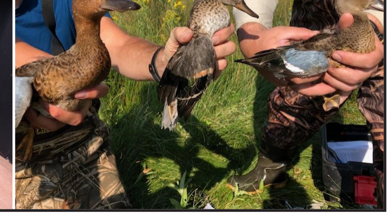
COLORADO PARKS & WILDLIFE

2023 Avian Research Summary Report

MARCH 2024



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COVER PHOTOS

Top:
Bald eagle with back-mounted transmitter (credit M. Midleton)

Bottom (left to right):
Brewer's sparrow nest (credit B. Walker)
Collecting plant data on habitat treatments
Bobwhite quail being measured and fitted with transmitter
Ducks captured for banding

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Colorado Parks and Wildlife Research Library
317 West Prospect, Fort Collins, CO 80526

WILDLIFE RESEARCH SUMMARIES

JANUARY – DECEMBER 2023

AVIAN RESEARCH PROGRAM

COLORADO DIVISION OF PARKS AND WILDLIFE
Research Center, 317 W. Prospect, Fort Collins, CO 80526

Executive Summary

This Wildlife Research Report contains abstracted summaries of wildlife research projects conducted by the Avian Research Program of Colorado Parks and Wildlife (CPW) during 2023. These are long-term projects (2–10 years) in various stages of completion, each of which addresses applied questions to benefit the management of various bird species and wildlife habitats in Colorado. More technical and detailed reports of most of these projects can be accessed from the project principal investigator listed at the beginning of each summary, or on the CPW website at: http://cpw.state.co.us/learn/Pages/ResearchBirds.aspx and http://cpw.state.co.us/learn/Pages/ResearchHabitat.aspx.

In 2023, research projects in the Program address various aspects of the ecology and management of wildlife populations and the habitats that support them, human-wildlife interactions, and new approaches to field methods in wildlife management. This report includes summaries of 11 current research projects addressing management-related information needs for a variety of species of conservation concern and game species and their habitats. These projects are grouped under Wildlife Habitat Conservation, Wildlife Spatial Ecology, Bird Conservation and Energy Development, Raptor Conservation, Sagebrush Bird Conservation, Grassland Bird Conservation, and Wetland Bird Conservation.

Also included in this report is a listing of publications produced during 2023, and presentations, workshops and participation on various committees and working groups by Avian Research staff during 2023. Communicating research results and using their subject matter expertise to inform management and policy issues is a priority for CPW scientists. Copies of peer-reviewed research publications can be obtained from the CPW Library.

We are grateful for the numerous collaborations that support these projects and the opportunity to work with and train graduate students and research technicians that will serve wildlife management in the future. Research collaborators include statewide CPW personnel, Bird Conservancy of the Rockies, Brigham Young University, Bureau of Land Management, City of Fort Collins, Colorado State University, Conoco-Phillips, Marathon Oil, Ranch Advisory Partners, Species Conservation Trust Fund, U.S. Fish and Wildlife Service, U.S. Forest Service, U.S. Geological Survey, Wildlands Photography and Bio-consulting, WPX Energy, and the private landowners who have provided access for research projects.

STATE OF COLORADO
Jared Polis, *Governor*

DEPARTMENT OF NATURAL RESOURCES
Dan Gibbs, *Executive Director*

PARKS AND WILDLIFE COMMISSION (December 2023)

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WETLAND BIRD CONSERVATION

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Effects of Esplanade herbicide at Bitterbrush State Wildlife Area

Period Covered: January 1, 2023 – December 31, 2023

Author: Danielle B. Johnston, CPW Habitat Researcher danielle.bilyeu@state.co.us

Principal Investigators: Danielle B. Johnston, Trevor Balzer (CPW Habitat Coordinator)

Project Collaborators: Colton Murray (Property Technician, Bitterbrush State Wildlife Area), Matt Madsen (Associate Professor, Brigham Young University)

EXTENDED ABSTRACT

Cheatgrass invasion shortens fire cycles. At Bitterbrush State Wildlife Area (BBSWA), this dynamic is responsible for loss of extensive thickets of bitterbrush since the 1970s (Figure 1). Although bitterbrush is recovering in some areas, the rate of recovery has not been sufficient to outpace the rate of losses. We seek to find ways to control cheatgrass and improve the recovery rate of bitterbrush in order to restore habitat function for big game. This report synthesizes five different experiments with that aim: The Indaziflam Trial, the Red Experiment, the Yellow Experiment, the White Experiment, and the Brown Experiment.

We began this study in spring 2019 by testing a promising new herbicide for cheatgrass control, indaziflam (trade name Rejuvra®, former trade name EsplAnade™) in the Indaziflam Trial. The product worked well to control cheatgrass, but cheatgrass control did not increase bitterbrush cover, bitterbrush leader length, or cover of other perennials in 2019-2022. We found evidence that indaziflam hindered bitterbrush germination 1 year post application and reduced cover of six weeks fescue, a native annual grass, 4 years post-application.

Although indaziflam did not prove helpful in establishing bitterbrush or improving the leader lengths of bitterbrush at BBSWA, it still has utility in breaking the cheatgrass/fire cycle because it provides excellent cheatgrass control. To minimize negative effects on bitterbrush germination and reduce cost, indaziflam should be applied in judiciously chosen firebreaks rather than by treating the entire landscape.

Our results for indaziflam may be indicative of responses to indaziflam in western Colorado in general, which seem to differ from responses in eastern Colorado. CPW biome coordinator Trent Verquer, NRCS colleagues, and CSU researchers report dramatic positive benefits of indaziflam for desirable species, including desirable annuals and rare species, for sites east of the continental divide. In contrast, despite effective cheatgrass control by indaziflam, fewer benefits to desirable species have been observed in western Colorado (Trevor Balzer, CPW biome coordinator, *pers. comm.*). The reasons for this difference is not clear, but may involve different patterns of precipitation.

The remainder of the experiments focused on factors that may hinder germination and early establishment. We closely examined the effect of indaziflam as well as NutraFix, a fertilizer, on bitterbrush and bottlebrush squirreltail germination and establishment in the Red Experiment, which was begun in fall 2020. Bitterbrush and bottlebrush squirreltail seeds were sown within rodent-proof cages bordered by insect control barriers in order to minimize the impact of rodents and insects and thereby isolate the effects of products. When seeds were planted the same year as product application, both indaziflam and NutraFix severely curtailed both bitterbrush and squirreltail seedling density. When seeds were planted about 15 months after product application, NutraFix had no effect on bitterbrush seedlings, and increased squirreltail seedlings. Indaziflam slightly reduced bitterbrush seedlings, and greatly reduced squirreltail seedlings. Indaziflam provided better continuing control of cheatgrass and desert alyssum, but also had a negative impact on hairy golden aster and unidentified perennial grass seedlings. Seedlings are notoriously sensitive to herbicides and fertilizers; light application rates, a lag time between application and seeding, and integration with other weed management strategies are required. Seeding bitterbrush after indaziflam at BBSWA requires at least a 15 month lag, and longer lags will be required for other desirable species such as bottlebrush squirreltail. Other sites are likely to differ, as indaziflam decays more quickly at sites with more active soil microbial communities. Additional research on indaziflam effects on non-target species, plant-back interval, and decay rates is needed.

Rodents and insects are two additional factors that can constrain bitterbrush establishment (Figure 2). The Yellow Experiment was designed to assess the relative importance of cheatgrass, rodents, and insects. Rodent control cage type (open or closed), cheatgrass competition (hand weeded or cheatgrass seed added) and insect herbivory (ambient or controlled) were crossed, and bitterbrush seedlings were monitored. There were three plantings in the fall of each year 2020-2022 in each of three locations, with monitoring the following spring and summer for each planting. We found that dynamics differed by location, even though all locations were on the same soil type and had similar surrounding vegetation (Table 1). At Maybell Sands 1, there were no significant main effects of treatments in any year. At Maybell Sands 2, rodent cage type had a very large effect on bitterbrush seedling density in every year, with especially dramatic differences in 2022. At Maybell Sands 3, rodent cage type had a slight effect in 2021, and cheatgrass treatment had a slight effect in 2022. In addition, there were cheatgrass treatment by insect control treatment interactions in 3 instances, and each of these had unique dynamics.

Rodent seed predation is an extremely limiting factor for bitterbrush establishment in some places. Year-to-year variability appears less than that of spatial variability (Table 1). Further research should focus on identifying factors that correlate with rodent seed predation, such as vegetation or topography variables, which could managers could assess in order to predict where rodents are likely to be a problem.

Cheatgrass does not seem to be a large limiting factor for bitterbrush establishment at BBSWA, although we did note a slight impact. In 2022, across sites in closed rodent control cages, plots with cheatgrass seed added averaged 11.2 ± 0.5 bitterbrush seedlings, while plots that had been weeded of cheatgrass averaged 13.2 ± 0.6 bitterbrush seedlings. In 2023, this difference was smaller: 7.8 ± 0.5 vs. 8.1 ± 0.5. Cheatgrass may be a more important limiting factor in areas with other soil types and precipitation patterns.

The level of insect herbivory varied by year, with a much lower percentage of bitterbrush seedlings showing signs of insect herbivory in 2023 than in any other year. 2023 was the only year that Bonide Eight® insecticide, the most effective treatment in the White Experiment (described below), was used in the Yellow Experiment. While we did not find a large effect of insect control in the Yellow Experiment, we as yet need to test an effective insecticide in a year with higher insect herbivory. In some combinations of plot type, site, and year, insect control had a large effect on bitterbrush seedling density.

The Brown Experiment, planted in 2021, crossed rodent control cage type (open or closed) with several rodent-deterrent seed coatings which had been shown to be effective in the lab by Dr. Matt Madsen. Similar to the Yellow Experiment, we found a large effect of rodent cage type. We did not find any rodent-deterrent seed coatings that were effective in the field. All of the coatings hindered bitterbrush emergence, and none of the coatings were successful enough at deterring rodents to compensate for the reduced emergence. The charcoal seed coating was the most promising, but additional research is needed to find an effective coating formula.

The White Experiment, planted in 2021, involved testing several methods of insect control, including an insecticidal seed coat and several spring-applied insecticides. The most successful treatment was two applications of Bonide Eight®, one shortly after emergence in the spring, and one about a month later. This treatment reduced the rate of herbivory on bitterbrush seedlings and increased bitterbrush seedling count by about 80% as compared to the least effective treatment. The result was consistent across the 4 study sites.

Measures to control rodent seed predation and spring insect herbivory may have a larger impact on bitterbrush seedling survival than measures to control cheatgrass at BBSWA. Spring application of Bonide Eight® insecticide is a management action which could be undertaken immediately to improve bitterbrush establishment. The insecticide should be applied during low-light, cool conditions to avoid injuring seedlings. In addition, care should be taken to avoid spraying flowering plants to avoid harm to pollinators. Due to its cost, the insecticide should only be applied if emerging bitterbrush seedlings are observed.

Fieldwork and data reporting are now complete for this study, and this is the final reporting year. A manuscript combining the Yellow and White experiments is planned. Addressing factors that impact on bitterbrush establishment at additional sites is warranted, as climatic and/or soil conditions could affect the way rodents, insects, cheatgrass, and management actions impact bitterbrush seedlings. A further investigation of the impacts of rodents, insects, and cheatgrass on bitterbrush, as well as mountain mahogany, is part of a new CPW study, Mountain Shrub Establishment in Colorado, which began in 2023.

	2021 (2020 planting)	**2022 (2021 planting)**	**2023 (2022 planting)**
Maybell Sands 1	No significant effects	Cheatgrass by insect control interaction (unintuitive dynamics)	No significant effects
Maybell Sands 2	Large effect of cage type	Huge effect of cage type; cheatgrass by insect control interaction	Large effect of cage type; cheatgrass by insect control interaction
Maybell Sands 3	Small effect of cage type	Small effect of cheatgrass control	4-way interaction; highest bitterbrush density with hand weeding, insect control, and closed cage

Table 1. Summary of significant effects in the Yellow experiment over three years. Note that no cheatgrass effects were examined in 2021 (2020 planting).

Figure 1. The study area in the northern half of Bitterbrush State Wildlife Area, Moffat County. Remnant bitterbrush patches are visible in this aerial imagery from 2017; areas without patches have burned. Black outlined plots indicate the locations of the Indaziflam Trial, Yellow Experiment, and Red Experiment. Brown Experiment blocks locations are shown in brown, and While Experiment sites blocks are shown in white.

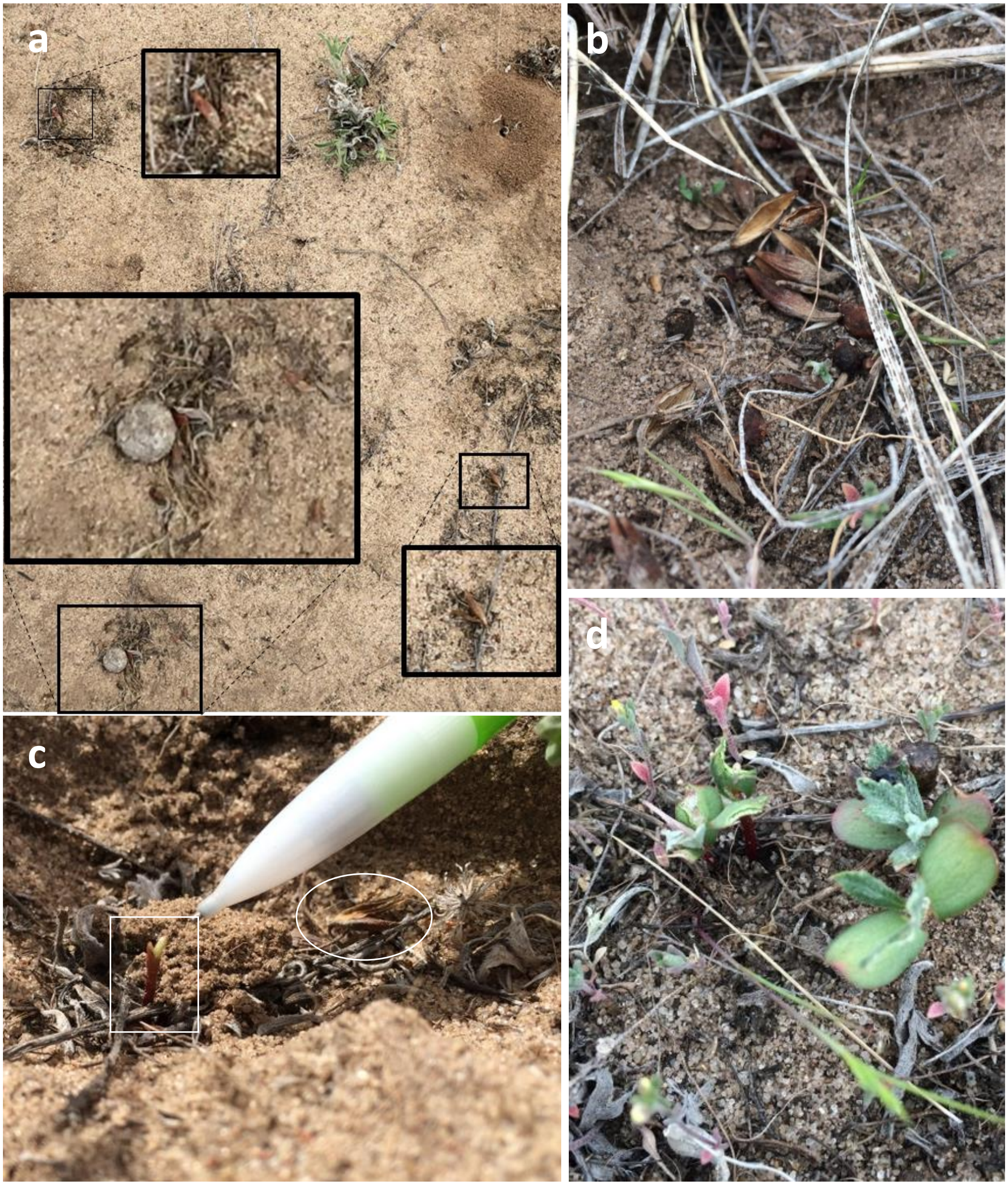

Figure 2. Bitterbrush seed predation and seedling herbivory in experimental subplots of the Indaziflam Trial: a) Aerial view of seedling subplot, with insets highlighting husks of bitterbrush seeds; b) Close-up of bitterbrush seed husks found atop where a seed cache had been buried; c) a bitterbrush seedling with all cotyledons and leaves browsed off (box) and a bitterbrush seed husk (oval); d) bitterbrush seedlings with evidence of insect browsing on cotyledons.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

NutraFix Rate Trials: Final Report

Period Covered: January 1, 2023 – December 31, 2023

Author and Principal Investigator: Danielle B. Johnston, CPW Habitat Researcher
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Project Collaborators: Kevin Gunnell, Great Basin Research Center Coordinator, Utah Division of Wildlife Resources; Tom Monaco, Research Ecologist, Agricultural Research Service, Logan, Utah; Trent Verquer, Habitat Coordinator; Todd Schmidt, Area 3 Wildlife Manager; Levi Kokes, Property Technician, Tamarack State Wildlife Area; Kirk Oldham, Area 7 Wildlife Manager; Ivan Archer, Area 7 Assistant Wildlife Manager; Buddy McNeel, Property Technician, Garfield Creek State Wildlife Area; Brian Gray, District Wildlife Manager; Mike Swaro, Area 6 Assistant Wildlife Manager; Colton Murray, Property Technician, Bitterbrush State Wildlife Area

EXTENDED ABSTRACT

NutraFix® (ACF West Geosynthetics, Inc.) is a uniquely formulated fertilizer which has proven effective for cheatgrass (*Bromus tectorum*) control in preliminary trials in Montana, Utah, and Colorado (Figure 1). It contains a high proportion of boron, a micronutrient which is toxic to cheatgrass at rates which may be neutral or beneficial to other species. Initial trials with the product indicate that application rates of 110 - 390 kg/ha (100 - 350 lbs/ac) can control cheatgrass while promoting desirable, perennial vegetation. More specifically, optimal rates will likely depend on site conditions, and that relationship may be complex. We sought to better understand how to use this product while minimizing cost and potential undesirable effects.

