or past/historical/prehistorical climate) on species habitat, populations, or individuals.
Climate change	Study explicitly addressed the effects of climate change on species habitat, populations, or individuals. Many products in this category are likely to consider projected future climate conditions.
Drought	Study addressed the effects of droughts or drought conditions on species habitat, populations, or individuals.
Management category—Invasive plant control or management efforts	
Weed management	Study addressed some aspect of weed management, which may include methods for controlling the abundance or spread of noxious weeds or nonnative invasive plants or assessed the effectiveness of weed control efforts.
Subtopic: Biocontrol	Study addressed invasive plant control efforts that use one or more species of introduced agent (for example, predator, herbivore, pathogen), often from the target species' native range.
Subtopic: Cultural control	Study addressed invasive plant control efforts that use soil solarization (clear plastic placed over moist soil), plastic mulches, grazing, flaming, prescribed burning, or competitive reseeding.
Subtopic: Herbicides	Study addressed invasive plant control efforts that use chemical agents.
Subtopic: Mechanical vegetation removal	Study addressed invasive plant control efforts that consist of mechanical removal using methods like hand pulling, removal with tools like loppers, girdling, shredding, hoeing, bulldozing or the use of other heavy equipment, tillage, cultivation, or mowing.
Management category—Relationships with other resources	
Wild horses and burros	Study addressed the relationship between wild horses or burros and species habitat, populations, or individuals.
Water	Study addressed the relationship between species habitat, populations, or individuals and water resources (for example, groundwater, surface water, hydrology, water quantity or quality, or water rights).

Table 1. Management categories and topics assessed for each product included in the bibliography.—Continued

Management topic	Definition
Management category—Relationships with other resources—Continued	
Soils or geology	Study addressed the relationship between species habitat, populations, or individuals and soils or geology, including biological soil crusts.
Cultural, historical, Native American, or archaeological sites or values	Study addressed cultural, historical, archaeological, or Native American resources.
Public health, safety, or enforcement	Study addressed public health or safety, or the enforcement of laws, statutes, or other regulations.
Paleontological resources	Study addressed fossils or fossilized remains.
Forest management/timber harvest	Study addressed the relationship between species habitat, populations, or individuals and forest or timber management.
Protected lands or areas	Study addressed lands with a formal protective designation such as national parks or monuments, Areas of Critical Environmental Concern, National Conservation Areas, National Scenic Byways, Wild and Scenic Rivers, wilderness areas, or areas with wilderness characteristics.
Wetlands/riparian	Study addressed the relationship between species habitat, populations, or individuals and wetland or riparian areas.
Sensitive/rare wildlife	Study addressed one or more sensitive, rare, or protected wildlife species, including insects.
Sensitive/rare fish	Study addressed one or more sensitive, rare, or protected fish species.
Sensitive/rare plants	Study addressed one or more sensitive, rare, or protected plant species.
Management category—Other	
Includes new geospatial data	Study makes publicly available newly created geospatial data relevant to species policy, planning, or management.
Human dimensions or economics	Study addressed the human dimensions or economics of species policy, planning, or management.

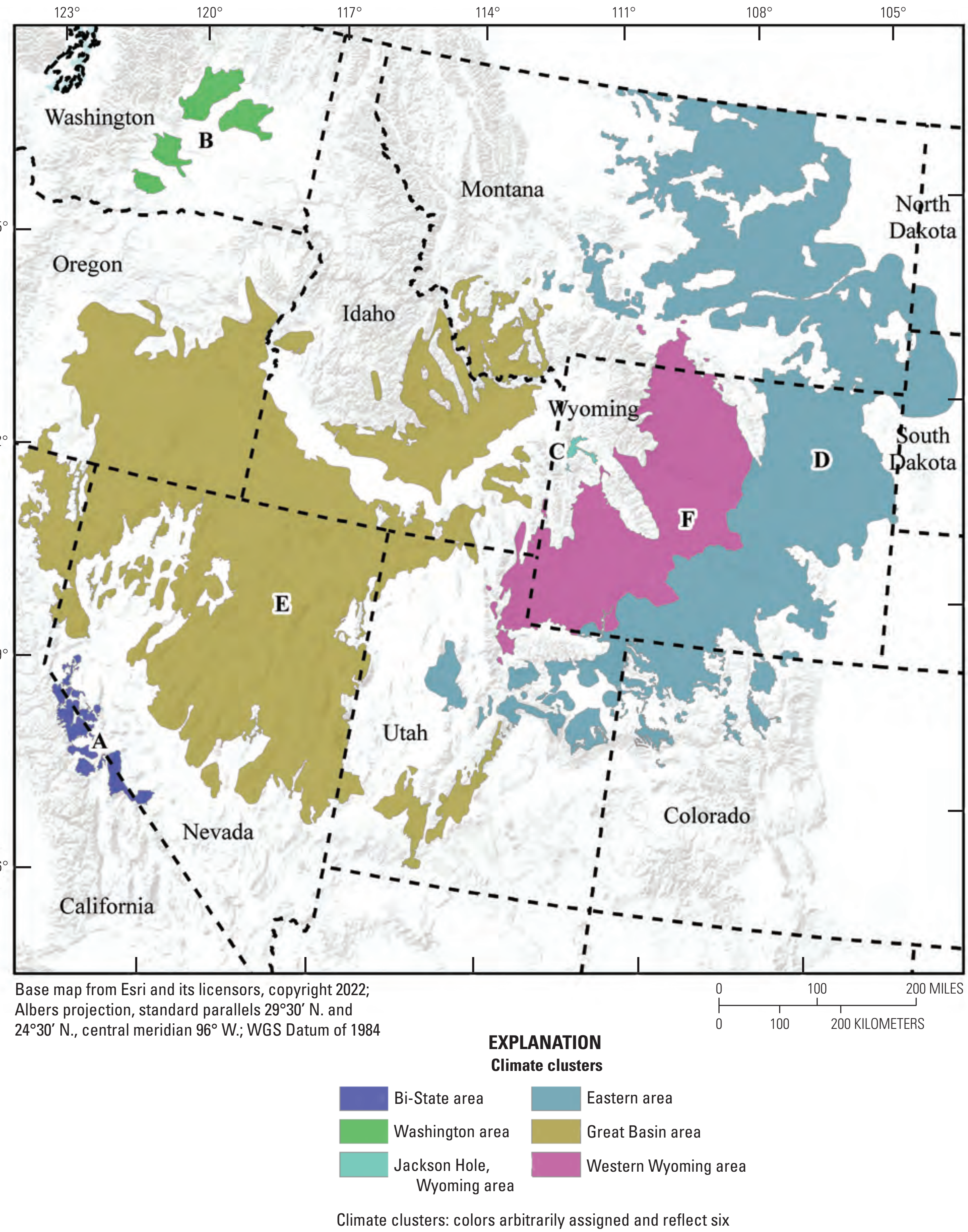

Figure 2. *Centrocercus urophasianus* (greater sage-grouse) hierarchical population monitoring framework for climate clusters in the western United States: A, Bi-State area; B, Washington area; C, Jackson Hole, Wyoming, area; D, eastern area; E, Great Basin area; F, western Wyoming area. (Modified from Coates and others, 2021.)

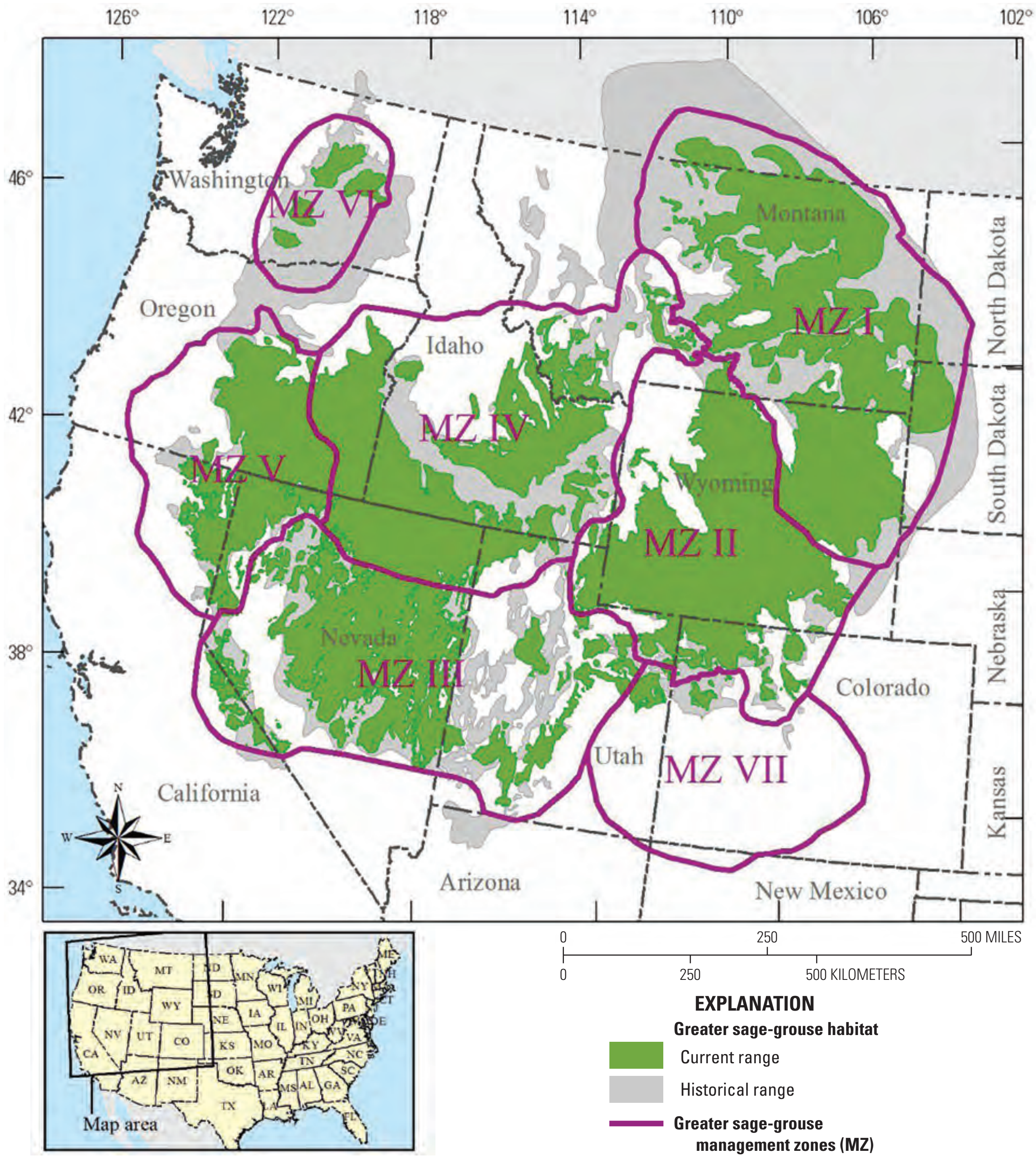

Figure 3. The current and historic distribution of *Centrocercus urophasianus* (greater sage-grouse) habitat in the western United States and the seven *Centrocercus urophasianus* (greater sage-grouse) management zones in the western United States. (Data from U.S. Fish and Wildlife Service [FWS], 2014c, d; Christiansen and Whitford, 2016.)

Results and Conclusions

We identified 56 potential products from Web of Science, 10 from Scopus, 4 from the USGS Publications Warehouse, 10 from ScienceBase, and 8 from Forest Service TreeSearch, for an initial total of 88 potential products. We included two additional products that were brought to our attention opportunistically and fit our criteria for inclusion but were not found during our standard search process. After manually removing 27 products that were duplicates, publications that were not peer-reviewed, and publications which did not present new data or focus on GUSG, we retained a total of 63 peer-reviewed published science and data products from all sources. Ten of these products had previously been summarized in Carter and others, 2020. Thus, we ultimately summarized 53 products for this GUSG annotated bibliography.

These 53 products addressed 46 management topics. Every product addressed "sensitive/rare wildlife" (essentially by definition, because GUSG is listed under the Endangered Species Act), and 23 products (43 percent) addressed broad-scale habitat characteristics. The management topics of population estimates or targets and behavior or demographics were addressed in 22 products each (42 percent). Genetics were addressed in 16 products (30 percent), habitat selection and site-scale habitat characteristics were addressed by 14 products each (26 precent), and 13 products (25 percent) addressed survival. Information about effect distance or spatial scale was included in 10 products (19 percent), and 8 products (15 percent) included new, publicly available geospatial data. Fuels and fuels management, fuel breaks, fences, mining, weed management, wild horses and burros, and paleontological resources were addressed by 1 product each.

These studies are part of the recent (since 2005) body of published peer-reviewed articles, reports, and data products that focus on GUSG in North America. We present this annotated bibliography as a resource for land managers to easily access and integrate this information into their decisions, and we recommend that users of this bibliography refer back to the original publication. Because GUSG and the sagebrush steppe are of growing conservation concern, this annotated bibliography may be updated periodically to incorporate new knowledge.

Review Process

In addition to our two internal author team reviews, we facilitated external reviews. This process was twofold and included (1) requesting input on each product summary from one or more authors of the original peer-reviewed publication, and (2) a formal peer review of the entire document by four independent reviewers and by the USGS Bureau Approving Official. This process is consistent with USGS Fundamental Science Practices (Fundamental Science Practices Advisory Committee, 2011).

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Abbreviations used in the following summaries: CC, climate cluster(s) (fig. 2) from Coates and others (2021); MZ, management zone(s) (fig. 3) from U.S. Fish and Wildlife Service (FWS; 2014c, d); Christiansen and Whitford (2016).

Aldridge, C.L., Saher, D.J., Childers, T.M., Stahlnecker, K.E., and Bowen, Z.H., 2012, Crucial nesting habitat for Gunnison sage-grouse—A spatially explicit hierarchical approach: The Journal of Wildlife Management, v. 76, no. 2, p. 391–406.

DOI: https://doi.org/10.1002/jwmg.268

Background: GUSG populations are declining because of habitat conversion associated with development. Understanding the habitat characteristics that drive nest selection across different spatial scales can help inform broad-scale land use and conservation planning.

Objectives: The authors sought to (1) create GUSG nesting models at landscape and patch scales, (2) map GUSG nesting habitat across spatial scales, (3) test the accuracy of the models, and (4) evaluate the effectiveness of landscape models for guiding GUSG management across the Gunnison Basin.

Methods: From 2000 to 2009, researchers captured, marked, and monitored 75 nesting GUSG females from 7 leks in the western portion of the Gunnison Basin population. Based on previous resource selection research, they developed various spatial variables to predict GUSG nest site selection. They grouped variables into eight categories: shrub percent cover, other vegetation, conifer, terrain, residential, roads, water, and vegetation indices. They also calculated density and distance metrics for several variables to understand these effects on nest site selection. They developed statistical models at landscape and patch scales and applied them to 44 GUSG lek locations to test model accuracy over a larger area.

Location: Colorado; Gunnison Basin

Findings: The landscape model predicted that GUSG nests occur in areas with high proportions of sagebrush cover, high mean vegetation productivity, and low road density, and occur a moderate distance from water and far from forests. The patch model predicted that GUSG nests occur in areas with variable proportions of sagebrush cover and higher vegetation productivity and occur in areas far from busy roads and a moderate distance from water sources and residential areas. Landscape and patch model predictions displayed high probabilities of corresponding with observed nests.

Implications: The authors suggest that their combined predictive model identifies areas of crucial GUSG nesting habitat and that nesting GUSG select patches within sagebrush landscapes to target specific resources and avoid disturbance. They note that their model can be a good starting point for identifying specific areas for GUSG conservation but caution that across the entire GUSG range the model should not be used without local GUSG habitat knowledge. They indicate that their maps and models can inform travel management plans, environmental impact statements, and general conservation planning for GUSG.

Topics: behavior or demographics; broad-scale habitat characteristics; site-scale habitat characteristics; habitat selection; effect distances or spatial scale; exurban development; infrastructure; water; soils or geology; protected lands or areas; wetlands/riparian; sensitive/rare wildlife

Apa, A.D., Aagaard, K., Rice, M.B., Phillips, E., Neubaum, D.J., Seward, N., Stiver, J.R., and Wait, S., 2021, Seasonal habitat suitability models for a threatened species—The Gunnison sage-grouse: Wildlife Research, v. 48, no. 7, p. 609–624.

DOI: https://doi.org/10.1071/WR20006

Background: Understanding GUSG seasonal habitat use for GUSG satellite populations can help target areas for conservation and facilitate more effective GUSG habitat management strategies.

Objectives: The authors sought to collaboratively develop seasonally specific habitat suitability models that predict breeding and summer habitat use for GUSG populations in occupied habitat and adjacent unoccupied habitat.

Methods: Researchers compiled 9,140 GUSG locations from nine different studies, occurring between April 1991 and June 2016, which tracked 406 GUSG individuals across 5 isolated populations. They produced local-level (120 meter [m] and 275 m) and population-scale (1,000 m and 4,000 m) buffers around GUSG locations. They developed habitat selection models for the breeding season (March 15 to July 15) and summer season (July 16 to September 30). They incorporated environmental variables in the models, including vegetation and water cover types, elevation, and density of and distance to roads. They created maps for the probability of GUSG habitat use in occupied and unoccupied habitat for each population.

