COLORADO PARKS & WILDLIFE

2022 Avian Research Summary Report

MARCH 2023

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WILDLIFE RESEARCH SUMMARIES

JANUARY – DECEMBER 2022

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 Section of Colorado Parks and Wildlife (CPW) during 2022. 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 2022, research projects in the Section 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 9 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 Sagebrush Bird Conservation, Wildlife Habitat Conservation, Grassland Bird Conservation, Raptor Conservation, and Wetland Bird Conservation.

Also included in this report is a listing of publications produced during 2022, and presentations, workshops and participation on various committees and working groups by Avian Research staff during 2022. 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. U.S. Forest Service, Geological Survey, Wildlands Photography and Bio-consulting, WPX Energy, and the private landowners who have provided access for research projects.

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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: L. Rossi

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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 remains 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 nine 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, 3) *breweri* that first nest in sagebrush then move upslope to renest in alpine willow/krummholz (i.e., itinerant breeding), 4) a distinct subpopulation of *breweri*, 5) a zone of introgression between *breweri* and *taverneri*, 6) a third, undiscovered subspecies, 7) post-breeding, dispersing *breweri*, 8) post-breeding *taverneri* at molt-migration stopover sites, or 9) non-breeding birds (either *breweri* or *taverneri*). The objectives of this project were to determine the taxonomic identity and breeding status of alpine Brewer's Sparrows across Colorado.

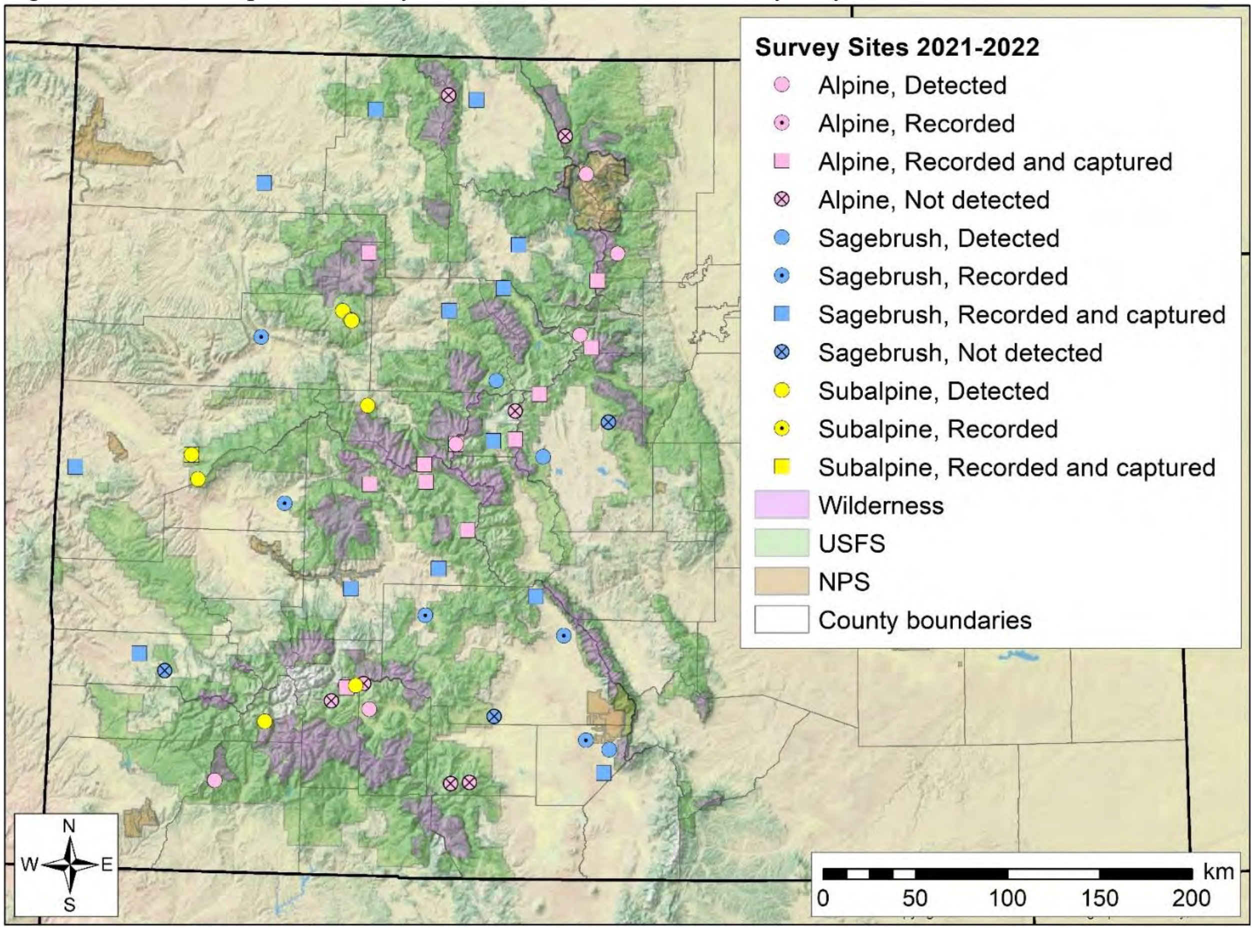
We first compiled historical observations using data from the Rocky Mountain Bird Observatory (1999-2005), Bird Conservancy of the Rockies (2008-2020), eBird (1995-2020), and VertNet (1903-1995), along with reports from birders and U.S. Forest Service biologists. We identified 178 historic observations of Brewer's Sparrows at 56 sites in alpine or subalpine shrubs above 3,000 m between 1 June and 15 July, and we identified 5 additional accessible potential breeding sites based on the presence of suitable habitat and elevation. In May–July 2021 and 2022, we visited 24 low-elevation sagebrush sites (1,746–2,937 m), 3 subalpine shrub sites (2,837–3,299 m), and 20 high-elevation alpine willow/conifer krummholz sites (3,267–3,764 m) to survey for Brewer's Sparrows (Fig. 1). When 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. Over two summers, we located Brewer's Sparrows at 13 alpine sites (Bristol Head, Cumberland Pass, Devil's Causeway, Guanella Pass, Hoosier Pass, Independence Pass, Italian Mountain, Jarosa Mesa,

Niwot Ridge, Rollins Pass, Scarp Ridge, Taylor Pass, Weston Pass) and 3 subalpine sites (Land's End, Indian Point, Spring Creek Pass). Volunteers and birders reported Brewer's Sparrows from 7 additional alpine sites (Eisenhower Tunnel, Kelso Mountain, Kennebec Pass, La Garita Cutoff, Lost Ranger Peak, Ute Trail [RMNP]) and 4 additional subalpine sites (Crane Park, Molas Pass, Thomas Lakes Trail, White Owl Lake) (Fig. 1). Territorial males at alpine sites were detected in large patches of 1-2 m tall diamondleaf willow (*Salix planifolia*), shortfruit willow (*S. brachycarpa*), and grayleaf willow (*S. glauca*) mixed with sparse Englemann spruce (*Picea englemanni*) or subalpine fir (*Abies lasiocarpa*) krummholz surrounded by tundra on drier slopes, ridges, and plateaus. We recorded 194 short songs from 182 males (128 in sagebrush, 48 in alpine, and 6 in subalpine), and captured and collected morphometric data on, and genetic samples from, 82 males (39 sagebrush, 43 alpine). We incidentally captured and collected genetic samples from 2 females and one unknown sex individual. No captured birds were molting. We confirmed breeding at one site (Rollins Pass) by capture of a female with a brood patch. The presence of numerous territorial males and pairs indicate breeding was probable at other occupied alpine sites.

We ruled out non-breeding explanations (hypotheses 7-9, above) based on confirmation of breeding and the absence of prebasic flight feather molt among captured birds. Although breeding habitat structure and composition and timing of breeding of alpine birds in Colorado were more similar to *taverneri*, the acoustic structure of songs, morphology, plumage, and mitochondrial haplotypes overlapped between alpine and sagebrush birds and closely matched those of range-wide *breweri*. This suggests alpine birds are *breweri* breeding in atypical habitat (ruling out hypotheses 1, 5, and 6, above). More detailed genetic and field data are needed to determine if alpine birds are part of the same population as *breweri* in sagebrush, itinerant breeders, or a distinct genetic and demographic subpopulation within *breweri* (hypotheses 2-4, above).

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 suggest that Brewer's Sparrows are likely much more widely distributed in alpine habitat than is currently known. Additional surveys are needed to determine their statewide breeding distribution and 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 needs 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.

Figure 1. Brewer's Sparrow survey sites in western Colorado, May-July 2021-2022.



Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Effects of Esplanade herbicide at Bitterbrush State Wildlife Area

Period Covered: January 1, 2021 – December 31, 2022

Author: Danielle B. Johnston

Principal Investigators: Danielle B. Johnston, CPW Habitat Researcher, danielle.biyeu@state.co.us; Trevor Balzer, CPW Habitat Coordinator

Project Collaborators: Colton Murray, CPW 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 1970's. 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.

We began this study in spring 2019 by testing a promising new herbicide for cheatgrass control, indaziflam (trade name Rejuvra®, former trade name EsplAnade™). The product has worked well to control cheatgrass, but cheatgrass control has not resulted in any changes in bitterbrush cover, bitterbrush leader length, or cover of other perennials in 2019-2022 (Figure1). 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.

In fall 2020 we began two new experiments to better understand limits on bitterbrush establishment. The Red Experiment isolated the impact of indaziflam as well as promising cheatgrass control fertilizer, NutraFix. Bitterbrush and bottlebrush squirreltail seeds were sown within rodent-proof cages bordered by insect control barriers. We found in 2021 that both indaziflam and NutraFix severely curtailed bitterbrush and squirreltail count. In 2022, two years post application, we saw only a slight and negligible reduction in bitterbrush count with indaziflam, but indaziflam continued to severely curtail squirreltail. NutraFix had no effect on bitterbrush count in 2022 and increased squirreltail count at the last measurement date. 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 requires at least a 2 year lag, and longer lags will be required for other desirable species such as bottlebrush squirreltail.

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 Yellow Experiment was designed to assess the relative importance of three known limitations to bitterbrush establishment: weeds, rodents, and insects. Rodent control cage type (open or closed), cheatgrass competition (hand weeded or cheatgrass seed added) and insect herbivory (ambient or reduced via Tanglefoot insect barrier) were crossed, and bitterbrush seedlings were monitored. There were three plantings in the fall of each year 2020-2022. The 2020 planting had some differences in the methods of treatment implementation, and the plots with cheatgrass control were not usable. We found that rodent control improved seedling survival initially, but by midsummer, insect control had a larger effect on survival. For the 2021 planting, we found that cheatgrass had only a slight impact on bitterbrush count. Rodents had a much larger impact, but the effect was extremely spatially variable. Insects had important effects which were mediated by interactions with other treatments in ways that differed by site. The 2022 planting will be monitored in 2023.

In fall 2021 we also planted two new experiments to test some management solutions for reducing rodent and insect impacts on bitterbrush establishment. The Brown Experiment 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 White Experiment 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 8, 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.

Both rodents and insects have had much larger effects on bitterbrush seedling counts than has cheatgrass. In 2021 and 2022, we had good bitterbrush germination in Yellow Experiment plots which did not have cheatgrass control but which were protected from rodents and insects. In contrast, rodents and insects have had larger effects, as seen in the Yellow, Brown, and White Experiments. It seems that at least in some years, cheatgrass control may not be necessary for bitterbrush establishment, but efforts to reduce the effects of rodents and/or insects could help. Spring application of Bonide 8 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.

Although indaziflam is not helpful in establishing 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 treating the entire landscape.

This study is nearing completion. The last planting of the Yellow Experiment will be monitored in 2023. Final recommendations will be made, and data from this study may inform a broader study to improve mountain shrub establishment in Colorado.