In fall 2020, we established replicated trials (n = 4) of 84, 168, and 336 kg/ha (75, 150, and 300 lbs/ac) application rates at Tamarack SWA (2 sites), Bitterbrush SWA, Garfield Creek SWA, and West Rifle Creek SWA (Figure 2). The sites vary in soil texture, precipitation, and plant community. We established a partnership with the Utah Division of Wildlife Resources, and they established 5 sites in Utah, testing the same 3 application rates.

Vegetation measurements were taken late May to early June, 2021-2023. In Colorado, the high rate of NutraFix resulting in a modest cheatgrass reduction of about 30% in the first year, a slight reduction of about 13% in the second year, and had no significant effect in the third year (Figure 3). At the medium and low rates, there was little effect on cheatgrass in any year. NutraFix did not result in any significant increase in desirable vegetation. The only species we noted that increased with NutraFix were non-native annual forbs, including tall tumblemustard (*Sisymbrium altissimum*), desert alyssum (*Alyssum desertorum*), and salsify (*Tragopogon dubius*). We found that the high rate of NutraFix decreased two native perennial species, rubber rabbitbrush (*Ericameria nauseosa*) and hairy golden aster (*Heterotheca villosa*), as well as one native annual, six weeks fescue (*Vulpia octoflora*).

Results from Utah from 2022 were available at the time of this report. In 2022, the high rate NutraFix controlled cheatgrass at only 2 of 5 sites, where it reduced cheatgrass cover by 25-50%. The native perennial western wheatgrass increased under NutraFix at one site, a species previously known to respond positively to the product. Non-native annual forbs also increased at Utah sites.

The discrepancy between the unimpressive results in this study and the impressive results from prior studies conducted both by CPW and others is not clear. Soil texture difference does not appear to be a parsimonious explanation for differences in performance. A possible explanation is that the very dry fall and winter of 2020-2021 prevented the product from dissolving quickly, and thus the timing of effective concentration in the soil did not coincide with cheatgrass growth. Another possible explanation is that the product is more effective at sites with certain dominant species, such as western wheatgrass.

Through a partnership with the Agricultural Resource Service in Logan, Utah, we sampled and analyzed soils for nitrate, ammonium, and Kjeldahl N at four time points from each study plot. We are interested in soil nitrogen because micronutrients can effect soil microbial activity and therefore nitrogen availability. A multivariate analysis including vegetation and soil data from all 10 sites across Colorado and Utah is planned.

At this time we do not recommend NutraFix application for cheatgrass control, due to inconsistent performance and cost.

Figure 1. a) control and b) treated pilot plot in Sharrard Park, near Rifle, CO on June 3, 2020. Treated plots were sprinkled with 330 lbs/ac NutraFix in early September, 2019. NutraFix controlled cheatgrass well at this site and allowed more green growth on a perennial grass (inset photos) in spite of dry conditions.

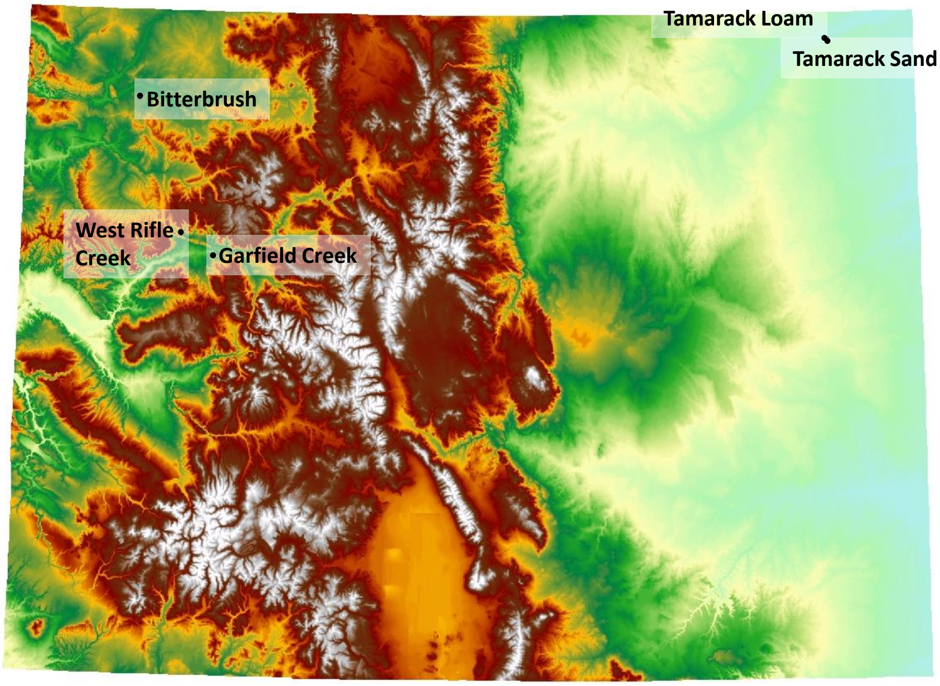

Figure 2. Locations for the five rate trial sites set up in 2020 in Colorado.

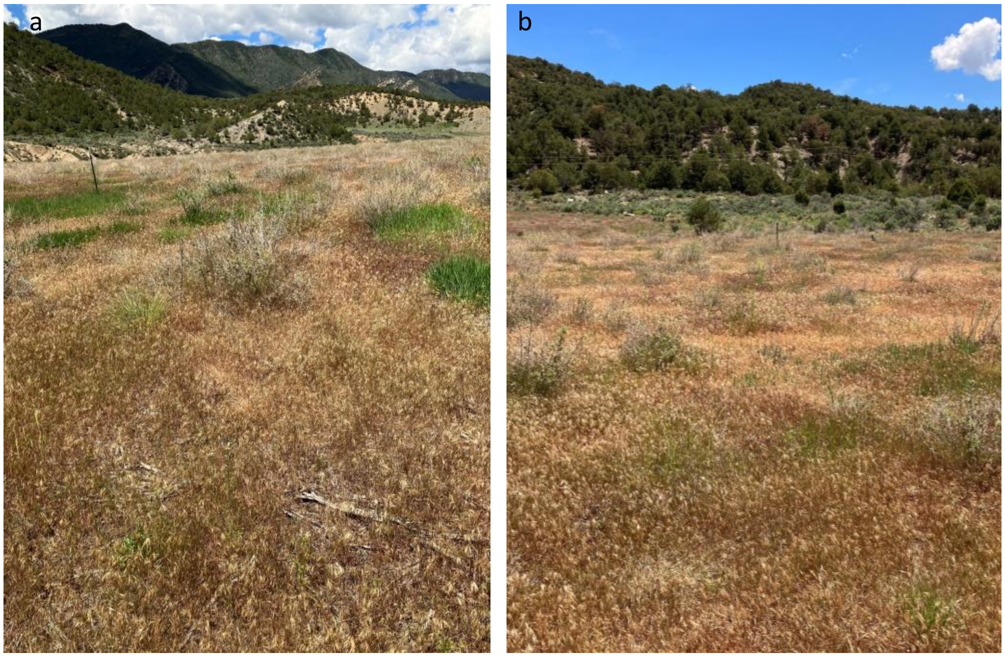

Figure 3. The high rate of NutraFix (a) did not greatly reduce cheatgrass cover compared to the control (b) at West Rifle Creek in 2022. Other sites had similar responses.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Mountain Shrub Establishment in Colorado

Period Covered: January 1, 2023 – December 31, 2023

Authors: Danielle B. Johnston, CPW Habitat Researcher danielle.bilyeu@state.co.us and Nathan Nelson, Colorado State University

Principal Investigators: Danielle B. Johnston, Mark Paschke (Shell Endowed Chair of Restoration Ecology, Colorado State University)

Project Collaborators: Nathan Nelson, Colorado State University; Jacob Lucero, Texas A&M assistant professor; Trevor Balzer, CPW Habitat Coordinator; JC Rivale, Little Hills State Wildlife Area Property Technician; Zane Stewart, Byers Canyon Property Technician; Dillon Sanders, Cherokee State Wildlife Area Property Technician; Jim Sebastian, Boulder County Open Space

EXTENDED ABSTRACT

Mountain shrubs such as bitterbrush and mountain mahogany provide a critical food source for mule deer and other wildlife in Colorado. These shrubs can be lost from landscapes due to fire, land use change, drought, and other factors. As climate change alters plant communities, we will need the ability to restore these species to landscapes. However, seedings of these species often fail, and the reasons for failure are not always clear. We seek to improve our understanding of establishment of these two key species.

Three factors known to impact the establishment of bitterbrush and mountain mahogany are weeds, insects, and rodents. A prior CPW study examined those three factors for bitterbrush only at Bitterbrush State Wildlife Area. Here, we seek to quantify the relative importance of these three factors more broadly across Colorado by expanding to 4 new sites and including mountain mahogany. The four sites are: Byer's Canyon (Byer's Canyon Rifle Range, Grand County), North Ridge (Little Hills SWA, Rio Blanco County), Hall Ranch (Boulder County), and Lower Cherokee (Cherokee SWA, Larimer County) (Figure 1).

Rodent activity was manipulated by planting seed in rodent control cages that were either closed or had an opening cut to allow rodent access (Figure 2). Cheatgrass (*Bromus tectorum*) was manipulated by either hand-weeding or adding cheatgrass seeds. Seed of either mountain mahogany or bitterbrush were hand-planted in each plot. Insect control will be via spring application of Bonide Eight® insecticide, a product that was shown to be effective for reducing herbivory on bitterbrush seedlings and increasing bitterbrush seedling density in a prior CPW study. Treatments are fully crossed and five replications per target species per site were established.

Activities in 2023 included selection of four new sites, experiment installation, establishment of a contract with CSU to fund a master's student, Nathan Nelson, to oversee the project, and deployment of 6 game cameras at each site to characterize small mammal communities. In spring 2024 we plan to apply the

insect control treatment and monitor seedling emergence and persistence. In fall 2024 we will move our plots slightly to accommodate a second planting so that the experiment can be repeated. We also plan to begin one or more additional experiments important to our understanding of bitterbrush and mountain mahogany establishment.

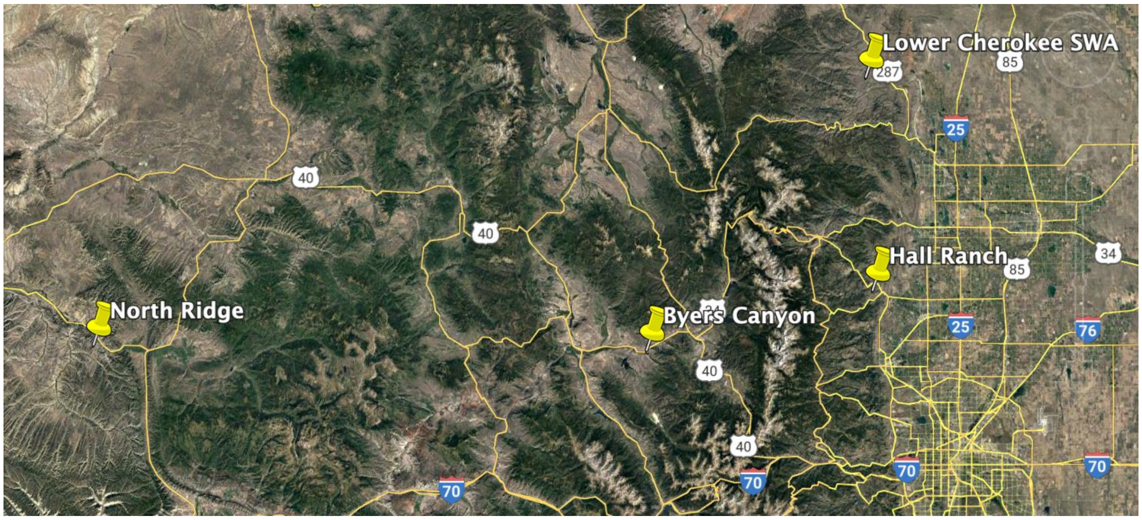

Figure 1. The locations of the four study areas, North Ridge (Rio Blanco County), Byers Canyon (Grand Gounty), Hall Ranch (Boulder County), and Lower Cherokee (Larimer County). Both of the target species, bitterbrush and mountain mahogany, are being studied at all four sites.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Spatial ecology and analysis of avian and mammalian wildlife

Period Covered: August 1 – December 31, 2023

Author and Principal Investigator: Nick Jaffe, CPW Spatial Ecologist nick.jaffe@state.co.us

Project Collaborators: Michelle Cowardin, Michelle Flenner, Jon Runge, Andy Holland, Tony Apa, Reesa Conrey, Amy Seglund, Liza Rossi, Brett Walker, Danielle Johnston, Chuck Anderson (Colorado Parks and Wildlife); Michelle Fink (Colorado Natural Heritage Program); Miranda Middleton (Colorado State University)

EXTENDED ABSTRACT

Evaluating wildlife location data provides substantial information for management. Location data reveal patterns of movement dynamics, species distribution (habitat suitability), and varying habitat use. Colorado Parks and Wildlife monitors myriad species of concern for conservation and hunting and thus needs to develop thorough and up-to-date assessments of the spatial patterns and processes of its target species. In collaboration with state wildlife biologists, avian researchers, and external partners, I have assisted in evaluating spatial data for several species and populations. Below, I list the active research projects I am associated with, and briefly detail the objectives and current status of each.

- **Ungulate Migration Corridor Mapping (with Michelle Cowardin, Michelle Flenner, Michelle Fink [CNHP], Jon Runge, and Andy Holland)** — Working with existing datasets compiled by Chloe Beaupré (former WCU M.S. student) we produced maps depicting summer and winter home ranges, as well as migration routes, for collared populations of elk, mule deer, and bighorn sheep. In collaboration with Jon Runge and Andy Holland, we developed a methodology to standardize these maps by the underlying population of collared animals for each Data Administrative Unit, so as to better represent proportional use of the landscape. These standardized map surfaces were provided to Michelle Fink and CNHP researchers for use in generating a connectivity model and mapping products, which will be incorporated into Colorado's Statewide Habitat Conservation and Connectivity Plan. Future objectives include developing a formal methodology for internal use by CPW to continue to develop and update connectivity analyses and products.

- **Bald Eagle home range size and selection analysis (with Reesa Conrey and Miranda Middleton [CSU])** — We used GPS data from a population of bald eagles in Colorado's Front Range to map seasonal home ranges, as part of Miranda Middleton's M.S. thesis project. We evaluated several different analytical methods for their effectiveness in mapping bald eagle home ranges while excluding excursive behaviors (which fall outside the scope of the study). An effective method was identified and applied to all eagles in the dataset. Future objectives include an analysis of factors affect bald eagle resource selection and home range size.

- **Pinyon Jay survey design (with Amy Seglund, Jon Runge, Liza Rossi)** — We developed a sampling scheme for use in upcoming surveys for Pinyon Jay and associated nesting colonies. Utilizing an existing sampling grid and logistical constraints (elevation and access to land), we identified all available sampling plots for Pinyon Jay in Colorado. Applying an occupancy probability map recently developed by the USFWS (Jason Tack) and a hierarchical clustering algorithm, we further stratified the available landscape into regions by spatial proximity and similarity in occupancy probability. Two regions were then selected for surveys. The methodology will be presented to the multi-state Pinyon Jay working group to provide an example from which partners can develop their own surveys. Future objectives include an evaluation of USFWS's map for predicting breeding jays (and identifying future survey locations) as well as an independent analysis of breeding jay resource selection.

- **Columbian Sharp-tailed Grouse Resource Selection (with Tony Apa)** — We used a dataset of Columbian Sharp-tailed Grouse (CSTG) VHF collar locations, compiled from nearly two decades of studies, to fit a scale-integrated resource selection function. The function integrates CSTG resource selection at both the coarser lek scale and the finer within-lek scale in order to predict potential habitat in environmentally similar areas of the state. Code for the analysis has been completed and the base model has been fitted and mapped. Competing models, examining different combinations of topographic, environmental, and biological variables are being developed for comparison. Future objectives include evaluating the utility of the final model using VHF data from translocated CSTG.

- **Greater Sage-Grouse long distance movement analysis (with Brett Walker)** — We are using GPS telemetry locations of Greater Sage Grouse (GRSG) to identify long-distance movements and space-use around leks. A project workflow has been developed by Brett Walker, which I then adapted into code. Data processing and analysis is ongoing.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Assessing High-Priority Bird Species Interactions with Renewable Energy

Period Covered: July 17 – December 31, 2023

Author and Pricipal Investigator: Casey M. Setash, CPW Avian Researcher casey.setash@state.co.us

Collaborators: Brandon Marette, Lexi Hamous-Miller, Karen Voltura, Taylor Elm, Dani Neumann, Molly West, Peter Foote, Brian Magee, Karlyn Armstrong, Cassidy English, Patrick Bachmann (CPW Energy Liaisons and Land Use Coordinators); Jim Gammonley (CPW Avian Research Leader); Hannah Alford, Don Buccholz, Anna Lundin (Korsail Solar Developers)

EXTENDED ABSTRACT

Renewable energy infrastructure is being developed rapidly across Colorado. The technology that powers infrastructure is improving while the extent of infrastructure on the landscape is simultaneously expanding, often with unknown or unforeseen impacts on wildlife. Based on known seasonal distributions and habitat associations, approximately 11 of Colorado's Tier I SWAP bird species and 28 Tier II species have the potential to be impacted by existing and proposed renewable energy infrastructure. Many of these species are grassland- or sagebrush-obligates, which are ecosystems that also lend themselves well to wind and solar development given their flat topography, wind and solar resources, and relationship to existing transmission lines. CPW Energy Liaisons and Land Use Coordinators are often contacted by developers and utilities companies to provide best management practices and mitigation recommendations, and have thus far based recommendations on limited peer-reviewed research and anecdotal observations. This project was initiated to better inform those recommendations and identify research gaps in the existing literature to target using rigorous field studies.