Location: Colorado; Crawford, Dove Creek, Piñon Mesa, Poncha Pass, San Miguel

Findings: The authors found that the Crawford GUSG population avoided piñon-juniper and rugged topography at the population scale during the breeding and summer seasons. Dove Creek GUSG during the breeding season avoided rugged topography at both scales, grasslands at the population scale, and agriculture at the local level. The Piñon Mesa GUSG during the breeding season avoided sagebrush at the population scale, and at the local level avoided areas with high road density, less rugged topography, and lower elevations, and coniferous and riparian areas. In the summer, the Piñon Mesa GUSG selected for piñon-juniper at the population scale and selected areas with less rugged topography, higher elevations, and increased road density at the local level. During the breeding season and at the population scale, the Poncha Pass GUSG selected mountain shrub and sagebrush and locally avoided sagebrush, coniferous forests, and forest shrublands. In summer, Poncha Pass GUSG avoided coniferous forests and forested shrublands at both scales and selected for piñon-juniper and grasslands at the local level. At the population scale during the breeding season, the San Miguel GUSG avoided piñon-juniper, grasslands, and areas with high road density. During the breeding season and summer, San Miguel GUSG avoided shrub communities and selected for sagebrush in rugged terrain at the local level.

Implications: The authors indicate individual GUSG populations have varied habitat use that changes between seasons and that habitat or population management actions need to be population specific. The authors suggest avoiding implementation of vegetation management broadly across the GUSG range.

Topics: behavior or demographics; translocation; broad-scale habitat characteristics; site-scale habitat characteristics; habitat selection; effect distances or spatial scale; infrastructure; wetlands/riparian; sensitive/rare wildlife

Apa, A.D., Gammonley, J.H., Neubaum, D.J., Phillips, E., Runge, J.P., Seward, N., Wait, S., and Weinmeister, B., 2022, Survival rates of translocated Gunnison sage-grouse: Wildlife Society Bulletin, v. 46, no. 1, article e1245, 18 p.

DOI: https://doi.org/10.1002/wsb.1245

Background: Translocating GUSG from the Gunnison Basin population to the satellite populations of the species was labeled a high-priority recovery action by the U.S. Fish and Wildlife Service. Thorough evaluations of the success and effect of specific translocation efforts are critical to developing a long-term population management strategy for GUSG across their range.

Objectives: The authors sought to (1) estimate GUSG survival by age and sex for the first year post-translocation, (2) compare survival between the first 75 days post-translocation and longer term, (3) estimate post-translocation survival for both spring and autumn releases across GUSG age and sex classes, (4) determine if translocations could be detected in annual lek counts, and (5) determine if different transmitter types affected male GUSG survival.

Methods: The authors captured and successfully translocated 309 GUSG from the Gunnison Basin population to the Crawford, Dove Creek, Piñon Mesa, Poncha Pass, and San Miguel populations between 2000 and 2014, though the total number of individuals and years translocations occurred were variable across all populations. All translocated birds were banded and 65 were fitted with a radio or satellite transmitter. The authors relocated GUSG fitted with radio transmitters weekly and recorded four locations daily of GUSG fitted with satellite transmitters, accounting for bird mortality and dropped transmitters. Finally, they carried out annual lek counts of males in all populations.

Location: Colorado; Crawford, Dove Creek, Gunnison Basin, Piñon Mesa, Poncha Pass, San Miguel

Findings: The authors found that survival of translocated GUSG was best predicted by the individual's age, sex, translocation season and subpopulation, and whether daily survival was lower during the first 75 days post-release than during the remainder of the first year. Across subpopulations, daily survival rate was higher for females and subadults than males and adults, respectively, and was lower during the first 75 days following release. The effect of translocations was not detectable in lek counts one year following release because of the variability of males attending leks; transmitter type did not affect survival rate. Male counts at leks were variable across populations at release sites.

Implications: The authors suggest managers closely monitor movement and survival of translocated individuals following release to ensure successful translocation methods and to consider local conditions, such as weather or snowpack, across both source and target populations when translocating GUSG. The authors highlight that sex and age of translocated individuals were the most important predictors of success and suggest that translocating younger individuals could improve survival following translocations. The authors caution against using lek counts as the only metric of either population size or success of translocation efforts.

Topics: survival; population estimates or targets; translocation; sensitive/rare wildlife

Apa, A.D., and Wiechman, L.A., 2015, Captive-rearing of Gunnison sage-grouse from egg collection to adulthood to foster proactive conservation and recovery of a conservation-reliant species: Zoo Biology, v. 34, no. 5, p. 438–452.

DOI: https://doi.org/10.1002/zoo.21228

Background: Rearing rare species in captivity (captive rearing) is often employed as a last-resort effort to prevent extinction. If managers could establish and maintain a successful GUSG captive-rearing program, it could be used to supplement populations instead of using translocations from wild populations and could provide institutional knowledge of rearing GUSG before the total population declines further.

Objectives: The authors sought to (1) study greater sage-grouse egg collection and rearing methods and modify them for GUSG, if necessary, (2) develop GUSG husbandry techniques across life stages, and (3) develop methods for keeping a captive GUSG flock over time.

Methods: From 2009 to 2011, the authors iteratively tested methods of obtaining eggs from wild GUSG, hatching eggs and raising chicks in captivity, and rearing juvenile and adult GUSG using husbandry techniques. The authors adapted to challenges by modifying their methods across years. After bringing GUSG into captivity, the authors raised chicks from eggs laid in captivity. The authors collected 137 eggs laid in the wild or in captivity for the study. The authors critically evaluated successes and modeled data across each life stage separately: egg collection, transport, storage, incubation, and hatch; chick and juvenile husbandry; and sub-adult and adult husbandry.

Location: Colorado; Gunnison Basin

Findings: The authors were able to successfully rear GUSG from eggs laid in the wild to breeding in captivity. The authors found that eggs from wild GUSG had a greater hatchability than eggs from captive GUSG and that egg storage, incubation, and mass did not influence hatch success. The authors discovered that, for captive GUSG, bacterial infections were a major cause of mortality for young chicks, and complications during habituation to captivity and contraction of West Nile virus were a major cause of mortality for adults. The authors further offered specific feedback, supported with statistical models, as to what methods yielded the highest survival rate: when to collect eggs; how to transport eggs, incubate eggs, hatch eggs, and rear chicks; and information related to diet, enclosure, and handling techniques.

Implications: The authors offer a prescriptive list of actions and techniques for maintaining a GUSG captive-rearing program. The authors suggest maintaining a captive-rearing program as a conservation tool for GUSG throughout all phases of artificial incubation and hatching, and during irregular hatching schedules. They also suggest that captive-rearing programs include West Nile virus prevention and protection, before GUSG populations decline further. The researchers also indicate that other existing techniques like translocations and habitat management could be used and note that captive populations may have unintended genetic issues.

Topics: survival; behavior or demographics; captive breeding; sensitive/rare wildlife

Apa, A.D., and Wiechman, L.A., 2016, Captive-breeding of captive and wild-reared Gunnison sage-grouse: Zoo Biology, v. 35, no. 1, p. 70–75.

DOI: https://doi.org/10.1002/zoo.21253

Background: Captive breeding and rearing is often considered a conservation tool for species with low population estimates in the wild, such as GUSG. Captive breeding and rearing could supplement other GUSG conservation approaches, but more clarity is needed about the methods and procedures of this management technique.

Objectives: The authors sought to evaluate the (1) breeding behavior of captive GUSG and (2) viability of female GUSG nesting and brood rearing in captivity.

Methods: In 2009, the researchers collected, incubated, and hatched 40 eggs from six wild GUSG females in the Gunnison Basin. The egg incubation effort produced a captive flock of eleven GUSG in 2010. The researchers supplemented the captive flock with seven wild GUSG from 2009 to 2011. The researchers constructed two aviaries that segregated individuals by sex using a removable net that allowed GUSG to mate seminaturally. The researchers observed mating from a blind and discontinued mating once all females were bred. In 2010, the researchers monitored nesting behavior of the captive females and collected 22 eggs from eight nests where females were either actively nesting or had prematurely stopped nesting behavior. The researchers allowed three nests with a total of 15 eggs to be naturally incubated by GUSG females in the aviary. The researchers fed invertebrates to 2 females with broods that hatched a total of 6 chicks in 2010. In 2011, the researchers collected all eggs for artificial incubation.

Location: Colorado; Gunnison Basin

Findings: The authors found that timing of mating activity in captivity was similar to reported dates for wild GUSG. All captive males attempted mating displays and most GUSG females mated in captivity. When the researchers allowed unprotected displaying behavior from two males competing for dominance, the subordinate male could not escape the dominant male, resulting in mortality. The authors found that captive males frequently displayed to nesting females, resulting in one female abandoning her nest. A third of brood-reared chicks survived in captivity. Females exhibited normal brood-rearing protective behavior in captivity even when approached by researchers during feeding.

Implications: The authors indicate that their findings can inform and improve future captive-breeding programs for GUSG. They suggest that habitat conservation for GUSG continue in conjunction with a captive-breeding program and that captive-reared offspring could be used for future translocations. They suggest not waiting for captive-breeding to become the only viable management tool for GUSG populations because of further population declines. For future GUSG captive-breeding programs, the authors also suggest larger enclosures, providing access to abundant vegetation, allowing females to freely select mates, and managing areas where females nest.

Topics: survival; behavior or demographics; captive breeding; sensitive/rare wildlife

Braun, C.E., Oyler-McCance, S.J., Nehring, J.A., Commons, M.L., Young, J.R., and Potter, K.M., 2014, The historical distribution of Gunnison sage-grouse in Colorado: The Wilson Journal of Ornithology, v. 126, no. 2, p. 207–217.

DOI: https://doi.org/10.1676/13-184.1

Background: The decline in GUSG abundance across their range is best understood by first considering the historic distribution and abundance of the species. Prior to the earliest biological surveys of GUSG, information about the distribution of the species can be gleaned from early written accounts, museum specimens, the spatial extent of habitat, and interviews with ranchers and wildlife managers working within the historical range of GUSG.

Objectives: The authors sought to (1) report the historical distribution of GUSG synthesized across information sources and (2) estimate when certain populations were extirpated in recent history.

Methods: The authors used field surveys from 1978 to 1999 across the GUSG range to detect any individuals. The authors used a literature search, museum specimens, and interviews with residents across the historic range of GUSG to estimate the distribution and likely extirpation dates of the species at the county level. This included historic journals with the first documented reports of flora and fauna in the area. To support their understanding of likely extirpation dates, the authors also used biological studies focused on the species to note the last verified observation of GUSG across former populations.

Location: Colorado; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Monticello, Piñon Mesa, Poncha Pass, San Miguel

Findings: The authors found that GUSG were historically heterogeneously distributed across riparian areas and intermountain basins in Colorado, were found south of the Eagle and Colorado Rivers, and consisted of many more populations than exist today. The authors developed county-by-county estimates of GUSG distribution, spanning from 1.6 million years ago to the present day. The authors summarized information for 22 Colorado counties, including the estimated year of extirpation when possible. The authors estimated that many former populations were lost between 1930 and 1970.

Implications: The authors' work complements previous efforts to document the historic range of GUSG, adding further context beyond expert assessments and genetic analyses of the species' former range. Understanding the extent and abundance of the historical GUSG population helps identify key aspects of the biology of the species and informs restoration efforts across the modern GUSG range. Specifically, the authors indicate that suitable habitat within historically occupied areas is limited, but they point to the Gunnison Basin as having greater restoration potential because of remaining intact habitat.

Topics: survival; population estimates or targets; broad-scale habitat characteristics; hunting/collectors; paleontological resources; sensitive/rare wildlife; human dimensions or economics

Braun, C.E., and Schroeder, M.A., 2015, Age and sex identification from wings of sage-grouse: Wildlife Society Bulletin, v. 39, no. 1, p. 182–187.

DOI: https://doi.org/10.1002/wsb.517

The summary of this article was previously published in Carter and others (2020, p. 27; https://doi.org/10.3133/ofr20201103).

Braun, C.E., and Williams, S.O., 2015, History of sage-grouse (*Centrocercus* spp.) in New Mexico: The Southwestern Naturalist, v. 60, nos. 2–3, p. 207–212.

DOI: https://doi.org/10.1894/MCG-14.1

The summary of this article was previously published in Carter and others (2020, p. 28; https://doi.org/10.3133/ofr20201103).

Bukowski, B.E., and Baker, W.L., 2013, Historical fire in sagebrush landscapes of the Gunnison sage-grouse range from land-survey records: Journal of Arid Environments, v. 98, p. 1–9.

DOI: https://doi.org/10.1016/j.jaridenv.2013.07.005

Background: GUSG habitat can be positively or negatively affected by fires, depending on the frequency, size, and intensity of burns. This creates a challenge for setting habitat management goals, as there is limited information about fire regimes prior to European settlement.

Objectives: The authors sought to (1) reconstruct historical fire regimes by estimating historic fire and landscape variables and (2) characterize historical vegetation patterns.

Methods: The authors used historical General Land Office survey data of section lines from 1872 to 1892 to reconstruct landscape-scale vegetation and fire regimes in five GUSG population areas. The authors coded historic vegetation surveyor entries by levels of shrub density, shrub species, and broad vegetation community categories. The authors then created maps of the historic vegetation community patches using geospatial software. They estimated frequency of historical fire events, areas within a historical fire that were unburned, historical fire sizes, where fires occurred across the landscape, and fire rotations (estimated time to burn across an area equal to a landscape of interest) using information on community succession and surveyor notes.

Location: Colorado; Crawford, Gunnison Basin, Piñon Mesa, Poncha Pass, San Miguel

Findings: The authors identified differences between historical and modern fires in five GUSG population areas. Historically, there were more small fires and fewer large fires, fire rotations were shorter, and fires left smaller unburned areas inside fire perimeters. Estimated historical fire rotations for sagebrush in the study area were long, greater than or equal to 178 years in Wyoming big sagebrush and greater than or equal to 90 years in mountain big sagebrush, and these fire rotations were within the range of estimated historical fire rotations for other sagebrush areas of the western United States. The authors found the historical landscape in the study area to mostly be dominated by contiguous sagebrush with interspersed areas of grassland resulting from fire. In most GUSG population areas, the authors found that a larger proportion than expected of the historical landscape consisted of sagebrush interspersed with trees. The authors classified historical sagebrush density as 85 percent “normal density or dense, not scattered” across the study area.

Implications: The authors indicate that preserving large, contiguous areas of sagebrush instead of using prescribed burning may be a more suitable management strategy for GUSG habitat and is consistent with historical fire regimes. The authors suggest several habitat management strategies from their findings that are beneficial to GUSG, including fire suppression in Wyoming big sagebrush, avoiding mowing or thinning sagebrush, and limiting tree-removal treatments.

Topics: broad-scale habitat characteristics; habitat restoration or reclamation; fire; cultural, historical, Native American, or archaeological sites or values; sensitive/rare wildlife

Cade, B.S., Edmunds, D.R., and Ouren, D.S., 2022, Quantile regression estimates of animal population trends: The Journal of Wildlife Management, v. 86, no. 5, article e22228, 19 p.

DOI: https://doi.org/10.1002/jwmg.22228

Background: Understanding how greater sage-grouse and GUSG populations change over time informs species conservation and management decisions, but current statistical models that estimate population changes have some shortfalls. As an alternative, population modeling approaches that use quantile regression can estimate an interval of population trends with greater accuracy and fewer statistical assumptions than the more commonly used approach of geometric mean regression.

Objectives: The authors sought to estimate greater sage-grouse and GUSG population changes over time by reanalyzing existing population data from both species using a quantile regression modeling approach.

Methods: The researchers used annual lek count data from two greater sage-grouse populations within (1997 to 2015) and outside (1993 to 2015) of greater sage-grouse core management areas. They also used GUSG annual male lek counts from a small population from 1978 to 2017. They used quantile regression to estimate a central 50 percent interval (0.25–0.75 quantiles) of population changes and compared it to mean regression modeling methods to estimate population changes for both species and to evaluate its efficacy.

Location: Colorado, Wyoming; Crawford; CC-D, CC-F; MZ I, MZ II, MZ VII

Findings: The author's quantile regression approach yielded smaller variations in population growth rates and less negative density dependence than traditional regression approaches in the greater sage-grouse populations they studied. The density-dependent models for quantile and mean regressions showed consistent variation of peak male numbers which were not associated with temporal trends in the core management area. They found that greater sage-grouse populations had the highest number of male counts in the first year, declined substantially three years later, and fluctuated annually in subsequent years. The 50 percent interval estimated from quantile regressions indicated annual fluctuations of 16 to 26 males. Greater sage-grouse population trends in noncore management areas had density-dependent population fluctuations that were less than those for the core management area but that reflected regional cyclical trends. GUSG populations varied depending on the density of males, with populations having nonlinear temporal trends, decreasing initially between 1979 and 1992, increasing substantially in size from 1992 to 1999, and then decreasing again from 1999 to 2010. The central 50 percent intervals from quantile regression indicated that a variation of 10 to 15 males was common between lower and higher counts within those temporal periods.

Implications: The authors suggest that land managers could use a quantile regression modeling approach, such as the one used in their study, to estimate sage-grouse population trends because of the imprecise nature of using lek counts to estimate total populations. Further, they indicate that the quantile regression method is most useful when annual population abundances fluctuate substantially, sample size is low, and if statistical assumptions of mean regression are uncertain.