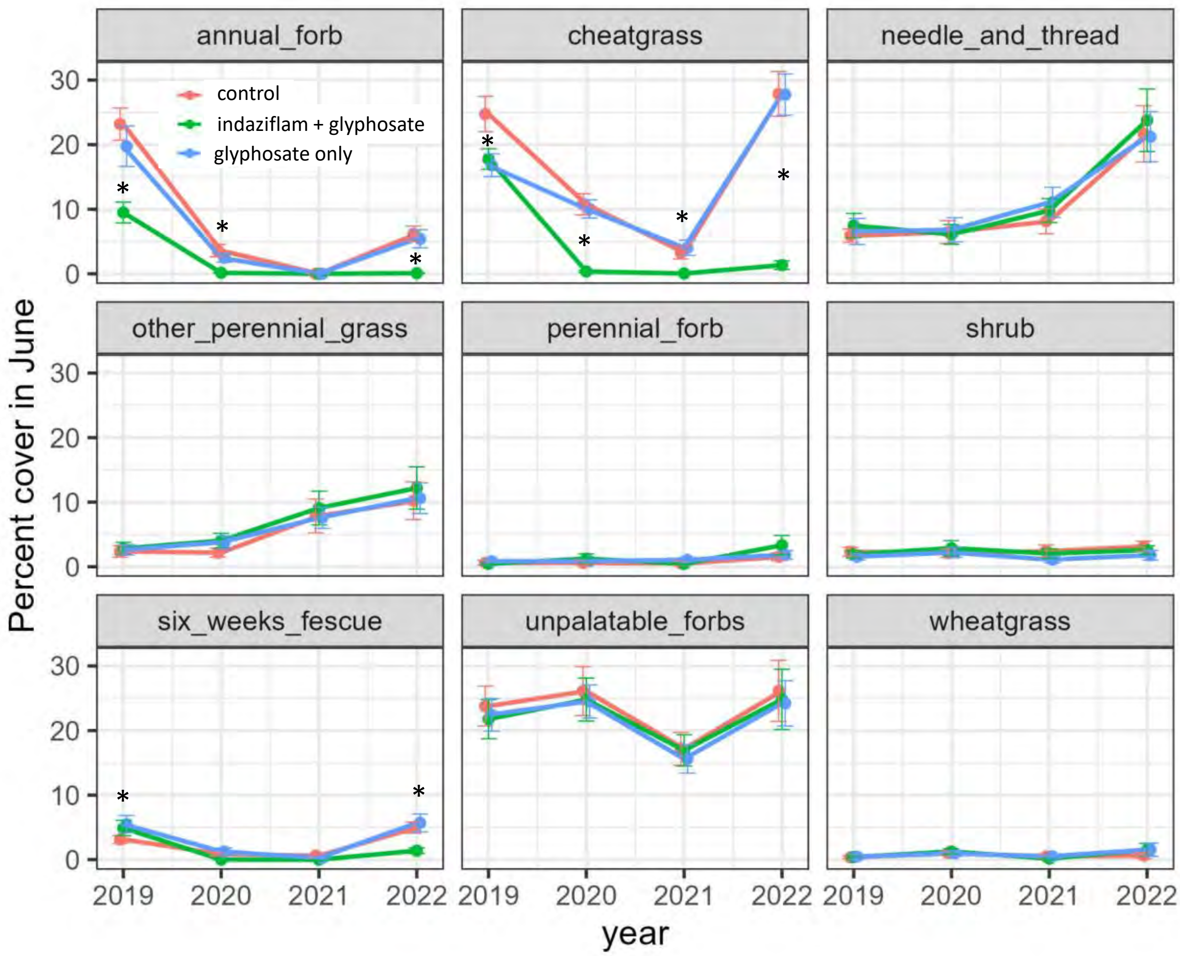


Figure 1. Plant cover responses to indaziflam + glyphosate and glyphosate only treatments at Bitterbrush State Wildlife Area, 2019 - 2022. Stars indicate that a significant contrast occurred between treatments within the given year ($\alpha = 0.05$). “other_perennial_grass” was primarily Sand Dropseed.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Pothole seeder demonstration studies

Period Covered: January 1, 2021 – December 31, 2022

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

Project Collaborators: Trevor Balzer, CPW Habitat Coordinator; Jim Garner, CPW Habitat Coordinator; Ivan Archer, CPW Assistant Area Wildlife Manager; Derek Lovoi, CPW Property Technician; Kevin Gunnell, Great Basin Research Center Coordinator, Utah Division of Wildlife Resources; Melissa Landeen, Great Basin Research Center Project Leader, Utah Division of Wildlife Resources; Todd Graham; Ranch Advisory Partners; Mary Conover, Owner, Mountain Island Ranch; Jon Moore, Ranch Manager, Mountain Island Ranch; Kenyon Fields, Mountain Island Ranch; Ken Holsinger, Ecologist, Bureau of Land Management

ABSTRACT

Both CPW research and external research has shown that seeding plants over a roughened surface has many benefits. For instance, the holes of roughened surfaces retain soil moisture, which can aid in plant establishment in arid areas. CPW research has also shown that roughened soil surfaces hinder the life cycle of annual plants. As many troublesome weeds in arid western North America are annuals, actions which favor perennials over annuals can be helpful when restoring degraded areas. To create a roughened soil surface efficiently, Ivan Archer and Derek Lovoi built a custom ‘pothole seeder’ in 2017-18. The seeder combines Truax® seed boxes over two gangs of large, notched disks. This study documents the results of the first few projects to use the seeder, which were conducted at Escalante SWA in Delta County, Mountain Island Ranch in Mesa County, Nash Wash in Grand County Utah, and Simms Mesa in Montrose County. For full site descriptions, methods, and additional treatments applied at each of these sites, please see prior reports.

Monitoring was completed at Escalante, Mountain Island Ranch, and Nash Wash in 2022. At each of these sites, two types of data were collected. Plant cover data via transects in treatment and control plots was used to measure the prevalence of weeds such as cheatgrass and Russian thistle. Plant density in small subplots was used to measure the prevalence of seeded species. For all of the sites, 2022 was the last year of monitoring for the primary projects. At Mountain Island Ranch, additional acreage was seeded in fall 2021 with the pothole seeder, and that acreage was also monitored in 2022. However that additional project is not formally part of this study. Results from the primary projects will be compiled in either a final report or a peer-reviewed publication.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

NutraFix Rate Trials

Period Covered: January 1, 2021 – December 31, 2022

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

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, CPW Habitat Coordinator; Todd Schmidt, CPW Area 3 Wildlife Manager; Levi Kokes, CPW Property Technician, Tamarack State Wildlife Area; Kirk Oldham, CPW Area 7 Wildlife Manager; Ivan Archer, CPW Area 7 Assistant Wildlife Manager; Buddy McNeel, CPW Property Technician, Garfield Creek State Wildlife Area; Brian Gray, CPW District Wildlife Manager; Mike Swaro, CPW Area 6 Assistant Wildlife Manager; Colton Murray, CPW Property Technician, Bitterbrush State Wildlife Area

EXECUTIVE SUMMARY

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. 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 1). The sites vary in soil texture, precipitation, and plant community.

Vegetation measurements in late spring 2022 revealed that NutraFix reduced cheatgrass cover only slightly, by about 13% across sites, when applied at the highest rate (Figure 2). At the medium and low rates, there was no discernable effect on cheatgrass. NutraFix did not have any significant effect on most perennial grasses. However, consistent with last year, we noted that the medium and high rates of NutraFix reduced cover of Indian ricegrass (*Achnatherum hymenoides*) at Bitterbrush SWA. We also noted that two non-native annual forbs, tall tumblemustard (*Sisymbrium altissimum*) and desert alyssum (*Alyssum desertorum*) responded positively to NutraFix. Six weeks fescue (*Vulpia octoflora*) and rubber rabbitbrush (*Ericameria nauseosa*) responded negatively.

Thus far, both the level of cheatgrass control and the benefits to desirable plants have been less dramatic than we expected based on prior results from Colorado and other states. We have consulted with the product developer and the reasons for this discrepancy are not clear. The formulation of the product changed slightly between applications made in 2019 and 2020; one possible explanation is that the newer product is less effective. The results could also be due to particular precipitation patterns concurrent with the 2020 application, or the particular plant communities where the product was applied.

We obtained soil samples in each plot in both spring and fall of 2022, as was done in 2021. Tom Monaco's lab at the Agricultural Resource Service in Logan, Utah has begun analyzing these for effects of NutraFix on nitrate, ammonium, and Kjeldahl N. Collaborators in Utah also set up 5 sites in 2020 and sampled them for vegetation and soils in 2022 using similar protocols as the Colorado sites. Prior work has shown that plant responses can change to NutraFix over time, which does not degrade in the manner of an herbicide, but is recycled in the plant community. Vegetation response and soils will be monitored through 2023.

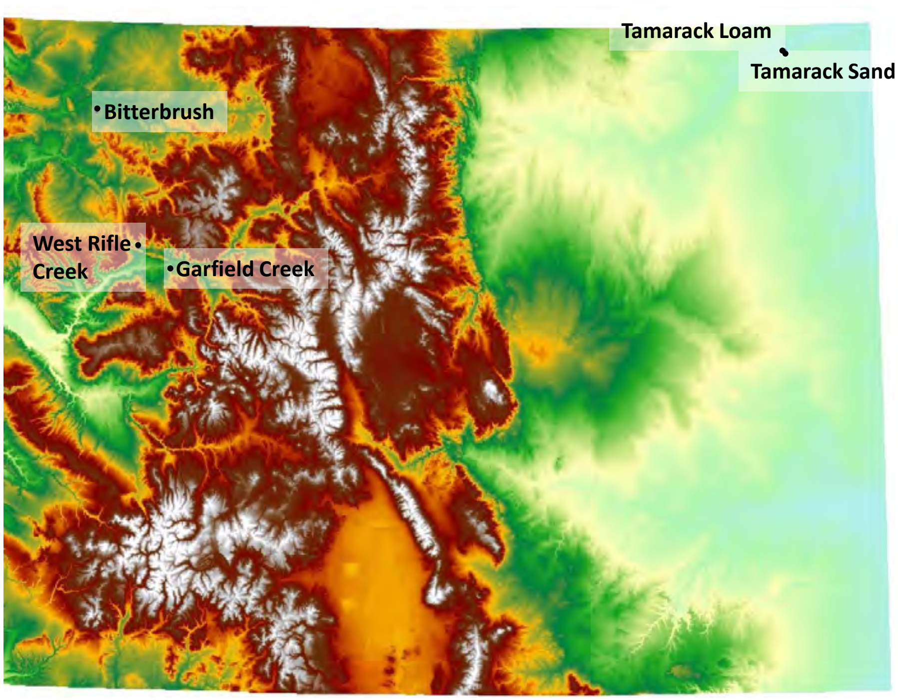


Figure 1. Locations for the five rate trial sites set up in 2020 in Colorado.

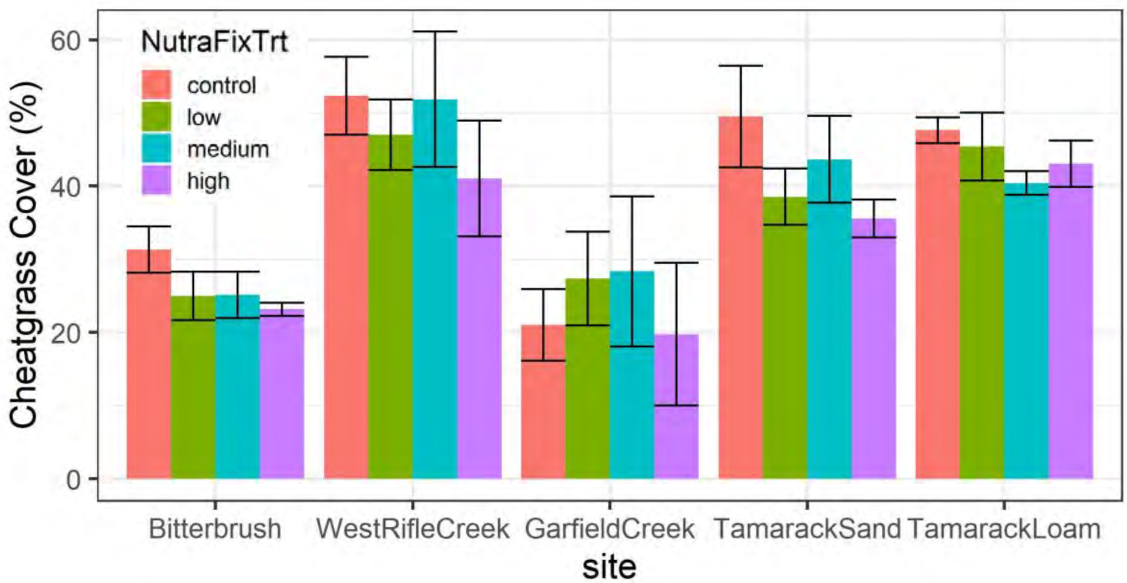


Figure 2. Cheatgrass cover two years post-treatment in response to NutraFix applied at 3 rates at 5 sites. Error bars= SE.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Avian response to plague management on Colorado prairie dog colonies

Period Covered: January 1 – December 31, 2022

Author and Principal Investigator: Reesa Yale Conrey, CPW Avian Researcher, reesa.conrey@state.co.us

Project Collaborators: Dan Tripp, CPW Wildlife Health Researcher; Jim Gammonley, CPW Avian Research Leader; Miranda Middleton and Cooper Mark, CPW research technicians; Erin Youngberg and Arvind Panjabi, Bird Conservancy of the Rockies; City of Fort Collins Natural Areas and Utilities Programs; Bureau of Land Management (Gunnison and Cañon City offices); National Park Service Florissant Fossil Beds National Monument; and CPW wildlife managers, biologists, park rangers, and property technicians from Areas 1, 4, 14, and 16.