An initial literature review revealed a preponderance of research focused on wind energy infrastructure and grouse species (although not always together), in addition to direct raptor mortalities related to collision with wind infrastructure. Impacts are often classified as either direct (e.g., collision mortalities) or indirect (e.g., disturbance, avoidance, or sub-lethal impacts) and can occasionally be beneficial for some species (e.g., providing nesting or perching infrastructure). Over 300 bird species have been reported to collide with wind turbines in the United States, but a small number of species often comprise disproportionate amounts the recorded mortalities (e.g., horned lark, mourning dove; AWWI 2020). Collisions are most common at facilities sited along migration corridors or within natural bottlenecks (e.g., Altamont Pass in California; Howell and DiDonato 1991, Orloff and Flannery 1992). Most direct mortalities at solar facilities result from birds flying through solar fluxes, where solar radiation is concentrated, and subsequently burned. Aerial insectivores appear most susceptible to this effect, in addition to falcons attracted to prey items associated with solar facilities (McCrary et al. 1986, WEST 2016).

Indirect effects of wind infrastructure have received the most research attention in relation to greater and lesser prairie-chickens and greater sage-grouse. Short term negative impacts on vital rates (e.g., adult

female survival, nest survival, brood survival) have been detected, but these effects appear to interact with other land-use characteristics and the need for long-term studies is often emphasized. Roads and disturbance appear to be the largest contributors to bird avoidance and reduced reproductive output across geographic scales in addition to electrocutions associated with transmission lines. Results of mitigation strategies such as wind turbine curtailment have been mixed, as have strategies to make turbines more visible to at-risk species (Conkling et al. 2020). It appears that preliminary macrositing decisions are most responsible for direct and indirect impacts on avian wildlife, but research on the efficacy of compensatory mitigation tactics is advancing and results may inform strategies to mitigate impacts when macrositing plans are not flexible.

Potential avenues for research identified in the literature review span several topics, including sampling design and methodology for mortality surveys and identifying high-risk development sites, basic life-history studies for species of conservation concern for which little research exists, the impact of macro- and micrositing decisions on direct and indirect effects, and the efficacy of mitigation strategies. Research questions under each of these umbrellas will be narrowed down with input from collaborators to identify priority questions and develop a more in-depth proposal over the coming year, with field work potentially beginning in spring/summer 2024 before known developments begin construction.

Progress and project components completed during July – December 2023:

- Completed a literature review of the impacts of renewable energy infrastructure on birds across the globe, with a focus on ecosystems similar to or in Colorado. Wrote a report on the findings from this review and an extensive list of potential research questions for review by collaborators.
- Distributed this report to energy liaisons and land use coordinators at CPW as an informative reference when making recommendations on future renewable energy development.
- Developed a map of projected wind energy development in Colorado based on wind speed, topography and elevation, land cover type, and distance to existing transmission lines. These projections will help guide selection of reference sites and potential development sites when designing future studies.

Project plans for 2024:

- Develop a map similar to the one described above for projected solar development in the state
- Build integrated species distribution models for focal SWAP species to identify high-risk or conflict zones with existing and projected renewable infrastructure
- Conduct a meta-analysis using published peer-reviewed literature and reports to evaluate the impacts of micrositing characteristics within wind farms on the mortality rates of different guilds of birds
- Conduct a before-after-control-impact (BACI) evaluation of abundance and distribution of focal SWAP bird species at and around renewable power plants using eBird data to inform key habitat setback thresholds and disturbance distances
- Write a proposal for an in-depth field study evaluating priority research questions identified by the literature review
- Initiate pilot field work at sites that have been selected for solar development but at which construction has not yet begun. Field work will involve methods detailed in a future study plan, but will likely involve avian point counts and vegetation surveys at sites of proposed development and reference sites.

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Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Occupancy, density, abundance, and productivity of burrowing owls nesting on black-tailed prairie dog colonies in Colorado

Period Covered: January 1 – December 31, 2023

Authors: Sarah Albright, Colorado State University, and Reesa Yale Conrey, CPW Avian Researcher
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Principal Investigators: Sarah Albright; William Kendall, USGS Colorado Cooperative Fish & Wildlife Research Unit; Reesa Yale Conrey

Project Collaborators: Liza Rossi, CPW

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EXTENDED ABSTRACT

The shortgrass prairie provides vital nesting and foraging habitat for many grassland birds. In Colorado, approximately 50% of the historic shortgrass prairie has been converted to other land uses (Neely et al. 2006). Black-tailed prairie dogs (BTPD: *Cynomys ludovicianus)* are important drivers of ecosystem function in the shortgrass prairie because their breeding and foraging behaviors alter the landscape and provide areas of shorter vegetation and burrow systems that support increased biodiversity of animals and plants (Cully et al. 2010). BTPD function as a keystone species in shortgrass prairie ecosystems and create important breeding and foraging habitat for grassland birds including burrowing owls (BUOW: *Athene cunicularia*: Klute et al. 2003, Smith and Lomolino 2004). Black-tailed prairie dog populations have declined by 90–98% since 1900 due to sylvatic plague outbreaks, habitat loss and alteration (Miller et al. 1994, Desmond et al. 2000). The burrowing owl is a species of conservation concern in the western US, threatened in Mexico, and endangered in Canada. BUOW are currently listed as a state threatened species in Colorado and are designated as a Tier 1 species of greatest conservation need in Colorado's State Wildlife Action Plan (Colorado Parks and Wildlife 2015). This has prompted the need for an updated population assessment of BUOW nesting in eastern Colorado, where the majority of Colorado's BUOW breed on BTPD colonies.

In this study, we provide an updated status assessment for BUOW on Colorado's eastern plains and seek to expand the current understanding of what BTPD colony attributes have the highest value for burrowing owl occupancy, density, and productivity. We specifically look at how colony size, activity status, and vegetation characteristics influence these population parameters on 180 survey plots throughout eastern Colorado. We surveyed some of the same plots using similar methodology as Tipton et al. (2008, 2009) in their 2005 study, facilitating comparisons 17–18 years later. This 2-year study will provide an updated status assessment of BUOW populations across the BTPD range in Colorado that will help calibrate BUOW population models incorporating prairie dog colony extent and inform future monitoring plans.

We used a BTPD colony shapefile prepared by CPW in 2020 (Colorado Parks and Wildlife 2020) as our sampling frame. This shapefile includes polygons that represent BTPD colonies with digitized

boundaries, created using imagery collected in 2019 by the National Agriculture Imagery Program (NAIP). This imagery was visually analyzed to identify 2,025 km^2 of BTPD colonies across eastern Colorado. We binned colonies from the 2020 shapefile into three sizes: small (≤ 10 ha), medium (11-299 ha), and large (300 ha). Most colonies in the shapefile were categorized as small or medium. The large category contained fewer colonies but accounted for ~35% of the total area covered by BTPD colonies in Colorado. Prairie dog colonies are extremely dynamic and boundaries may have changed since 2019; therefore, we overlaid our potential survey plots on 2021 NAIP imagery to increase the probability that there were still prairie dog burrows on the plot. We surveyed 90 plots per year (180 total), using a spatially balanced sampling design to select potential plots. Plots were 1 km^2 with a transect running through such that the observer was always 250 m away from the plot boundary to ensure that the entirety of the plot is adequately surveyed.

We visited each plot four times, two visits before owlet emergence and two after, between early May and early August. We used a double observer approach to increase the overall detection probability of owls. During each visit, observers walked the transect noting the distance, location, and age (adult or juvenile) of each owl detected. We conducted vegetation surveys to determine if vegetation height or cover influenced BUOW occupancy, abundance, or productivity.

We tested covariates in a model selection framework. Covariates included latitude, BTPD colony size, BTPD activity level, cattle grazing, mean vegetation height of plot, percent cover of grass, forb, shrub, and bare ground, survey time, wind speed, temperature, number of predators seen, and observer team. We estimated occupancy using the static Multistate Occupancy Estimation model (Nichols et al. 2007) in Program MARK (White and Burnham1999) with two states: ‘occupied’ and ‘occupied with successful reproduction’. We estimated density and abundance using a combination of distance sampling and the Huggins closed capture model (Huggins 1989) in Program MARK (White and Burnham 1999). We estimated productivity using a poisson generalized linear model.

Our preliminary occupancy analysis of the 2022 and 2023 field seasons indicates that prairie dog activity level and latitude influence burrowing owl occupancy. Across 2 years we surveyed 180 plots and found that 72% of plots were occupied with burrowing owls and 52% of plots had successful reproduction as evidenced by juvenile presence above ground. We found that 27% of plots were unoccupied by burrowing owls. The probability of a plot being occupied and having successful reproduction was higher ($\psi 2=0.81$, 95% CI [0.66, 0.90]) (Figure 1) than the probability of a plot being occupied regardless of successful reproduction ($\psi 1=0.78$, 95% CI [0.68, 0.86]). Our top model indicated that prairie dog activity level had a significant positive effect on the probability of a plot being occupied and having successful reproduction (Table 1). Southern Colorado had the highest probability of burrowing owl occupancy, compared to central and northern Colorado.

Preliminary distance sampling models estimate that there are 2,173 (95% CI [1,979, 2,368]) adult and 1,488 (95% CI [1,439, 1,538]) juvenile burrowing owls in eastern Colorado. The average density of burrowing owls is D=4.62 adults (95% CI [3.84, 5.39]) and D=4.05 juveniles (95% CI [2.94, 5.15]) per 100 ha. Densities were higher on plots with cattle grazing, active prairie dog colonies, and greater forb cover. Densities were lower on plots with increased shrub cover. Southern Colorado had the highest density of adult and juvenile burrowing owls, and burrowing owl density was positively correlated with BTPD activity level (Figures 2 and 3). BUOW productivity was similar across latitudes and BTPD activity levels.

Preliminary results suggest that more southern portions of Colorado with high BTPD activity levels have higher occupancy rates and densities of BUOW. Colony size and vegetation characteristics except forb and shrub cover were generally not helpful predictors of BUOW population parameters. We expect this project to be completed during 2024.

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Table 1. Beta estimates from the top burrowing owl occupancy model

β parameter	Estimate	SE and 95% CI
Effect of colony activity level on ψ(1)	-0.16	0.29 [-0.72, 0.41]
Effect of colony activity level on ψ(2)	1.16*	0.43 [0.32, 2.01]
Effect of latitude on ψ(1,2)	-0.38*	0.17 [-0.71, -0.046]
Effect of survey year on *p*(1)	1.17	0.69 [-0.17, 2.51]
Effect of survey year on *p*(2)	-0.56	0.016 [-1.31, 0.19]
Effect of temp on δ	-0.067*	0.026 [-1.20, -0.014]
Effect of survey year on δ	-0.94*	0.42 [-1.77, -0.11]

β parameter = effect size of covariate on real parameter estimates. SE = standard error. CI = confidence interval.

Figure 1. Probability of burrowing owl occupancy with successful reproduction. The top model included latitude and BTPD activity level.

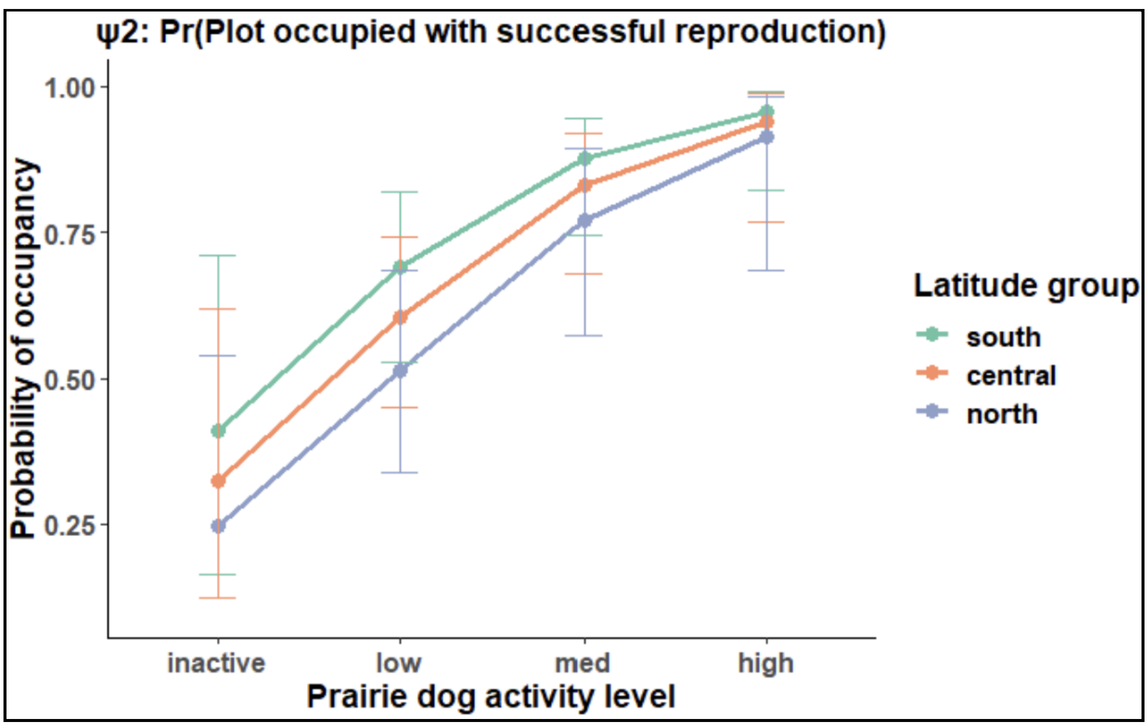


Figure 2. Adult burrowing owl density for each latitude and prairie dog colony activity level. Density was significantly higher in colonies with high prairie dog activity level compared to medium and low activity colonies. Compared to central and northern Colorado, southern Colorado had higher densities of adult owls on low and high activity colonies but similar densities on medium colonies ($p < 0.0001$).

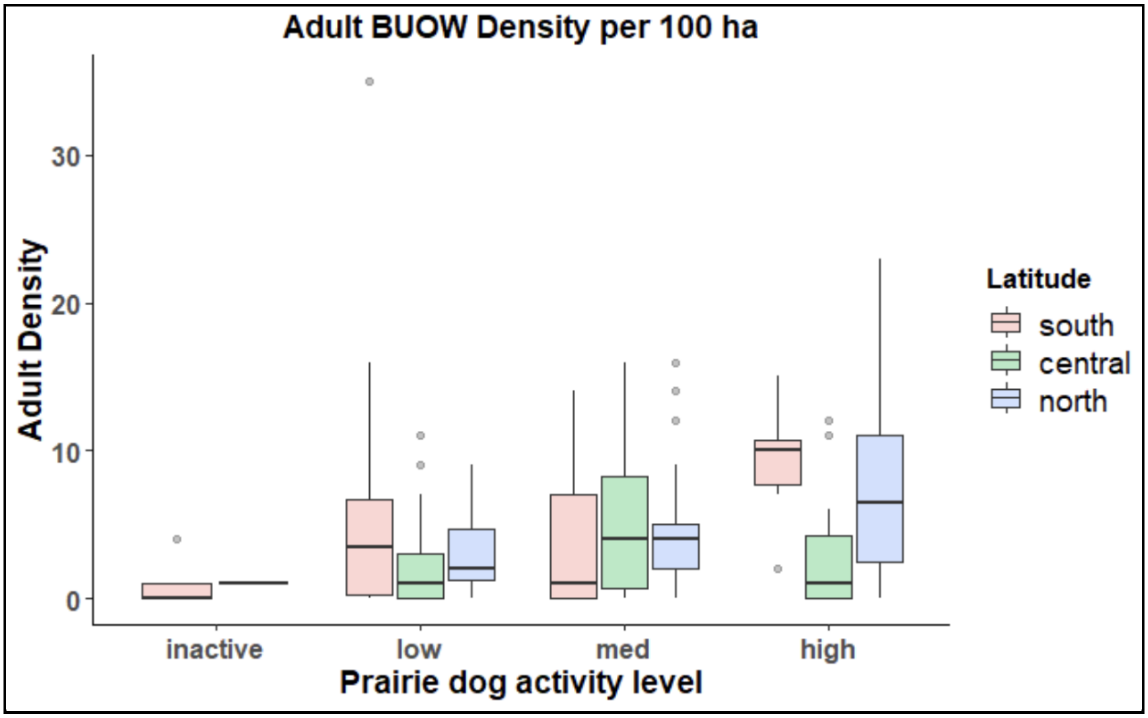
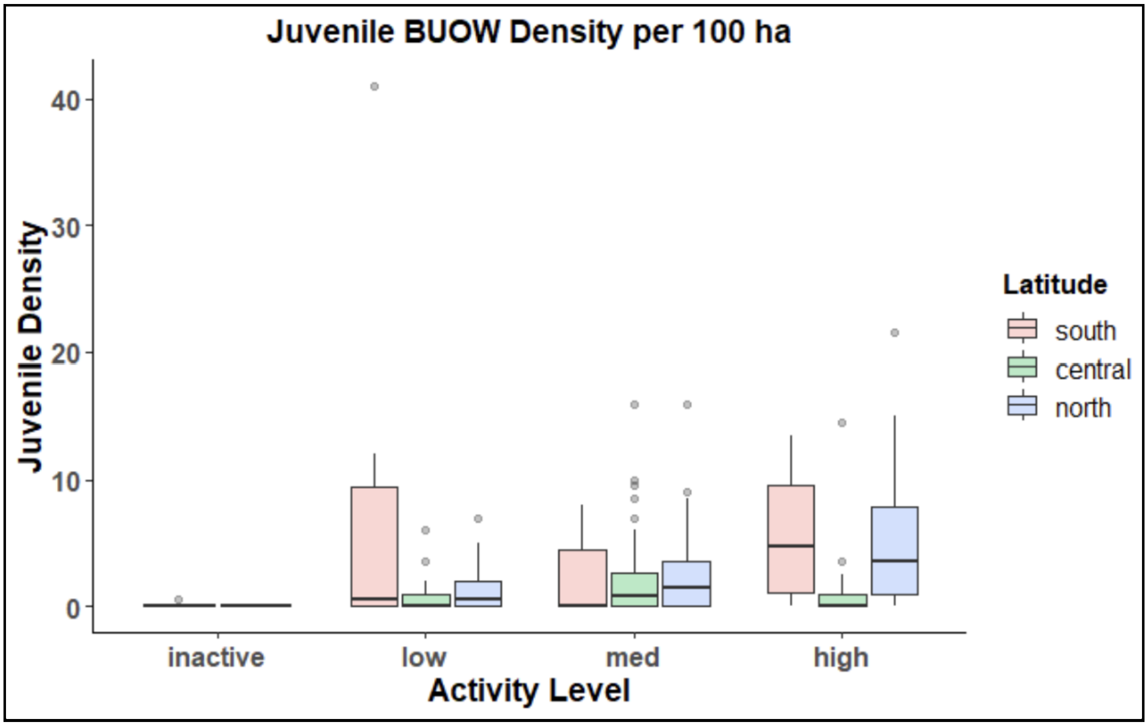


Figure 3: Juvenile burrowing owl density for each latitude and prairie dog colony activity level. Density was significantly higher in colonies with high prairie dog activity level compared to medium and low activity colonies. Compared to central and northern Colorado, southern Colorado had higher densities of juvenile owls on high activity colonies but similar densities on low and medium colonies ($p < 0.0001$). Density was similar across latitudes on low and medium activity colonies.



Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Behavioral and demographic patterns of nesting bald eagles along a gradient of human disturbance on the Front Range corridor in Colorado

Period Covered: January 1 – December 31, 2023

Authors: Reesa Yale Conrey, CPW Avian Researcher reesa.conrey@state.co.us, and Miranda Middleton, Colorado State University

Principle Investigators: Reesa Yale Conrey, Miranda Middleton, Jim Gammonley

Collaborators: Matt Smith, Bruce Snyder, Jean Snyder (Bird Conservancy of the Rockies); Mike Lockhart (Wildlands Photography and Bio-consulting); William Kendal (Colorado Cooperative Fish & Wildlife Research Unit); U.S. Fish and Wildlife Service; Front Range cities and counties; private landowners

CPW staff: Mike Sherman, Lance Carpenter, Rebecca Boyce, Liza Rossi, Robert Sacco, Northeast Region staff from Areas 2, 4, and 5

External funders: Denver Audubon's Lois Webster Fund; U.S. Fish and Wildlife Service Region 6 Migratory Bird Program

EXTENDED ABSTRACT

Urbanization results in habitat loss and fragmentation (Czech et al. 1997), but some generalist species have adapted to urban environments (Rullman & Marzluff 2014). The bald eagle (*Haliaeetus leucocephalus*) is a Tier 2 species of greatest conservation need in the Colorado State Wildlife Action Plan (Colorado Parks and Wildlife 2015), with legal protections from the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act. Historically, bald eagles occurred in northcentral Colorado during migration and winter, but the state was considered to be only a peripheral part of the breeding range (Craig 1979). Following the banning of DDT, bald eagles have recovered from dramatic population declines. Although the number of breeding pairs of bald eagles in the contiguous United States has doubled over the past 10 years (USFWS 2020), there is still concern about the status of local and regional populations and the potential impacts of land use changes on bald eagles. Bald eagles are a high-profile species with strong interest from the public, and along the Colorado Front Range corridor where bald eagles and humans coexist in close proximity, public awareness of bald eagles is high and citizens closely track individual bald eagles and their nests. With a rapidly expanding human population along the Front Range, development and other forms of land use change regularly create concerns about impacts on bald eagles, and Colorado Parks and Wildlife (CPW) is required to provide consultation on land use issues affecting eagle nests.

In recent decades, a relatively high concentration of breeding pairs has become established in the Colorado Front Range (Wickersham 2016), and the number of known occupied bald eagle nests has

increased exponentially (Fig. 1). In Front Range counties, the number of occupied bald eagle nests has risen from one nest in the 1980s to > 130 nests today. Human activity may negatively impact bald eagles at breeding sites or winter roosts (Buehler 2020). CPW and the U.S. Fish and Wildlife Service have recommended disturbance buffer distance and timing restrictions for bald eagle nests and roost sites (U.S. Fish and Wildlife Service 2007, CPW 2020). However, bald eagles exhibit a wide range of tolerance and responses to various human activities and their proximity (Buehler 2020), making it challenging to develop disturbance mitigation recommendations that are both defensible and consistent.

The goal of this study is to better understand current demographics and space use of bald eagles breeding along the northern Front Range, and the impact of human disturbance and changing land use on these measures. We are conducting this project during 2020–2025. Specific objectives include 1) Estimate demographic parameters (breeding effort, nest success, productivity, and adult survival) and trends for bald eagles breeding in the northern Front Range. 2) Examine land use, human activity, and eagle responses to disturbance near nests. 3) Quantify and compare space use (home range, foraging areas, and daily movements) of bald eagles nesting along a gradient from sites with little historical and no new disturbance activity to sites with relatively high historical disturbance levels and significant new disturbance activity during the study.

The study area includes the Front Range corridor of northcentral Colorado in Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, Jefferson, Larimer, and Weld counties. This is an area of rapid human population growth (18% growth from 2000 to 2020) and a relatively high concentration of bald eagles throughout the year. Nests are routinely exposed to varying levels of disturbance and most have been closely monitored for multiple years to determine annual occupancy and success.

In 2023, Bird Conservancy of the Rockies (BCR) continued its Bald Eagle Watch program, where volunteers monitor known bald eagle nests. BCR and CPW have standardized monitoring protocols that provide detailed information to determine nest activity and fate, as well as habitat features and potential disturbance sources. In the northern Front Range during 2023, 132 nests (Fig. 1 and 2) were occupied by breeding pairs (including 19 new nests), 118 nests were initiated (confirmed incubation), and 89 nests produced 160 fledged young (75% apparent nest success). Of successful nests, 36% produced one fledgling, 48% produced two fledglings, and 16% produced three fledglings (mean = 1.80 fledglings per successful nest). Compared to 2022, when Highly Pathogenic Avian Influenza (HPAI) is believed to have contributed to a 20% decline in apparent nest success, 2023 resulted in near normal nest success but fewer fledglings per successful nest. It also appeared that turnover in breeding adults may have led to a lower rate of nest initiation than normal, a hypothesis supported by territory loss of five tagged male eagles. No tagged eagles are known to have died from HPAI since December 2022.

CPW obtained a statewide land use and land cover dataset consisting of five layers which quantified oil and gas development, wind and solar energy development, transmission lines, and residential and commercial development between 1970 and 2020 (Sushinsky 2020) and then incorporated roads (Colorado Department of Transportation) and trails. We have also acquired a human modification layer that combines these and other land use layers into an overall index of human footprint (Theobald *unpub. report*). We mapped known bald eagle nests over the human modification index (Fig. 2) and are currently studying the impact of land use on eagle home range size and resource selection.

We are assessing home ranges, resource selection, and movement with solar-powered transmitters using a GPS/GSM (Global Positioning System/Global System for Mobile Communications) platform, in which the tag's location is determined and recorded everywhere via satellite connections, but data are only transmitted once per day when the bird is in a cell service area. These transmitters are smaller and less expensive than satellite tags. We are altering the fix frequency for each tag based on battery performance, with fix frequencies averaging once per hour to every 30 sec during flight. We are attempting to capture one member per pair of eagles at active nest sites, fitting them with a transmitter using a break-away backpack style X-harness. The harnesses are designed to drop off within 4 – 5 years after marking. The current model has a total weight less than 50 g (1% body mass of an adult male). Blood samples are tested for toxic elements such as lead, and all eagles captured since the HPAI outbreak are being swabbed for HPAI.

As of 26 January 2024, we have tagged 39 bald eagles with 16 tags still deployed and transmitting data (Table 1). We have tagged 29 breeding adults, two nonbreeding adults, one subadult, and seven juveniles, with similar numbers of males and females. Some individuals have died, dropped their tags, had tag failures, or gone missing. The number of tag-days per bird to date averaged 430 days, ranging from 15 days (transmitter failed due to manufacturing defects) to 1124 days as of 26 January 2024 (Table 1). Blood lead tests have been completed for 20 captured eagles. Of these, one was lethal, seven were subclinical (elevated but sublethal), and 12 were normal. We have had 10 mortalities from electrocution (2), vehicle strikes (2), West Nile Virus (1), HPAI (1), lead poisoning (1), and unknown causes (3) among tagged eagles (Table 1). Mean time to death was ~7 months among tagged eagles that died; however, other eagles have lived for 3 years since tagging. Thus far all tagged females have continued to hold their territories, while five males have abandoned or lost their territories due to mate loss (HPAI) or intruder males.

Miranda Middleton has mapped seasonal home ranges for tagged breeding eagles (Fig. 2), with considerable variation among individuals (Fig. 3) and seasons (Fig. 4). Males generally have larger home ranges than females, and home ranges are larger during the pre-nesting and non-nesting seasons than during the incubation, nestling, or post-fledge periods (Fig. 4). Seasonal home ranges mapped thus far have ranged from 0.6 km^2 (female during nestling period) – 708.2 km^2 (male during non-nesting season), with a mean of 21.6 km^2 for females and 67.7 km^2 for males (Fig. 4). Analyses of factors associated with home range size and resource selection are ongoing. These factors include season, sex, nest fate, numbers of nearby eagle nests, land cover, water, prairie dog colonies, and human infrastructure or land use.

It appears that territorial adults that breed in the Front Range are resident year-round. Some territorial adults almost never go farther than 5 km from their nests, even during the nonbreeding season. Some individuals have taken a hiatus (days to weeks) from their home ranges during the post-fledge and non-nesting seasons. In contrast, all nonbreeding eagles have ranged widely and some have made extensive movements of up to 2300 km. It appears that rivers, reservoirs, and prairie dog colonies are used extensively for foraging. We plan to examine these patterns with more formal analyses over the coming years.

We will continue to annually monitor nesting activity and land use patterns at all known nests through the 2025 nesting season. We will continue to monitor the eagles currently tagged, and we will attempt to capture and mark at least five more eagles in 2024. Results will be used to model bald eagle population trajectory and expected impacts of predicted future land use change, and to make recommendations on minimizing and mitigating disturbances near nests. This study will provide a better understanding of this species' tolerance of and adaptability to human activities and land use changes. The results will also improve long-term bald eagle monitoring efforts in Colorado.

Progress and project components completed during 2023:

- Monitored 132 occupied bald eagle nests on the Front Range with multiple visits per site.
- Captured and attached transmitters to 9 more eagles, for total sample size of 39 eagles marked.
- Monitored tags, altering duty cycles as needed to maximize locations while preserving battery life.

- Co-advised graduate student Miranda Middleton, who is analyzing data for her project: bald eagle foraging site selection and home range size in an urbanizing landscape.
- Coordinated with many partners, volunteers, landowners, and others to access nest sites and provide information and training about bald eagles. Prepared eagle data summaries for partners, gave presentations to three groups, and met with a Colorado Outdoors author for an upcoming article.

Plans for 2024:

- Monitor all occupied bald eagle nests on the Front Range at least every two weeks.
- Deploy tags on five or more eagles, redeploying recovered tags and completing most of the trapping phase of this project.
- Continue to evaluate movement data and space use by transmittered birds.
- Continue to process current and historical data on bald eagle nests, including human activity and potential disturbances near nests.
- M. Middleton will finish her M.S. thesis.
- Continue coordination and information sharing with partners.

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Table 1. Sample size and number of tag-days for bald eagles tagged in the Front Range of Colorado as of 26 January 2024. Tagged eagles may continue to transmit data, be recovered as mortalities, drop tags or wear failed tags, or go missing (lost outside cellular service areas).

	Sample Size of Tagged Eagles					Days with Tag		
	Transmit	Mortality	Drop/Fail	Missing	TOTAL	Min	Mean	Max
Breeding Adults								
Females	5	3	6	1	15	15	371	1124
Males	7*	5	2		14	55	510	963
Nonbreeding Adults								
Females	0	0	0	1	1	934	934	934
Males	1**	0	0	1	2	130	463	796
Juveniles***								
Females	1	2	0		3	80	293	584
Males	2	0	0	2	4	35	333	922
TOTAL	16	10	8	5	39	15	430	1124

*Five males were tagged as breeding adults but have since left or lost territories, with tags still transmitting. They are considered breeding adults prior to territory loss and nonbreeding adults after territory loss, but are enumerated here as breeding males. **One nonbreeding male was tagged as a subadult but is now an adult. ***Birds tagged as fledged juveniles transition to subadults after their hatch year, but are enumerated here as juveniles.

Figure 1. Number of observed occupied bald eagle nests, 1975–2023, in Colorado. These were nest observations reported to the CPW statewide raptor nest database, so some changes may reflect differences in effort or reporting over time.

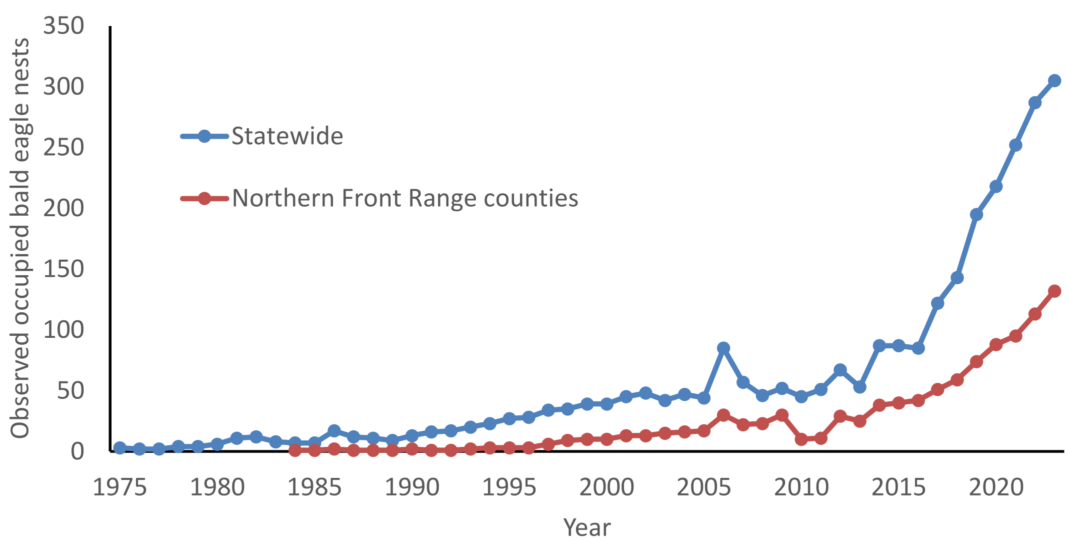


Figure 2. Home ranges for tagged breeding eagles in the Front Range of Colorado overlaid on a human modification layer developed by Theobald (unpublished report). These are composite home ranges, based on the total extent of merged seasonal home ranges for each eagle: pre-nesting, incubation, nestling, post-fledge, and non-nesting. Foraging areas (water and prairie dog colonies) are cross-hatched.

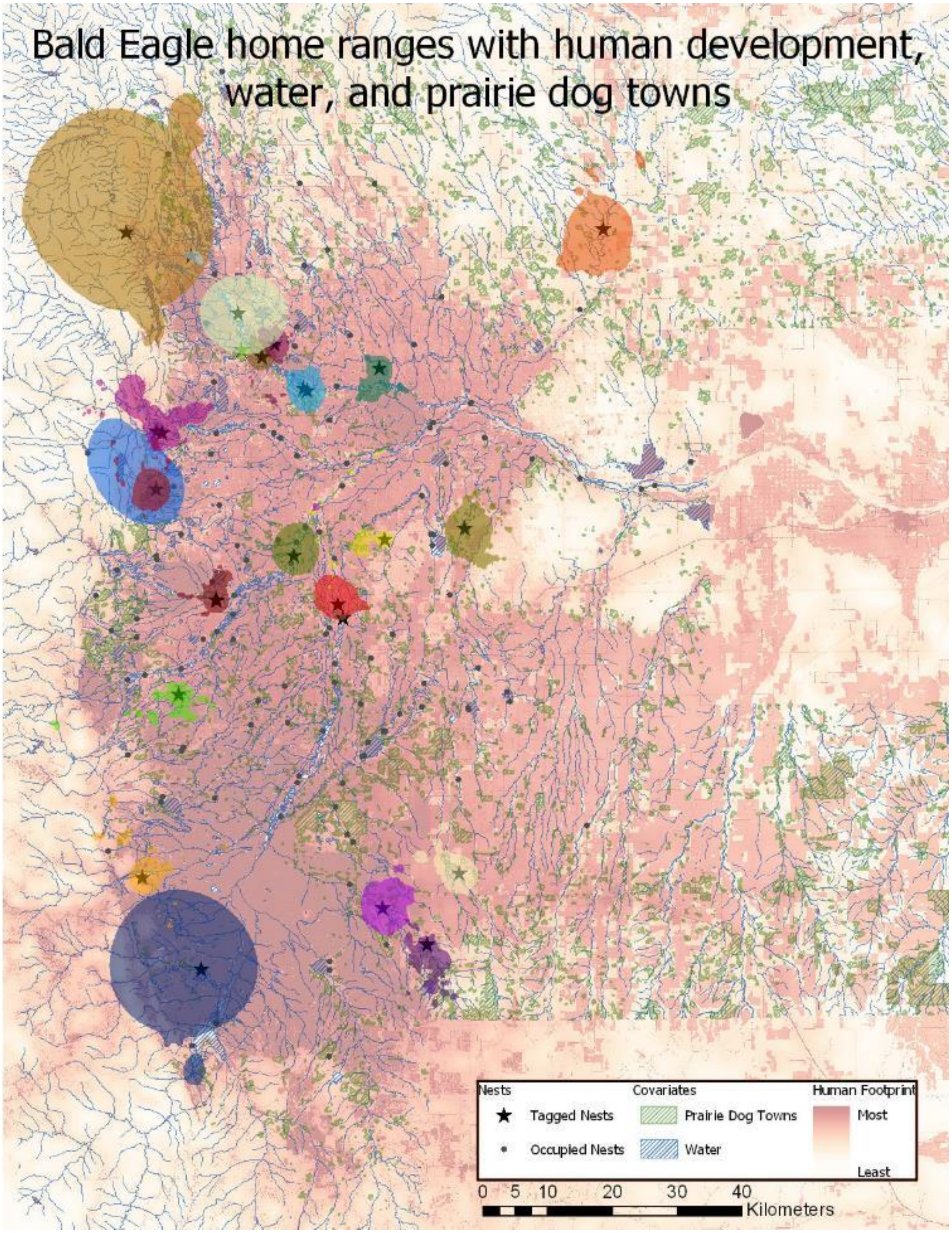


Figure 3. Example of seasonal home ranges for two adult male breeding bald eagles during the nestling period of 2023 in the Colorado Front Range. Both nests were eventually successful. Home ranges are relatively small during the nestling period. Below left: one of the most rural male home ranges in our sample, with ~8 people per mile^2. Below right: the most urban home range in our sample, with ~8600 people per mile^2. The highest use areas are shown in turquoise (see also 400 m and 800 m nest buffers), with lower use areas shading from purple to pink. Water, prairie dog colonies, and other nearby bald eagle nests are also shown, as they are predicted to influence home range size and resource selection.