Topics: behavior or demographics; population estimates or targets; sensitive/rare wildlife

Card, D.C., Schield, D.R., Reyes-Velasco, J., Fujita, M.K., Andrew, A.L., Oyler-McCance, S.J., Fike, J.A., Tomback, D.F., Ruggiero, R.P., and Castoe, T.A., 2014, Two low coverage bird genomes and a comparison of reference-guided versus de novo genome assemblies: PLoS One, v. 9, no. 9, article e106649, 13 p.

DOI: https://doi.org/10.1371/journal.pone.0106649

Background: Bird species have small genomes relative to other vertebrates, making it appealing to analyze their genomic structure using novel modern techniques. Focusing on mapping the genomic structure of specific bird species is a useful step in advancing genetic analyses across all bird species. Accurately mapping the genome of avian species can be informative for management decisions where the species is an ecosystem engineer, such as Clark's nutcracker, or has a small population size, such as GUSG.

Objectives: The authors sought to compare older and more modern genetic analyses on (1) GUSG and (2) Clark's nutcracker.

Methods: The authors used a previously collected genetic sample from a GUSG individual and a genetic sample from a single Clark's nutcracker to compare an older genomic analytical technique to a more modern genomic analytical technique.

Location: Colorado; Gunnison Basin

Findings: The authors were able to successfully compare the older and newer genomic analytical techniques. They found that each technique performed similarly but not without some variability when producing genomic assemblies. The authors offered additional information about the evolutionary history of Clark's nutcracker and GUSG and when each species may have diverged from its most recent ancestor.

Implications: The authors offer novel genetic analyses on GUSG genomic information that can be used in addition to low-cost analyses. They suggest that the new genomic analytical technique they tested shows promise in providing cost-efficient analyses for additional vertebrate species. The authors caution that the new genomic analytical technique may be prone to inaccuracy depending on the quality of the reference genome being used to analyze new data and the target species relatedness to the reference genome.

Topics: genetics; sensitive/rare wildlife

Castoe, T.A., Poole, A.W., de Koning, A.P.J., Jones, K.L., Tomback, D.F., Oyler-McCance, S.J., Fike, J.A., Lance, S.L., Streicher, J.W., Smith, E.N., and Pollock, D.D., 2012, Rapid microsatellite identification from Illumina paired-end genomic sequencing in two birds and a snake: PLoS One, v. 7, no. 2, article e30953, 10 p.

DOI: https://doi.org/10.1371/journal.pone.0030953

Background: Technological advances in deoxyribonucleic acid (DNA) sequencing have allowed researchers to study portions of wildlife genomes more efficiently and at a lower cost than traditional analytical methods. Previously, researchers performed exploratory analyses with a newer genetic technique to sequence loci for the Burmese python, which has relatively high genomic frequency loci. The utility of this technique has not been tested on species with low genomic frequency loci, such as GUSG and Clark's nutcracker.

Objectives: The authors sought to (1) test a novel genetic method to sequence genome sets for GUSG and Clark's nutcracker, and (2) compare these new sequence results to previously sequenced Burmese python genome.

Methods: The researchers used previously collected samples to extract DNA for their analysis. They used material from the liver of one captive-bred Burmese python, the blood of one GUSG, and the muscle from one Clark's nutcracker. They performed a series of genetic analyses to identify genome sequence sets, comparing the utility of a newer versus an older analytical method as well as the success of the newer technique across the snake and bird genomes.

Location: Colorado; Gunnison Basin

Findings: The authors identified more loci in the python than in the GUSG and Clark's nutcracker. They found that the genetic technique they were testing was able to identify more sets of genome sequences at a lower cost than traditional techniques.

Implications: The authors suggest that the genetic technique used in their study was effective and inexpensive compared to other genetic methods, and that the method is reliable for species that have fewer sequenced loci, such as birds.

Topics: genetics; sensitive/rare wildlife

Chambers, J.C., Beck, J.L., Campbell, S., Carlson, J., Christiansen, T.J., Clause, K.J., Dinkins, J.B., Doherty, K.E., Griffin, K.A., Havlina, D.W., Henke, K.F., Hennig, J.D., Kurth, L.L., Maestas, J.D., Manning, M., Mayer, K.E., Mealor, B.A., McCarthy, C., Perea, M.A., and Pyke, D.A., 2016, Using resilience and resistance concepts to manage threats to sagebrush ecosystems, Gunnison sage-grouse, and greater sage-grouse in their eastern range—A strategic multi-scale approach: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, General Technical Report RMRS-GTR-356, 143 p.

DOI: https://doi.org/10.2737/RMRS-GTR-356

The summary of this article was previously published in Carter and others (2020, p. 43–44; https://doi.org/10.3133/ofr20201103).

Davis, A.J., Hooten, M.B., Phillips, M.L., and Doherty, P.F., Jr., 2014, An integrated modeling approach to estimating Gunnison sage-grouse population dynamics—Combining index and demographic data: Ecology and Evolution, v. 4, no. 22, p. 4247–4257.

DOI: https://doi.org/10.1002/ece3.1290

Background: Estimating GUSG population trends across time is difficult because of the variability in data, including lek counts. Combining demographic information and lek counts could help increase the accuracy of estimated population trends, which can better inform GUSG management decisions.

Objectives: The authors sought to (1) compare lek count and demographic data to estimate GUSG population trends through time and (2) model yearly population estimates of GUSG.

Methods: The authors used data from a previous study that captured, marked, and tracked female GUSG from 2005 to 2010 in the Gunnison Basin and estimated various reproduction and survival rates. In addition, the authors used another dataset created when researchers and managers collected maximum male counts at leks from 1953 to 2012. The authors modeled population growth using these two datasets and compared the value of population growth derived from each dataset. They modeled population growth using data only from 1996 to 2012 because of the standardization of data collection methods during that time frame. To extrapolate to the full time series (1953 to 2012), they used simulations to fill in estimated data for years that had missing data and developed an integrated population model that used both datasets. The researchers also estimated GUSG population sizes yearly from 1996 to 2012 in the same study area.

Location: Colorado; Gunnison Basin

Findings: The authors found that the GUSG population growth rate in their study area was slightly declining but mostly stable from 1996 to 2012. Population growth rates fluctuated more, and population estimates were generally higher when those values were derived from the lek count data compared to the demographic data. From 1953 to 2012, the average population growth rate for GUSG in the Gunnison Basin was near stable although slightly negative, but there was considerable uncertainty around the estimate. Similarly, the authors found the GUSG population size to be relatively stable from 1996 to 2012 with considerable variability around the estimate.

Implications: The authors indicate that population estimates that incorporate demographic and lek count data are more accurate and have less variability than population estimates from either dataset alone. They note that using their modeling approach over longer time periods leads to less-biased estimates than using traditional population modeling techniques applied to shorter time periods.

Topics: survival; behavior or demographics; population estimates or targets; sensitive/rare wildlife

Davis, A.J., Phillips, M.L., and Doherty, P.F., Jr., 2015, Nest success of Gunnison sage-grouse in Colorado, USA: PLoS One, v. 10, no. 8, article e0136310, 12 p.

DOI: https://doi.org/10.1371/journal.pone.0136310

Background: GUSG is a species of conservation concern, but there has been little research on GUSG nest success. Understanding what factors contribute to GUSG nest success would provide insight into GUSG demographics and improve population estimates and habitat management.

Objectives: The authors sought to investigate the influence of vegetation, nest timing, precipitation, female age, and nest age on GUSG nest success.

Methods: Researchers captured, marked, and tracked 181 GUSG females from the Gunnison Basin population from 2005 to 2010 and 11 from the San Miguel population between 2007 and 2010. The researchers located 177 GUSG nests in the Gunnison Basin population and 20 nests in the San Miguel population. After females left the nest, the researchers estimated the height and percent cover of shrubs and grass at 7 points along a 30-meter (m) transect centered at the nest. To estimate nest survival rates, the authors modeled nest success based on nest age, year of nesting attempt, nest initiation start week; percent grass and shrub cover, average grass and shrub height; female age (yearling or adult); and annual precipitation before nest initiation.

Location: Colorado; Gunnison Basin, San Miguel

Findings: The authors found that nest age, year, and start week were most strongly correlated with GUSG nest success. Vegetation characteristics, precipitation, and female age did not strongly correlate with nest success. Nests initiated early in the breeding season were more likely to succeed than nests initiated later, and the daily survival rate of nests decreased as incubation progressed over time. Nest success in both populations fluctuated greatly among years and ranged from 4 to 60 percent in the Gunnison Basin and 12 to 52 percent in the San Miguel population. Small sample sizes in the San Miguel population prevented direct comparison between the two populations studied.

Implications: The authors caution against determining implications of nest success over short time periods because of the large fluctuations that they observed in GUSG nest success rates among years. The authors note that vegetation characteristics measured at nests in their study were within GUSG habitat management guidelines recommended by other researchers. They indicate that while vegetation was not correlated with nest success in their study, vegetation characteristics across nest sites had low variability and may be a strong driver for nest site selection. The authors state that the factors that were strongly correlated with nest success may also capture unmeasured variables such as predator densities or habitat quality.

Topics: survival; behavior or demographics; population estimates or targets; site-scale habitat characteristics; weather and climate patterns; sensitive/rare wildlife

Davis, A.J., Phillips, M.L., and Doherty, P.F., Jr., 2015, Survival of Gunnison sage-grouse *Centrocercus minimus* in Colorado, USA: Journal of Avian Biology, v. 46, no. 2, p. 186–192.

DOI: https://doi.org/10.1111/jav.00473

Background: Evaluating the factors associated with declining GUSG populations is important for the conservation of GUSG. The survival rate for GUSG has been shown to differ among and within years, and research shows vital rates can be considerably different between populations of the same species. It is unclear if the survival rates differ between the small San Miguel population and the larger Gunnison Basin population or if there are differences in survival between sexes and age groups across those populations.

Objectives: The authors sought to estimate survival rates (1) over time, (2) between sexes and age groups, and (3) between the Gunnison Basin and San Miguel populations.

Methods: From 2005 to 2010, researchers captured and radiomarked 128 adults and 86 yearling GUSG from the Gunnison Basin population, and from 2007 to 2010 they captured and radiomarked 25 adult GUSG from the San Miguel population. They classified second or later breeding season individuals as adults and first breeding season individuals as yearlings. Females were monitored during the nesting and brood-rearing months, whereas males were located during spring and summer. They determined survival rates over time and across populations, sex, age, and season, and included snow depth as a survival predictor.

Location: Colorado; Gunnison Basin, San Miguel

Findings: The authors found that survival rates differed because of the interaction of sex and season. Female survival was lowest during the May through October brood-rearing season but was less variable through the year than males. Male survival was lowest during the March to April breeding season, and males had a lower survival probability than females overall. There were no differences in survival annually or across the entire study period. Snow depth and age were not predictors of survival. The authors concluded that there were no differences in survival rates between populations.

Implications: The authors suggest that survival rates for adult GUSG in both the Gunnison Basin and San Miguel populations were similar and constant across years. They indicate that the San Miguel population may be declining overall because of the lack of recruitment rather than adult mortality. The authors suggest that managers focus on other demographic rates, such as nest success or yearling recruitment, to facilitate population growth rates.

Topics: survival; behavior or demographics; population estimates or targets; water; sensitive/rare wildlife

Davis, A.J., Phillips, M.L., and Doherty, P.F., Jr., 2016, Declining recruitment of Gunnison sage-grouse highlights the need to monitor juvenile survival: The Condor, v. 118, no. 3, p. 477–488.

DOI: https://doi.org/10.1650/CONDOR-15-165.1

Background: GUSG are a species of conservation concern, but there is little research on GUSG survival early in their life cycle. Research on survival rates of chicks and juveniles could inform population estimates for GUSG and be used to evaluate the effectiveness of habitat management actions.

Objectives: The authors sought to (1) estimate chick and juvenile survival, (2) determine GUSG population recruitment changes over time, and (3) compare recruitment and survival differences between the Gunnison Basin and San Miguel populations.

Methods: From 2005 to 2010, the researchers captured, marked, and tracked 290 GUSG chicks and 87 juveniles in the Gunnison Basin and San Miguel populations. The researchers estimated daily survival for GUSG chicks (1 to 30 days post hatch) and monthly survival for juveniles (30 days post hatch through 31 March). They estimated recruitment by combining the survival estimates of both life stages. The authors also modeled the influence of population source, season, year, hatch timing, chick age, hen age, and cumulative survival trends across years on GUSG chick and juvenile survival.

Location: Colorado; Gunnison Basin, San Miguel

Findings: The authors stated that chick survival could be higher in the Gunnison Basin population than in the San Miguel population, although sample sizes were very small in the San Miguel population and were omitted from the remainder of the analyses. Chick age, hen age, and hatch week had little to no effect on chick survival. Season and the trend of juvenile survival across years had the greatest effects on juvenile GUSG survival in the Gunnison Basin population. Juvenile survival was lower in the summer and early fall and higher in the winter and early spring. Hatch week, year, and month had little to no effect on juvenile survival. The authors found that GUSG recruitment in the Gunnison Basin population varied but decreased slightly throughout the study period.

Implications: The authors indicate that GUSG chick and juvenile survival could be incorporated into population modeling to increase the accuracy of population estimates for the species. They suggested that juvenile monitoring continue in the Gunnison Basin population and be monitored in other isolated GUSG populations. They also indicate that juveniles that survive to October will likely survive to the following spring breeding season. The authors suggest that habitat management activities for GUSG focus on summer vegetation requirements to increase survival for chicks and juveniles.

Topics: survival; behavior or demographics; population estimates or targets; sensitive/rare wildlife

Dinkins, J.B., Duchardt, C.J., Hennig, J.D., and Beck, J.L., 2021, Changes in hunting season regulations (1870s–2019) reduce harvest exposure on greater and Gunnison sage-grouse: PLoS One, v. 16, no. 10, article e0253635, 17 p.

DOI: https://doi.org/10.1371/journal.pone.0253635

Background: Understanding the long-term effects of hunter harvest on populations of greater sage-grouse and GUSG is needed to make informed hunting guidelines. Further exploration of historical and modern hunting regulations is warranted to evaluate the effects on sage-grouse populations across the range.

Objectives: For both greater sage-grouse and GUSG, the authors sought to (1) describe historical harvest management across the range of each species over the past 150 years, (2) quantify hunting regulation changes in the past 25 years, and (3) compare hunting regulation changes between harvest area boundaries and the current range of each species.

Methods: The authors facilitated a literature search to compile information about hunting regulations from the 1870s to 2019 across the greater sage-grouse and GUSG range. For greater sage-grouse, they determined harvest boundaries and hunting regulations and estimated potential occupancy for the entire range relative to areas that were within 8 kilometers (km) of active leks. For GUSG, they compared differences between harvest boundaries until hunting was closed in 1999. They also estimated the number of hunters and harvested birds across both species' ranges.

Location: Alberta (Canada), California, Colorado, Idaho, Montana, Nevada, North Dakota, Oregon, Saskatchewan (Canada), South Dakota, Utah, Washington, Wyoming; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Monticello, Piñon Mesa, Poncha Pass, San Miguel; CC-A, CC-B, CC-C, CC-D, CC-E, CC-F; MZ I, MZ II, MZ III, MZ IV, MZ V, MZ VI, MZ VII

Findings: The authors found that the length and timing of hunting seasons varied from the 1870s to 2018. From 1995 to 2018, the total area open to hunting greater sage-grouse declined in most states because of long- and short-term harvest closures. Areas within 8 km of greater sage-grouse leks had greater potential hunting pressure than other areas within the harvest boundaries. For GUSG, total hunting area decreased until it was closed in 1999, and it is unlikely that any GUSG were harvested after 1995, based on State reports. They found that from 1995 to 2018, greater sage-grouse average bag limits and possession limits decreased, average season length greatly decreased, and the number of hunters decreased. Harvest patterns were similar for both species over the timeframe studied.

Implications: The authors indicate that wildlife agencies throughout the range responded to declining populations of both species by restricting hunting. They also indicate that the total area of hunting closures is deceptively large, as closures were smaller in areas with higher greater sage-grouse occupancy. The authors suggest that reducing hunting boundaries in areas with the lowest occupancy of grouse might be problematic when assessing the effectiveness of hunting closures at mitigating population declines.

Topics: population estimates or targets; hunting/collectors; sensitive/rare wildlife; human dimensions or economics

Doherty, K.E., Hennig, J.D., Dinkins, J.B., Griffin, K.A., Cook, A.A., Maestas, J.D., Naugle, D.E., and Beck, J.L., 2018, Understanding biological effectiveness before scaling up range-wide restoration investments for Gunnison sage-grouse: Ecosphere, v. 9, no. 3, article e02144, 18 p.

DOI: https://doi.org/10.1002/ecs2.2144

Background: Efforts to recover GUSG populations include large-scale habitat restoration, such as removing conifers and increasing sagebrush cover. Spatial tools that can be used to prioritize areas for habitat restoration may aid efforts to recover GUSG populations.

Objectives: The authors sought to (1) model potential GUSG breeding habitat using known lek locations across the GUSG range, and (2) use the model to predict if conifer removal or sagebrush reestablishment increased potential habitat.

Methods: The authors modeled GUSG breeding habitat based on data from 94 active GUSG leks (based on 2015 surveys) and 188 reference locations. They quantified vegetation, topographic, and disturbance variables within 4-km and 0.56-km buffers around each lek at a 30-m resolution. Finally, they simulated three conifer removal scenarios that removed trees in areas of ≤10 percent, ≤20 percent, and ≤30 percent tree canopy cover and predicted potential increases in GUSG habitat that could occur as a result of the removals.