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EXTENDED ABSTRACT

Prairie dogs (*Cynomys* sp.) are highly susceptible to plague, a disease caused by the non-native bacterium *Yersinia pestis,* introduced to the Great Plains of North America in the 1940s–50s (Ecke and Johnson 1952, Antolin et al. 2002). Plague epizootics may have cascading effects on species associated with prairie dog (*Cynomys* spp.) colonies, such as black-footed ferrets (*Mustela nigripes*), ferruginous hawks (*Buteo regalis*), and burrowing owls (*Athene cunicularia*). Colorado Parks and Wildlife (CPW) has completed a study of plague management in prairie dogs, in which oral vaccine treatments were compared to placebo baits and insecticidal dusting of burrows (Tripp et al. 2017). Our objective is to quantify the effects of plague and plague management on avian species and mammalian carnivores associated with colonies of black-tailed (*C. ludovicianus:* BTPD) and Gunnison's (*C. gunnisoni*: GUPD) prairie dogs. Working at sites receiving vaccine, placebo, insecticidal dust, and no treatment, we have sampled colonies before, during, and after plague epizootics. We also compared on- and off-colony areas at GUPD sites during 2013-2015, in order to better quantify the effect of GUPD on shrub-steppe communities.

Study areas include BTPD colonies in north-central Colorado and GUPD colonies in western and central Colorado. BTPD study colonies are dominated by short and mid-grasses (especially blue grama *Bouteloua gracilis* and buffalograss *B. dactyloides*) and located in Larimer and Weld counties on City of Fort Collins Soapstone Prairie Natural Area (SPNA) and Meadow Springs Ranch (MSR). GUPD study colonies are dominated by sagebrush (especially big sagebrush *Artemisia tridentata*) mixed with other shrubs and grasses and located in the Gunnison Basin (Gunnison County), northwest Saguache County, Woodland Park area (Teller County), South Park (Park County), and Baca National Wildlife Refuge (Saguache County). Study sites were grazed by cattle and native grazers, especially prairie dogs, pronghorn (*Antilocapra americana*), jackrabbits (*Lepus* sp.), and cottontails (*Sylvilagus* sp.).

Data collection has included avian point counts, summer and winter raptor surveys, burrowing owl surveys and nest monitoring, monitoring of all raptor nests located opportunistically, remote camera data targeting mammalian carnivores, and percent ground cover, visual obstruction, and species

composition of vegetation at points, nests, and along randomly located transects. From 2013-2015, we also monitored passerine nests and surveyed for mountain plover (*Charadrius montanus*).

In 2022, we conducted avian point counts and sampled vegetation along transects on BTPD colonies at SPNA and MSR. As before, we sampled over the largest colony extent from 2012 – present, wherever open prairie dog burrows (active or inactive) occurred within 100 m of the point. CPW staff did point counts at 480 locations on MSR and sampled vegetation at 1 – 2 transects per colony, depending on colony size, across SPNA and MSR. We also surveyed for burrowing owls and monitored raptor nests across both properties. Our collaborators with Bird Conservancy of the Rockies (BCR) completed point counts across the entire property at SPNA.

Over a 3-year period starting in fall 2013, plague epizootics occurred over >80% of the BTPD study area. Some colonies, particularly those receiving dust or vaccine, had increasing prairie dog numbers since initially declining during the peak of the epizootic, while others, especially untreated areas, continued at severely reduced acreage (Tripp et al. 2017). Precipitation has varied greatly over the course of this study, from slightly dry to very wet, compared to the 30-year average. This plague cycle began during a dry period but peaked during two wet years.

Plague management via vaccine delivery and insecticidal dust can reduce the impact of plague on prairie dogs (Tripp et al. 2017) and their associates, with some avian species such as ferruginous hawks occurring with greater probability on active or recently active colonies. Smaller scale applications within larger BTPD complexes did not eliminate plague but helped to maintain pockets of live prairie dogs and promote population recovery. This mosaic of active and plague-affected areas retains habitat for species associated with colonies. Not surprisingly, species that prey upon prairie dogs or preferentially forage in short stature grasslands are the most likely to benefit from plague management.

Research phases:

- 2013–2015: vaccine research by CPW Wildlife Health. CPW Avian Research did extensive avian sampling at BTPD sites, on and off GUPD colonies, and nest searching.
- 2016: first use of plague vaccine as a management tool for CPW. Avian Research at GUPD sites shifted from Gunnison Basin to South Park.
- 2017–2019: broader plague management by CPW Terrestrial staff at all GUPD study sites and some BTPD sites. Avian sampling was replicated at all original BTPD and GUPD sites.
- 2021: avian point counts and vegetation transects completed on GUPD colonies in Gunnison Basin.
- 2022: avian point counts, vegetation transects, and raptor nest monitoring (including burrowing owl surveys) completed on BTPD colonies at SPNA and MSR.

Progress and completed project components in 2022:

- Avian point counts completed on BTPD colonies at SPNA and MSR. CPW staff completed 480 point counts on MSR. BCR staff completed point counts across the entire SPNA property.
- Vegetation transects (1 – 2 per colony) completed across SPNA and MSR by CPW staff.
- Burrowing owl nests monitored on BTPD colonies at SPNA and MSR.
- Data entry and QC completed.

Plans for 2023 and beyond:

- A 3-year rotation (3 sites, 1 site per year) had been planned to track longer-term impacts of different plague management strategies on the community of wildlife associated with prairie dog colonies. However, other research priorities and time constraints will preclude further sampling on prairie dog colonies until other research projects are completed. In addition, this project has already generated a huge amount of data that have only been partly evaluated thus far.
- Continue data analyses and preparation of manuscripts:

- Changes in grassland bird densities at BTPD sites over two plague and recovery cycles (15+ years), co-authored with BCR.
- Changes in bird density or occupancy at GUPD sites, with comparisons of active vs. plagued sites and on- vs. off-colony sites.
- Grassland bird nest survival and relationship to plague, weather, carnivore occupancy, and other factors.
- Site use/occupancy of mammalian carnivores, with comparisons of active vs. plagued sites.
- Site use of raptors, with comparisons of active vs. plagued sites.
- Changes in plant community related to plague, weather, and other factors.

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Figure 1. Photos from BTPD and GUPD sites in Colorado. a) GUPD consuming experimental bait. b) Ferruginous hawk seen during a winter raptor count. c) Visual obstruction measurement. d) Burrowing owl on BTPD site. e) Coyote and badger photographed by remote camera.

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, 2022

Authors: Reesa Yale Conrey and Sarah Albright

Principal Investigators: Sarah Albright, Colorado State University; William Kendall, USGS Colorado Cooperative Fish & Wildlife Research Unit; Reesa Yale Conrey, CPW Avian Researcher, reesa.conrey@state.co.us

Project Collaborators: Liza Rossi and Tina Jackson, CPW Species Conservation Coordinators

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 (BUOW) 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 are surveying 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 two-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 (Fig. 1) on 2021 NAIP imagery to increase the probability that there were still prairie dog burrows on the plot. We are surveying a minimum of 90 plots during each field season that are each visited up to four times. A new sample will be chosen in 2023 in order to maximize sample size and spatial coverage of the large study region. We are using a spatially balanced sampling design to select potential plots. Plots are 1 km^2 with a transect running through such that the observer is 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 late April and early August. We are using a double observer approach to increase the overall detection probability of owls. During each visit, observers walk the transect noting the distance, location, and age (adult or juvenile) of each owl detected. We are conducting vegetation surveys to determine if vegetation height or cover influence BUOW occupancy, abundance, or productivity.

We will test covariates in a model selection framework. Covariates include 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 are estimating 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 are estimating 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 are estimating productivity using a poisson generalized linear model.

In 2022, we surveyed 89 plots on BTPD colonies. We detected adult BUOW on 60 plots and juveniles on 48 plots. Latitude and BTPD activity level were significant factors influencing the probability of occupancy, regardless of reproductive status. Burrowing owl occupancy was significantly higher in southern colonies and those with high BTPD activity (Fig. 2). For medium and highly active BTPD colonies, plots that were occupied with adults also had successful reproduction (Fig. 3). Southern Colorado had the highest density of adult burrowing owls and burrowing owl density was positively correlated with BTPD activity level (Fig. 4).

Results from 2022 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 were generally not helpful predictors of BUOW population parameters. The 2023 season will feature an improved double observer protocol and will double the overall sample size of survey plots.

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Figure 1. Diagram of the plot and transect walked during burrowing owl surveys. Vegetation measurements are taken 1 m off the dashed transect line.

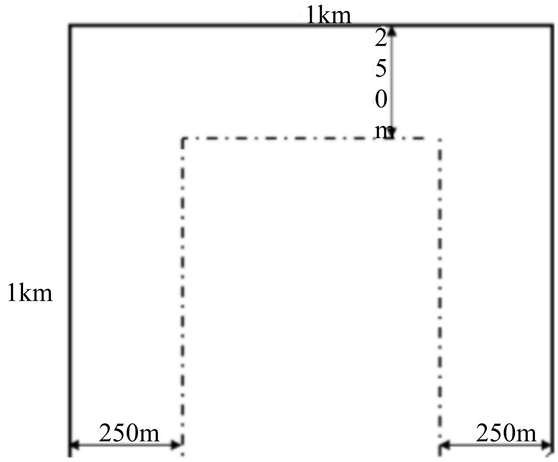


Figure 2: Probability of occupancy. Top model included latitude and BTPD activity level (p(detection)=0.44; 95% CI [0.213-0.697]).

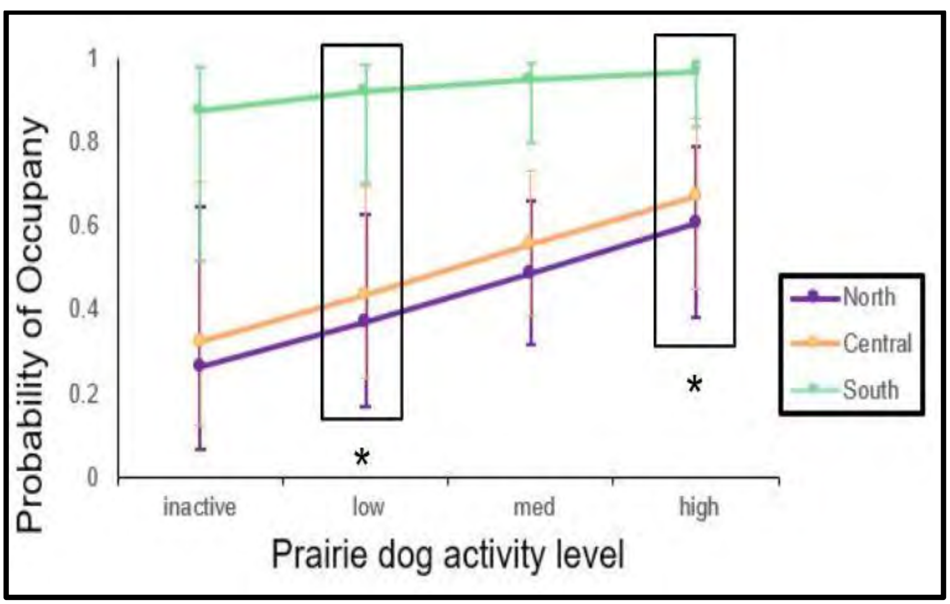


Figure 3: Probability of occupancy with successful reproduction. Top model included latitude and BTPD activity level (p(detection)=0.94; 95% CI [0.890-0.980]).