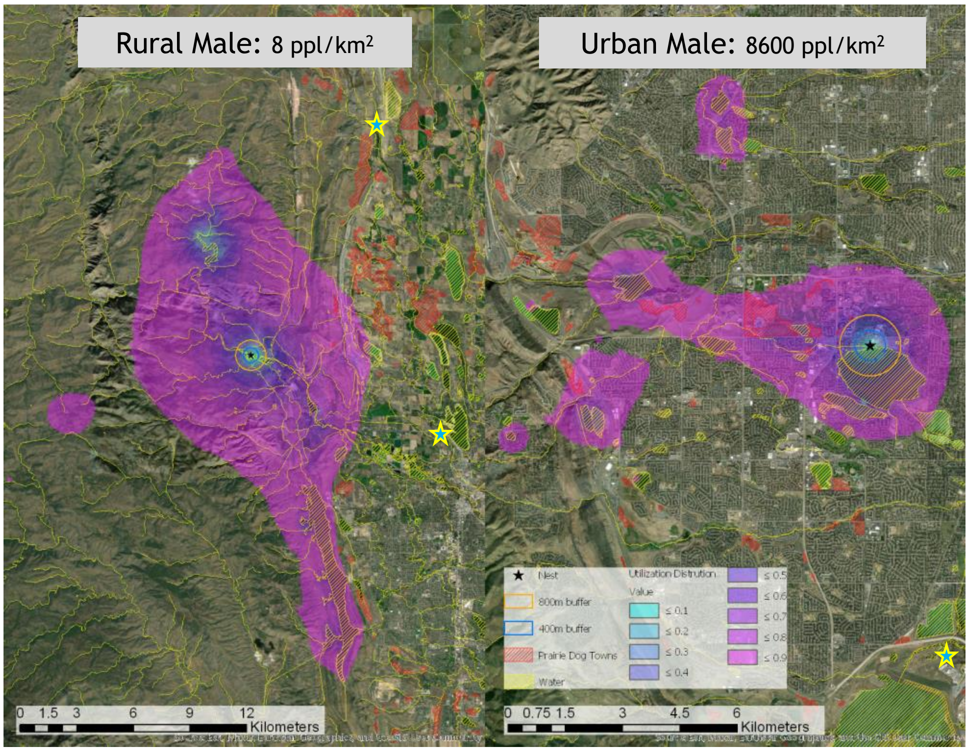
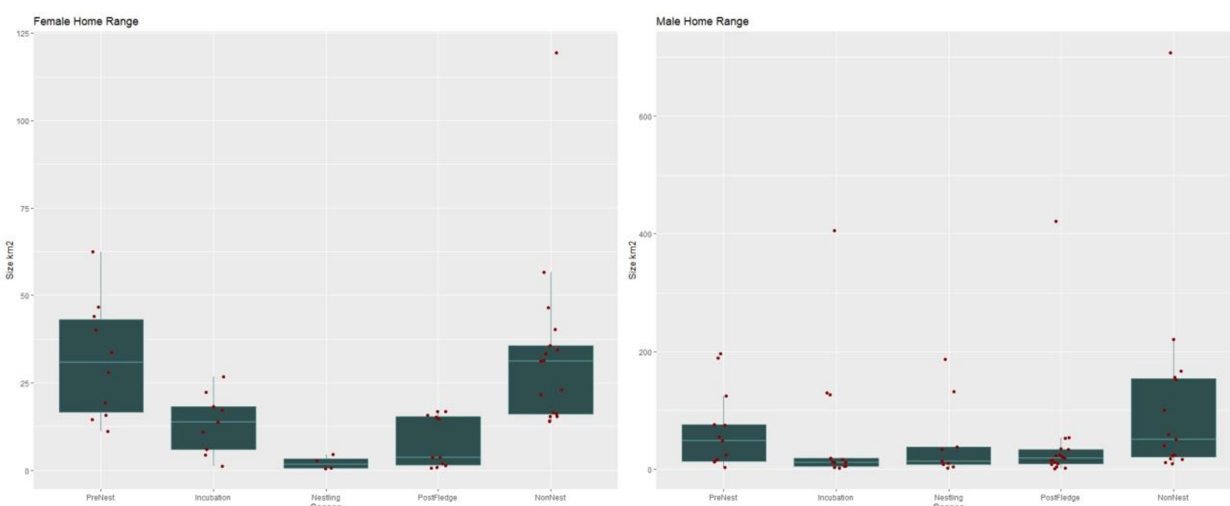


Figure 4. Seasonal home range sizes for adult breeding bald eagles tagged in the Colorado Front Range. Note the difference in scale: on average, males have larger home ranges and more variation in home range size than females. Home ranges were largest during the pre-nesting and non-nesting seasons.



Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Resolving the breeding status and taxonomic identity of Brewer's Sparrows (*Spizella breweri*) in high-elevation, alpine habitats near treeline in Colorado

Period Covered: January 1 – December 31, 2022

Author and Principal Investigator: Brett L. Walker, CPW Avian Researcher, brett.walker@state.co.us

Project Collaborators: Liza Rossi

EXTENDED ABSTRACT

Discoveries of previously unknown breeding populations continue to expand our knowledge of the distribution, ecology, and conservation status of migratory songbirds. The Brewer's Sparrow (*Spizella breweri*), a small, migratory songbird, has experienced long-term breeding population declines in Colorado (-2.06%/yr) and is currently a Tier 2 priority species in our State Wildlife Action Plan. The only subspecies known to breed in Colorado, the sagebrush Brewer's Sparrow (*S. b. breweri*), is considered a "sagebrush obligate". Since the early 1900s, Colorado has had numerous summer records of Brewer's Sparrows in alpine willow and conifer krummholz habitats near treeline, but the taxonomic identity and breeding status of these birds was unclear. A less well-known subspecies, the "Timberline" Brewer's Sparrow (*S. b. taverneri*), nests in stunted shrubs and krummholz near treeline in the Canadian Rockies, but their closest known breeding populations are in northwestern Montana. We identified several possible explanations for the occurrence of Brewer's Sparrows in alpine areas of Colorado in summer. Birds could be: (1) previously unknown populations of *taverneri* nesting in typical habitat, (2) *breweri* nesting in atypical habitat (2a) that interbreed with populations in sagebrush, (2b) that do not interbreed with populations in sagebrush but have not yet diverged, or (2c) that first nest in sagebrush then move upslope to renest in alpine willow/krummholz [i.e., itinerant breeders], (3) hybrids and backcrosses in a zone of introgression between *breweri* and *taverneri*, (4) a third, undiscovered subspecies, or (5) non-breeding birds (e.g., post-breeding, dispersing *breweri*, *taverneri* at molt-migration stopovers, summering transient *breweri* or *taverneri*). Objectives of this project were to determine the taxonomic identity and breeding status of alpine Brewer's Sparrows in Colorado.

We first compiled historical observations using data from the Rocky Mountain Bird Observatory (1999-2005), Bird Conservancy of the Rockies (2008-2020), eBird (1995-2020), and VertNet (1903-1995), along with reports from birders and U.S. Forest Service biologists. We identified 186 historic observations of Brewer's Sparrows at 59 alpine sites (3309–4288 m) in June-July from 1914–2022 (Fig. 1). We surveyed 24 mid-elevation sagebrush sites (1,746–3,042 m) and 22 high-elevation alpine willow/conifer krummholz sites (3,267–3,764 m) in May-July 2021–2023 (Fig. 2). When Brewer's Sparrows were present, we documented locations of territorial males, evidence of breeding, recorded males' songs, collected habitat data, and captured birds to collect morphometric data and blood and feather samples for genetic analyses. Volunteers and birders surveyed 21 alpine sites and 5 subalpine sites. We detected Brewer's Sparrows at 14 alpine sites and volunteers and birders detected them at 15 alpine sites (including some also surveyed by CPW). Combined, we detected 100 adult Brewer's

Sparrows at 25 alpine sites and 16 males at 5 subalpine sites (Fig. 2). We confirmed breeding at three alpine sites and considered breeding probable at an additional 13 alpine sites and 1 subalpine site. Territorial males at alpine sites were detected in large patches of diamondleaf willow (*Salix planifolia*), shortfruit willow (*S. brachycarpa*), and grayleaf willow (*S. glauca*) averaging 0.9-1.8 m tall mixed with sparse Englemann spruce (*Picea englemanni*) or subalpine fir (*Abies lasiocarpa*) krummholz averaging 1.3-5.0 m tall surrounded by tundra on drier slopes, ridges, and plateaus (Fig. 3).

Although breeding habitat and timing of breeding of alpine birds in Colorado closely matched those of *taverneri*, the acoustic structure of songs, morphology, plumage, and mitochondrial and genomic DNA overlapped between alpine and sagebrush birds and closely matched those of range-wide *breweri*. This indicates that alpine birds are *breweri* breeding in atypical habitat, but additional field data are needed to determine whether alpine birds are itinerant breeders. We ruled out non-breeding explanations based on confirmation of breeding and the absence of prebasic flight feather molt among captured birds.

Confirmation of Brewer's Sparrows at multiple alpine sites across the state, the large number of historic observations, and the relative inaccessibility of most alpine willow and krummholz treeline habitat in Colorado in June when Brewer's Sparrows are most detectable suggest that Brewer's Sparrows are likely much more widely distributed in alpine willow-krummholz in Colorado than is currently known. Additional surveys and habitat suitability modeling are needed to refine our knowledge their statewide breeding distribution and estimate their abundance in alpine areas. The presence of Brewer's Sparrows in alpine areas throughout the state expands the species' known breeding distribution and breeding habitat associations in Colorado. Distribution and habitat information will need to be updated in CPW's conservation assessment and species' status assessment in the State Wildlife Action Plan and in U. S. Forest Service management plans. Our results also complicate interpretation of differences in timing of breeding and breeding habitat as supporting criteria for subspecific identification and taxonomic delineation in this species.

Publications:
Walker, B. L., A. A. Yappert, C. L. Brennan, C. M. Bossu, and A. W. Jones. In review. Field surveys and sampling guided by citizen science and monitoring data reveal a novel alpine breeding distribution and vegetation associations of a declining, habitat-specialist songbird in Colorado, USA. Avian Conservation and Ecology.

Walker, B. L. 2024. In press. Applying citizen science data to quantify differences in song between controversial avian taxa, the sagebrush and timberline subspecies of the Brewer's Sparrow (*Spizella breweri*). Western North American Naturalist.

Figure 1. Historic records of Brewer's Sparrow (*Spizella breweri*) at alpine and subalpine sites in western Colorado from 1 June-31 July, 1914–2022. See Appendix S2: Table S1 for location details.

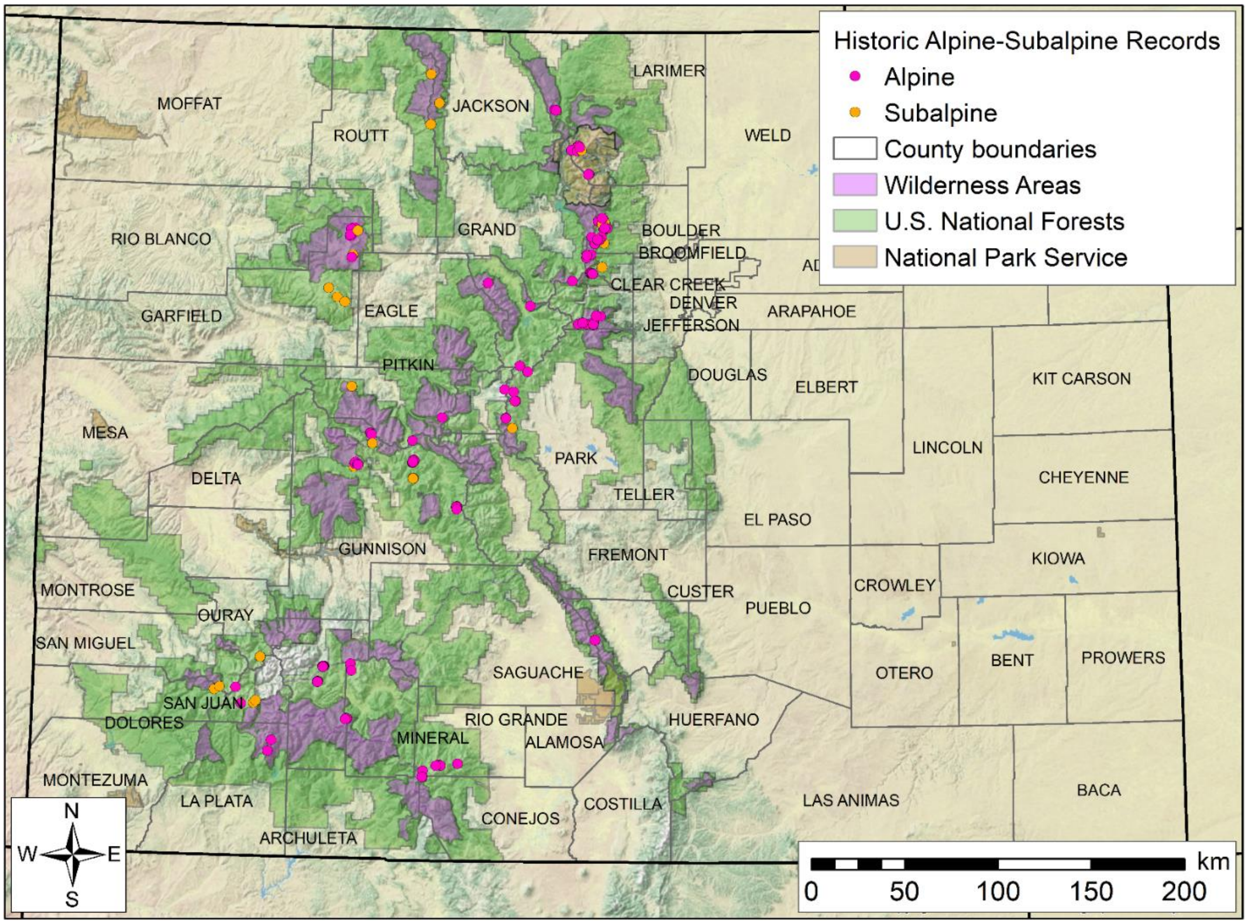


Figure 2. Results of Brewer's Sparrow surveys at alpine and sagebrush sites by Colorado Parks and Wildlife (CPW) and at additional sagebrush, subalpine, and alpine sites by volunteers and birders in western Colorado in May-July, 2021–2023.