Location: Colorado, Utah; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Monticello, Piñon Mesa, Poncha Pass, San Miguel

Findings: The authors found that the top variables in their model of GUSG breeding habitat were related to high sagebrush and low tree cover, and low topographic roughness. Predicted GUSG habitat was associated with higher sagebrush cover and lower tree canopy cover. Removing trees in areas with tree canopy cover up to 10 percent increased predicted occupied habitat substantially, and predicted habitat continued to increase when removing trees in areas with tree canopy cover up to 30 percent.

Implications: The authors suggest that large-scale tree removal projects and working to ensure sagebrush recovery after tree removal will likely improve GUSG habitat. However, they indicate that reducing conifers in areas that are not predominantly sagebrush is unlikely to promote habitat use for GUSG during the breeding season. They also indicate that the strong landscape-scale influence of tree canopy cover on GUSG habitat makes coordination among public and private land managers important for implementing effective habitat improvement projects.

Topics: broad-scale habitat characteristics; site-scale habitat characteristics; habitat selection; habitat restoration or reclamation; conifer expansion; weather and climate patterns; drought; water; sensitive/rare wildlife

Donnelly, J.P., Allred, B.W., Perret, D., Silverman, N.L., Tack, J.D., Dreitz, V.J., Maestas, J.D., and Naugle, D.E., 2018, Seasonal drought in North America's sagebrush biome structures dynamic mesic resources for sage-grouse: Ecology and Evolution, v. 8, no. 24, p. 12492–12505.

DOI: https://doi.org/10.1002/ece3.4614

The summary of this article was previously published in Carter and others (2020, p. 91; https://doi.org/10.3133/ofr20201103).

Fike, J.A., Oyler-McCance, S.J., Zimmerman, S.J., and Castoe, T.A., 2015, Development of 13 microsatellites for Gunnison sage-grouse (*Centrocercus minimus*) using next-generation shotgun sequencing and their utility in greater sage-grouse (*Centrocercus urophasianus*): Conservation Genetics Resources, v. 7, no. 1, p. 211–214.

DOI: https://doi.org/10.1007/s12686-014-0336-z

The summary of this article was previously published in Carter and others (2020, p. 108; https://doi.org/10.3133/ofr20201103).

Gerber, B.D., Hooten, M.B., Peck, C.P., Rice, M.B., Gammonley, J.H., Apa, A.D., and Davis, A.J., 2019, Extreme site fidelity as an optimal strategy in an unpredictable and homogeneous environment: Functional Ecology, v. 33, no. 9, p. 1695–1707.

DOI: https://doi.org/10.1111/1365-2435.13390

Background: Understanding site fidelity to breeding patches and seasonal habitat can provide information about GUSG demographics. Site fidelity characterizes faithfulness to a breeding patch, or multiple-leks areas separated by natural boundaries, and has been linked to breeding success. GUSG fidelity and variables influencing patch selection warrant further research.

Objectives: The authors sought to (1) characterize GUSG site fidelity within and across breeding patches, (2) describe the environmental variability of breeding patches spatially and across time, (3) examine range size during the breeding seasons to estimate environmental quality within breeding patches, and (4) evaluate patch quality based on modeled GUSG survival across age classes.

Methods: The researchers captured and marked 94 female GUSG between 2004 and 2010 in the Gunnison Basin population. They tracked GUSG across the breeding and brooding seasons with a minimum of 10 relocations per season. They evaluated nest success and measured vegetation at 177 nest sites. They also quantified variability within and among six breeding patches by assessing vegetation characteristics, annual precipitation, and soil factors. They then used a GUSG survival model to estimate survival across age classes for chicks, juveniles, and adults across breeding patches and seasons and evaluated if predation affected nest success. Finally, they examined the movement of individual females' nesting locations across years to determine fidelity to nest sites and used female locations throughout the breeding season to determine fidelity to breeding patches.

Location: Colorado; Gunnison Basin

Findings: Most female GUSG were faithful to a single patch across breeding and brooding seasons. The authors found that vegetation varied more within breeding patches than across patches. None of the environmental variables they measured significantly affected nest success or GUSG survival. They found that the likelihood of nest failure because of predation was similar to the likelihood of nest success, which did not vary spatially or over time. GUSG movements indicated that patch quality varied between seasons. Generally, survival did not vary across age classes or breeding patches. Almost all females remained within their breeding patch across breeding and brooding seasons. On average females who were unsuccessful in nesting the first year moved twice the distance the second year compared to females with successful nests.

Implications: The authors suggest that management actions that cause habitat disturbances should consider GUSG fidelity to breeding patches. GUSG show high site fidelity across spatial scales, and subsequently, within-patch dynamics may drive population trends. The authors indicate that site fidelity did not influence nest success, and that site fidelity may be a result of homogenous vegetation and unpredictable predation. They also indicate that changes in habitat quality in one breeding patch are unlikely to affect individuals in another breeding patch during the breeding and brooding seasons.

Topics: survival; behavior or demographics; site-scale habitat characteristics; habitat selection; predators or predator control; weather and climate patterns; soils or geology; sensitive/rare wildlife

Harju, S.M., Coates, P.S., Dettenmaier, S.J., Dinkins, J.B., Jackson, P.J., and Chenaille, M.P., 2021, Estimating trends of common raven populations in North America, 1966–2018: Human–Wildlife Interactions, v. 15, no. 3, p. 248–269.

DOI: https://doi.org/10.26077/c27f-e335

Background: Common ravens are known to prey on several sensitive species, including greater sage-grouse and GUSG. However, current knowledge of raven abundance and population estimates is limited.

Objectives: The authors sought to estimate raven abundance and population rate of change (1) at two regional scales and (2) within and outside of the range of nine sensitive species.

Methods: The researchers compiled raven counts from approximately 4,100 Breeding Bird Survey routes from 1966 to 2018 in the United States and Canada. They estimated raven abundance in broad (level I) and finer (level II) ecoregions and within and outside of the ranges of nine sensitive species: California condor, greater sandhill crane, Mojave Desert tortoise, greater sage-grouse, GUSG, marbled murrelet, piping plover, western snowy plover, and least tern.

Location: North America; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Monticello, Piñon Mesa, Poncha Pass, San Miguel; CC-A, CC-B, CC-C, CC-D, CC-E, CC-F; MZ I, MZ II, MZ III, MZ IV, MZ V, MZ VI, MZ VII

Findings: The authors found that raven abundance increased across the United States and Canada but varied across ecoregions. Eight of the 15 level I ecoregions showed increases in raven abundance with highest increases in the Great Plains and western United States. Rates of population change were also variable across ecoregions but increased annually on average, with highest estimates in the Great Plains. Eighteen of the 34 level II ecoregions had increases in raven abundance, most notably in the north-central plains and southwestern coastal area of North America. They found higher raven abundance and an increased rate of population change for ravens within the ranges of 7 of the 9 sensitive species (all but piping plover and least tern) compared to outside of those ranges.

Implications: The authors indicate that raven abundance has increased over the last half century and could pose an increased predation risk to seven sensitive species, including greater sage-grouse and GUSG. They note that the finer-scale level II ecoregion estimates for raven abundance could be more useful than level I for greater sage-grouse and GUSG predator management, including lethally removing ravens or raven reduction actions.

Topics: population estimates or targets; predators or predator control; sensitive/rare wildlife

Homer, C.G., Aldridge, C.L., Meyer, D.K., and Schell, S.J., 2013, Multiscale sagebrush rangeland habitat modeling in the Gunnison Basin of Colorado: U.S. Geological Survey Open-File Report 2013–1049, 12 p.

DOI: https://doi.org/10.3133/ofr20131049

Background: Developing accurate land-cover maps in sagebrush ecosystems can facilitate landscape monitoring and quantification of characteristics of GUSG habitat.

Objectives: The authors sought to create a statistically rigorous method to inventory and monitor sagebrush habitat by developing and assessing (1) protocols for field sampling data to support remote sensing models, (2) a fine-scale model of land cover, and (3) a coarse-scale model of land cover based on the finer-scale data.

Methods: In summer 2007, researchers sampled vegetation characteristics in the field, including percent cover of herbaceous vegetation, bare ground, litter, and shrubs, at 331 plots, using a stratified sample derived from 2.4-m-resolution, fine-scale satellite data across the study area. Within shrub cover, the authors also measured percent sagebrush, percent big sagebrush, percent Wyoming big sagebrush, and shrub height. The researchers then used the average of the field vegetation measurements per plot to predict continuous proportions of land-cover components within a pixel and then used predictions to train fine-scale (2.4-m resolution) satellite data to create a land-cover model across the extent of that high-resolution imagery. Using the 2.4-m-resolution predictions, the researchers then refined the fine-scale land-cover estimates to train coarse-scale satellite imagery (30-m resolution). They assessed the models predicted fit accuracy of the data by using a subset of sampled plots not used for model development.

Location: Colorado; Gunnison Basin

Findings: The authors produced maps of all vegetation metrics across the study area at a fine (2.4 m) and coarse (30 m) spatial resolution. The authors found the plot-sampling method effectively reflected the variation in spectral bands in the remotely sensed data. They found their models to be relatively accurate at both scales, though prediction confidence decreased when extrapolating data to the coarser-scale model.

Implications: The authors indicate that their methods demonstrate improvements in land-cover classification through field-collected vegetation and remote sensing. The authors noted that variation in accuracy from the process of scaling up estimated land-cover components was comparable to previous results using similar methods in other study areas within the sagebrush ecosystem. They indicate that the percent vegetation components are accurate within the Gunnison Basin only, and that estimated land-cover components outside of the area should be used with caution.

Topics: broad-scale habitat characteristics; sensitive/rare wildlife

Jeffries, M.I., and Finn, S.P., 2019, The sagebrush biome range extent, as derived from classified Landsat imagery: U.S. Geological Survey data release.

DOI: https://doi.org/10.5066/P950H8HS

Background: Mapping the extent of the sagebrush biome in the United States can be useful for communicating information about species reliant on sagebrush, including greater sage-grouse, GUSG, and pygmy rabbits.

Objectives: The authors sought to create a data layer mapping the extent of the sagebrush biome in the United States using Landsat imagery.

Methods: The researchers used a percentage sagebrush vegetation layer derived from Landsat imagery and reclassified at 1-km spatial resolution. They omitted gaps in sagebrush cover and sections outside a buffered 10-km boundary around the reclassified sagebrush layer. They also omitted areas with less than 5 or greater than 100 percent sagebrush cover, which were considered errors from the derived imagery. They also omitted areas of sagebrush in high elevation areas in California and areas of sand sagebrush in the Midwest. They refined the boundary by incorporating ranges and management areas for three sagebrush obligate species.

Location: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, Wyoming; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Monticello, Piñon Mesa, Poncha Pass, San Miguel; CC-A, CC-B, CC-C, CC-D, CC-E, CC-F; MZ I, MZ II, MZ III, MZ IV, MZ V, MZ VI, MZ VII

Findings: The authors created a contiguous layer mapping the distribution of the sagebrush biome in the western United States.

Implications: The authors indicate the layer is a simplified and smoothed sagebrush biome range boundary in the United States that was created for illustrating the extent of the sagebrush biome. They note that the sagebrush biome extends into Canada, but that the distribution of sagebrush into Canada was not included because of limited data. They caution that the layer should not be used for analyses involving summary or future ground conditions.

Topics: sensitive/rare wildlife; includes new geospatial data

Knapp, C.N., Chapin, F.S., III, and Cochran, J.O., 2015, Ranch owner perceptions and planned actions in response to a proposed Endangered Species Act listing: Rangeland Ecology & Management, v. 68, no. 6, p. 453–460.

DOI: https://doi.org/10.1016/j.rama.2015.08.003

Background: Large areas of GUSG habitat occur on private lands. Understanding how ranch owners may react to the federal listing of GUSG under the Endangered Species Act is important for continued public support for species conservation.

Objectives: The researchers sought to (1) document ranch owners' opinions on GUSG federal listing and (2) discover how ranch owners may respond to listing GUSG as threatened or endangered.

Methods: In November 2012, researchers interviewed 41 ranch owners who resided within the Gunnison Basin. Researchers selected a representative sample of ranch owners based on land ownership size, prioritizing owners with greater land ownership and who actively used permits to graze on public land. Their surveys included quantitative and qualitative open-ended questions that stimulated discussion about the future of the ranching community, opinions about GUSG, and affects to ranching resulting from a GUSG listing. The researchers compared ranch owners' responses when presented with hypothetical GUSG prelisting and postlisting scenarios.

Location: Colorado; Gunnison Basin

Findings: All ranch owners interviewed stated they were involved in some type of conservation practice for GUSG, and that the threat of federal listing motivated local conservation efforts; however, ranch owners indicated that they would decrease future participation in these practices if GUSG were listed. Most ranch owners stated that it is important for the GUSG to survive into the future, but few believed GUSG should be federally listed. Ranch owners expressed that listing GUSG would negatively affect ranching operations: for example, if GUSG were listed, ranchers were concerned that ranching operations may shift from public to private lands. However, ranch owners' responses were mixed when asked about their understanding of how listing decisions may affect their ranch. Most ranch owners believed listing GUSG would have a neutral impact on grouse numbers and would not address threats posed by predators. Few ranch owners offered alternatives to listing for GUSG conservation, but some stated it would be acceptable to list subpopulations and exclude the Gunnison Basin population. Ranch owners stated they were more likely to sell their land if GUSG were listed compared to not listed. Several ranch owners were concerned with the future of ranching in the community, but they believed their ranch would still be operating in 10 years.

Implications: The authors indicate that ranch owners' opinions on federal listing of GUSG may be influenced by concerns circulating in the ranching community and personal beliefs more than factual information. The authors suggest more communication between the ranching community and federal agencies to increase public support for GUSG habitat conservation.

Topics: grazing/herbivory; water; public health, safety, or enforcement; wetlands/riparian; sensitive/rare wildlife; human dimensions or economics

Knapp, C.N., Cochran, J., Chapin, F.S., III, Kofinas, G., and Sayre, N., 2013, Putting local knowledge and context to work for Gunnison sage-grouse conservation: Human–Wildlife Interactions, v. 7, no. 2, p. 195–213.

DOI: https://doi.org/10.26077/sttc-fb95

Background: Published information about GUSG is limited, and insight from local experts, who either study GUSG or reside within the community surrounding GUSG habitat, may provide new observations and different perspectives to inform GUSG management.

Objectives: The authors assessed historical and current knowledge of GUSG by interviewing local experts they categorized as either (1) formal (those with an academic degree related to GUSG, such as biology or ecology) or (2) observational (those without formal academic training related to GUSG) experts.

Methods: Researchers sampled interview participants using referrals and facilitated open-ended interviews with 14 observational and 12 formal experts. Observational experts included ranchers, long-time residents, nonbiologist agency employees, and politicians, while formal experts included academic and agency biologists. The researchers coded interview data to identify common themes about knowledge of GUSG in the Gunnison Basin.

Location: Colorado; Gunnison Basin

Findings: Overall, observational experts primarily made observations of GUSG in the spring, summer, and fall, whereas formal experts made most of their observations during the spring lekking season. Observational experts characterized GUSG habitat as intact sagebrush with a diverse grass understory, similar to published literature. Novel habitat types included hay meadows, areas with patches of serviceberry, and snow caves for thermal insulation in the winter. Formal experts stated that overlapping seasonal habitat use made it difficult to distinguish life-stage habitats, such as nesting, from other habitat types. Several interviewees stated that GUSG are less territorial, harder to capture, and more prone to flushing than greater sage-grouse. Most interviewees agreed that GUSG populations are threatened by habitat degradation. However, formal and observational experts had mixed opinions about the relative importance of threats such as fire, predation, and mechanical treatments that remove sagebrush. Commonly stated conservation strategies included restoring habitat, improving grazing practices, creating conservation easements, and using road closures. Participants also said that more research is needed on the relationship between grazing and GUSG to inform decision making about GUSG management.

Implications: The authors suggest that engaging local communities in conservation is important for resource management and that observational experts may have a wide range of perspectives and insights not seen in scientific literature including long-term observations about GUSG across seasons and life-history stages, insights into future research applications, and a better understanding of values and controversial topics. Formal experts may provide information about GUSG biology.

Topics: behavior or demographics; population estimates or targets; site-scale habitat characteristics; habitat selection; recreation; predators or predator control; fire; grazing/herbivory; infrastructure; agriculture; drought; sensitive/rare wildlife; human dimensions or economics

Lukacs, P.M., Seglund, A., and Boyle, S., 2015, Effects of Gunnison sage-grouse habitat treatment efforts on associated avifauna and vegetation structure: Avian Conservation & Ecology, v. 10, no. 2, article 7, 13 p.

DOI: https://dx.doi.org/10.5751/ACE-00799-100207

Background: Vegetation treatments implemented to enhance wildlife habitat have occurred throughout the GUSG range, but the effects of these habitat treatments on GUSG and other wildlife species are rarely monitored. Long-term monitoring of how habitat management affects GUSG, nontarget wildlife, and vegetation composition could better inform future management decisions.

Objectives: The authors sought to measure the long-term effects of sagebrush habitat treatments implemented for GUSG on (1) eight species of sagebrush-associated avifauna other than GUSG and (2) vegetation characteristics.