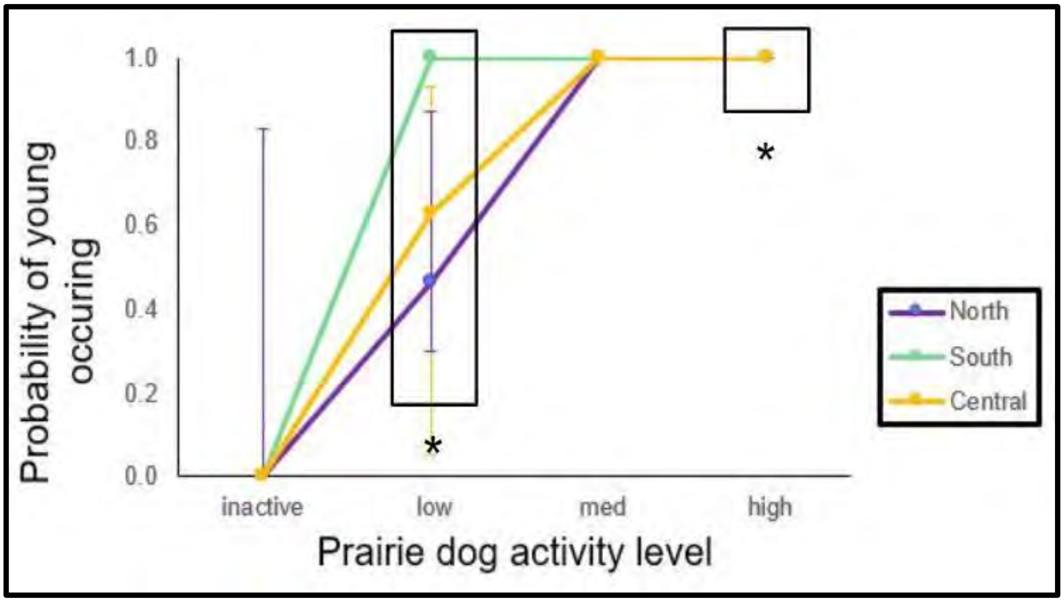
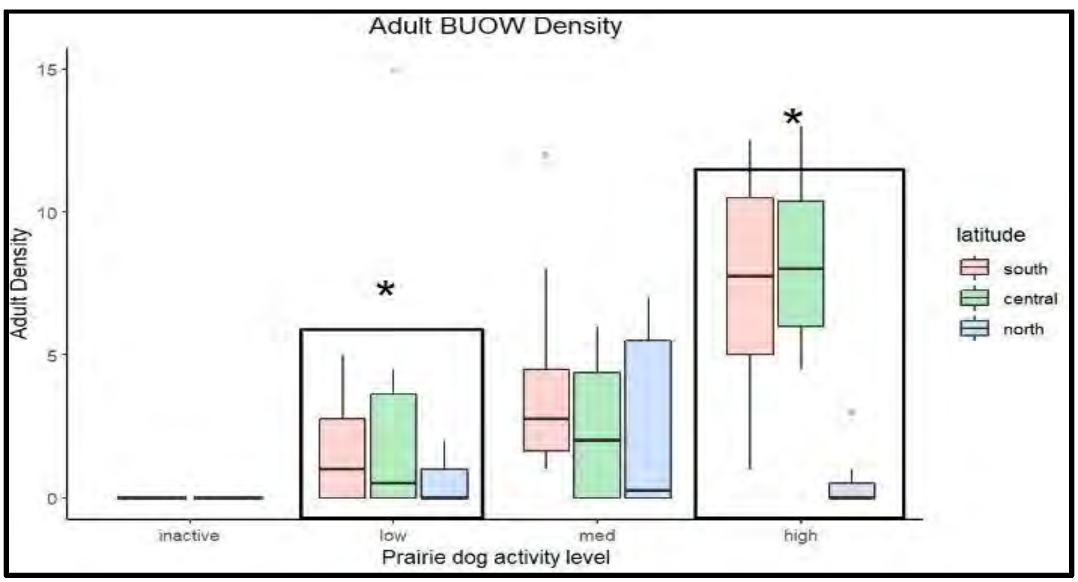


Figure 4: Average adult BUOW density. Significant covariates included latitude and BTPD activity level. Adult density was higher in colonies with high BTPD activity.



Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Golden eagles in Colorado: monitoring methods and status evaluation

Period Covered: January 1 – December 31, 2022

Author**:** Reesa Yale Conrey

Principle Investigators: R. Yale Conrey reesa.conrey@state.co.us, A. Estep, J. Gammonley

Collaborators: K. Aagaard (formerly of CPW); Bird Conservancy of the Rockies; U.S. Fish and Wildlife Service; U.S. Forest Service; Bureau of Land Management; National Park Service; Boulder County; other agencies who have submitted nest data; Cornell Lab of Ornithology

Species Conservation Unit, GIS Unit, and CPW Biologists: especially L. Rossi (SCON); J. Thompson (Resource Stewardship); R. Sacco (GIS); M. Sherman & Senior Terrestrial Biologists (TERR).

EXTENDED ABSTRACT

Raptor monitoring databases have generated important insights into various aspects of raptor ecology and can provide a sound foundation for management of individual species or within the larger context of managing targeted habitats (Greenwood 2007). CPW has a statewide raptor nest database developed by R. Sacco (GIS Unit), which currently contains records for > 12,000 nest locations of 30 species going back to the 1970s. Until recently, the nest database was primarily being used by CPW at a site-specific scale in the oil and gas consultation process (Colorado House Bill 07-1298) and other local-scale land use input. This continues to be an important function of the raptor data, and Colorado Senate Bill 181 requires annual updates of the raptor data for COGCC (Colorado Oil and Gas Conservation Commission). As part of this research project, the potential of these data to assess raptor populations at regional and statewide scales has been evaluated and field protocols are being optimized to yield more useful information. From 2020–2021, Avian Research and Terrestrial staff completed a raptor nest monitoring protocol and revised the nest datasheet, with a goal of standardizing monitoring methods statewide and ensuring that relevant data are reported in fields that can be queried for analysis. In addition, we are working to evaluate monitoring methods and population status of golden eagles (hereafter, GOEA), a Tier 1 Species of Greatest Conservation Need (CPW 2015).

The CPW raptor nest database contained nest records for 12,248 locations on 30 January 2023 (Table 1), having grown from 8,696 locations in 2016 due to increased sampling effort. For the first time since we initiated this project in 2016, the majority of nest locations have a known status (active, inactive, or destroyed), while 49.5% (6,067 nests) have an unknown or undetermined status with no information about occupancy during the past 5 years. This proportion has been reduced from 70% in 2016, because many historic nest sites have been revisited to update their status.

We have completed distribution models using the CPW nest database for four priority species: bald eagle, golden eagle, ferruginous hawk, and prairie falcon (Aagaard et al. 2021). We used generalized linear models to identify the relationship between nest locations and explanatory covariates relating to

land cover, temperature, topography, and prey distribution. We investigated the effect of differential use of available locations by comparing four different selection frames.

In 2019, we began an SCTF-funded raptor project that focuses on GOEA in the SE Region of Colorado (Fig. 1); this focus was agreed upon by statewide Regional, Terrestrial, and Research staff during a September 2018 meeting. Objectives are to better describe GOEA population status and analyze the cost:benefit ratio of monitoring methods that incorporate detection probability (therefore allowing estimation of abundance and trend), minimize sampling bias (which will also produce improved distribution models), explore use of citizen science (e.g., eBird) data, and estimate productivity at a subset of nests. Since initiating this project, we have increased the number of active GOEA nests in the statewide database, as well as the proportion with known status (active, inactive, or destroyed) relative to those with unknown or undetermined status (Table 1B).

In April 2019, we piloted a method for aerial raptor nest surveys with the potential to survey large areas efficiently, estimate detection probabilities, and minimize road bias. Using a CPW Cessna aircraft, we flew north-south transects as well as one tributary and one canyon route that covered most of Crowley and ~half of Otero County in Area 12. Observers did not have access to historic nest locations, so both historic and new or unknown nests could be legitimately detected. We used double-observer methods and distance sampling, categorizing nest detections into one of three strata (plains, canyon/bluff, or associated with water) and placed into ¼ mile distance bins. We attempted to record UTMs on the transect when the plane drew even with the nest. We also recorded structural characteristics (e.g., intact/dilapidated and tree species) whenever possible, plus time, weather, and altitude. Not all nests were occupied when flights occurred in early April (it was necessary to fly before leaf-out) and individual birds were hard to identify beyond ½ mile, so follow-ups during ground-truthing or from the air were needed to determine occupancy status and raptor species. As a result of 2019 flights, we detected ~80 raptor nest structures, most of which were not previously included in the statewide database. Flights were not possible in 2020 due to COVID-19 restrictions.

During April - May 2021, we surveyed ~320 km (200 miles) of canyons and ~185 km (115 miles) of tributaries (riparian corridors) in SE Colorado in Areas 11 and 12 to compare survey practicality and nest detection rate for a rotor (Quicksilver Air R-44 helicopter) and fixed-wing (CPW Cessna plane). Flight time was approximately 1.5 days in each aircraft. Due to COVID-19 restrictions, only a single observer was permitted in the aircraft, so we could not test a protocol with multiple observers. However, the same route was followed in both aircraft, and the observer (A. Estep) did not have waypoints for previously detected nests with her. Thus we attempted to have a "blind" and independent second survey. More nests were detected by the rotor (40) than the fixed wing (31), and many more nests were detected in the tributaries (49) than in the canyons (5), even though the canyon survey covered more ground (Table 2). Of the nests detected, 31% were detected by both aircraft, while 43% were detected only from the rotor and 26% were detected only from the fixed-wing. False positives (5) occurred more often when shadows were long later in the day. Visibility was a problem for the observer when flying away from the sun, although the pilots preferred this. For the observer, it was preferable to fly on sunny days, moving east in the morning and west in the afternoon to avoid having the sun at the observer's back.

Tributary surveys from the helicopter were more efficient and had higher detection probability than the fixed-wing because the rotor can fly more slowly, hover, and turn with smaller radius. In addition, the observer could survey both sides of the canyons and the entire Purgatoire corridor (but not the wider Arkansas corridor) in a single pass through the large front windows. In the back seat of the fixed-wing, visibility is limited to a side view, plus the plane cannot fly as slowly as the rotor; thus it was necessary to make a pass in both directions to view the whole canyon or tributary. However, the helicopter required much more frequent refueling (every 1.5 hours) and is more expensive for CPW, so a cost:benefit analysis should consider this as well. We recommend that if helicopter surveys for raptor nests are used in future, they focus on tributary habitats because of the density of nesting substrate around riparian corridors. The advantage of the rotor was less pronounced in canyons than in tributaries. Plains habitats are much more easily surveyed by fixed-wing than canyons or waterways.

During April 2022, we surveyed most of Prowers County (the easternmost ¼ of the county near Kansas was not completed due to high winds), southern Washington County (south of US-36), and northern Lincoln County (north of I-70) in Areas 12 and 14 from a CPW fixed wing aircraft. As in 2019, we had two observers on the right side of the aircraft and a single observer on the left side. Nests detected by one observer were inadvertently omitted from May – June ground-truthing, so the nests that were detected from the air by R. Conrey (and not by a second observer) were not ground-truthed until September, meaning that 2022 occupancy and raptor species identification was not possible for this subset of nests. Ground truthing was completed during the nesting season for all other nests, and eagle nests were visited multiple times so that productivity could be determined. We detected 7 previously known nests, 69 new nests (later confirmed via ground trothing), and 49 potential nests that could not be ground truthed (Table 3). These 49 undetermined structures could not be ground truthed due to access issues including distance from public roads (19), leaf-out or epicormic shoots that blocked views (15), topography that blocked views (14), and recently downed trees that might have contained a nest destroyed after aerial surveys (1). We also recorded five false positives caused by epicormic shoots (3) and unknown reasons (2). Of the 94 potential nests detected on the right side of the plane, 32 nests were detected by both observers, 23 were detected only by the front observer, and 39 were detected only by the rear observer (Table 3).

Analyses of these data are ongoing, including an evaluation of detection probability and the efficacy of distance sampling versus double-observer methods for plains habitats. Distance sampling is not viable along linear features like canyons and rivers, because detection distance is limited by the width of the topographical feature.

Other data sources have potential to contribute to our understanding of Colorado raptors, including eBird, Breeding Bird Survey, and Colorado Breeding Bird Atlas. As we are better able to achieve survey coverage through flights, we hope to further evaluate how citizen science data can be used along with survey data collected by CPW staff, partners, and volunteers in distribution or occupancy modeling. We have not yet assessed the utility of these data sources or attempted broadscale ground-based surveys along public roads.