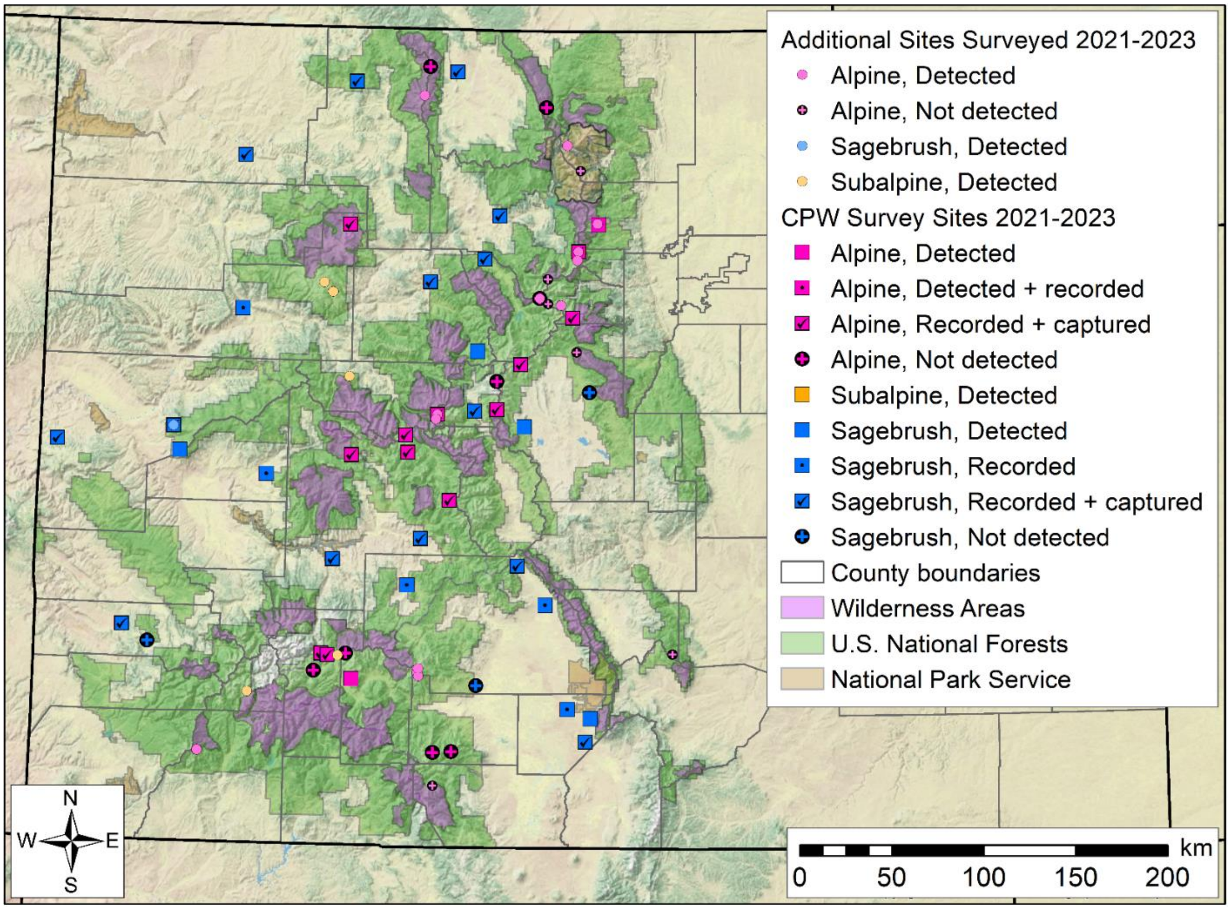


Figure 3. Examples of typical vegetation structure, species composition, and topography at alpine sites where Brewer's Sparrows were detected in western Colorado, including: (A) Devil's Causeway, (B) Scarp Ridge, (C) Independence Pass, (D) Taylor Pass, (E) Guanella Pass, and (F) Jarosa Mesa. Birds were typically found in patches of willows or willows mixed with sparse conifer krummholz in relatively dry soil on ridges, slopes, and plateaus.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Using seasonal and dispersal movements of greater sage-grouse to inform management for connectivity

Period Covered: January 1 – December 31, 2022

Author and Principal Investigator: Brett L. Walker, CPW Avian Researcher, brett.walker@state.co.us

Project Collaborators: Brian Holmes, Liza Rossi, Michelle Cowardin, Nick Jaffe (CPW)

EXTENDED ABSTRACT

Wildlife often undertake long-distance movements, most commonly when migrating between seasonal ranges, when dispersing as juveniles or post-breeding adults, and when dispersing between populations. Conserving and managing habitat within movement corridors is critical for maintaining connectivity between seasonal habitats within populations, maintaining demographic and genetic connectivity between populations, and ensuring the long-term persistence of local and regional populations. Loss of connectivity is often a problem for small, isolated, peripheral subpopulations at risk of low effective population size, loss of genetic diversity and adaptive potential, and increased inbreeding. Translocations from larger populations can prevent demographic and genetic problems caused by loss of connectivity, but proactive efforts to manage habitat in movement corridors between core and peripheral populations may be a more effective long-term conservation strategy. We are investigating habitat use and selection by greater sage-grouse during long-distance seasonal and dispersal movements to inform efforts to maintain connectivity among populations at the southern edge of the species' range. There are numerous unresolved questions about how greater sage-grouse make such movements in terms of timing, distance, stopovers, movement strategies, the influence of landscape context and topography on movement, and habitat use and selection during movements. Such information will be valuable for assess current linkage zones and informing management, conservation, and restoration within those areas. We are using existing GPS telemetry data from greater sage-grouse management and research projects across Colorado to conduct this investigation. We have compiled telemetry data from all CPW projects planning to contribute data, and are working on code to analyze movements, habitat use, and habitat selection.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Efficacy of using herbicide to control cheatgrass as a habitat management tool to improve northern bobwhite habitat

Period Covered: January 1 – December 31, 2023

Author and Principal Investigator: Adam C. Behney, CPW Avian Researcher
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Project Personnel: Trent Verquer, Levi Kokes (CPW)

EXTENDED ABSTRACT

Cheatgrass is an exotic, annual grass that rapidly invades areas after a disturbance and outcompetes native plants. Areas that have been invaded by cheatgrass offer little heterogeneity in vegetation structure or species composition (Knapp 1996), which many animals rely on to satisfy their various resource needs. Northern bobwhites are a species of conservation concern and rely on heterogeneity in vegetation structure for various life-stages. Areas with abundant forbs and bare ground are necessary to support abundant invertebrates, which chicks eat, and allow chicks to move through the vegetation easily while foraging. Cheatgrass can outcompete native forbs, reducing the value of these areas to bobwhites, especially broods. Using a randomized block design, we evaluated the herbicide indaziflam as a treatment to reduce cheatgrass cover at Tamarack State Wildlife Area in northeastern Colorado (Figure 1). We sampled vegetation before and after treatment as well monitored northern bobwhite movements, survival, and habitat selection in relation to the herbicide treatments. The specific objectives of this project are to:

1. Assess the effect of indaziflam treatments on vegetation characteristics thought to be important for bobwhite brood habitat selection related to horizontal and vertical structure and plant species diversity.
2. Assess habitat selection of bobwhites during brood-rearing, nesting, and nonbreeding seasons in relation to indaziflam treatments and general vegetation characteristics.
3. Estimate survival of bobwhite chicks and assess effect of indaziflam treatments on survival.

We successfully treated all treatment plots on schedule in summer 2022 and 2023. We attempted to capture northern bobwhites in Feb-Apr, 2023, but were unsuccessful. The winter of 2022-2023 was severe and presumably, reduced the quail population at the study area, which is consistent with our observations of not seeing any quail during the trapping period. We trapped again in Sep-Oct, 2023, catching and deploying transmitters on nine quail in two coveys.

We conducted a total of 172 vegetation samples during three sampling occasions (summer 2022, early summer 2023, late summer 2023) at random points within each treatment and control plots to evaluate the vegetation response to treatments. Indaziflam treatment appeared to be effective at reducing cheatgrass

abundance (Figure 2). Treated plots tended to have somewhat greater forb and native bunchgrass abundance than untreated control plots (Figures 3 and 4).

We sampled vegetation at covey and associated random locations, weekly, from October–present (mid-December) for a total of 76 samples. Bobwhite locations tended to have less cheatgrass, less bunchgrass, and similar amounts of forbs compared with random available locations (Table 1). Three of 17 locations were in a treated plot, the rest were in control plots or not in research plots.As of mid-December, 2023, one bobwhite had died due to predation, and eight were alive.

Field work for this project will continue until September 2024. We will trap from Feb-Apr, 2024 and monitor marked quail throughout the summer nesting season.

LITERATURE CITED

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Table 1. Mean (SD) percent cover of cheatgrass, forbs, and native bunchgrasses at northern bobwhite used locations and random available locations during fall 2023.

Location type	Percent cheatgrass	Percent forbs	Percent bunchgrass
Used	0.07 (0.15)	0.24 (0.18)	0.09 (0.18)
Available	0.11 (0.18)	0.25 (0.23)	0.16 (0.21)

Figure 1. Experimental design of study to evaluate effect of indaziflam herbicide on northern bobwhites at Tamarack State Wildlife Area. Year one treatments were treated in summer 2022 and year two treatments were treated in summer 2023.

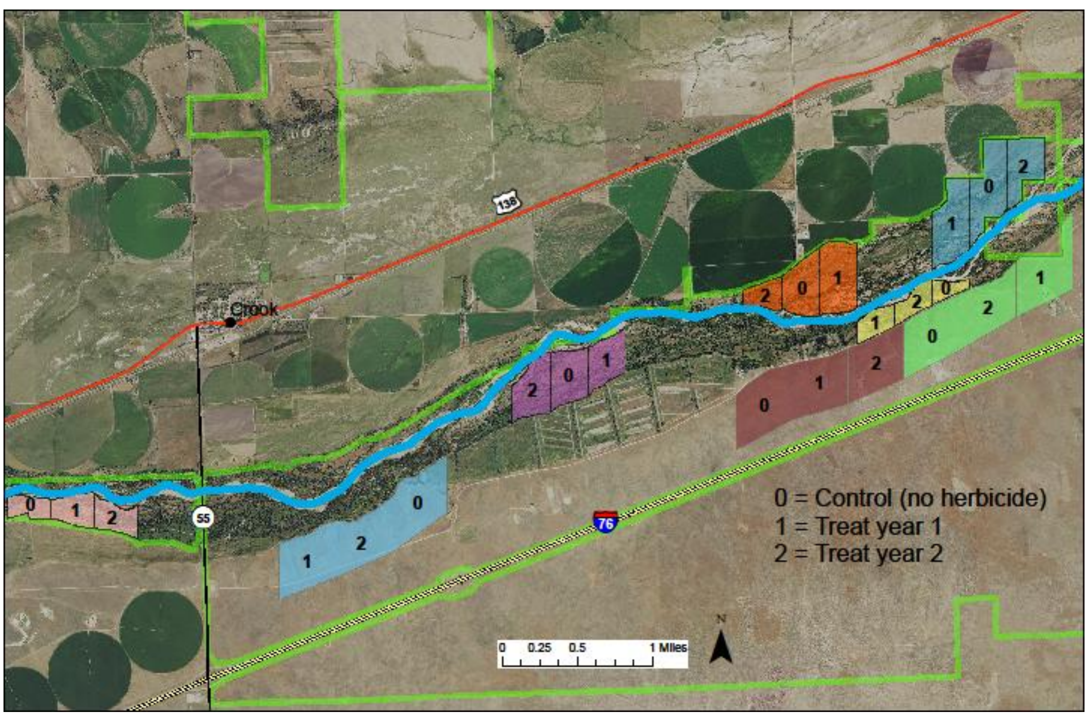


Figure 2. Cheatgrass percent cover from pooled control and treatment plots during two sampling occasions in 2023. Treatment plots included in this figure were treated in summer 2022 with indaziflam.

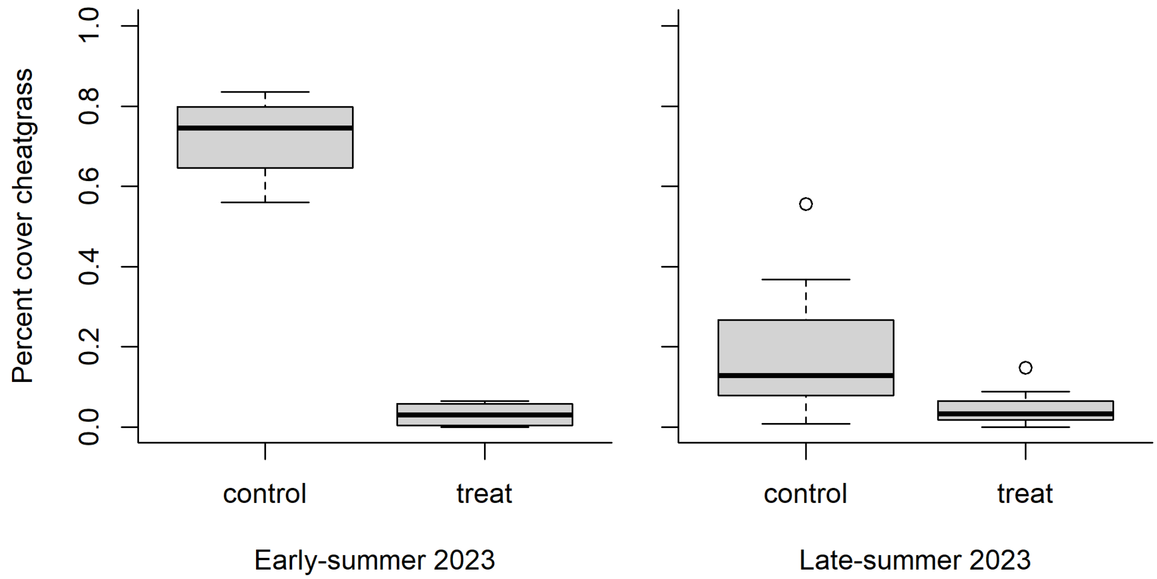


Figure 3. Forb percent cover from pooled control and treatment plots during two sampling occasions in 2023. Treatment plots included in this figure were treated in summer 2022 with indaziflam.

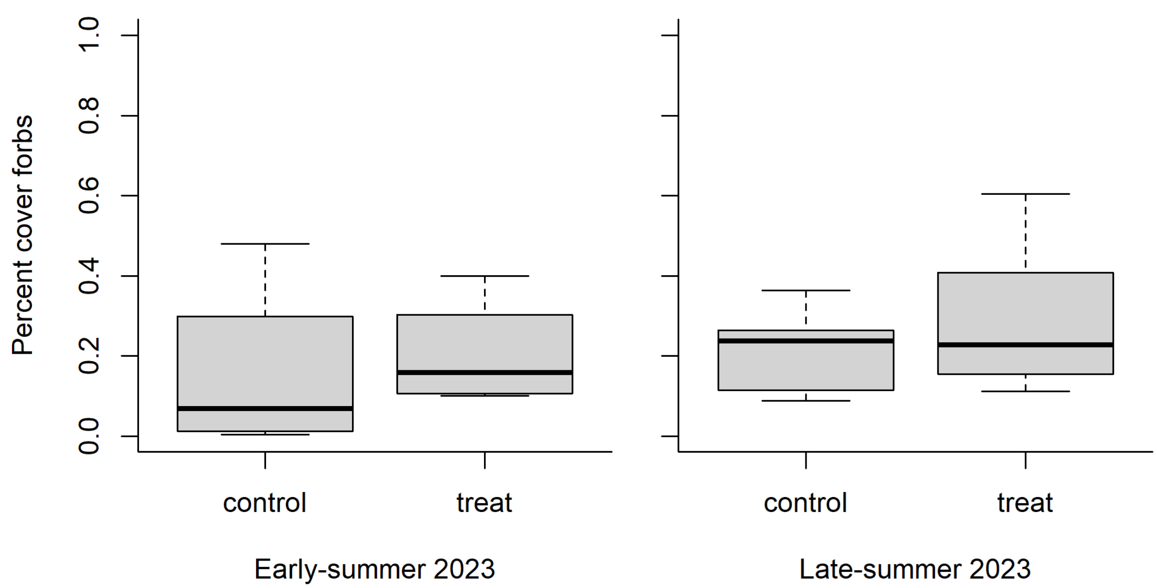
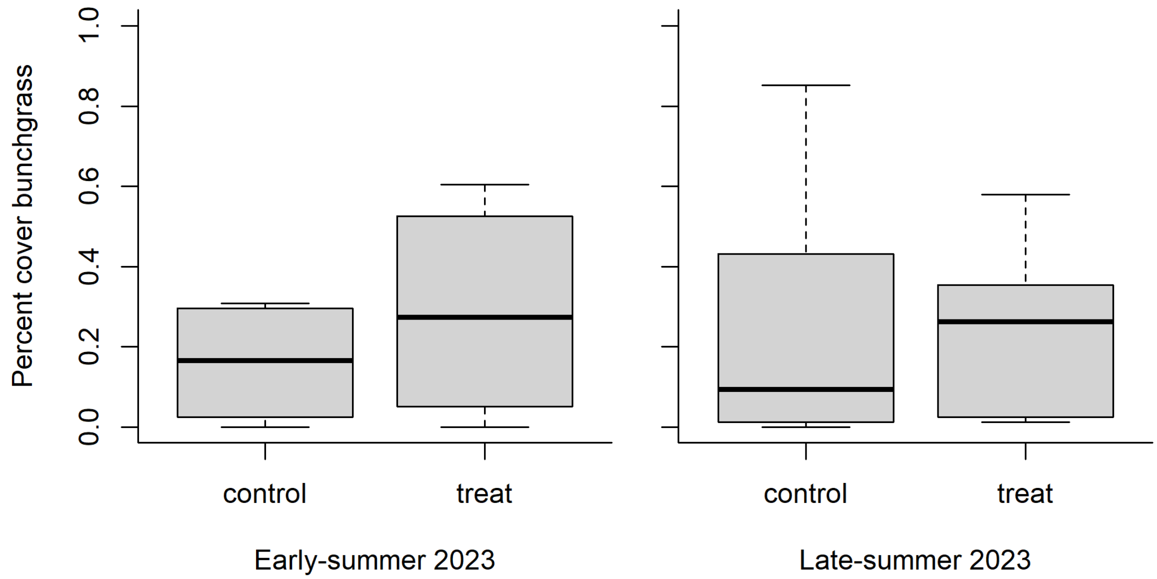


Figure 4. Native bunchgrass percent cover from pooled control and treatment plots during two sampling occasions in 2023. Treatment plots included in this figure were treated in summer 2022 with indaziflam.



Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Estimates and determinants of duck production in North Park, Colorado

Period Covered: 1 January 2023 – 31 December 2023

Authors and Principal Investigators: Adam C. Behney, CPW Avian Researcher, adam.behney@state.co.us; James H. Gammonley, CPW Avian Research Leader; Casey M. Setash, Colorado State University and CPW Avian Researcher

EXTENDED ABSTRACT

Assessing waterfowl use and productivity throughout the Intermountain West can inform habitat management practices across various land use regimes. The North Platte River Basin (hereafter, North Park) in north central Colorado has historically held important breeding and stopover habitat for ducks and is expected to become increasingly important as water demands increase across the state. In 2018, we began a study to examine duck breeding populations and production in North Park, in relation to wetland habitat conditions. Specific study objectives include:

1) Use satellite imagery and annual measures of hydrology, salinity, and vegetation composition and structure on a representative sample of wetlands to quantify wetland habitat conditions annually.
2) Use breeding pair counts, adjusted for detection probability, on a sample of wetlands to estimate overall breeding populations of ducks annually.
3) Assess nest site selection and nest survival for nests located on private and public land to estimate habitat effects on reproductive success.
4) Use brood counts, adjusted for detection probability, on a sample of wetlands to estimate duck production annually.
5) Use annual pre-season capture and banding of ducks to estimate annual survival rates, fidelity rates, harvest rates, and harvest distribution.