Methods: Researchers used a land treatment database to identify six areas of mechanical habitat treatments that met the following conditions: they were implemented specifically to improve GUSG habitat by reducing sagebrush cover and reseeding with native grasses and forbs, were spread across the GUSG range, and were at least 4 years old. In 2010 and 2011, the researchers carried out three separate point count surveys at each site and sampled vegetation characteristics at each survey location during the spring and summer. Using the data collected, the researchers estimated occupancy and density of birds and the effects of the treatment across the entire site and at point sampling locations. The researchers repeated their sampling protocols for point counts and vegetation surveys in nearby untreated areas to represent control conditions.

Location: Colorado; Gunnison Basin, Piñon Mesa, San Miguel

Findings: The authors found that bird density and occupancy were not related to site vegetation characteristics. On treated sites, one species had lower densities and another species had higher densities compared to control sites. The authors found that 2 of the 8 species had lower occupancy on treated sites, whereas 1 species had increased occupancy. The only vegetation characteristic consistently influenced by past treatments was shrub cover, which trended lower across treated sites. The authors state that relationships between avian species density and vegetation sampled at survey points within sites were highly variable and may have been influenced by annual precipitation.

Implications: The authors found limited effects of GUSG habitat treatments on other bird species, indicating limited negative consequences from these treatments on nontarget wildlife. The difference in avifauna abundance the authors did find may be because of the treatment-induced changes in shrub cover they observed. The authors questioned the efficacy of mechanical treatments in improving GUSG habitat quality broadly under the umbrella of GUSG management.

Topics: population estimates or targets; broad-scale habitat characteristics; site-scale habitat characteristics; habitat restoration or reclamation; sagebrush removal; sensitive/rare wildlife

Lupis, S.G., Messmer, T.A., and Black, T., 2006, Gunnison sage-grouse use of conservation reserve program fields in Utah and response to emergency grazing—A preliminary evaluation: Wildlife Society Bulletin, v. 34, no. 4, p. 957–962.

DOI: https://doi.org/10.2193/0091-7648(2006)34[957:GSUOCR]2.0.CO;2

Background: The Conservation Reserve Program (CRP) provides incentives for landowners to establish grasslands on former croplands, which can be used for emergency grazing during severe drought. CRP grasslands could provide nesting, brood-rearing, and general habitat for GUSG. However, use of CRP grasslands by GUSG is largely unknown.

Objectives: The authors sought to (1) determine if GUSG select CRP grasslands for general habitat use across two spatial scales, (2) assess whether CRP grasslands have adequate vegetation cover for GUSG, and (3) monitor the response of GUSG use in CRP-enrolled grasslands that have been grazed by livestock on an emergency basis.

Methods: From 2001 to 2002, researchers captured, marked, and monitored 13 GUSG in San Juan County, Utah, to determine the locations of individuals, nests, and broods. They statistically assessed habitat selection at the site and landscape scale. For the site scale, they collected field data on percent canopy cover of forbs, shrubs, and grasses along transects centered at sites that birds use and random locations. For the landscape scale, they compared observations of CRP use with expected use across areas encompassing known bird locations. The authors also noted when CRP grasslands were grazed, and they collected biomass, stocking rate, and vegetation metrics at GUSG locations and compared the data to ungrazed CRP grasslands.

Location: Utah; Monticello

Findings: The authors found that GUSG used CRP grasslands for nesting, brood rearing, and general habitat but did not preferentially select for CRP. CRP grasslands did not meet GUSG breeding or fall seasonal habitat guidelines but provided adequate cover and foraging. GUSG males and broodless females frequented CRP fields less where grazing was ongoing. However, one brood-rearing female did not exhibit avoidance during or after emergency grazing on CRP lands.

Implications: The authors indicate that, although their sample size was small, CRP grasslands are likely providing habitat throughout different GUSG life stages. They suggest sustained implementation of CRP grasslands to help stabilize the GUSG population in the study area.

Topics: behavior or demographics; broad-scale habitat characteristics; site-scale habitat characteristics; habitat selection; grazing/herbivory; agriculture; sensitive/rare wildlife

Messmer, T.A., Hasenyager, R., Burruss, J., and Liguori, S., 2013, Stakeholder contemporary knowledge needs regarding the potential effects of tall structures on sage-grouse: Human–Wildlife Interactions, v. 7, no. 2, p. 273–298.

DOI: https://doi.org/10.26077/f83b-5466

Background: Tall structures are commonly built to support public infrastructure, energy transmission, and resource extraction. Research indicates that these tall structures could negatively affect sage-grouse conservation, but robust scientific evidence of negative affects is lacking. Consulting stakeholders from broad backgrounds can help identify current knowledge gaps and prioritize new research objectives related to the effects of tall structures on sage-grouse.

Objectives: The authors sought to (1) summarize literature related to the effects of tall structures on sage-grouse, (2) summarize siting and mitigation policies for tall structures, (3) catalog research and knowledge gaps around tall structures in sage-grouse habitat, and (4) prioritize research needs related to the conservation implications of tall structures in sage-grouse habitat.

Methods: In 2010, the authors, in association with the Utah Wildlife-in-Need Foundation, organized a series of focus group workshops, inviting a curated list of individuals from industry, academia, and government. The authors compiled relevant information beforehand so that the 30 participants could be well informed. They also followed up by phone and email with the 60 individuals that did not attend the workshop in person. The authors used facilitated discussion and consensus in the workshops to identify shared concerns and achieve their third and fourth research objectives surrounding the effects of tall structures. After summarizing findings from the focus group discussions, the authors used a literature review to further contextualize their findings.

Location: Alberta (Canada), British Colombia (Canada), California, Colorado, Idaho, Montana, Nevada, North Dakota, Oregon, South Dakota, Utah, Washington, Wyoming; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Monticello, Piñon Mesa, Poncha Pass, San Miguel; CC-A, CC-B, CC-C, CC-D, CC-E, CC-F; MZ I, MZ II, MZ III, MZ IV, MZ V, MZ VI, MZ VII

Findings: Focus group participants generated eight concerns related to tall structure effects on sage-grouse conservation and prioritized current research gaps. The eight concerns they identified were all related to a lack of knowledge regarding how tall structures might directly or indirectly affect GUSG populations, in the form of absence of explicitly applicable data collected using rigorous experimental design. Stakeholders generated supplementary questions related to how future research could be performed to close the knowledge gaps the workshops identified.

Implications: The study found that there were no published, peer-reviewed results from controlled experiments designed to test for effects of tall structures on GUSG. Further, the authors indicate that management guidelines for best practices for siting tall structures and mitigating possible negative effects are also untested. The authors suggest consulting stakeholders throughout the research process and when developing management practices to not only collect contemporary knowledge of a conservation challenge but also identify and address stakeholder concerns.

Topics: survival; broad-scale habitat characteristics; site-scale habitat characteristics; effect distances or spatial scale; predators or predator control; energy development; exurban development; infrastructure; sensitive/rare wildlife; human dimensions or economics

Minias, P., Bateson, Z.W., Whittingham, L.A., Johnson, J.A., Oyler-McCance, S., and Dunn, P.O., 2016, Contrasting evolutionary histories of MHC class I and class II loci in grouse—Effects of selection and gene conversion: Heredity, v. 116, no. 5, p. 466–476.

DOI: https://doi.org/10.1038/hdy.2016.6

Background: Immune response genes at the species or population level are thought to be driven by parasites or pathogens and are categorized as two classes: intracellular or extracellular. Intracellular immune response genes protect against viruses, and extracellular immune response genes protect against parasites. Exploring the molecular evolution of both classes of immune response genes in several prairie grouse species could provide insight on evolutionary selective pressures that affect grouse.

Objectives: The authors sought to (1) characterize different forms of the two classes of immune response genes in five species of prairie grouse, (2) describe the evolutionary mechanisms acting on immune response genes, and (3) compare the evolutionary mechanisms between both classes of immune response genes in grouse.

Methods: The researchers extracted DNA from blood and tissue samples collected from 1997 to 2011. The samples were from 183 greater prairie-chickens and 20 to 22 individuals from the grouse species of, GUSG, greater sage-grouse, sharp-tailed grouse, and lesser prairie-chicken. The researchers used genetic analyses to determine the different forms of immune response genes and evolutionary processes affecting the immune response genes in each grouse species.

Location: Colorado, Utah, Wyoming

Findings: The authors found similar forms of both classes of immune response genes among all five prairie grouse species. They found different evolutionary mechanisms driving the genetic variation between the two classes of immune response genes for prairie grouse. Genetic variation was strongly caused by positive selection and frequent gene conversion in extracellular immune response genes and less so in intracellular immune response genes for all prairie grouse species.

Implications: The authors indicate that prairie grouse have more genetic variation in their extracellular immune response genes than in their intracellular immune response genes because of the various parasites that can be detrimental to demographic rates such as nest success and adult survival. They indicate that, because of the relatedness of immune response genes between greater sage-grouse and GUSG, GUSG is likely at an intermediate stage of speciation from greater sage-grouse.

Topics: genetics; sensitive/rare wildlife

Minias, P., Bateson, Z.W., Whittingham, L.A., Johnson, J.A., Oyler-McCance, S., and Dunn, P.O., 2018, Extensive shared polymorphism at non-MHC immune genes in recently diverged North American prairie grouse: Immunogenetics, v. 70, no. 3, p. 195–204.

DOI: https://doi.org/10.1007/s00251-017-1024-4

Background: Understanding the immune function of wildlife species is important to understand how disease outbreaks occur, or what the consequences of the inadvertent spread of pathogens are on small populations. By considering the evolutionary history of immune function across closely related species, genetic analyses can inform our larger understanding of a species' biology.

Objectives: The authors sought to compare genetic patterns in a set of 5 immune genes across 5 closely related species of grouse from 2 genera, including 3 species of prairie grouse and 2 species of sage-grouse.

Methods: The authors analyzed DNA from blood and feather samples from 3 species of prairie grouse and 2 species of sage-grouse collected between 1990 and 2011. The authors used 247 samples of 1 prairie grouse species and 30 samples each of the remaining 4 species. They amplified key DNA regions from each of the five study genes and sequenced those regions using established methods. They then used statistical modeling to analyze genetic selection and diversity and the amount of genetic difference between species and genera based on frequency of specific DNA sequences across the sample.

Location: Colorado, Nevada, Utah, Wyoming; CC-D, CC-E, CC-F; MZ I, MZ II, MZ III, MZ IV

Findings: Immune genes were similar within species of prairie grouse and sage-grouse but were not similar across the two genera. The authors indicate that this relatedness in immune genes within genera is likely due to previous hybridization between species, incomplete separation of species across evolutionary time, and a large ancestral population from which the species descended. Unrelatedness across genera indicates no convergent evolution within the immune genes the authors studied.

Implications: The authors state that the genetic similarities they found indicate that within the prairie grouse and sage-grouse genera, the species still have closely related immune function. In other words, GUSG and greater sage-grouse share immune genetics that the two species inherited from their common ancestor, despite an absence of modern evidence of hybridization between the two species.

Topics: genetics; sensitive/rare wildlife

Minias, P., Dunn, P.O., Whittingham, L.A., Johnson, J.A., and Oyler-McCance, S.J., 2019, Evaluation of a chicken 600K SNP genotyping array in non-model species of grouse: Scientific Reports, v. 9, article 6407, 10 p.

DOI: https://doi.org/10.1038/s41598-019-42885-5

Background: Cutting-edge genetic analyses are developed often with model species, and researchers must first test the suitability of new methods on the genetics of wild species before scaling up to analyses that are useful to conservation and management. Using a previously studied genome for the domestic chicken and a new genetic technique, researchers can explore differences in closely related species such as GUSG and greater sage-grouse.

Objectives: The authors sought to test the viability of a novel genetic analytical technique on five species of North American grouse.

Methods: The authors collected blood samples between 1996 and 2006 to extract DNA from five species of grouse: GUSG, greater sage-grouse, sharp-tailed grouse, greater prairie-chicken, and lesser prairie-chicken. The authors used a commercially available reference genome from the domestic chicken, a model species that is closely related to their study species. They used this reference genome to test a novel genetic analysis for two individuals from each species to examine patterns of genetic diversity.

Location: Not specified

Findings: The authors were able to successfully apply novel genetic analytical techniques to the genetic samples from the five grouse species in their study. In the study they were able to distinguish between samples of the two genera, sage-grouse and prairie-chickens, but not between species within genera. The authors found further evidence that a relatively small portion of the genome in bird species is responsible for the body mass and plumage differences between closely related species, such as GUSG and greater sage-grouse.

Implications: The authors indicate that this technique may be useful in addressing key challenges in conservation, such as understanding population genetics, local adaptations, and evolutionary selection pressures. Specifically, this technique may improve the ability to annotate the entire genome of a species and understand the genetic drivers behind specific traits, a key challenge in wild and threatened species like GUSG.

Topics: genetics; sensitive/rare wildlife

Oh, K.P., Aldridge, C.L., Forbey, J.S., Dadabay, C.Y., and Oyler-McCance, S.J., 2019, Conservation genomics in the sagebrush sea—Population divergence, demographic history, and local adaptation in sage-grouse (*Centrocercus* spp.): Genome Biology and Evolution, v. 11, no. 7, p. 2023–2034.

DOI: https://doi.org/10.1093/gbe/evz112

The summary of this article was previously published in Carter and others (2020, p. 181; https://doi.org/10.3133/ofr20201103).

Oh, K.P., and Oyler-McCance, S.J., 2020, Sample collection information and whole genome data for greater and Gunnison sage-grouse range generated in the Molecular Ecology Lab during 2015–2018: U.S. Geological Survey data release.

DOI: https://doi.org/10.5066/P9G9CCQE

Background: Genomic sequencing can be used as a technique to understand patterns in genetic adaptations for GUSG and greater sage-grouse populations.

Objectives: The authors sought to collect whole genome sequences of GUSG and greater sage-grouse to evaluate patterns of genetic variation.
Methods: Researchers extracted DNA from a blood sample of one male GUSG and performed two different types of sequencing to construct a genome from a large number of DNA fragments. They first established a draft genome, incorporating existing genetic information from other galliform species. They then extracted an additional 90 samples of DNA, including 15 samples from five greater sage-grouse populations and 15 additional samples from GUSG, and included these samples in their whole-genome sequencing.

Location: Alberta (Canada), California, Colorado, Nevada, Washington, Wyoming; Gunnison Basin; CC-A, CC-B, CC-C, CC-D; MZ I, MZ II, MZ III, MZ VI, MZ VII

Findings: The authors created a dataset that contains a sample of genomic sequences for GUSG and greater sage-grouse.

Implications: The authors suggest that this dataset can be used to assess patterns of genetic variation and determine if local adaptation is occurring in both GUSG and greater sage-grouse.

Topics: genetics; sensitive/rare wildlife; includes new geospatial data

Ouren, D.S., 2021, Lek disturbance buffer analysis data, western Colorado, derived from Gunnison sage grouse location data 2010–2014: U.S. Geological Survey data release.

DOI: https://doi.org/10.5066/P9O877CJ

Background: More information is needed about the spatial and temporal movements of GUSG for different populations. This data release supported research by Ouren and others (2019; https://doi.org/10.3996/012018-JFWM-003).

Objectives: The author provides datasets about GUSG (1) spatial and temporal habitat characteristics, (2) distance to nearest leks, and (3) home range areas for two different populations across seasons.

Methods: The author assessed the relationship of GUSG seasonal activity using location data from 12 marked females in the Crawford and Gunnison Basin populations. They collected location data for breeding, late brooding, and winter seasons from 2010 to 2014. The author evaluated the average distance to leks for all locations and by season and evaluated the home ranges for each population by season.

Location: Colorado; Crawford, Gunnison Basin

Findings: The datasets provide information about GUSG movement for the western Gunnison Basin and Crawford populations. The first dataset shows the movement of individuals over time and the distance between locations, the elevation, the distance to the nearest lek, and the lek disturbance buffer designation. The second dataset shows the distance to the nearest lek for each individual and per population. The third dataset shows the home range for each population and season.

Implications: The author presents data that their team collected in order to learn more about GUSG seasonal habitat use and movements and the effectiveness of current buffer distances intended to protect the two populations.

Topics: behavior or demographics; habitat selection; effect distances or spatial scale; sensitive/rare wildlife; includes new geospatial data

Ouren, D.S., Cade, B.S., Holsinger, K.W., and Siders, M.S., 2019, Are lek disturbance buffers equitable for all Gunnison sage-grouse populations?: Journal of Fish and Wildlife Management, v. 10, no. 1, p. 51–61.

DOI: https://doi.org/10.3996/012018-JFWM-003

Background: Lek disturbance buffers around GUSG leks were established to protect habitat from anthropogenic and environmental threats. Disturbance buffers are areas that encompass the seasonal habitat around and associated with leks at multiple spatial scales. However, there is minimal information about whether the current size of disturbance buffers around leks is effective for conserving GUSG populations.

Objectives: The authors sought to (1) assess the relationship between established lek disturbance buffers and GUSG habitat use by season and (2) provide resource managers with information about the effectiveness of using GUSG lek disturbance buffers for conserving GUSG populations.

Methods: The researchers captured, marked, and used location data for 4 female GUSG from the western Gunnison Basin population and 8 female GUSG from the Crawford population from 2010 to 2014. They tracked movement for three seasons (breeding, late brood-rearing, and winter) near 11 active leks in the western Gunnison Basin population and 5 active leks in the Crawford population. Researchers used location data from marked individuals to assess seasonal habitat use within three lek disturbance buffers at 966 m, 3,217 m, and 6,437 m from active leks.