Progress and project components completed during 2022:

- Continued effort by staff and volunteers to find new nests and improve information in the statewide raptor database by revisiting historic nest sites.
- Completed additional nest survey transects from fixed wing aircraft in Prowers, north Lincoln, and south Washington Counties, which we later attempted to ground truth.
- A subset of eagle nests was observed multiple times to estimate apparent nest survival and productivity.

Plans for 2023:

- Continue data queries and quality control for the statewide raptor nest database. Assess whether data are of sufficient quality to calculate apparent nest survival rates and summarize threat data.
- No plans for survey flights in 2023, instead focusing on evaluation of data already collected.
- Visits to some undetermined (potential) nest structures that couldn't be previously ground truthed to determine their status, as schedules permit.

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Table 1. Number of nest site records for Colorado raptors. Active nests are those known to be occupied within the past 5 years. Inactive nests are those known to be unoccupied within the past 5 years. Destroyed nests are those known to be no longer usable (e.g., tree or branch has fallen), including historic locations with no structure present. Unknown nests are those that have not been visited within the past 5 years, excluding destroyed nests. Undetermined nests are those for which status could not be determined by an observer within the past 5 years. Annual counts are based on queries made in January, so data submitted after that time won't be reflected until queried again the following year.

A. Number of nest site records in the CPW raptor nest database.

YEAR	NUMBER OF NESTS				
	Active	Inactive	Destroyed	Unk/Undeter	Total
2016	1477	474	618	6127	8696
2017	1846	811	704	5947	9308
2018	1824	736	857	6300	9717
2019	1852	860	1194	6071	9977
2020	2360	1340	1598	5799	11097
2021	2392	1590	1879	6033	11894
2022	2416	1686	2079	6067	12248

B. Number of nest records for Golden Eagle in the CPW raptor nest database. Changes represent increased effort to find new nests and revisit historic nest locations.

YEAR	NUMBER OF GOEA NESTS				
	Active	Inactive	Destroyed	Unk/Undeter	Total
2018	166	191	107	1571	2035
2019	194	216	266	1372	2048
2020	211	249	350	1268	2078
2021	229	255	365	1252	2101
2022	245	304	415	1182	2146

Table 2. Comparison of raptor nest surveys from a helicopter (rotor) and fixed-wing plane (FW) in SE Colorado during spring 2021. We surveyed ~320 km of canyons and ~185 km of tributaries, replicating the survey for both aircraft. Nests could be detected by both aircraft or just one.

Nest Detections	Rotor Only	FW Only	Both	Nest TOTAL
Canyon	1	0	4	5
Tributary	22	14	13	49
TOTAL	23	14	17	54

Figure 1. Raptor nests detected during flights over canyons and tributaries in SE Colorado during 2021. Rotor flights were 31 March – 1 April and fixed-wing flights were 2 May and 5 May. Symbology shows nests discovered using both methods vs. rotor-only or fixed-wing-only.

Colorado Parks and Wildlife

WILDLIFE 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, 2022

Authors**:** Reesa Yale Conrey and Miranda Middleton

Principle Investigators: R. Yale Conrey, CPW Avian Researcher, reesa.conrey@state.co.us; M. Middleton, CPW and Colorado State University; J. Gammonley, CPW Avian Research Leader

Collaborators: Bird Conservancy of the Rockies (M. Smith & B. Snyder); Wildlands Photography and Bio-consulting (M. Lockhart); Colorado Cooperative Fish & Wildlife Research Unit (W. Kendall); K. Aagaard (formerly CPW); U.S. Fish and Wildlife Service; Front Range cities & counties; private landowners

CPW staff: M. Sherman, L. Carpenter, & R. Boyce (TERR); L. Rossi (SCON); R. Sacco (GIS); NE Region staff from Areas 2, 4, & 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). 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 > 100 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 2020–2024. Specific objectives include: 1) Quantify changes in land use around bald eagle nests along the northern Front Range over the past three decades. 2) Quantify and compare demography (breeding effort, breeding success, survival) and space use (home range, foraging areas, 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. 3) Quantify nonbreeding survival, movements, and space use of bald eagles in relation to anthropogenic features.

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.

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). We also incorporated roads (Colorado Department of Transportation) and trails, static layers without temporal data. We calculated a development index within 20 km^2 of each Front Range bald eagle nest by summing the unweighted distance layers (from nests to wind turbines, solar arrays, power lines, oil and gas wells, roads, and trails) and layers related to urbanization (exurban, suburban, urban, and commercial/industrial). We mapped the development index for four decades (1990 – 2020) and overlaid bald eagle nest locations, revealing the level of land use change seen in the Front Range and the degree to which bald eagle nests are now surrounded by development (Fig. 2).

In 2022, 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 2022, 113 nests were occupied by breeding pairs, 99 nests produced 234 nestlings, and 71 nests produced 183 fledged young (63% apparent nest success). Of successful nests, 28% produced one fledgling, 51% produced two fledglings, and 21% produced three fledglings (mean = 1.93 fledglings per successful nest).

Apparent nest success dropped 15 – 20% in 2022, compared to the 2016–2021 average rate. The outbreak of Highly Pathogenic Avian Influenza (HPAI) was suspected but could only be confirmed for one nestling. A new strain of avian influenza first emerged in 2021 that causes severe disease in many avian species. The outbreak in Colorado began in March 2022 and accelerated in fall 2022, with many thousands of poultry and wild bird deaths, especially in waterbirds and raptors. Three adult eagles have died from HPAI this fall and winter.

We are assessing movement and habitat use 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 tags that transmit signals to satellites. We can alter the fix frequency for each tag based on battery performance, and most tags take locations every 15 min while stationary to every 30 sec while flying. We are attempting to capture one member per pair of eagles at active nest sites, fitting them with a GPS/GSM transmitter using a break-away backpack style X-harness. The harnesses are designed to drop off within 4 – 5 years after marking. The original four units had total weight of the transmitter and harness of approximately 70 g (< 2% body mass of an adult male). The newer 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 31 January 2023, we have tagged 30 bald eagles with 19 tags still deployed and 18 transmitting data (Table 1). We have tagged 22 breeding adults, two non-breeding adults, one subadult (now an adult), and five juveniles, with similar numbers of males and females. Eagles have been tagged from July 2020 to August 2022, and some individuals have died or dropped their tags; therefore, the number of tag-days per bird has varied from 16 days (transmitter failed due to manufacturing defects) to 922 days as of 31 January 2023 (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 seven mortalities from electrocution, West Nile Virus, HPAI, lead poisoning, and vehicle strikes among tagged eagles (23% of our total sample), and four eagles have dropped their tags (Table 1).

One preliminary finding is 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. Daily movements of breeding adults appear to be larger during the nestling phase (Fig. 3), and home ranges mapped thus far have ranged from 4 – 100 km^2. Some individuals have taken a hiatus (days to weeks) from their territories in late summer or early fall. In contrast, all nonbreeding eagles have ranged widely and some have made extensive movements of up to 2100 km (Fig. 4). It appears that rivers, reservoirs, and prairie dog colonies are used extensively for foraging. Most foraging takes place near the nest, but territorial birds sometimes range farther. 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 2024 nesting season. We will continue to monitor the eagles currently tagged, and we will attempt to capture and mark 10 or more additional eagles in 2023. 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 2022:

- Monitored 113 occupied bald eagle nests on the Front Range with multiple visits per site.
- Captured and attached transmitters to 10 more eagles, for total sample size of 30 eagles marked.
- Monitored tags, altering duty cycles as needed to maximize locations while preserving battery life.
- Co-advised graduate student Miranda Middleton, who has a final draft of her proposal and exploratory analyses on 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 and HPAI. Prepared eagle data summaries for six different entities, mainly partners who granted access for trapping, to support their land management and eagle conservation goals. Gave presentations to seven groups and co-authored an article about efforts to track a tagged bird in Alberta:
    - Holroyd, G. and R. Conrey. 2022. A Colorado visitor to Beaverhill Lake. The Willet 35(3): 12-13 (http://beaverhillbirds.com/media/2309/vol35-3-november2022-2.pdf).

Plans for 2023:

- Monitor all occupied bald eagle nests on the Front Range at least every two weeks.
- Deploy tags on 10 or more eagles, redeploying recovered tags.
- 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 finalize her M.S. proposal and complete her fieldwork and preliminary analyses.
- 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 31 January 2023.

	Sample Size of Tagged Eagles				Days with Tag		
	Still Tagged	Mortality	Tag Drop	TOTAL	Min	Mean	Max
Breeding Adults							
Females	6	3	2	11	16	349	922
Males	7	2	2	11	189	406	605
Non-breeding Adults							
Females	1	0	0	1	835	835	835
Males	2*	0	0	2	130	278	426
Juveniles							
Females	1	2	0	3	80	174	226
Males	2	0	0	2	179	372	564
TOTAL	19*	7	4	30	-	-	-

*One non-breeding adult male went to Canada and has not transmitted data since April 2022; his fate is unknown. The second non-breeding male was tagged as a subadult but is now an adult.

Figure 1. Number of observed occupied bald eagle nests, 1975–2022, 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.

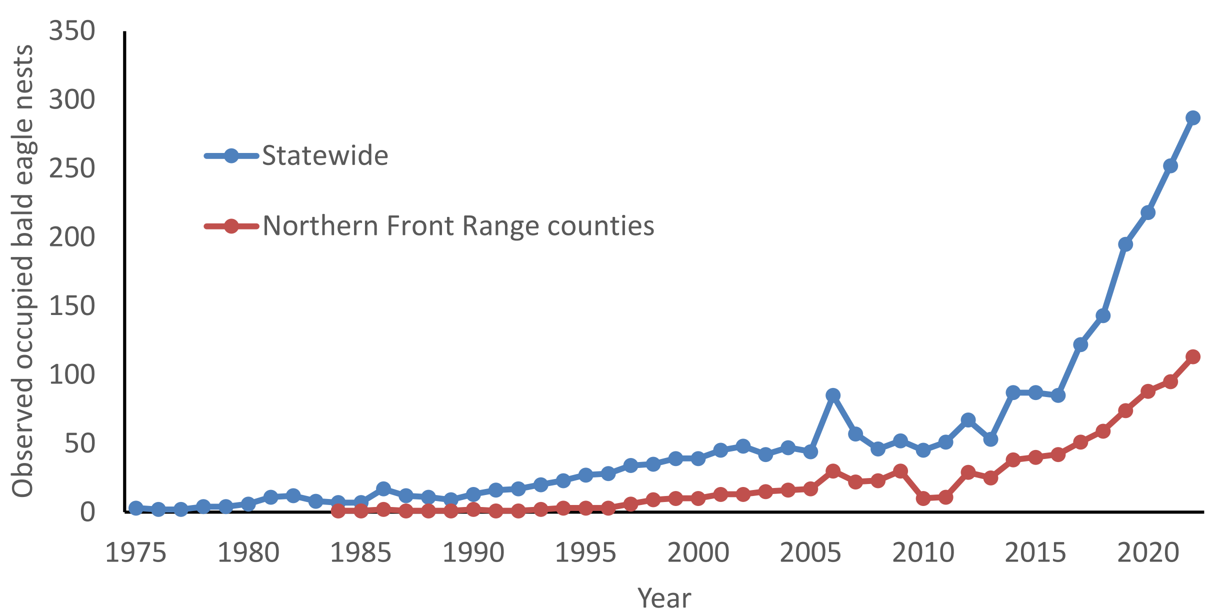


Figure 2. Development index values at bald eagle nests in the Front Range of Colorado. Development layers included oil and gas, solar and wind energy, transmission lines, trails, roads, and residential and commercial development. The index was created by summing the unweighted distance layers from each pixel to these anthropogenic features. Lighter colors represent more highly developed areas. White dots are bald eagle nest locations, shown in each decade for reference, although not all nests were occupied in all decades. The study area is outlined in white.