Breeding Pair Abundance

At five large reservoirs (Walden Reservoir, Cowdrey Reservoir, Lake John, Muskrat Reservoir, and 18 Island Reservoir), we counted ducks weekly to track patterns of abundance in North Park through the end of the spring migration period. Observers drove around the site and counted the number of each species of duck present.

We conducted duck pair counts on basin wetlands, reservoirs, and sections of ditches and riparian areas across public and private land in North Park. The methods we used for each count depended on the type of site. On riparian areas and ditches, we conducted independent double observer surveys to estimate detection probability. We randomly selected 500-m sections of riparian corridors along the primary river channel or ditch running through Arapahoe NWR and private lands. Two observers conducted each survey, walking on opposite river banks and feigning data-taking behaviors to maintain independence. Following completion of the survey, observers compared notes and determined if any ducks were missed by either observer which was used to estimate detection probability. For all detections, observers noted the social status of ducks (paired, lone male, etc.).

We found that the frequent movement of ducks within basin wetlands and reservoirs impeded the mapping process necessary to conduct independent double observer pair counts. Therefore, we conducted dependent double observer surveys (Nichols et al. 2000) on basin wetlands with two observers, one primary and one secondary. The primary observer scanned through the site noting the species and social status of each duck seen. The secondary observer recorded data but also scanned the site and made note of any ducks missed by the primary observer. With this system, the secondary observer sees all the ducks seen by the primary observer plus any missed by the primary observer.

We used the hierarchical multinomial-Poisson mixture model developed by Shirley et al. (2012) in a Bayesian framework to jointly estimate detection probability and duck abundance for dependent double observer pair counts. We modeled counts $y1_i$ (primary observer) and $y2_i$ (counted by secondary observer only) during survey *i* as Poisson variables, where the mean (μ_i) was equal to the product of latent abundance (λ_i) and the detection probabilities for each encounter history:

$$y1_i \sim \text{Poisson}(\mu1_i)$$
$$y2_i \sim \text{Poisson}(\mu2_i)$$

$$\mu1_i = \lambda_i * p1_i$$
$$\mu2_i = \lambda_i * (1-p1_i) * p2_i$$

where $p1_i$ and $p2_i$ were detection probabilities for the primary and secondary observer, respectively, during survey *i*. Detection probabilities were allowed to vary among people serving as primary and secondary observers.

For riparian sites where independent double observer surveys were used, within the same overall model, we estimated abundance and detection using another parameterization of the hierarchical multinomial-Poisson model (Kery and Royle 2016, Christianson and Winnie 2023). In this model, count $y1_i$, $y2_i$, and $y3_i$ represent the number of individuals detected by observer 1 only, observer 2 only, and both observers, respectively. Counts were modeled as a Poisson distribution with means (μ_i) as the product of true abundance during the survey (λ_i) and multinomial cell probabilities for each encounter history:

$$\mu1_i = \lambda_i * p1_i * (1 - p2_i)$$
$$\mu2_i = \lambda_i * (1-p1_i) * p2_i$$
$$\mu3i = \lambda_i * p1_i * p2_i$$

Again, $p1_i$ and $p2_i$ were allowed to vary by the person serving as each observer.

For both survey types, we allowed λ_i to vary among sites and with vegetation and hydrology characteristics during each survey:

$$\log(\lambda_i) = \mathbf{X\beta}$$

Where $\mathbf{X\beta}$ was a matrix of survey-specific covariates and a vector of coefficients. We included the following covariates for abundance: percentage of the surveyed wetland that was made up of open water, herbaceous emergent vegetation, robust emergent vegetation (e.g., bulrush and cattails), and shrub-scrub vegetation (e.g., willows, greasewood, etc.). None of these variables were correlated (max $|r| = 0.36$). We considered covariates important if their coefficient's 90% credible interval excluded zero. We calculated total indicated breeding pairs (hereafter IBP) for each site as a derived quantity in the model by extracting the maximum estimated abundance among the repeated surveys at each site.

We conducted 262 dependent double observer surveys on basin wetlands in 2023. Out of 3,469 duck detections during these surveys, 106 were missed by the primary observer. Detection probability varied among observers and ranged from 0.91 to 0.99. We conducted 24 independent double observer surveys on riparian areas, irrigation ditches, and hay fields. Out of 46 duck detections, 4 were missed by an observer. Detection probability varied among observers for independent double observer surveys and ranged from 0.50 to 0.97. We conducted breeding duck pair surveys at 84 sites in 2023.

Site maximum pair abundance for all species combined varied from 0 to 119 pairs and was positively influenced by the percent of the site classified as herbaceous emergent vegetation (β = 0.06, SE = 0.03) and robust emergent vegetation (β = 0.21, SE = 0.03). Gadwall were the most abundant species detected (n = 707), followed by mallards (n = 404), lesser scaup (n = 389), green-winged teal (n = 366), northern shoveler (n = 326), and ruddy ducks (n = 302). Overall we counted 16 species of ducks.

At 5 large reservoirs, we conducted 4 rounds of duck pair counts between 2-May and 29-Jun. Duck abundance decreased throughout the survey period (Figure 1). By the third round of sampling, pair counts for most species had declined and then remained somewhat steady or increased in the fourth count.

Nest Monitoring

We searched nest plots in flood-irrigated hay meadows on private and public land throughout the breeding season. Some of these plots were associated with restoration projects being conducted by Ducks Unlimited from 2019-2022. We therefore located nests associated with flood irrigation to evaluate the importance or impact of flood irrigation on nesting waterfowl.

We searched 1,141 ha for duck nests in 2023. We located 61 nests of seven species throughout the 2023 breeding season. Using all 191 dabbling duck nests located in North Park since the start of the study in 2018, nest density adjusted for nests that failed before being located was 0.06 nests/ha (SD = 0.03) in shrub-scrub habitat, 0.23 (SD = 0.09) in riparian, 0.12 (SD = 0.06) in hay meadows, 0.10 (SD = 0.02) in graminoid meadows interspersed with shrubs, 0.11 (SD = 0.03) in strictly graminoid meadows, and 0.22 (SD = 0.06) along irrigation ditches. The probability that a nest plot contained zero nests was 0.38. All but five of the nests located in 2023 (91.8%) were on Arapahoe NWR, with the others located on BLM land. Twenty-eight monitored nests successfully hatched at least one duckling in 2023, and most nests failed due to depredation (n = 22). The most parsimonious model of nest survival included a categorical predictor for whether the nest was on public or private land. Estimates of daily nest survival rate from the public/private model were 0.93 (SD = 0.04) on public land and 0.95 (SD = 0.02) on private land, which translate to 33-day nest survival rates of 0.14 (SD = 0.11) on public land and 0.20 (SD = 0.09) on private land.

Brood Abundance and Production

For counting broods, we used independent double observer surveys. Two observers in separate vehicles counted all ducklings by species and age at each site. At the end of the surveys, they compared notes and noted any ducklings missed by either observer. Brood counts were all conducted as independent double observer surveys and we estimated detection probability and abundance as described above for independent double observer pair surveys (Kery and Royle 2016, Christianson and Winnie 2023). Similar to pair counts, we extracted the overall number of broods per site as the maximum estimated number of broods among the repeated surveys at each site. Then as a derived quantity, we divided total brood abundance by total pair abundance (brood:pair ratio) at each site as an estimate of site productivity.

We conducted 177 independent double observer and three single observer surveys for broods. Out of 792 brood detections, 428 were missed by an observer. Brood detection varied by observer from 0.44 to 0.61.

Site maximum brood abundance for all species combined varied from 0 to 120 and was positively influenced by percent of site that was flooded (β = 0.45, SE = 0.15), percent of site containing robust emergent vegetation (β = 1.11, SE = 0.18), percent shrub cover (β = 0.35, SE = 0.16), and percent of site containing submersed aquatic vegetation (β = 0.61, SE = 0.21). Brood:pair ratio varied from 0 to 7 among sites for all duck species combined.

Duck Banding

We trapped ducks during 30 July – 10 September, using swim-in traps baited with cracked corn at 7 wetland sites, each with 1 – 2 traps per site (Mauser and Mensik 1992). We also captured ducks using an airboat and spotlights at night on four sites. We marked ducks with standard U.S. Geological Survey (USGS) legbands and released them at their capture sites. We classified captured ducks to species, age, and sex using plumage characteristics and cloacal examination. We classified age as local, hatch year, or after hatch year. We defined local birds as unfledged ducklings that we could reasonably assume had hatched locally, and only attached bands to ducklings with legs large enough to hold a legband. We recorded the band number of all recaptured ducks. We reported information on ducks we banded to the USGS Bird Banding Laboratory.

During pre-season trapping operations (15 August – 16 September) we banded 773 ducks of 13 species (Table 1). Our pre-season trapping effort was comprised of 324 trap-days with baited swim-in traps (45% of the banded sample), and 4 nights of spotlighting from an airboat (55% of the banded sample). Mallards were the most common species (42%) of our banded sample. We captured gadwall (24% of the banded sample) primarily (98%) with spot-lighting. We banded 94 cinnamon and blue-winged teal (12% of the total banded sample); of these, we classified locals (young incapable of flight), hatch year females, and after hatch year females as unidentified teal, because we could not reliably distinguish between the two species in these cohorts. However, given the much higher proportion of cinnamon teal than blue-winged teal in the study area, we suspect that most of these unidentified teal were cinnamon teal.

At the time of this report, 110 ducks we banded in 2018, 109 ducks we banded in 2019, 204 ducks we banded in 2020, 61 ducks we banded in 2021, 156 ducks we banded in 2022, and 43 (total = 683) had been harvested by hunters and reported to the USGS Bird Banding Laboratory, including 538 mallards, 73 gadwall, 14 cinnamon teal, 16 shovelers, 7 green-winged teal, 11 wigeon, 3 pintails, 2 Mexican ducks, 8 lesser scaup, 4 redhead, and 7 canvasback. Among mallards, juveniles and adult males have been harvested at higher rates than adult females (Table 2). Most mallards (71.3%) were harvested in Colorado, in 36 different counties (Table 3). Mallards banded in North Park during 2018-2023 were also harvested in 16 other states, including 78 different counties, and the provinces of Alberta and Saskatchewan in Canada (Table 3).

Future Work

We have completed field work related to this initial phase of the project. We will analyze data and submit publications in 2024. We plan to conduct some field work in summer 2024 (pair and brood counts, banding), to maintain data continuity before starting the next phase of this project.

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Table 1. Numbers of ducks banded in North Park during pre-season capture efforts in 2023. LM = local male, LF = local female, HYM = hatch year male, HYF = hatch year female, AHYM = after hatch year male, and AHYF = after hatch year female.

Species	AHYF	AHYM	HYF	HYM	LF	LM	Total
Mallard	15	58	93	140	4	11	321
Gadwall	20	48	29	40	32	15	184
Cinnamon/blue-winged teal[a]	7	1	32	46	8	0	94
American wigeon	6	13	12	19	7	4	61
Lesser scaup	3	0	7	1	14	5	30
Shoveler	5	1	6	10	0	2	24
Canvasback	0	0	11	7	0	3	21
Green-winged teal	6	1	1	5	1	0	14
Pintail	1	0	5	2	1	2	11
Redhead	1	1	1	2	3	1	9
Mexican duck	0	3	0	0	0	0	3
Ruddy duck	0	0	1	0	0	0	1
Total	64	126	198	272	70	43	773

[a]We could not reliably distinguish between cinnamon and blue-winged teal for locals and females.

Table 2. Numbers of mallards banded in North Park during 2018-2023 in different age and sex cohorts and reported shot by hunters to the USGS Bird Banding Lab during hunting seasons through December 31, 2023.

		Number	Number harvested (% of banded sample)					
Banded cohort	Band year	banded	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023	2023-2024
AHY male	2018	168	10 (6.0%)	11 (6.5%)	5 (3.0%)	0	2 (1.2%)	1 (0.6%)
	2019	234	-	23 (9.8%)	8 (3.4%)	9 (3.8%)	8 (3.4%)	1 (0.4%)
	2020	246	-	-	16 (6.5%)	14 (5.7%)	11 (4.5%)	5 (2.0%)
	2021	306	-	-	-	22 (7.2%)	10 (3.3%)	4 (1.3%)
	2022	239	-	-	-	-	25 (10.5%)	8 (3.3%)
	2023	58	-	-	-	-	-	4 (6.9%)
AHY female	2018	69	1 (1.4%)	2 (2.9%)	0	0	0	0
	2019	104	-	4 (3.8 %)	1 (1.0%)	1 (1.0%)	0	0
	2020	108	-	-	10 (9.3%)	2 (1.9%)	2 (1.9%)	2 (1.9%)
	2021	95	-	-	-	2 (2.1%)	0	2 (2.1%)
	2022	68	-	-	-	-	4 (5.9%)	0
	2023	15	-	-	-	-	-	2 (13.3%)
HY male	2018	221	29 (13.1%)	12 (5.4%)	2 (0.9%)	5 (2.3%)	3 (1.4%)	2 (0.9%)
	2019	109	-	12 (11.0%)	6 (5.5%)	0	5 (4.6%)	0
	2020	266	-	-	25 (9.4%)	22 (8.3%)	6 (1.5%)	4 (1.5%)
	2021	57	-	-	-	6 (10.5%)	3 (3.5%)	3 (3.5%)
	2022	186	-	-	-	-	45 (16.7%)	8 (4.3%)
	2023	140	-	-	-	-	-	19 (13.6%)
HY female	2018	131	13 (9.9%)	5 (3.8%)	0	0	0	0
	2019	73	-	3 (4.1%)	1 (1.4%)	0	1 (1.4%)	0
	2020	200	-	-	23 (11.5%)	5 (2.5%)	6 (3.0%)	1 (0.5%)
	2021	38	-	-	-	1 (2.6%)	2 (5.3%)	0
	2022	95	-	-	-	-	11 (11.6%)	0
	2023	93	-	-	-	-	-	1 (1.1%)
L male	2018	12	1 (8.3%)	0	0	0	0	0
	2019	7	-	1 (14.3%)	0	0	0	0

	2020	25	-	-	5 (20.0%)	0	1 (4.0%)	1 (4.0%)
	2021	0	-	-	-	0	0	0
	2022	10	-	-	-	-	1 (10.0%)	0
	2023	11	-	-	-	-	-	0
L female	2018	14	2 (14.3%)	0	0	0	0	0
	2019	11	-	1 (9.1)	0	0	0	0
	2020	28	-	-	3 (10.7%)	0	0	0
	2021	0	-	-	-	0	0	0
	2022	6	-	-	-	-	0	0
	2023	4	-	-	-	-	-	0
Total	2018	615	56 (9.1%)	30 (4.9%)	7 (0.7%)	5 (0.8%)	5 (0.8%)	3 (0.5%)
	2019	538	-	44 (8.2%)	16 (%)	10 (1.9%)	14 (0.7%)	1 (0.2%)
	2020	873	-	-	82 (9.4%)	43 (4.9%)	26 (3.0%)	13 (1.5%)
	2021	496	-	-	-	31 (6.3%)	15 (3.0%)	9 (1.8%)
	2022	604	-	-	-	-	87 (14.4%)	16 (2.6%)
	2023	321	-	-	-	-	-	26 (8.1%)

Table 3. Distribution by U.S. states and counties, and Canadian provinces, of the number (% of total) of direct (harvested during the hunting season immediately following banding) and indirect (harvested during hunting seasons one or more years after banding) recoveries of mallards banded in North Park, 2018-2023, reported by hunters to the USGS Bird Banding Lab through December 31, 2023.