Location: Colorado; Crawford, Gunnison Basin

Findings: The researchers found that individuals in the western Gunnison Basin population moved substantial distances across seasons. The Crawford population increased movements away from leks between breeding and late brood-rearing seasons; however, the population remained closer to leks in the winter compared to the western Gunnison Basin population. The western Gunnison Basin population home range and distance between leks was larger than the Crawford population, and the population displayed movement throughout the year. All lek disturbance buffers provided greater protection of habitat for the western Gunnison Basin population compared to the Crawford population.

Implications: The authors indicate that the utility of lek disturbance buffers in protecting GUSG habitat depends on the distance between leks. The lek disturbance buffers overlapped in the smaller Crawford population, resulting in less protected habitat. The authors suggest that resource managers account for population distributions when using lek disturbance buffers, and use buffers in addition to habitat conservation when developing land management plans.

Topics: behavior or demographics; population estimates or targets; broad-scale habitat characteristics; habitat selection; effect distances or spatial scale; protected lands or areas; sensitive/rare wildlife

Ouren, D.S., Ignizio, D.A., Siders, M., Childers, T., Tucker, K., and Seward, N., 2014, Gunnison sage-grouse lek site suitability modeling: U.S. Geological Survey Open-File Report 2014–1010, 18 p.

DOI: https://doi.org/10.3133/ofr20141010

Background: Counting individuals present at lek sites during the mating season has been a key method for estimating GUSG population sizes. The Crawford GUSG population is small and there is little information about seasonal habitat and range movements. Researchers can use geospatial technology and historical data to identify potentially unknown lek sites and inform habitat conservation efforts.

Objectives: The authors sought to (1) map existing locations of GUSG leks, (2) develop models to identify sites similar to known leks within the Crawford population's range, (3) combine modeling results with expert knowledge to identify locations that may be suitable for GUSG leks, and (4) suggest sampling points within the modeled potential lek areas.

Methods: After mapping known lek sites, the researchers modeled potential GUSG lekking sites for the Crawford population using a set of environmental variables that explain the distribution of known leks, based on previous studies. These variables included soil moisture, canopy moisture, vegetation, bare soil, distance to water, elevation, and slope, which were derived from geospatial images. Researchers assessed these lek suitability maps of the Crawford study area to correct model errors and identify sampling points in potential lekking sites that were modeled as high suitability and based on expert knowledge of GUSG.

Location: Colorado; Crawford

Findings: Model outputs identified areas from low to high suitability for potential leks activity across the Crawford population's range. The authors found that vegetation type was not a significant indicator of lek presence, likely because of either the resolution of their vegetation data or an inability for vegetation data at the point level to predict lek presence. They found that areas with less vegetation cover and more bare ground were associated with lek activity but the authors filtered unsuitable areas with these characteristics because sparse vegetation cover was also associated with agriculture and snow-covered mountains where GUSG are unlikely to be found. The authors found that elevation did not predict lek locations, likely because of the lack of elevational range within their dataset.

Implications: The authors suggest that using existing knowledge about known lek sites combined with a modeling approach may be beneficial in identifying areas where land managers can sample to find previously unknown leks.

Topics: broad-scale habitat characteristics; site-scale habitat characteristics; agriculture; water; soils or geology; sensitive/rare wildlife

Oyler-McCance, S.J., Cornman, R.S., Jones, K.L., and Fike, J.A., 2015, Genomic single-nucleotide polymorphisms confirm that Gunnison and greater sage-grouse are genetically well differentiated and that the Bi-State population is distinct: The Condor, v. 117, no. 2, p. 217–227.

DOI: https://doi.org/10.1650/CONDOR-14-174.1

The summary of this article was previously published in Carter and others (2020, p. 185; https://doi.org/10.3133/ofr20201103).

Oyler-McCance, S.J., Cornman, R.S., Jones, K.L., and Fike, J.A., 2015, Z chromosome divergence, polymorphism and relative effective population size in a genus of lekking birds: Heredity, v. 115, no. 5, p. 452–459.

DOI: https://doi.org/10.1038/hdy.2015.46

The summary of this article was previously published in Carter and others (2020, p. 186; https://doi.org/10.3133/ofr20201103).

Oyler-McCance, S.J., Oh, K.P., Zimmerman, S.J., and Aldridge, C.L., 2020, The transformative impact of genomics on sage-grouse conservation and management, *of* Hohenlohe, P.A., and Rajora, O.P., eds., Population Genomics—Wildlife, *of* Rajora, O.P., ed., Population Genomics: Cham, Switzerland, Springer, p. 523–546.

DOI: https://doi.org/10.1007/13836_2019_65

Background: GUSG and greater sage-grouse populations are declining across their ranges and there has been an increasing amount of research focused on understanding population characteristics, using both genetic and genomic methods.

Objectives: The authors sought to describe the 20-year development of genetic and genomic studies on GUSG and greater sage-grouse.

Methods: The authors synthesized literature of GUSG and greater sage-grouse that reviews conservation statuses, life history traits, genetic studies, and future directions that may be useful to land managers.

Location: Alberta (Canada), California, Colorado, Idaho, Montana, Nevada, North Dakota, Oregon, Saskatchewan (Canada), South Dakota, Utah, Washington, Wyoming; Cerro Summit-Cimarron-Sims, Crawford, Dove Creek, Gunnison Basin, Monticello, Piñon Mesa, Poncha Pass, San Miguel; CC-A, CC-B, CC-C, CC-D, CC-E, CC-F; MZ I, MZ II, MZ III, MZ IV, MZ V, MZ VI, MZ VII

Findings: Sage-grouse are dependent on multiple sagebrush species for their diet, cover, and nesting. Individual populations may be adapted to certain sagebrush species' composition within their habitat, selecting high nutrient leaves with lower secondary compounds. In both sage-grouse species, small proportions of male grouse will mate with a majority of females, which results in variable reproductive success and lower genetic diversity. Genetic sampling includes collecting wings, blood, and less-invasive feathers or fecal pellets. Research has shown that GUSG and greater sage-grouse are two distinct species and within the greater sage-grouse species, there is genetic diversity between populations. Genomic mapping also shows that historically, greater sage-grouse had stable populations, while GUSG populations have consistently declined over time. Several studies have shown neighboring sage-grouse populations to be more genetically related and populations in isolated habitat patches to be less related than populations in continuous habitat. Landscape features that promote GUSG and greater sage-grouse depend on habitat composition, including sagebrush, nesting habitat, and tall shrubs. Genetic flow may be impeded by conifers, rough topography, and agriculture.

Implications: The authors suggest genomic techniques detected low genetic diversity in small, isolated populations of greater sage-grouse and within fragmented populations of GUSG. They suggest that managing genetically diverse populations through translocations and habitat considerations is important for conservation but suggest managers consider managing each population of GUSG independently.

Topics: population estimates or targets; translocation; genetics; dispersal, spread, vectors, and pathways; broad-scale habitat characteristics; sensitive/rare wildlife

Oyler-McCance, S.J., and St. John, J., 2010, Characterization of small microsatellite loci for use in non invasive sampling studies of Gunnison sage-grouse (*Centrocercus minimus*): Conservation Genetics Resources, v. 2, no. 1, p. 17–20.

DOI: https://doi.org/10.1007/s12686-009-9122-8

Background: Incorporating genetic analyses into mark-recapture GUSG research can provide more accurate population estimations and identification of individuals. However, traditional genetic techniques of capturing GUSG and collecting blood samples are costly and invasive. Developing a genetic technique for analyzing lower quality genetic samples, including fecal material or dropped feathers, could provide a useful alternative for researchers.

Objectives: The authors sought to develop genetic markers for use in analyzing GUSG blood, feathers, and fecal samples that are of low quantity and quality for DNA testing.

Methods: The authors used blood and fecal samples from 20 previously captured GUSG from the Gunnison Basin population to isolate microsatellite loci for use in future genetic analyses.

Location: Colorado; Gunnison Basin

Findings: The authors were able to successfully catalog microsatellite loci that could be used to enhance future GUSG analyses from low-quality samples. The authors found low levels of genetic diversity across the GUSG they used in their sample, which is consistent with previous findings that GUSG, as a species, has low genetic variability.

Implications: The authors offer useful genetic information to streamline future genetic analyses from low-quality GUSG samples. Using low-quality samples, such as from fecal material, offers less-expensive and less-invasive opportunities to collect genetic information from individuals. Specifically, this technique could be used to predict population size or survival rates more accurately than conventional methods.

Topics: genetics; sensitive/rare wildlife

Oyler-McCance, S.J., St. John, J., Taylor, S.E., Apa, A.D., and Quinn, T.W., 2005, Population genetics of Gunnison sage-grouse—Implications for management: Journal of Wildlife Management, v. 69, no. 2, p. 630–637.

DOI: https://doi.org/10.2193/0022-541X(2005)069[0630:PGOGSI]2.0.CO;2

Background: The GUSG range has decreased because of habitat loss and fragmentation, resulting in multiple small, isolated satellite populations. The complex terrain surrounding remaining GUSG habitat and large geographic extent of populations may prevent individuals from dispersing between populations. Comparing genetic markers across satellite populations may reveal genetic diversity of GUSG populations and determine if individuals ever disperse between populations, which can help inform management objectives.

Objectives: The authors sought to estimate (1) population structure, (2) genetic diversity, and (3) genetic relatedness across GUSG satellite populations.

Methods: Researchers trapped 197 GUSG across six satellite populations, collected blood and feather samples, and extracted DNA. They used multiple DNA genetic analyses to determine differences in genetic diversity within and among populations.

Location: Colorado, Utah; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Monticello, Piñon Mesa, San Miguel

Findings: Across species, GUSG have much lower levels of genetic diversity than greater sage-grouse. The Gunnison Basin population had the highest population-level genetic diversity, and every other population had far lower levels of genetic diversity. The authors found that all populations were genetically distinct from each other because of small population sizes, reduced gene flow, and geographic isolation. They found that some individuals within the San Miguel populations had genetic similarities to individuals in the Dove Creek, Monticello, and Crawford populations. They also found some genetic similarities between individuals from the San Miguel and Cerro Summit-Cimarron-Sims Mesa populations. The authors found no evidence that individuals were dispersing out of the largest and most genetically diverse Gunnison Basin population.

Implications: The authors suggest that the low levels of genetic diversity for the GUSG species should be a conservation concern. They indicate that the Dove Creek, Monticello, and Piñon Mesa populations are at high risk of negative genetic affects from their low genetic diversity and small population sizes. They suggest management actions to maintain genetic diversity, namely translocating individuals between populations. They also suggest increasing habitat conservation and restoration efforts in areas between the San Miguel and Gunnison Basin populations to facilitate movement between the two populations.

Topics: behavior or demographics; population estimates or targets; genetics; dispersal, spread, vectors, and pathways; effect distances or spatial scale; sensitive/rare wildlife

Oyler-McCance, S.J., Zimmerman, S.J., Aldridge, C.L., and Apa, A.D., 2019, Sample collection information and microsatellite data for Gunnison sage-grouse pre and post translocation: U.S. Geological Survey data release.

DOI: https://doi.org/10.5066/P920WO0Q

Background: Understanding the long-term effects of translocations on GUSG population genetics is important to the conservation of the isolated populations of GUSG that persist today. Genetic data obtained before and after translocations from a population offer key insight to the survival and success of translocated GUSG. This data release supported research by Zimmerman and others (2020); https://doi.org/10.1186/s12864-020-06783-9).

Objectives: The authors provide datasets representing (1) genetic structure and diversity for 6 GUSG populations prior to any translocations and (2) genetic structure and diversity of 4 GUSG satellite populations after the translocation of individuals from the Gunnison Basin population.

Methods: The authors amplified 22 microsatellite genetic markers using laboratory methods. The authors carefully screened the data to eliminate false positives and repeated their analyses for populations before and after translocations occurred.

Location: Colorado, Utah; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Piñon Mesa, San Miguel

Findings: The data captured genetic structure and diversity for 6 GUSG populations before translocations and 4 GUSG populations after translocation.

Implications: This dataset offers a historical view of population genetics before translocations occurred and represents a valuable before-and-after perspective of genetic change that could have occurred as a result of the translocations.

Topics: population estimates or targets; translocation; genetics; sensitive/rare wildlife

Prather, P.R., and Messmer, T.A., 2010, Raptor and corvid response to power distribution line perch deterrents in Utah: Journal of Wildlife Management, v. 74, no. 4, p. 796–800.

DOI: https://doi.org/10.2193/2009-204

Background: Raptors and corvid species use power distribution poles to perch and nest upon, and the poles could be a factor in increased predation on GUSG, especially in open sage-grouse habitat where there were no tall perches naturally. There is limited knowledge of the effects on avian predators of retrofitting distribution line poles with perch deterrents.

Objectives: The authors sought to understand raptor and corvid responses to five types of perch deterrents on power distribution poles in GUSG-occupied habitat.

Methods: In 2006, researchers installed 5 different commercially produced perching deterrents on power distribution poles—cones, triangles, spikes, and either 1 or 2 reflective hazing products—and used poles with no deterrents installed as a control. In winters 2007 and 2008, the researchers carried out perching surveys 2 times per day, 5 days per week and recorded observations of both raptors and corvids perched on poles. They recorded species, numbers, perch location, and exact positions on individual poles.

Location: Utah; Monticello

Findings: The most commonly recorded predators were golden eagles, common ravens, and rough-legged hawks, and these species became the focus of the authors' analyses. They observed four additional bird of prey species perching during their surveys but excluded them in their analyses because of low frequency. There were no statistical differences either year in the number of birds perched on poles without deterrents and poles that had deterrents installed. There were also no statistical differences in the number of perching events or between predator species across treatments. Predators avoided perching on deterrents but perched on structures next to deterrents. The two reflective hazing products were damaged because of weather and thus were not assessed in this study. The authors did not observe any direct predation events on GUSG.

Implications: The authors found that the commercially tested products used to deter avian predators were not successful. They suggest that deterrents would need to be retrofitted to cover all parts of the pole, such as the insulators and cross arms, and made to withstand severe weather common to GUSG habitat.

Topics: predators or predator control; infrastructure; sensitive/rare wildlife

Remington, T.E., Deibert, P.A., Hanser, S.E., Davis, D.M., Robb, L.A., and Welty, J.L., 2021, Sagebrush conservation strategy—Challenges to sagebrush conservation: U.S. Geological Survey Open-File Report 2020–1125, 327 p.

DOI: https://doi.org/10.3133/ofr20201125

Background: A broad and comprehensive understanding of the importance of the sagebrush ecosystem and the threats facing it would benefit resource managers in the conservation of greater sage-grouse, GUSG, and associated plant and animal species.

Objectives: The authors sought to (1) demonstrate sagebrush ecosystem importance to wildlife and people, (2) identify threats and challenges to sagebrush conservation, and (3) summarize management actions occurring in the sagebrush ecosystem.

Methods: The authors reviewed information about the sagebrush ecosystem, including information on habitat selection, life history, population trends, and conservation status of several sagebrush-dependent and sagebrush-associated wildlife species. The authors also presented information about threats and challenges for managing the sagebrush ecosystem and summarized information on restoration, adaptive management, monitoring, and public engagement. The authors discuss sagebrush conservation as it relates to the management of GUSG and greater sage-grouse.

Location: North America; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Monticello, Piñon Mesa, Poncha Pass, San Miguel; CC-A, CC-B, CC-C, CC-D, CC-E, CC-F; MZ I, MZ II, MZ III, MZ IV, MZ V, MZ VI, MZ VII

Findings: The sagebrush ecosystem occupies approximately half of its historic extent, and nearly a quarter of the sagebrush habitat occurs within priority habitat management areas, which have protective measures for GUSG and greater sage-grouse. Multiple State and Federal agencies have implemented efforts to reduce or offset the direct affects from habitat disturbances to GUSG and greater sage-grouse. However, the habitat overlap with sage-grouse species and other sagebrush dependent and sagebrush-associated species varies depending on seasonal habitats. Fire frequency and size has increased with climate change and increased the spread of invasive annual grasses. Nearly a fifth of priority and suitable habitat areas for greater sage-grouse and pygmy rabbits have burned in the last two decades. Conifer removal in sagebrush habitat has been successfully implemented but only in a small portion of the ecosystem. Wild horses and burros, and poorly managed livestock grazing can have varying negative effects on the ecosystem, but well-managed grazing has shown beneficial effects for wildlife. Mining, energy development, and cropland conversion threaten sagebrush conservation in different areas.

Implications: The authors suggest implementing conservation efforts that increase the resistance and resilience of the sagebrush ecosystem to threats, which may be more effective in protecting seasonal habitats for sagebrush dependent and sagebrush-associated species compared to using the umbrella species concept. Scaling up restoration efforts and collaborating across agencies to adaptively manage and monitor wildlife species may benefit GUSG management.

Topics: survival; behavior or demographics; population estimates or targets; broad-scale habitat characteristics; site-scale habitat characteristics; habitat selection; habitat restoration or reclamation; effect distances or spatial scale; recreation; predators or predator control; fire; fuels and fuels management; fuel breaks; nonnative invasive plants; sagebrush removal; conifer expansion; grazing/herbivory; fences; energy development; mining; infrastructure; agriculture; weather and climate patterns; climate change; drought; weed management; weed management subtopic: cultural control; weed management subtopic: herbicides; weed management subtopic: mechanical vegetation removal; wild horses and burros; soils or geology; cultural, historical, Native American, or archaeological sites or values; public health, safety, or enforcement; protected lands or areas; wetlands/riparian; sensitive/rare wildlife; human dimensions or economics

Rice, M.B., Apa, A.D., and Wiechman, L.A., 2017, The importance of seasonal resource selection when managing a threatened species—Targeting conservation actions within critical habitat designations for the Gunnison sage-grouse: Wildlife Research, v. 44, no. 5, p. 407–417.