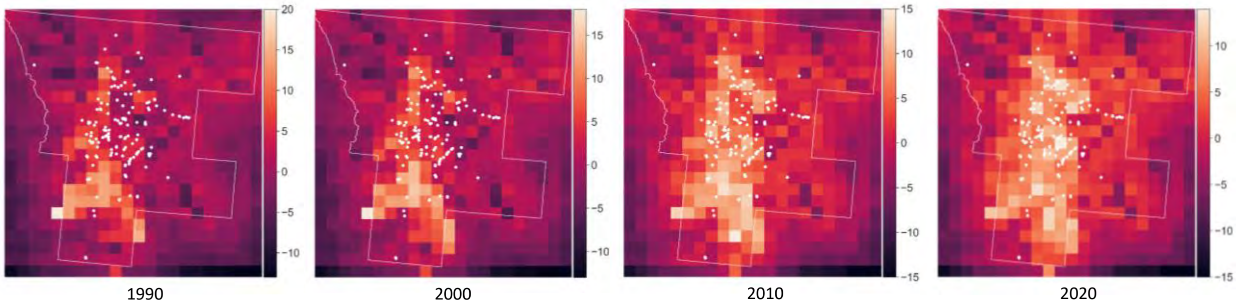


Figure 3. Example of locations collected with GPS/GSM transmitters attached to adult male breeding bald eagles over 24 hours during the spring nestling period in the Colorado Front Range. Below left: the most rural territory in our sample, with 3 people per sq mile. This tag was set to a moderate duty cycle, taking locations every 15 min. Below right: the most urban territory in our sample, with 3325 people per sq mile. This tag was set to a more aggressive duty cycle, taking fixes every 30 sec during flight and every 15 min while stationary.

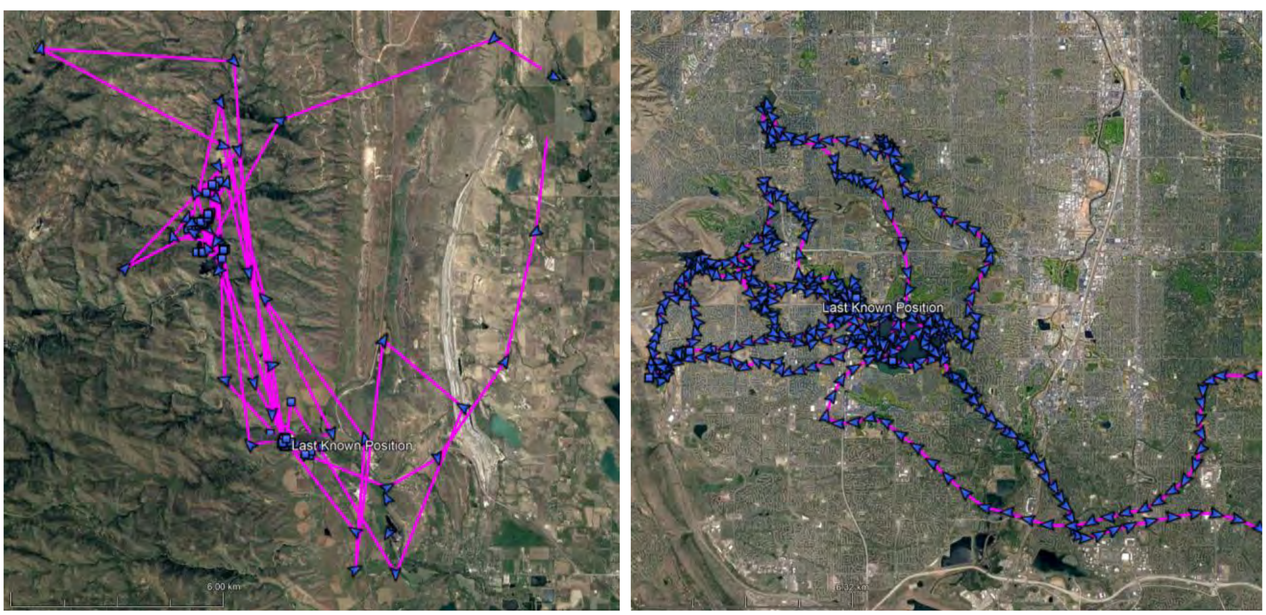
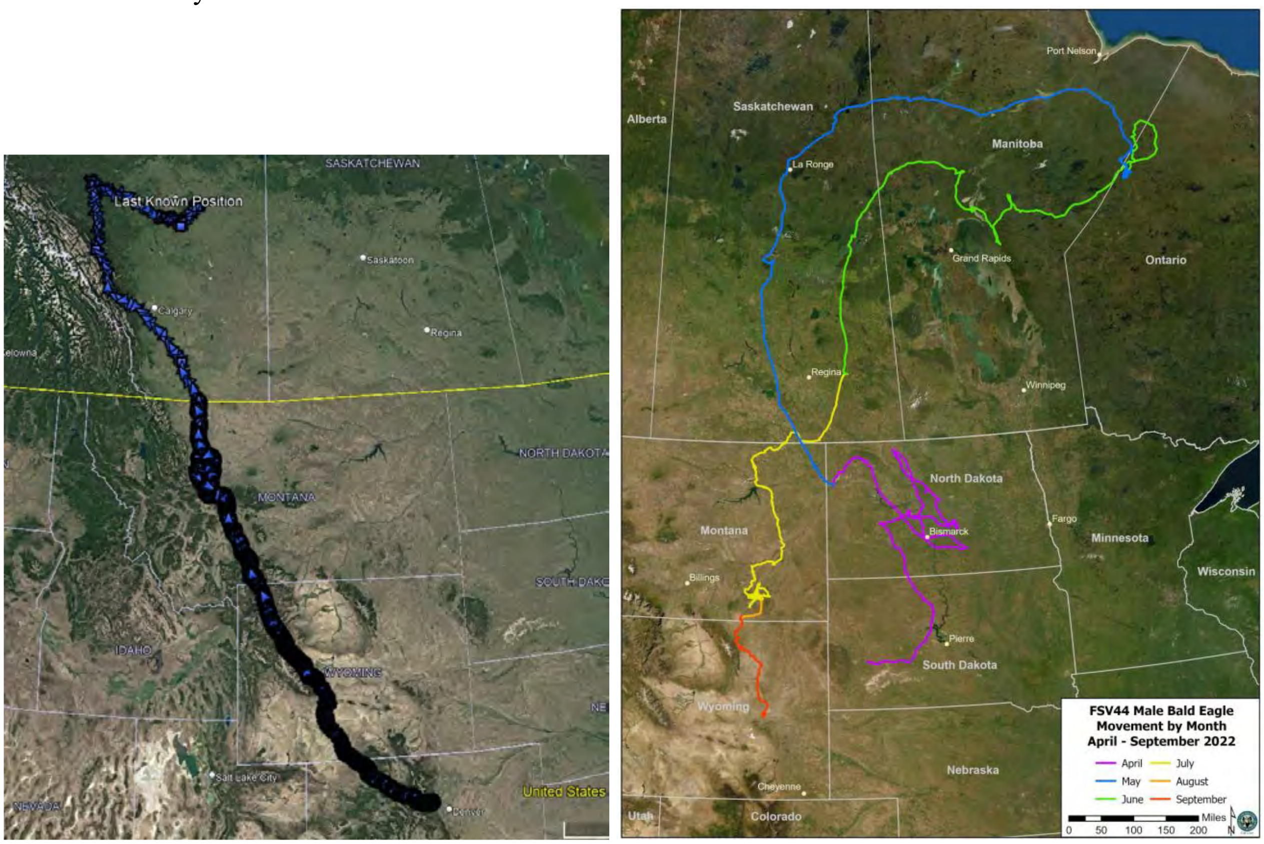


Figure 4. Example of movements observed from GPS/GSM transmitters attached to juvenile bald eagles at their natal nests in the Colorado Front Range. Below left: dispersal of a juvenile female from her natal nest in mid-July at ~6 weeks post-fledge. This female traveled at the fastest rate of any eagle in our sample, at > 200 miles/day (322 km/day) for part of her journey, moving from her natal nest in Colorado to her northernmost point in Alberta (~950 miles, 1530 km) in 9 days. Below right: migratory movements of a 1-year old male, moving northward in spring and southward in fall. This male dispersed into Wyoming after he fledged in 2021 but moved much farther in 2022. He traveled the farthest of any eagle in our sample (~1300 miles, 2100 km), moving from a wintering area near his natal nest in Colorado to near Hudson Bay in Canada.



Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Estimates and determinants of duck production in North Park, Colorado

Period Covered: 1 January 2022 – 31 December 2022

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

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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 (Nichols et al. 2000) surveys on basin wetlands. Dependent double observer surveys involved 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 conducted 268 dependent double observer surveys on basin wetlands in 2022. Out of 3,165 duck detections during these surveys, 54 were missed by the primary observer. The most parsimonious model of detection probability allowed detectability to vary among observers, species group (divers, large dabblers, small dabblers), and linearly with group size (Table 1). Estimated detection probability was between 0.98 and 1.00 for each combination of observer and species, at mean group size. Detectability increased with group size ($\beta_{group} = 0.19 \pm 0.09$). We conducted 118 independent double observer surveys on riparian areas, irrigation ditches, and hay fields. Out of 101 duck detections, 10 were missed by an observer. The best model of detection probability for independent double observer surveys allowed detectability to vary among species (2 groups: dabbling ducks versus diving ducks; Table 2). Estimated detection probabilities were 0.96 ± 0.02 for dabbling ducks and 0.75 ± 0.17 for diving ducks.

At 5 large reservoirs, we conducted 4 rounds of duck counts between 20-Apr and 15-Jun. Duck abundance decreased throughout the survey period, but we did observe a slight uptick during the last survey (Figure 1). We conducted 409 pair counts on 75 basin wetlands, 20 hay meadows, 13 riparian transects, and 12 irrigation ditch transects from 20-Apr until 24-Jun. Summed across all sites, we observed 3,388 total indicated breeding pairs of 16 duck species, including 763 mallards, 626 gadwall, 180 cinnamon teal, and 171 lesser scaup. We modeled pair abundance separately for these species in addition to all ducks combined. For all ducks combined, mallards, and cinnamon teal, a cubic effect of day was the most parsimonious time trend model; whereas, for gadwalls and lesser scaup, a quadratic time trend was best. Total pair abundance across species declined early in the breeding season and then was relatively stable through June, whereas, individual species pair abundance varied through time (Figure 2). We then added vegetation variables to the best time trend model. For all ducks combined and each species separately, open water was an important, positive, predictor of pair abundance. For gadwall, percent shrub/scrub (negative relationship) and robust emergent vegetation (positive relationship) were also important predictors of pair abundance.

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 1,311 ha for duck nests in 2022. We located 32 nests of eight species throughout the 2022 breeding season. Unadjusted nest density was 0.02 nests/ha in shrub-scrub habitat, 0.03 in riparian, 0 in hay meadows, 0.02 in graminoid meadows interspersed with shrubs, 0.04 in strictly graminoid meadows, 0.06 in emergent marsh, and 0 along irrigation ditches. All but three of these nests (90.6%) were located on Arapahoe NWR, with the others located on private, BLM, and SWA properties. Only five monitored nests successfully hatched at least one duckling in 2022, and most nests failed due to depredation ($n = 20$). The most parsimonious model explaining variation in nest survival included a covariate for nest initiation date ($\beta = -0.07$, SD = 0.23). None of the habitat predictors we included in a global model were associated with nest survival. At the mean nest initiation date, daily survival rate was 0.906 (SD = 0.018) equating to overall nest success of 0.05 (SD = 0.03) across species and habitats.

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. We assessed detection probability from our independent double observer surveys of duck broods using Huggins closed capture models (Huggins 1989, Huggins 1991) in Program MARK. We set c_2=p_2 to represent the fact that the likelihood of the second observer detecting a particular brood did not depend on whether the first observer detected it (Pagano and Arnold 2009). We incorporated species, species group (dabbling ducks, teal, diving ducks), and duckling age class as individual covariates. We pooled ducklings into age classes I, II, or III because we did not believe detection would vary within each of those age classes (Gollop and Marshall 1954). We then used detection estimates from the top model to adjust brood counts and estimate abundance of each age class across species. For each pond, we calculated a duckling:pair ratio by dividing the maximum estimate of duckling abundance at that pond in each of the three age classes by the maximum estimate of indicated breeding pairs at that pond throughout the breeding season. We also calculated a brood:pair ratio using maximum brood abundance divided by the maximum pair abundance, where a brood is defined as a group of ducklings associated with a single pair (Pagano et al. 2014). We then used linear models to assess relationships between duckling abundance and habitat characteristics of surveyed wetlands. We evaluated single-covariate models only, using covariates expressing the percentage of the surveyed wetland that was open water, herbaceous emergent vegetation, robust emergent vegetation, and shrub-scrub vegetation. We compared these to an intercept-only null model.