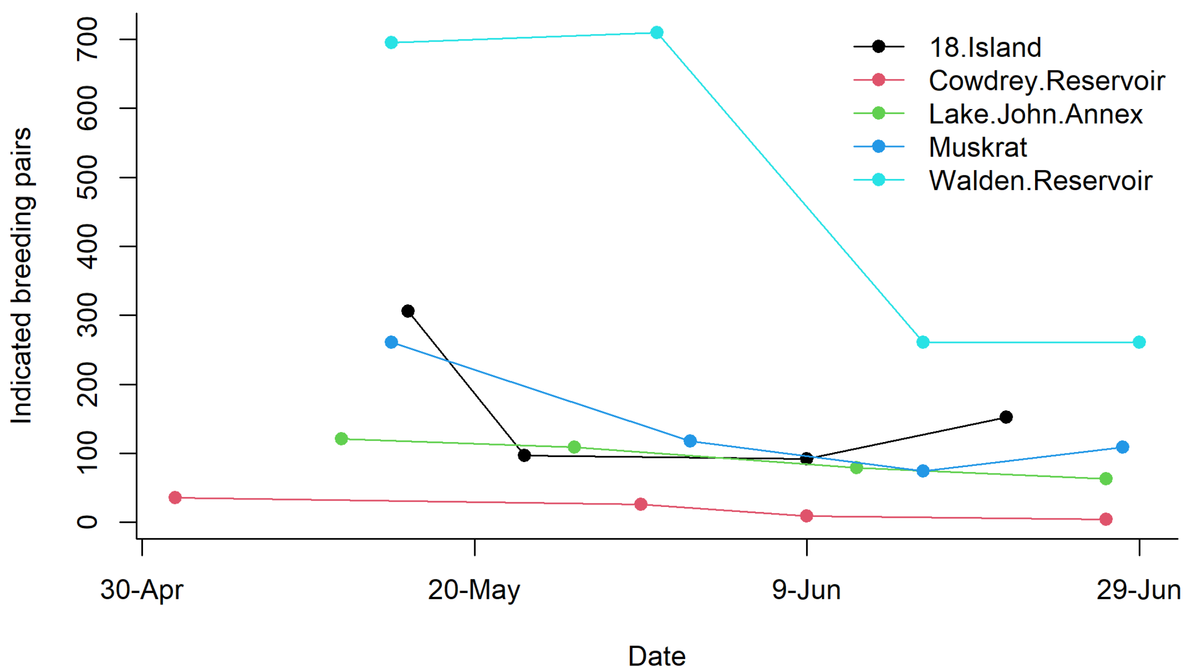
State	County	Direct recoveries	Indirect recoveries
Colorado	Total	260 (79.6)	121 (58.5)
	Adams	4 (1.2)	4 (2.0)
	Alamosa	6 (1.9)	5 (2.4)
	Bent	2 (0.6)	1 (0.5)
	Boulder	7 (2.2)	4 (2.0)
	Chaffee	1 (0.3)	0
	Conejos	1 (0.3)	1 (0.5)
	Costilla	2 (0.6)	2 (1.0)
	Crowley	1 (0.3)	1 (0.5)
	Delta	1 (0.3)	4 (2.0)
	Dolores	0	1 (0.5)
	Douglas	1 (0.3)	0
	Eagle	7 (2.2)	0
	El Paso	1 (0.3)	0
	Fremont	0	1 (0.5)
	Garfield	5 (1.5)	0
	Grand	15 (4.6)	5 (2.4)
	Gunnison	2 (0.6)	1 (0.5)
	Jackson	91 (28.0)	16 (7.8)
	Kiowa	0	1 (0.5)
	La Plata	1 (0.3)	1 (0.5)
	Larimer	6 (1.9)	4 (2.0)
	Las Animas	3 (0.9)	1 (0.5)
	Logan	4 (1.2)	6 (2.9)
	Mesa	3 (0.9)	1 (0.5)
	Montrose	1 (0.3)	4 (2.0)
	Morgan	7 (2.2)	4 (2.0)
	Otero	7 (2.2)	3 (1.5)
	Park	8 (2.5)	4 (2.0)
	Pitkin	1 (0.3)	0
	Prowers	1 (0.3)	0
	Pueblo	12 (3.7)	2 (1.0)
	Rio Grande	5 (1.5)	6 (2.9)
	Routt	6 (1.9)	1 (0.5)
	Saguache	9 (2.8)	3 (1.5)
	Summit	2 (0.6)	0
	Weld	35 (10.8)	34 (16.6)
	Unknown	2 (0.6)	0
Arizona	Total	2 (0.6)	0
	Coconino	1 (0.3)	0
	Maricopa	1 (0.3)	0
California	Total	0	1 (0.5)

	Tehama	0	1 (0.5)
Idaho	Total	0	3 (1.5)
	Franklin	0	1 (0.5)
	Payette	0	1 (0.5)
	Power	0	1 (0.5)
Kansas	Total	3 (0.9)	5 (2.4)
	Barton	1 (0.3)	0
	Crawford	0	1 (0.5)
	Marion	0	1 (0.5)
	Mitchell	1 (0.3)	0
	Pottawatomie	0	1 (0.5)
	Sumner	0	1 (0.5)
	Trego	1 (0.3)	1 (0.5)
Kentucky	Total	0	1 (0.5)
	Ballard	0	1 (0.5)
Missouri	Total	0	1 (0.5)
	Holt	0	1 (0.5)
Montana	Total	1 (0.3)	2 (1.0)
	Beaverhead	0	1 (0.5)
	Big Horn	0	1 (0.5)
	Yellowstone	1 (0.3)	0
Nebraska	Total	4 (1.2)	9 (3.9)
	Garden	1 (0.3)	0
	Keith	2 (0.6)	1 (0.5)
	Lincoln	1 (0.3)	2 (1.0)
	Loup	0	1 (0.5)
	Morrill	0	1 (0.5)
	Scotts Bluff	0	4 (2.0)
New Mexico	Total	40 (12.3)	27 (13.2)
	Bernalillo	1 (0.3)	2 (1.0)
	Catron	1 (0.3)	0
	Chaves	4 ()	0
	Dona Ana	1 (0.3)	3 (1.5)
	Eddy	1 (0.3)	0
	Mora	0	1 (0.5)
	Otero	1 (0.3)	0
	Quay	1 (0.3)	1 (0.5)
	Rio Arriba	2 (0.6)	1 (0.5)
	Roosevelt	1 (0.3)	0
	San Juan	4 (1.2)	4 (2.0)
	Sandoval	0	1 (0.5)
	Santa Fe	1 (0.3)	0
	Sierra	3 (0.9)	3 (1.5)

	Socorro	10 (3.1)	7 ()
	Valencia	9 (2.8)	4 (2.0)
Nevada	Total	1 (0.3)	1 (0.5)
	Lyon	0	1 (0.5)
	Nye	1 (0.3)	0
Oklahoma	Total	4 (1.2)	6 (2.9)
	Caddo	0	2 (1.0)
	Carnegie	0	1 (0.5)
	Carter	1 (0.3)	0
	Garfield	1 (0.3)	0
	Logan	0	1 (1.1)
	Oklahoma	0	2 (1.0)
	Pottawatamie	1 (0.3)	0
	Stephens	1 (0.3)	0
Oregon	Total	0	1 (0.5)
	Lane	0	1 (0.5)
South Dakota	Total	0	1 (0.5)
	Fall River	0	1 (0.5)
Texas	Total	7 (2.2)	12 (5.9)
	Carson	1 (0.3)	0
	Crosby	0	1 (0.5)
	Dallam	0	1 (0.5)
	El Paso	0	1 (0.5)
	Haskell	1 (0.3)	1 (0.5)
	Hockley	0	1 (1.1)
	Hudspeth	1 (0.3)	1 (0.5)
	Irion	0	1 (0.5)
	Lamb	0	2 (1.0)
	McCulloch	1 (0.3)	0
	Oldham	2 (0.6)	1 (0.5)
	Reeves	0	1 (0.5)
	Terry	1 (0.3)	0
Utah	Total	3 (0.9)	8 (3.9)
	Boxelder	0	2 (1.0)
	Cache	0	1 (0.5)
	Davis	0	1 (0.5)
	Duchesne	2 (0.6)	0
	Piute	0	1 (0.5)
	Salt Lake	0	2 (1.0)
	Uintah	1 (0.3)	0
	Weber	0	1 (0.5)
Wyoming	Total	2 (0.6)	9 (2.9)
	Albany	1 (0.3)	3 (2.4)

	Carbon	1 (0.3)	0
	Converse	0	1 (0.5)
	Fremont	0	1 (0.5)
	Goshen	0	1 (0.5)
	Lincoln	0	2 (1.0)
	Sublette	0	1 (0.5)
Canada	Total	0	3 (1.5)
	Alberta	0	1 (0.5)
	Saskatchewan	0	2 (1.0)
Total recoveries		327	211

Figure 1. Total duck pair counts at five large reservoirs in North Park, Colorado during spring and summer 2023.



Publications, presentations, workshops and committee involvement by Avian Research staff January – December 2023

PUBLICATIONS

Behney, A. C. 2023. Are breeding activities risky for northern bobwhites? An assessment of survival costs of reproduction. Journal of Avian Biology 2023:e03036.

Donnelly, J. P., D. E. Naugle, J. M. Knetter, **J. H. Gammonley**, B. A. Grisham, N. C. Nowak, and D. P. Collins. In press. Wetland scarcity and flood-irrigated agriculture structures summering sandhill crane distribution in western North America. Ecology and Evolution DOI: 10.1002/ece3.10998

Gammonley, J. H. 2024. Duck walk: a birder's improbable path to hunting as conservation (book review). Ornithological Applications 126, DOI: 10.1093/ornithapp/duad063

Hobbs, N. T., **D. B. Johnston, K. N.** Marshall, E. C. Wolf, and D.J. Cooper. Accepted. Does restoring apex predators to food webs restore ecosystems? Large carnivores in Yellowstone as a model system. Ecological Monographs DOI: 10.1002/ecm.1588

Johnston, D. B. and C. R. Anderson. 2023. Plant and mule deer responses to tree removal by three mechanical methods. Wildlife Society Bulletin 47:2 DOI: 10.1002/wsb.1421

Johnston, D. B. and R. K. Mann. In press. Rangeland pitting for revegetation and annual weed control. Rangelands, DOI: 10.1016/j.rala.2023.11.002

Vest, J. L., D. A. Haukos, N. D. Niemuth, **C. M. Setash**, **J. H. Gammonley**, and J. H. Devries. 2023. Chapter 13. Waterfowl and wetland burds. Pages 417-469 in L. B. McNew, D. K. Dahlgren, and J. L. Beck, editors. Rangeland wildlife ecology and conservation. Springer Press.

Walker, B. L. 2023. Applying citizen science data to quantify differences in song between controversial avian taxa, the sagebrush and timberline subspecies of the Brewer's Sparrow (*Spizella breweri*). Western North American Naturalist 83:550-568.

Walker, B. L., A. A. Yappert, C. L. Brennan, C. M. Bossu, and A. W. Jones. Accepted. Field surveys and sampling guided by citizen science and monitoring data reveal a novel alpine breeding distribution and vegetation associations of a declining, habitat-specialist songbird in Colorado, USA. Avian Conservation and Ecology.

Wolske, J. M., **A. C. Behney**, and L. A. Powell. 2023. Nonbreeding season survival of northern bobwhite in northeastern Colorado. Wildlife Biology 2023:e01126.

PRESENTATIONS

Albright, S. R. (presenter), W. L. Kendall, and **R. Y. Conrey**. Occupancy, abundance and productivity of burrowing owls nesting in eastern Colorado. Colorado Parks and Wildlife State Parks Annual Raptor Monitoring Meeting. Denver, CO, 5 November 2023.

Albright, S. (presenter), W. Kendall, and **R. Y. Conrey**. Occupancy, density, and productivity of burrowing owls nesting in eastern Colorado. Front Range Student Ecology Symposium. Fort Collins, CO, 23 February 2023.

Behney, A. C. 2023. Bobwhite life history and a summary of research in Colorado. Northern Colorado Pheasants Forever. Oral Presentation.

Conrey, R. Y. (presenter), M. M. Middleton, M. Smith, B. D. Snyder, and J. H. Gammonley. CPW collaboration with BCR BEW. Presented as part of Bird Conservancy of the Rockies Bald Eagle Watch, Annual Training for new volunteers. Statewide (virtual), 21 January 2023.

Conrey, R. Y. (presenter), M. M. Middleton, M. Smith, B. D. Snyder, and J. H. Gammonley. Front Range bald eagles: research update. Presented as part of Bird Conservancy of the Rockies Bald Eagle Watch, Annual Training for experienced volunteers. Statewide (virtual), 21 January 2023.

Conrey, R. Y. (presenter), E. Youngberg, D. W. Tripp, M. M. Middleton, and A. Panjabi. Black-tailed prairie dog colonies provide habitat for Colorado's grassland birds. Broomfield Bird Club seminar (virtual), 15 February 2023.

Conrey, R. Y. (presenter), M. M. Middleton, M. Smith, B. D. Snyder, and **J. H. Gammonley**. Front Range bald eagles: research update. USFWS/CPW Eagle Coordination meeting. Denver, CO (virtual), 30 October 2023.

Conrey, R. Y. (presenter), M. M. Middleton, M. Smith, B. D. Snyder, and **J. H. Gammonley**. Front Range bald eagle research. Civitas/CPW Eagle Coordination meeting. Virtual, 20 December 2023.

Johnston, D. B. (presenter) and C. R. Anderson. January 4, 2023. How you chop matters: plant and mule deer responses to tree removal by three mechanical methods. Habitat Partnership Program Annual Meeting, Grand Junction, CO.

Johnston, D. B. February 28, 2023. Cheatgrass control update: indaziflam, potholing, and NutraFix. Colorado Parks and Wildlife Technician In-service, Grand Junction, CO.

Johnston, D. B. March 1, 2023. Cheatgrass control case studies: indaziflam, potholing, and NutraFix. Gunnison Cheatgrass Workshop, Gunnison, CO.

Johnston, D. B., Gunnell, K. (presenter), Monaco, M. and M. Landeen. March 1, 2023. Micronutrient fertilizer impacts on cheatgrass and desirable species.Western Society of Weed Science Annual Meeting, Boise, ID.

Johnston, D. B. (presenter) and C. R. Anderson. March 10, 2023. How you chop matters: plant and mule deer responses to tree removal by three mechanical methods. Colorado Section of The Wildlife Society Annual Meeting, Grand Junction, CO.

Johnston, D. B. April 10, 2023. Cheatgrass and cheatgrass management. Colorado Mesa University Restoration Ecology class lecture for Dr. Justin Pomerantz, Grand Junction, CO.

Johnston, D. B. and C. R. Anderson (presenter). May 16, 2023. Plant and mule deer responses to tree removal by three mechanical methods. 15th Biennial Deer and Elk Workshop, Western Association of Fish and Wildlife Agencies, Flagstaff, AZ.

Johnston, D. B. and D. Neumann. The Colorado Seed Mix Tool. Presented to Habitat Partnership Program Committee meetings on: August 21 (White River Committee), August 23 (Lower Colorado

River Committee), August 31 (Gunnison Basin Committee), September 20 (Middle Park Committee), and November 11 (San Juan Basin Committee). Additional meetings presented by D. Neumann.

Middleton, M. M. (presenter), **R. Y. Conrey,** and L. Pejchar. Bald eagle foraging site selection and home range size in an urbanizing landscape. Front Range Student Ecology Symposium. Fort Collins, CO, 23 February 2023.

Middleton, M. M. (presenter), **R. Y. Conrey,** and L. Pejchar. Bald eagle foraging site selection and home range size in an urbanizing landscape. Colorado Chapter of the Wildlife Society Annual Meeting, joint with Utah. Grand Junction, CO, 9 March 2023.

Neumann, D. and **D. B. Johnston.** January 5, 2023. The Colorado Seed Mix Tool. Habitat Partnership Program Annual Meeting, Grand Junction, CO.

Neumann, D. and **D. B. Johnston.** August 29, 2023. The Colorado Seed Mix Tool. Colorado Parks and Wildlife Terrestrial Section Meeting, Gothic, CO

Neumann, D. and **D. B. Johnston.** September 13, 2023. The Colorado Seed Mix Tool. Colorado Parks and Wildlife Northwest Region Meeting, Stagecoach, CO.

Neumann, D. and **D. B. Johnston.** November 2, 2023. The Colorado Seed Mix Tool. Colorado State University Extension webinar, virtual.

Setash, C. M. (presenter), **A. C. Behney**, **J. H. Gammonley**, D. N. Koons. 2023. Riding the wetland wave: Can waterfowl track invertebrate resources throughout the breeding season? National Section of The Wildlife Society Meeting. Louisville, KY. November 2023.

Setash, C. M. (presenter), **A. C. Behney**, **J. H. Gammonley**, D. N. Koons. Duck Soup: A holistic view of breeding waterfowl ecology in the arid Intermountain West. Boulder County Audubon Society Presentation. October 2023.

Setash, C. M. (presenter), **A. C. Behney**, **J. H. Gammonley**, D. N. Koons. Duck Soup: A holistic view of breeding waterfowl ecology in the arid Intermountain West. CSU Field Ornithologists Presentation. October 2023.

Walker, B. L. Colorado Chapter of The Wildlife Society annual meeting. Feb 2023. Solving the mystery of Colorado's alpine Brewer's Sparrows. Grand Junction, CO.

Walker, B. L. Colorado Field Ornithologists/Western Field Ornithologists joint meeting. July 2023. Solving the mystery of Colorado's alpine Brewer's Sparrows. Breckenridge, CO.

WORKSHOPS, COMMITTEES, AND OTHER ASSIGNMENTS

Behney, A. C. Associate Editor, Wildlife Society Bulletin.

Behney, A. C. Treasurer, Colorado Chapter of The Wildlife Society.

Behney, A. C. (chair) Pacific Flyway Study Committee Work and Business meetings, Grand Junction, CO, February 2023.

Behney, A. C. Pacific Flyway Council meeting, St. Luois, MO, March 2023.

Behney, A. C. North American Waterfowl Management Plan Human Dimensions and Public Engagement Team meeting. June 2023.

Behney, A. C. (chair) Pacific Flyway Study Committee meeting, Winter Park, CO, August 2023.

Behney, A. C. South Platte Focus Area Committee Meetings. March, June, September, December 2023

Conrey, R. Y. Faculty Committee member for M.S. candidate Sarah Albright, Colorado State University.

Conrey, R. Y. Faculty Committee member for M.S. candidate Miranda Middleton, Colorado State University.

Conrey, R. Y. Review Committee, Lois Webster Fund grant program, Denver Audubon Society.

Gammonley, J. H. Faculty Committee member for Ph.D. candidate Casey Setash, Colorado State University. Dissertation: Setash, C. M. 2023. Breeding waterfowl productivity in a flood-irrigated agricultural landscape.

Gammonley, J. H. Science Committee, North American Duck Symposium (Ducks9), August – December, 2023.

Gammonley, J. H. CPW Wetlands Program Application Review Team. February/March 2023.

Gammonley, J. H. Central Flyway Waterfowl, Webless Migratory Game Bird, and Central Management Unit Dove Technical Committee meetings, South Padre Island, TX, February 7-9, 2023.

Gammonley, J. H. Central Flyway Wing Bee, Emporia, KS, February 21-23, 2023.

Gammonley, J. H. Central Flyway Technical Committee and Council meetings, Bozeman, MT, August 28 – September 1, 2022.

Johnston, D. B. Co-advisor for Nathan Nelson, Colorado State University M.S. Candidate. Participated in weekly meetings. Oversaw experimental design for new study of mountain shrub establishment in Colorado. Made field visits for site selection and experiment installation.

Johnston, D. B. Symposium Organizer for High Altitude Revegetation conference, held April 12, 2023, Fort Collins, CO. Symposium title: Seed mixes:Tools and Considerations.

Johnston, D. B. Seed Mix Working Group Co-Leader. Meetings held January- December. Helping develop structure and function of a tool to provide seed mix guidance for Colorado.

Johnston, D. B. CPW Animal Care and Use Committee.

Setash, C. M. Faculty Committee member for Ph.D. candidate Casey Weissburg, University of Colorado – Denver.

Walker, B. L. Core Team member, USGS rangewide seasonal habitat mapping analysis for greater sage-grouse.

Walker, B. L. (chair) CPW Animal Care and Use Committee.

COLORADO PARKS WILDLIFE