DOI: https://dx.doi.org/10.1071/WR17027

Background: GUSG critical habitat was designated under the Endangered Species Act, but the designation does not incorporate information about GUSG seasonal movements or habitat suitability. Developing seasonal habitat models for GUSG may help land managers identify priority areas for habitat restoration to aid in the recovery of GUSG populations.

Objectives: The authors sought to (1) develop GUSG habitat models for breeding and summer seasons and (2) compare modeled seasonal habitat with critical habitat designated through the Endangered Species Act.

Methods: The researchers captured and marked 210 GUSG from March to May 2004 to 2010. The researchers categorized GUSG locations by breeding or summer season and estimated daily movement distances for all individuals in both seasons. They then compared currently used habitat and available habitat locations. The researchers classified vegetation into eight categories using remotely sensed imagery. They also incorporated elevation data, human development density and distance, and distance to sagebrush, wetlands, and forests. They combined all of these data into seasonal habitat models. Finally, they compared the seasonal habitat models with the established critical habitat designation.

Location: Colorado; Gunnison Basin

Findings: The authors found that in breeding and summer seasons, GUSG were found in areas with greater proportions of sagebrush, high water density, and farther from roads and residences. In the summer model, GUSG were likely to use more diverse habitat types, including higher preference for irrigated agricultural land and areas with higher bare ground. In the breeding season model, GUSG were more likely to be in sagebrush, grasslands, and areas with high water density, and were less likely to be near wetlands. They found that the modeled summer and breeding season habitat area was comparable to the current critical habitat designation, but that direct comparison is difficult because critical habitat designations do not consider critical shifts in seasonal movement.

Implications: The authors suggest that the seasonal models from this study provide a more nuanced analysis of a long-term dataset with other key environmental variables that can be used for management actions. They recommend that land managers use the seasonal models from this study as current best available science to incorporate into the critical habitat designation for restoration and conservation actions. They recognize that for managers to use an adaptive approach in GUSG population conservation, these models would also need to be combined with other decision-analysis policies and economic considerations.

Topics: behavior or demographics; population estimates or targets; dispersal, spread, vectors, and pathways; broad-scale habitat characteristics; habitat selection; weather and climate patterns; water; soils or geology; sensitive/rare wildlife; human dimensions or economics

Rowland, M.M., 2019, The effects of management practices on grassland birds—Greater sage-grouse (*Centrocercus urophasianus*), chap. B *of* Johnson, D.H., Igl, L.D., Shaffer, J.A., and DeLong, J.P., eds., The effects of management practices on grassland birds: U.S. Geological Survey Professional Paper 1842, 50 p.

DOI: https://doi.org/10.3133/pp1842B

The summary of this article was previously published in Carter and others (2020, p. 214; https://doi.org/10.3133/ofr20201103).

Runge, C.A., Withey, J.C., Naugle, D.E., Fargione, J.E., Helmstedt, K.J., Larsen, A.E., Martinuzzi, S., and Tack, J.D., 2019, Single species conservation as an umbrella for management of landscape threats: PLoS One, v. 14, no. 1, article e0209619, 17 p.

DOI: https://doi.org/10.1371/journal.pone.0209619

The summary of this article was previously published in Carter and others (2020, p. 216; https://doi.org/10.3133/ofr20201103).

Saher, D.J., O'Donnell, M.S., Aldridge, C.L., and Heinrichs, J.A., 2022, Balancing model generality and specificity in management-focused habitat selection models for Gunnison sage-grouse: Global Ecology and Conservation, v. 35, article e01935, 21 p.

DOI: https://doi.org/10.1016/j.gecco.2021.e01935

Background: GUSG occur in several isolated populations across differing landscapes. Understanding seasonal habitat selection patterns at multiple scales for isolated GUSG populations can help inform specific habitat management prescriptions that support species conservation. This research is supported by Saher and others (2021; https://doi.org/10.5066/P93WFW13).

Objectives: The authors sought to use a management-centric modeling approach to (1) determine GUSG habitat selection patterns across populations in the breeding and summer seasons and at the landscape and patch spatial scales, and (2) create habitat suitability maps for each GUSG population.

Methods: To model habitat selection, the authors used GUSG locations that were previously collected between 1991 and 2016 from six GUSG populations. Habitat selection was modeled at the landscape (1 to 6.4 km) and patch (45 to 570 m) scales during two seasons—breeding (from April 1 to July 15) and summer (from July 16 to September 30). They incorporated multiple management-relevant habitat variables and environmental variables in their habitat selection models, including sagebrush and shrub cover, forest cover, mesic resources, terrain metrics, urban features, water resources, agriculture, and other vegetation variables. They used models to assess habitat selection responses to changes in scales to the variables and to map suitable habitat for each population.

Location: Colorado; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Piñon Mesa, Poncha Pass, San Miguel

Findings: The authors found that GUSG selected for increased cover or height of sagebrush or other shrubs in most populations, especially during the breeding season. Most GUSG populations avoided trees during both seasons and avoided residential development during the breeding season. GUSG populations often selected landscapes with wet meadows during the breeding season across spatial scales. GUSG populations displayed different responses to herbaceous cover, terrain metrics, water resources, and agriculture. Overall, the authors found that GUSG populations displayed similarities and differences in responses to management-relevant habitat variables and environmental variables depending on the spatial scale and season.

Implications: The authors indicate that generalized management approaches may not reflect different resource selection patterns across isolated GUSG populations. The authors state that because GUSG respond differently to resource conditions at the patch and landscape spatial scales, the authors suggest managers consider GUSG population responses to habitat improvements at both scales. They suggest that management-centric habitat suitability maps can inform appropriate site-specific management decisions. They caution that the maps should be used as a tool alongside practical management experience to effectively guide habitat management and conservation.

Topics: behavior or demographics; broad-scale habitat characteristics; site-scale habitat characteristics; habitat selection; habitat restoration or reclamation; effect distances or spatial scale; nonnative invasive plants; exurban development; water; wetlands/riparian; sensitive/rare wildlife; includes new geospatial data

Saher, J., O'Donnell, M.S., Aldridge, C.L., and Heinrichs, J.A., 2021, Gunnison sage-grouse habitat suitability of six satellite populations in southwestern Colorado—San Miguel, Crawford, Piñon Mesa, Dove Creek, Cerro Summit-Cimarron-Sims, and Poncha Pass: U.S. Geological Survey data release.

DOI: https://doi.org/10.5066/P93WFW13

Background: Identifying specific habitat needs for each isolated GUSG population is necessary for conservation planning. Building habitat suitability models that combine management variables with ecological variables, which differ between isolated populations, can influence approaches for local habitat improvement actions that support species conservation. This data release supported research by Saher and others (2022; https://doi.org/10.1016/j.gecco.2021.e01935).

Objectives: The authors sought to create habitat suitability maps for six isolated GUSG populations (1) at two scales (patch and landscape) and (2) for two life stages (breeding and summer).

Methods: The authors compiled GUSG locations from 1991 to 2016 from the San Miguel, Crawford, Piñon Mesa, Dove Creek, Cerro Summit-Cimarron-Sims Mesa, and Poncha Pass populations. They quantified the relationships between environmental conditions and GUSG habitat selection patterns. They developed habitat selection models at two scales (patch and landscape) and for two seasons (breeding season from April 1 to July 15 and summer season from July 16 to September 30).

Location: Colorado; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Piñon Mesa, Poncha Pass, San Miguel

Findings: The authors present habitat suitability data layers for six isolated GUSG populations. For each population there are up to six geospatial data layers, representing selected habitat at patch scales and landscape scales for the breeding season and summer from Colorado Parks and Wildlife and U.S. Fish and Wildlife Service data.

Implications: The authors indicate that their maps help resource managers understand the complex habitat needs of isolated GUSG populations and to inform location-specific management actions for effectively improving habitat.
Topics: behavior or demographics; broad-scale habitat characteristics; site-scale habitat characteristics; habitat selection; habitat restoration or reclamation; sensitive/rare wildlife; includes new geospatial data

Stanley, T.R., Aldridge, C.L., Saher, D.J., and Childers, T.M., 2015, Daily nest survival rates of Gunnison sage-grouse (*Centrocercus minimus*)—Assessing local- and landscape-scale drivers: The Wilson Journal of Ornithology, v. 127, no. 1, p. 59–71.

DOI: https://doi.org/10.1676/14-003.1

Background: Investigating the landscape and local factors that influence GUSG nest survival is crucial for targeting GUSG nesting habitat management and management actions intended to increase population growth.

Objectives: The authors sought to (1) estimate daily nest survival for GUSG, and (2) investigate local- and landscape-scale habitat characteristics that may influence GUSG nest survival.

Methods: Researchers captured, put radio collars, and tracked 73 female GUSG from 2000 to 2009 and located 92 GUSG nests in two areas of the western portion of the Gunnison Basin. To identify local-scale habitat characteristics, researchers surveyed vegetation around nests and measured sagebrush canopy cover, percent grass and forb cover, average grass and forb height, and visual obstruction from vegetation. To quantify landscape-level habitat characteristics, the researchers used geospatial data products that captured several shrub and herbaceous vegetation cover metrics, vegetation productivity, and anthropogenic variables at various scales. They also used the variables to construct statistical models to help explain GUSG nest survival.

Location: Colorado; Gunnison Basin

Findings: The authors found that approximately half of GUSG nests were successful, with at least one egg hatching. There was variation in survival among study areas, but models with local-scale and landscape-scale habitat characteristics were competitive, though local models were slightly better. The top-performing local-scale model indicated that nest survival increased as average grass height increased, and decreased as average forb height and sagebrush canopy cover decreased. However, the relationship of nest success with sagebrush canopy cover was unclear because of outliers in the data, and when the outliers were removed there was no effect of sagebrush cover on survival, similar to other studies, but the authors note that nest survival increased as the proportion of big sagebrush increased at the landscape scale. Landscape and local-scale models were similar in explaining overall GUSG nest survival, and the models they used could not robustly explain the variability in nest survival.

Implications: The authors indicate that GUSG nest survival in their study was higher than previously reported and that other vital rates could be prioritized for research to better understand drivers of GUSG population decline. The authors suggest the habitat variables they measured may not have been strongly associated with GUSG nest survival because of insufficient variability in the metrics across GUSG nests, possibly owing to strong selection for required resource conditions. They caution that their study results are limited to the western Gunnison Basin area and may not apply to the greater GUSG population.

Topics: survival; behavior or demographics; broad-scale habitat characteristics; site-scale habitat characteristics; effect distances or spatial scale; protected lands or areas; sensitive/rare wildlife

Stiver, J.R., Apa, A.D., Remington, T.E., and Gibson, R.M., 2008, Polygyny and female breeding failure reduce effective population size in the lekking Gunnison sage-grouse: Biological Conservation, v. 141, no. 2, p. 472–481.

DOI: https://doi.org/10.1016/j.biocon.2007.10.018

Background: The effective size of a population indicates the population's ability to maintain genetic diversity into the future. GUSG populations may have elevated extinction risk because of low effective population size, which may be driven by factors such as lek mating system, skewed sex ratios, and high rates of predation.

Objectives: The authors sought to estimate the (1) true population size and (2) effective population size of a GUSG population and how changes in (3) true population size, (4) mating system, and (5) female breeding success influence effective population size.

Methods: The authors collected field data to estimate true and effective population sizes. They captured and marked 39 males and 46 females, primarily in the winters of 2003 and 2004, and surveyed six leks in March to May in 2003 and 2004. They measured clutch size, hatch success, nest fate, and survival rates. They also estimated effective population size using a previously published equation based on number of breeding individuals, sex ratio, survival rate, reproductive lifespan, and variability in male and female reproductive success. Finally, they simulated data for female reproductive and breeding success, population size, and levels of skewed mating (in other words, random mating versus few males monopolizing mating) to determine the influence of these variables on effective population size.

Location: Colorado; San Miguel

Findings: Estimated true population size was approximately 216 birds, with a sex ratio of more than 2 females per male. Effective population size was less than one-fifth of the true population size. Both sexes exhibited high variability in reproductive success. Hatching rates were low, and simulated decreases in female reproductive and breeding success lowered effective population size. Simulated increases in total population size decreased male reproductive success because of greater skewed mating on larger leks, resulting in a lower ratio of effective population to total population.

Implications: The authors suggested that the estimated effective size for their study population was low enough that issues associated with lack of genetic diversity were likely occurring, and that their measured rate of hatching success likely indicated inbreeding. In addition, the authors indicated that, based on population monitoring data from other GUSG populations, inbreeding depression could be occurring in all GUSG populations except the Gunnison Basin population. The authors also suggested that the female breeding success rate may influence effective population size in GUSG and other grouse species.

Topics: behavior or demographics; population estimates or targets; genetics; sensitive/rare wildlife

Storch, I., 2007, Conservation status of grouse worldwide—An update, *in* Ellison, L.N., ed., Proceedings of the 10th International Grouse Symposium, Luchon, France, September 26–October 3, 2005: Wildlife Biology, v. 13, suppl. 1, p. 5–12.

DOI: https://doi.org/10.2981/0909-6396(2007)13[5:CSOGWA]2.0.CO;2

Background: Many grouse populations are declining globally, including GUSG and greater sage-grouse. Information on regional population trends and possible threats to grouse is needed to prioritize global conservation actions.

Objectives: The author sought to collect and summarize information about population declines and current threats to grouse species to inform a global action plan.

Methods: In 2004, the researchers sent a questionnaire to state agencies, nongovernmental organizations, and researchers in 50 countries where 18 known grouse species occur. They focused questions on population trends, threats, and the status of grouse species within the country. They received 168 country- and species-specific questionnaire responses. The researchers also collected additional information about grouse species from experts and recent literature.

Location: Colorado, Idaho, Montana, Nevada, North Dakota, Oregon, South Dakota, Utah, Washington, Wyoming; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Monticello, Piñon Mesa, Poncha Pass, San Miguel; CC-A, CC-B, CC-C, CC-D, CC-E, CC-F; MZ I, MZ II, MZ III, MZ IV, MZ V, MZ VI, MZ VII

Findings: The author found that the conservation statuses of several grouse species have declined since 2000, including GUSG and greater sage-grouse. GUSG populations have declined and are considered a species of conservation concern because of low population sizes, restricted and fragmented occupied range, and habitat degradation related to anthropogenic land use and development. Only the Gunnison Basin GUSG population increased in 2005 and other populations decreased. Greater sage-grouse are of conservation concern because of reduction in population sizes and occupied range, and a major threat reported is habitat loss from oil and gas development. The questionnaire revealed that about half of the local populations of prairie grouse species, including GUSG and greater sage-grouse, had negative population trends. Important threats to grouse species globally included degradation, loss, and fragmentation of habitat. Threats reported less often included small population size, predation, direct exploitation, human disturbance, and climate change.

Implications: The author indicated that targeted conservation of grouse habitat and habitat guidelines that are area specific are needed for grouse management worldwide. The author suggested that preventing further habitat loss and degradation and increasing restoration of North American grasslands and shrublands would benefit GUSG and greater sage-grouse populations.

Topics: population estimates or targets; broad-scale habitat characteristics; grazing/herbivory; energy development; infrastructure; climate change; sensitive/rare wildlife; human dimensions or economics

U.S. Geological Survey (USGS)—Gap Analysis Project (GAP), 2018, Gunnison sage-grouse (*Centrocercus minimus*) bGUSGx_CONUS_2001v1 habitat map: U.S. Geological Survey data release.

DOI: https://doi.org/10.5066/F7FB5180

Background: Habitat distribution modeling combines remotely sensed vegetation and landscape conditions and the known range of a species to predict where the species may occur across the landscape. These models can inform land management activities and guide prioritization of conservation actions.

Objectives: The authors sought to map the spatial arrangement of environments suitable for occupation by GUSG.

Methods: Between 2008 and 2013, as part of the U.S. Geological Survey Gap Analysis Project to provide biodiversity assessments, the authors used a deductive model to predict areas suitable for GUSG occupation within its known range. They developed the model by combining literature and expert knowledge to identify multiple types of geospatial information: landform, climate, vegetation, hydrology, and others.

Location: Colorado, Utah; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Monticello, Piñon Mesa, Poncha Pass, San Miguel

Findings: The GUSG habitat map predicts where the species may occur based on habitat associations.

Implications: The authors indicated that the habitat map provides basic understanding of habitat availability across the range of GUSG and can be used in combination with other spatial datasets to assess threats to GUSG habitat.

Topics: broad-scale habitat characteristics; sensitive/rare wildlife; includes new geospatial data

U.S. Geological Survey (USGS)—Gap Analysis Project (GAP), 2018, Gunnison sage-grouse (*Centrocercus minimus*) bGUSGx_CONUS_2001v1 range map: U.S. Geological Survey data release.

DOI: https://doi.org/10.5066/F7ZS2VGM

Background: Species range maps can facilitate species distribution modeling and conservation and threat assessments.

Objectives: The authors sought to map the known range extent for GUSG.