We conducted 175 independent double observer surveys for broods. Out of 5,884 duckling detections, 2190 were missed by an observer. The best model of brood detection probability included observer and species (large dabbler, small dabbler, diver; Table 3). Detection ± SE ranged from 0.63 ± 0.03 to 0.88 ± 0.01 among observers and species. We conducted 328 brood counts at 119 sites from 25-Jul through 2-Sep. We observed broods of 11 duck species with gadwall being the most common followed by lesser scaup, mallard, and cinnamon teal. Summed across surveys and sites, we observed 6,263 ducklings (986 broods). On average, we conducted three brood surveys per site. Similar to the analysis for pair counts, we modeled duckling abundance for all duck species combined. For the species-specific analyses, an excess of counts with zero ducklings observed necessitated modeling presence/absence of broods rather than duckling abundance for mallards, gadwall, lesser scaup, and cinnamon teal. For all ducks combined, date in cubic form ($date^3$) was the best temporal trend of duckling abundance, which peaked in early August (Fig. 3). Percent of the site that was flooded positively influenced duckling abundance. For gadwall, mallards, and cinnamon teal, a quadratic time trend ($date^2$) was best, whereas for lesser scaup a cubic trend was the best temporal predictor of duckling presence. Duckling presence for gadwall, mallards, lesser scaup, and cinnamon teal peaked in early to mid-August. Percent of the site that was flooded was the best habitat variable predicting gadwall, mallard, and cinnamon teal duckling presence and presence was positively related to percent flooded. Percent herbaceous vegetation was best in predicting lesser scaup duckling presence and was negatively related to duckling presence.

Mean brood-pair ratio was greatest for gadwall and least for mallards (Table 4). Overall mean ± SD brood-pair ratio was 0.29 ± 0.70 and duckling-pair ratio was 1.80 ± 4.16 (Table 4).

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 982 ducks of 11 species (Table 5). Our pre-season trapping effort was comprised of 300 trap-days with baited swim-in traps (70% of the banded sample), and 4 nights of spotlighting from an airboat (30% of the banded sample). Mallards comprised the majority (62%) of our banded sample. We captured gadwall (20% of the banded sample) primarily (94%) with spot-lighting. We banded 38 cinnamon and blue-winged teal (4% 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, 105 ducks we banded in 2018, 99 ducks we banded in 2019, 175 ducks we banded in 2020, 41 ducks we banded in 2021, and 93 ducks we banded in 2022 (total = 513) had been harvested by hunters and reported to the USGS Bird Banding Laboratory, including 402 mallards, 58 gadwall, 5 cinnamon teal, 7 unidentified teal (likely cinnamon teal), 11 shovelers, 7 green-winged teal, 7 wigeon, 2 pintails, 2 Mexican ducks, 7 lesser scaup, 3 redhead, and 2 canvasback. Among mallards, juveniles and adult males have been harvested at higher rates than adult females (Table 6). Most mallards (73.6%) were harvested in Colorado, in 36 different counties (Table 8). Mallards banded in North Park during 2018-2022 were also harvested in 13 other states, including 58 different counties, and the provinces of Alberta and Saskatchewan in Canada (Table 7).

We plan to continue annual field work through 2023.

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Table 1. Model selection results for duck detection probability on basin wetlands using dependent double observer sampling in North Park, Colorado during 2022.

Model	K	ΔAIC_c	w_i
Observer (6 levels) + species (3 levels) + group size	9	0.0	0.7
Observer (6 levels) + species (2 levels) + group size	8	2.2	0.2
Observer (6 levels)	6	13.0	0.0
Observer (6 levels) + species (2 levels)	7	14.6	0.0
Observer (6 levels) + species (3 levels)	8	14.8	0.0
Group size	2	39.2	0.0
Species (2 levels) + group size	3	40.8	0.0
Species (3 levels) + group size	4	41.1	0.0
Species (2 levels)	2	61.0	0.0
Null	1	61.1	0.0
Species (3 levels)	3	61.9	0.0

Table 2. Model selection results for duck detection probability on riparian areas, ditches, and hay meadows using independent double observer sampling in North Park, Colorado during 2022.

Model	K	ΔAIC_c	w_i
Species (2 levels)	2	0.0	0.3
Null	1	1.4	0.2
Species (2 levels) + habitat type	4	1.7	0.1
Species (3 levels)	3	1.9	0.1
Habitat type	3	2.6	0.1
Species (2 levels) + habitat type + group size	5	3.6	0.1
Observer	6	3.7	0.1
Species (2 levels) + habitat type + group size + observer	10	6.0	0.0

Table 3. Model selection results for duck brood detection probability using independent double observer sampling in North Park, Colorado during 2022.

Model	K	ΔAIC_c	w_i
Observer + species (3 levels)	8	0.0	1.0
Observer	5	66.2	0.0
Habitat type + species (3 levels)	7	201.0	0.0
Species (3 levels)	4	201.5	0.0
Species (2 levels)	3	205.1	0.0
Habitat type	4	263.5	0.0
Null	1	264.6	0.0

Table 4. Brood and duckling-pair ratios with associated standard deviation and minimum and maximum values across sites in North Park, Colorado during 2022.

	Brood-pair ratio				Duckling-pair ratio			
Species	Mean	SD	Min	Max	Mean	SD	Min	Max
Cinnamon teal	0.09	0.32	0.00	2.00	0.58	2.47	0.00	20.00
Mallard	0.07	0.21	0.00	1.07	0.54	1.54	0.00	8.00
Gadwall	0.38	0.83	0.00	4.00	2.64	5.90	0.00	29.00
Lesser scaup	0.13	0.43	0.00	3.00	0.90	3.25	0.00	23.00
All ducks	0.29	0.70	0.00	6.00	1.80	4.16	0.00	33.00

Table 5. Numbers of ducks banded in North Park during pre-season capture efforts in 2022. 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	68	239	95	186	6	10	604
Gadwall	23	18	29	38	37	55	200
Shoveler	3	2	13	13	8	9	48
Cinnamon/blue-winged teal[a]	3	1	20	12	1	1	38
Lesser scaup	1	0	8	4	4	15	32
American wigeon	6	7	4	4	6	3	30
Green-winged teal	2	3	0	4	0	1	10
Mexican duck	0	8	0	1	0	0	9
Redhead	2	3	0	0	1	2	8
Pintail	0	0	2	0	0	1	3
Total	108	281	171	262	63	97	982

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

Table 6. Numbers of mallards banded in North Park during 2018-2022 in different age and sex cohorts and reported shot by hunters during hunting seasons through December 31, 2022.

		Number	Number harvested (% of banded sample)				
Banded cohort	Band year	banded	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
AHY male	2018	168	10 (6.0%)	11 (6.5%)	5 (3.0%)	0	1 (0.6%)
	2019	234	-	23 (9.8%)	8 (3.4%)	9 (3.8%)	2 (0.9%)
	2020	246	-	-	16 (6.5%)	14 (5.7%)	5 (2.0%)
	2021	306	-	-	-	22 (7.2%)	1 (0.3%)
	2022	239	-	-	-	-	14 (5.9%)
AHY female	2018	69	1 (1.4%)	2 (2.9%)	0	0	0
	2019	104	-	4 (3.8 %)	1 (1.0%)	1 (1.0%)	0
	2020	108	-	-	10 (9.3%)	2 (1.9%)	1 (0.9%)
	2021	95	-	-	-	2 (2.1%)	0
	2022	68	-	-	-	-	4 (5.9%)
HY male	2018	221	29 (13.1%)	12 (5.4%)	2 (0.9%)	5 (2.3%)	2 (0.9%)
	2019	109	-	12 (11.0%)	6 (5.5%)	0	2 (1.8%)
	2020	266	-	-	25 (9.4%)	22 (8.3%)	4 (1.5%)
	2021	57	-	-	-	6 (10.5%)	2 (3.5%)
	2022	186	-	-	-	-	31 (16.7%)
HY female	2018	131	13 (9.9%)	5 (3.8%)	0	0	0
	2019	73	-	3 (4.1%)	2 (2.7%)	0	0
	2020	200	-	-	23 (11.5%)	5 (2.5%)	3 (1.5%)
	2021	38	-	-	-	1 (2.6%)	1 (2.6%)
	2022	95	-	-	-	-	3 (3.2%)
L male	2018	12	1 (8.3%)	0	0	0	0
	2019	7	-	1 (14.3%)	0	0	0
	2020	25	-	-	5 (20.0%)	0	1 (4.0%)
	2021	0	-	-	-	0	0

	2022	10	-	-	-	-	1 (10.0%)
L female	2018	14	2 (14.3%)	0	0	0	0
	2019	11	-	1 (9.1)	0	0	0
	2020	28	-	-	3 (10.7%)	0	0
	2021	0	-	-	-	0	0
	2022	6	-	-	-	-	0
Total	2018	615	56 (9.1%)	30 (4.9%)	7 (0.7%)	5 (0.8%)	3 (0.5%)
	2019	538	-	44 (8.2%)	17 (3.2%)	10 (1.9%)	4 (0.7%)
	2020	873	-	-	82 (9.4%)	43 (4.9%)	14 (1.6%)
	2021	496	-	-	-	31 (6.3%)	4 (0.8%)
	2022	604	-	-	-	-	53 (8.8%)

Table 7. 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, 2018-2022, reported by hunters through December 31, 2022.

State	County	Direct recoveries	Indirect recoveries
Colorado	Total	211 (78.2)	85 (61.7)
	Adams	4 (1.5)	3 (2.2)
	Alamosa	4 (2.4)	5 (1.1)
	Bent	2 (1.0)	1 (1.1)
	Boulder	5 (1.9)	4 (2.2)
	Chaffee	1 (0.5)	0
	Conejos	1 (0.5)	1 (1.1)
	Costilla	2 (1.0)	1 ()
	Crowley	0	1 ()
	Delta	1 ()	2 (1.1)
	Dolores	0	1 (1.1)
	Douglas	1 (0.5)	0
	Eagle	7 (3.4)	0
	El Paso	1 (0.5)	0
	Fremont	0	1 (1.1)
	Garfield	3 (0.5)	0
	Grand	13 (4.9)	5 (4.4)
	Gunnison	2 (0.5)	0
	Jackson	77 (26.2)	10 (6.7)
	Kiowa	0	1 ()
	La Plata	1 (0.5)	1 (1.1)
	Larimer	6 (1.5)	1 (1.1)
	Las Animas	3 (1.5)	1 (1.1)
	Logan	2 ()	5 (2.2)
	Mesa	2 (1.0))	1 (1.1)
	Montrose	0	2 (2.2)
	Morgan	5 (2.4)	3 (3.3)
	Otero	6 (2.9)	3 (2.2)
	Park	5 (2.4)	4 ()
	Pitkin	1 (0.5)	0
	Prowers	1 (0.5)	0
	Pueblo	8 (3.4)	1 (1.1)
	Rio Grande	4 (1.9)	2 (1.1)
	Routt	4 (1.9)	1 (1.1)
	Saguache	9 (2.9)	2 (1.1)
	Summit	2 (0.5)	0
	Weld	28 (8.7)	22 (15.6)
Arizona	Total	2 (1.0)	0
	Coconino	1 (0.5)	0
	Maricopa	1 (0.5)	0
Idaho	Total	0	2 ()

	Payette	0	1 ()
	Power	0	1 ()
Kansas	Total	2 (1.0)	2 (2.2)
	Barton	1 (0.5)	0
	Crawford	0	1 (1.1)
	Trego	1 (0.5)	1 (1.1)
Missouri	Total	0	1 (1.1)
	Holt	0	1 (1.1)
Montana	Total	1 (0.5)	1 ()
	Big Horn	0	1 ()
	Yellowstone	1 (0.5)	0
Nebraska	Total	4 (1.5)	4 (3.3)
	Garden	1 (0.5)	0
	Keith	2 (0.5)	1 ()
	Lincoln	1 (0.5)	1 (1.1)
	Morrill	0	1 (1.1)
	Scotts Bluff	0	1 (1.1)
New Mexico	Total	29 (12.1)	15 (11.1)
	Bernalillo	1 (0.5)	0
	Chaves	3 ()	0
	Dona Ana	1 (0.5)	1 ()
	Mora	0	1 (1.1)
	Otero	1 ()	0
	Rio Arriba	1 (0.5)	0
	Roosevelt	1 (0.5)	0
	San Juan	3 (0.5)	2 (2.2)
	Sandoval	0	1 (1.1)
	Santa Fe	1 (0.5)	0
	Sierra	2 (1.0)	3 (1.1)
	Socorro	8 (3.4)	6 ()
	Valencia	7 (3.4)	1 (1.1)
Nevada	Total	1 ()	1 (1.1)
	Lyon	0	1 (1.1)
	Nye	1 ()	0
Oklahoma	Total	3 (1.0)	6 (5.6)
	Caddo	0	2 (1.1)
	Carnegie	0	1 (1.1)
	Carter	1 ()	0
	Garfield	1 (0.5)	0
	Logan	0	1 (1.1)
	Oklahoma	0	2 (2.2)
	Pottawatamie	1 (0.5)	0