Methods: Using 2001 ground conditions, the authors determined whether locations at the subwatershed scale were part of the GUSG range based on data gathered about established range maps, species accounts, and available species occurrences. They also refined the map by determining the species' seasonal and reproductive habitat and whether the species is native, introduced, reintroduced, or vagrant.

Location: Colorado, Utah; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Monticello, Piñon Mesa, Poncha Pass, San Miguel

Findings: The species range map depicts the known geographic limits within which GUSG can be found.

Implications: The authors indicated that the species range map provides basic spatial boundaries for building species distribution models and assessing the status of a species' range.

Topics: broad-scale habitat characteristics; sensitive/rare wildlife; includes new geospatial data

Walsh, D.P., Stiver, J.R., White, G.C., Remington, T.E., and Apa, A.D., 2010, Population estimation techniques for lekking species: Journal of Wildlife Management, v. 74, no. 7, p. 1607–1613.

DOI: https://doi.org/10.2193/2009-353

Background: For lekking animals, simple lek counts are often used as an index of population size. Although lek counts may provide insights into large-scale population trends over long time periods, the utility of lek counts is limited when rigorous and defensible population estimates are required, because such counts are affected by detection probability that varies over time. Using mark-resight techniques instead of simple lek counts can produce rigorous population estimates with associated measures of precision to guide management decisions.

Objectives: The authors evaluated the utility of two mark-resight analytical methods for estimating abundances of (1) GUSG and (2) greater sage-grouse.

Methods: The authors captured and uniquely marked 75 greater sage-grouse in the winter of 2000 and attempted resighting in the spring of 2001, and 37 GUSG were captured and attempted to be resighted in 2003 and 2004. They also fitted most individuals from both species with a radio transmitter. The marked sample included individuals that had been captured and marked in previous studies. The researchers counted marked and unmarked individuals during resighting events on 15 greater sage-grouse leks and 6 GUSG leks in 2003 and 3 GUSG leks in 2004. The authors then evaluated two statistical models to estimate sage-grouse population sizes based on their mark-resight results.

Location: Colorado; San Miguel; CC-D; MZ II

Findings: The authors found similar abundance estimates between the two statistical models for both the greater sage-grouse and GUSG populations included in this study. One model produced population estimates with less uncertainty but had stricter model assumptions. Additionally, it allowed the assessment of various hypotheses and the incorporation of biological relevant factors into the estimation procedures, which was not possible with the second estimator.

Implications: Regardless of the analytical technique, when population estimates are necessary, the authors advocate using mark-resight methods to monitor populations of lekking animals, especially species or populations of conservation concern. In these cases, the authors assert that, despite the increase in resources required for these methods over traditional lek counts, the costs are outweighed by the ability to rigorously estimate abundance with associated measures of precision, which is not possible without making untenable assumptions using the lek count index. Subsequently, the authors advocate for using the model with less uncertainty despite the potential issue that unmarked birds could have been counted at multiple leks within a sampling bout. The authors base their recommendation on this model's flexibility in modeling underlying methodological and biological processes, the capability to use formal model selection techniques to determine the model that best describes these processes, and the generation of generally more precise population estimates than the other mark-resight estimator evaluated.

Topics: population estimates or targets; sensitive/rare wildlife

Wisdom, M.J., Meinke, C.W., Knick, S.T., Schroeder, M.A., 2011, Factors associated with extirpation of sage-grouse, chap. 18 *of* Knick, S.T., ed., Greater sage-grouse—Ecology and conservation of a landscape species and its habitats: Berkeley, Calif., University of California Press, p. 451–472.

DOI: https://doi.org/10.1525/california/9780520267114.003.0019

Background: Declining populations of GUSG and greater sage-grouse are associated with range contraction; however, the specific environmental changes are unclear. Understanding the environmental variables associated with the currently occupied and extirpated range of GUSG and greater sage-grouse may provide insight into conservation planning and species recovery efforts.

Objectives: The authors sought to identify (1) environmental factors associated with occupied and extirpated areas by both species of sage-grouse, (2) occupied areas that may be vulnerable to extirpation, (3) priority areas for conserving habitat for both sage-grouse species, and (4) research needs about environmental conditions.

Method: First, the researchers used a previously developed range map for GUSG and greater sage-grouse and historical location accounts to determine areas currently occupied by sage-grouse and areas where both species are extirpated. They then identified 22 environmental variables associated with extirpation at large spatial scales: 9 variables represented habitat characteristics, 5 variables represented abiotic factors, and 8 variables represented anthropogenic disturbances. They analyzed how environmental variables differ between occupied and extirpated areas. They then applied the best performing models to determine environmental similarities between extirpations in each region.

Location: California, Colorado, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, Wyoming; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Monticello, Piñon Mesa, San Miguel; CC-A, CC-B, CC-C, CC-D, CC-E, CC-F; MZ I, MZ II, MZ III, MZ IV, MZ V, MZ VI, MZ VII

Findings: The authors found that in occupied areas, sagebrush patches were closer to each other and larger in size compared to extirpated ranges. They also found that higher elevations, lower soil water capacity, and higher soil salinity were associated with occupied ranges. Areas with lower agriculture and human density, higher public land ownership, and areas farther away from roads, transmission lines, and cellular towers were associated with occupied ranges. The model analysis also indicated that sagebrush patch area, elevation, distance to transmission lines, cellular towers, and land ownership best classified differences between occupied and extirpated areas. Lower elevation areas along the periphery of occupied ranges or populations that are in fragmented habitats may have higher risks of extirpation because of the extirpated and occupied ranges being most similar in those areas. There are data gaps about livestock grazing, roads, and anthropogenic development.

Implications: The authors suggest that managers focus on sage-grouse strongholds, which are areas of contiguous habitat, to support species conservation. For greater sage-grouse, this includes the westernmost areas of the occupied range and areas throughout Wyoming. The authors indicate that there are no strongholds for GUSG and suggest that managers work to reduce threats and increase habitat restoration efforts for the species.

Topics: survival; population estimates or targets; broad-scale habitat characteristics; habitat selection; effect distances or spatial scale; nonnative invasive plants; conifer expansion; infrastructure; agriculture; drought; water; soils or geology; sensitive/rare wildlife

Zimmerman, S.J., Aldridge, C.L., Apa, A.D., and Oyler-McCance, S.J., 2019, Evaluation of genetic change from translocation among Gunnison sage-grouse (*Centrocercus minimus*) populations: The Condor, v. 121, no. 1, 14 p.

DOI: https://doi.org/10.1093/condor/duy006

Background: Translocating individuals between populations can help conserve genetic diversity in species that exist in isolated populations like GUSG. Studying the change in population genetics of GUSG satellite populations that are supplemented by translocated individuals could both quantify the effect of previous translocations as well as guide future translocations as a management tool for conserving genetic diversity.

Objectives: The authors sought to determine if (1) genetic diversity increased in GUSG satellite populations after translocation, (2) the population genetic structure decreased between the source and translocated populations, and (3) there was evidence translocated GUSG reproduced successfully with resident GUSG.

Methods: State employees translocated 287 GUSG from the Gunnison Basin to satellite populations from 2000 to 2013, excluding Poncha Pass The researchers created pre- and post-translocation genetic datasets for all GUSG populations from previously collected blood samples and feather samples. The blood samples were from 254 GUSG individuals and were collected between 1996 and 2004, pre-translocation. The 785 feather samples were left on 73 leks in satellite populations and were collected between 2006 and 2012, post-translocation. The researchers performed genetic and statistical analyses to compare changes in genetic diversity within and differentiation among GUSG for the source and satellite populations pre-translocation and post-translocation. They also determined through genetic analyses if there was evidence that translocated GUSG had successfully reproduced with resident GUSG in each satellite population.

Location: Colorado, Utah; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Monticello, Piñon Mesa, San Miguel

Findings: The authors found that genetic diversity increased in all recipient GUSG satellite populations post-translocation, after accounting for natural genetic diversity loss over time. The Gunnison Basin population's genetic diversity remained constant pre- and post-translocation. The authors found a significant decrease in the genetic differentiation between the Gunnison Basin and Piñon Mesa populations after translocation. All other satellite populations that received translocated individuals, with the exception of Cimarron, had a decreasing but not significant trend in genetic differentiation with the Gunnison Basin population. The authors found that translocated GUSG showed some evidence of reproduction with resident GUSG in all recipient satellite populations, but the degree of reproduction varied across satellite populations. The authors found evidence suggesting that individuals from various populations may be naturally dispersing to other satellite populations more frequently than previously assumed.

Implications: The authors indicate that translocation efforts affected the genetic makeup of GUSG satellite populations, and that their results could be used to prioritize translocation to GUSG populations that would receive the greater benefits to genetic diversity. The authors note that translocation success is driven by multiple interacting factors, and translocations would need to continue indefinitely to sustain population genetic diversity if habitat quality and connectivity between all populations are not improved.

Topics: behavior or demographics; translocation; genetics; dispersal, spread, vectors, and pathways; sensitive/rare wildlife

Zimmerman, S.J., Aldridge, C.L., Hooten, M.B., and Oyler-McCance, S.J., 2022, Scale-dependent influence of the sagebrush community on genetic connectivity of the sagebrush obligate Gunnison sage-grouse: Molecular Ecology, v. 31, no. 12, p. 3267–3285.

DOI: https://doi.org/10.1111/mec.16470

Background: Habitat fragmentation and degradation from natural and anthropogenic causes can physically isolate GUSG populations and reduce gene flow. However, it is not clear which landscape factors play a role in influencing gene flow and how that varies across spatial scale.

Objectives: The authors sought to (1) assess the degree of influence of different landscape factors that affect gene flow between distinct GUSG populations rangewide and among leks within the Gunnison Basin population, and (2) simulate hypothetical management actions that could affect gene flow as an example of how the findings could be applied.

Methods: The authors used 254 rangewide GUSG blood samples, collected between 1996 and 2004. Within the Gunnison Basin population, they collected 624 samples, which represented 49 of the 70 leks active between 2006 and 2014. They also evaluated spatial and environmental factors that influence GUSG dispersal, including vegetation composition and structure, topography, habitat selection, anthropogenic development density and distance to development, and climate variables. They then fit models to identify the combination of environmental factors and the magnitude of influence of those factors that best described gene flow at both scales, among populations rangewide and among leks within the Gunnison Basin. Finally, they simulated hypothetical management actions, such as increasing or decreasing sagebrush height, to illustrate how the modeled relationships can be used to understand the potential effects of landscape change on genetic connectivity.

Location: Colorado; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Piñon Mesa, San Miguel

Findings: The authors found that among populations range wide, models predicted that habitat, climate, and phenology characteristics individually influenced gene flow primarily at fine to moderate spatial scales, and anthropogenic and topographic characteristics primarily influenced gene flow at coarse spatial scales. The authors illustrated relative predicted change to gene flow in response to exaggerated landscape change using simulation for both scales, demonstrating how the modeled gene flow relationships might be applied to conservation and management.

Implications: The authors identified factors that influence genetic connectivity between GUSG leks in the Gunnison Basin and among populations, which can vary over spatial scales. They indicated that management actions that promote taller shrubs (primarily sagebrush) and high-quality nesting habitat are important for genetic connectivity between leks in the Gunnison Basin population, whereas gene flow among populations rangewide is primarily influenced by the presence of sagebrush habitat.

Topics: genetics; dispersal, spread, vectors, and pathways; broad-scale habitat characteristics; habitat selection; conifer expansion; energy development; infrastructure; agriculture; weather and climate patterns; sensitive/rare wildlife; includes new geospatial data

Zimmerman, S.J., Aldridge, C.L., Oh, K.P., Cornman, R.S., and Oyler-McCance, S.J., 2019, Signatures of adaptive divergence among populations of an avian species of conservation concern: Evolutionary Applications, v. 12, no. 8, p. 1661–1677.

DOI: https://doi.org/10.1111/eva.12825

Background: Identifying ecologically relevant genetic differences between isolated populations of GUSG could inform management actions that influence the genetic makeup of a population, such as translocations. Adaptive divergence, or uniquely adapted traits of a population, can be explicitly identified through genetic analysis and then used to better understand specific populations. If locally adapted genetic diversity can be correctly characterized across populations, it could be used to both inform habitat conservation goals and assess critical ecological relationships between GUSG individuals and the environment.

Objectives: The authors sought to determine if (1) GUSG populations showed adaptive divergence and (2) GUSG adaptive divergence could be linked to the environment or gene function or both.

Methods: The authors selected 60 individual blood samples for DNA extraction and single nucleotide polymorphism (SNP) genotyping from a set of 254 individuals collected between 1996 and 2004. The 60 individuals included were distributed across six GUSG populations to characterize differences. The authors identified 72 potential environmental covariates from previous research and ultimately selected 8 minimally correlated environmental variables that captured site and climatic conditions across populations. The authors then identified signatures of adaptive divergence among populations and also explored gene functions associated with adaptive divergence.

Location: Colorado; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison, Piñon Mesa, San Miguel

Findings: The authors found that the Cimmaron, Crawford, and Gunnison populations were the most adaptively similar, and the Dove Creek, Piñon Mesa, and San Miguel populations had the most adaptive genetic diversification. These results closely track both geographic isolation and habitat differences across populations. The authors state that the described adaptive genetic divergence across populations indicates that GUSG immune function and metabolism may be driving adaptive divergence. The metabolic adaptive divergence the authors found could be linked to the digestion of the anti-herbivory compounds that sagebrush and other plants produce, which vary depending on local habitat.

Implications: The authors state that different GUSG populations may have locally adapted metabolic function, meaning that the dominant vegetation where each population resides may be driving evolutionary differences across populations. Further, the authors identify genetic differences across populations that may indicate different histories of exposure to viruses and subsequent population-specific immune responses to viruses. The genetic differences the authors identified may need to be considered for translocating GUSG individuals or when selecting seed sources for restoration. Specifically, ignoring genetic differences across populations when carrying out management or conservation actions, such as translocations, could disrupt locally adapted genetic diversity.

Topics: genetics; broad-scale habitat characteristics; effect distances or spatial scale; sensitive/rare wildlife

Zimmerman, S.J., Aldridge, C.L., and Oyler-McCance, S.J., 2020, An empirical comparison of population genetic analyses using microsatellite and SNP data for a species of conservation concern: BMC Genomics, v. 21, article 382, 16 p.

DOI: https://doi.org/10.1186/s12864-020-06783-9

Background: Conservation decision making can place a high value on genetic information, especially when genomics is implicated in a particular decision, such as assigning conservation status, defining distinct populations, and engaging in costly actions like species translocations. Using the best available analytical techniques for genetic analyses of rare species is a challenge, as methods in genetics have advanced greatly in recent years.

Objectives: The authors sought to (1) compare genetic diversity metrics, (2) compare genetic differentiation, and (3) compare GUSG population clustering across two datasets derived from GUSG genetic samples, with one dataset created using an established analytical method and the other using a recently developed analytical method.

Methods: The authors used 254 GUSG blood samples collected in 2005 to generate genetic data by applying the older microsatellite technique; they used a subset of 60 individuals from the larger sample to generate genetic data by applying the newer single nucleotide polymorphism (SNP) technique. The authors then used common statistical approaches to estimate and compare how both datasets characterize genetic diversity, genetic differentiation, and evolutionary independence of populations.

Location: Colorado; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Monticello, Piñon Mesa, San Miguel

Findings: The authors found that the genetic dataset created using the newer analytical method produced nearly the same genetic differentiation and diversity patterns as the older analytical method. The results from both methods were most similar when ranking GUSG populations across genetic parameters, but the magnitude of their estimates differed. The newer method, SNP, was more precise in clustering genetically similar populations of GUSG. The authors support adopting SNP analyses for GUSG and other rare species but highlight where microsatellite analyses will remain useful both as stand-alone analyses and as a benchmark for comparison to SNP methods.

Implications: The authors found that the SNP method was advantageous over the older microsatellite method because SNP-generated estimates of genetic diversity have less uncertainty, are better able to differentiate populations, and create an opportunity to consider local adaptation. As novel genetic techniques are applied to conservation challenges, the authors advise against using specific thresholds in genetic data when making management decisions and instead emphasize using broader evolutionary context; for example, focusing on relative instead of absolute genetic differences between populations.

Topics: population estimates or targets; genetics; sensitive/rare wildlife

Zimmerman, S.J., Oyler-McCance, S.J., Aldridge, C., Oh, K.P., and Cornman, S., 2020, Sample collection information and SNP data for Gunnison sage-grouse across the species range generated in the Molecular Ecology Lab during 2015–2018: U.S. Geological Survey data release.

DOI: https://doi.org/10.5066/P94ET592

Background: Examining DNA patterns in individuals across GUSG populations may help to provide information about local-scale genetic variation within the species.

Objectives: The authors sought to collect genetic information related to local adaptation for GUSG individuals across the species range.

Methods: The authors obtained blood samples from 60 GUSG individuals and performed a series of DNA analyses to identify genetic variation across populations.

Location: Colorado, Utah; Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Gunnison Basin, Piñon Mesa, San Miguel

Findings: The authors provide a genomic dataset of GUSG individuals across six populations to determine signs of local genetic adaptation.

Implications: The researchers collected information to understand patterns of local adaptation; however, management implications were not addressed.

Topics: genetics; sensitive/rare wildlife

Publishing support provided by the Science Publishing Network
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Maxwell and others—**Annotated Bibliography of Scientific Research on Gunnison Sage-Grouse Published from January 2005 to September 2022**—OFR 2023–1079

ISSN 2331-1258 (online)
https://doi.org/10.3133/ofr20231079