South Dakota	Total	0	1 (1.1)
	Fall River	0	1 (1.1)
Texas	Total	7 (3.4)	5 (5.6)
	Carson	1 (0.5)	0
	Crosby	0	1 (1.1)
	Haskell	1 (0.5)	0
	Hockley	0	1 (1.1)
	Hudspeth	1 (0.5)	1 (1.1)
	McCulloch	1 (0.5)	0
	Oldham	2 (1.0)	1 (1.1)
	Reeves	0	1 (1.1)
	Terry	1 (0.5)	0
Utah	Total	3 (1.0)	7 (3.3)
	Boxelder	0	2 ()
	Davis	0	1 (1.1)
	Duchesne	2 (0.5)	0
	Piute	0	1 ()
	Salt Lake	0	2 (1.1)
	Uintah	1 (0.5)	0
	Weber	0	1 (1.1)
Wyoming	Total	1 (0.5)	6 (2.1)
	Albany	1 (0.5)	3 (2.2)
	Goshen	0	1 ()
	Lincoln	0	1 (1.1)
	Sublette	0	1 (1.1)
Canada	Total	0	2 (1.1)
	Alberta	0	1 (1.1)
	Saskatchewan	0	1 ()
Total recoveries		264	138

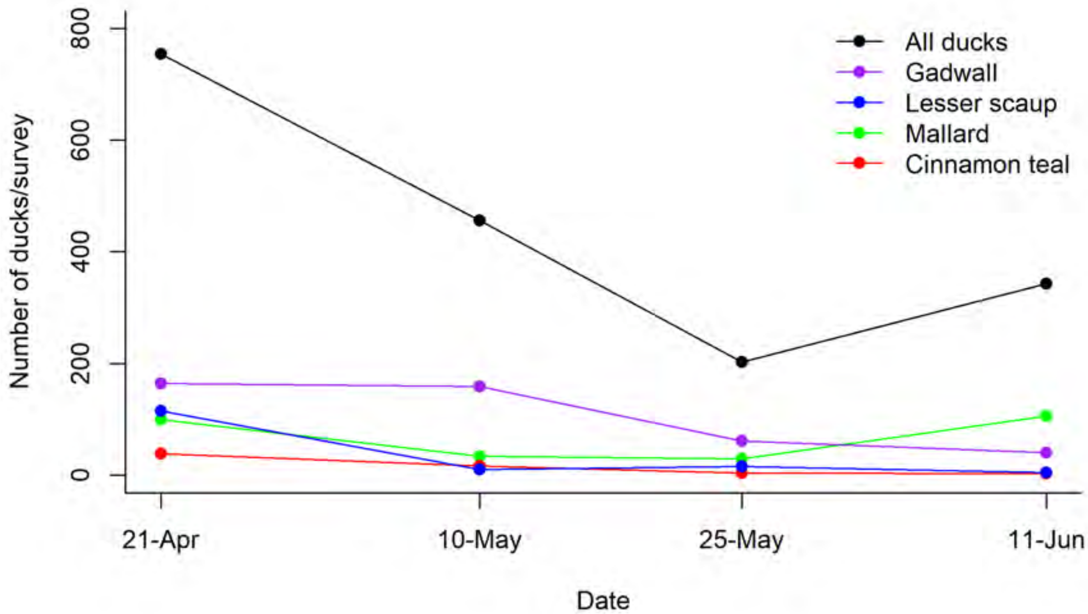

Figure 1. Number of ducks detected per survey for four surveys throughout the 2022 duck breeding season at five large reservoirs in North Park, Colorado.

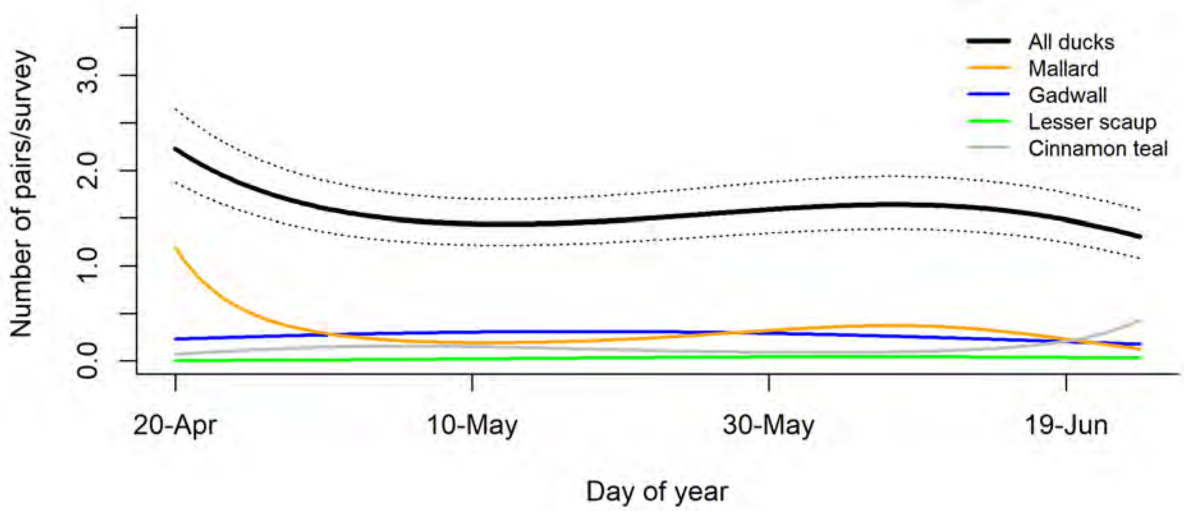

Figure 2. Number of indicated breeding pairs per survey per wetland for all ducks and select species throughout the 2022 duck breeding season in North Park, Colorado. Dotted lines indicate ± 1 SE.

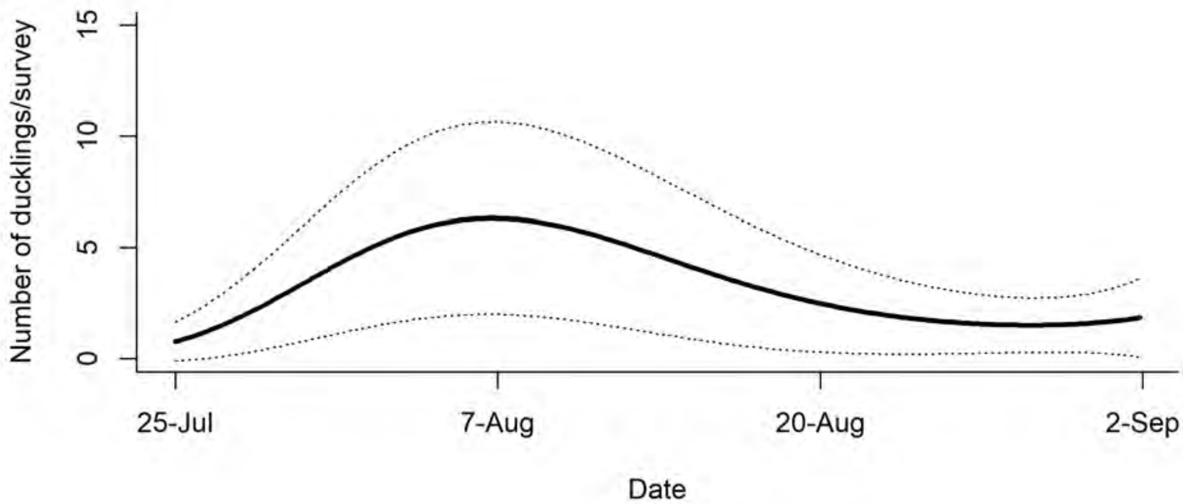

Figure 3. Model-estimated time-trend of duckling abundance for all ducks combined throughout the 2022 breeding season in North Park, Colorado. Dotted lines indicate ± 1 SE.

Publications, presentations, workshops and committee involvement by Avian Research staff January – December 2022

PUBLICATIONS

Apa, A. D., **J. H. Gammonley**, D. J. Neubaum, E. Phillips, J. P. Runge, N. Seward, S. Wait, and B. Weinmeister. 2022. Survival rates of translocated Gunnison sage-grouse. Wildlife Society Bulletin e1245. https://doi.org/10.1002/wsb.1245

Gammonley, J. H., and J. P. Runge. 2022. Duck hunter activity, success, and satisfaction on public hunting areas. Journal of Wildlife Management e22210.https://doi.org/10.1002/jwmg.22210

Holroyd, G. and **R. Conrey**. 2022. A Colorado visitor to Beaverhill Lake. The Willet 35(3): 12-13. (http://beaverhillbirds.com/media/2309/vol35-3-november2022-2.pdf)

Johnston, D.B. and C. R. Anderson. *Accepted* Nov 11, 2022. Plant and mule deer responses to tree removal by three mechanical methods. Wildlife Society Bulletin DOI: 10.1002/wsb.1421

Neubaum, D., and **K. Aagaard**. 2022. Use of predictive distribution models to describe habitat use by Colorado bats. Journal of Wildlife Management 86:e22178.https://doi.org/10.1002/jwmg.2217820

Walker, B. L. 2022. Resource selection by greater sage-grouse varies by season and infrastructure type in a Colorado oil and gas field. Ecosphere. DOI:10.1002/ecs2.4018.

PRESENTATIONS, WORKSHOPS, AND COMMITTEES

Apa, A.D. CPW science support, United States Fish and Wildlife Service Gunnison Sage-grouse Recovery Team.

Apa, A. D., A. C. Behney, D. B. Johnston, and **B. L. Walker.** CPW Animal Care and Use Committee.

Behney, A. C. Faculty co-advisor for M.S. degree candidate Joseph Wolske, University of Nebraska Lincoln. Thesis: Wolske, J. M. 2022. Nonbreeding season survival and habitat selection of northern bobwhite in northeastern Colorado.

Behney, A. C. Pacific Flyway Study Committee Work and Businaess Meeting. February 2022.

Behney, A. C. Pacific Flyway Study Committee Meeting. August 2022.

Behney, A. C. South Platte Focus Area Committee Meetings. Mar, Jun, Sep, Dec 2022.

Behney, A. C. 2022. Duck research in the South Platte River corridor. Oral presentation (virtual), South Platte Wetland Focus Area Committee Meeting.

Behney, A. C. 2022. Benefits of playa buffers as bird habitat. Oral presentation, 3rd Playa Research Symposium, Kearney, NE.

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. IMBCR for PLJV (Integrated Monitoring in Bird Conservation Regions for Playa Lakes Joint Venture) Advisory Committee.

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

Conrey, R. Y. CPW Front Range Bald Eagle Study. Oral presentation, as part of Bird Conservancy of the Rockies Bald Eagle Watch, Annual Volunteer Training. Statewide (virtual), 22 January 2022.

Conrey, R. Y., M. M. Middleton, M. Smith, B. D. Snyder, and J. H. Gammonley. Bald eagles in our backyard: population trends, habitat use, and human impacts on Colorado's Front Range eagles. Oral presentation, Colorado State University Field Ornithologists seminar. Fort Collins, CO, 18 April 2022.

Conrey, R. Y., M. M. Middleton, M. Smith, B. D. Snyder, and J. H. Gammonley. Bald eagles in our backyard: population trends, habitat use, and human impacts on Colorado's Front Range eagles. Oral presentation, City of Aurora Open Space and Natural Resources staff and volunteer annual meeting. Aurora, CO, 26 May 2022.

Conrey, R. Y., M. M. Middleton, M. Smith, B. D. Snyder, and J. H. Gammonley. Bald eagles in our backyard: population trends, habitat use, and human impacts on Colorado's Front Range eagles. Oral presentation, Denver Audubon Conservation Committee meeting. Statewide (virtual), 9 September 2022.

Conrey, R. Y., M. M. Middleton, M. Smith, B. D. Snyder, and J. H. Gammonley. Bald eagles in our backyard: population trends, habitat use, and human impacts on Colorado's Front Range eagles. Colorado State Parks, Oral presentation, Annual Meeting of Raptor Monitoring Volunteer Program. Denver, CO (in person/hybrid), 5 November 2022.

Conrey, R. Y. Bald eagles and more Colorado raptors. Presentation for 1st grade science class. Wellington, CO, 10 November 2022.

Conrey, R. Y., M. M. Middleton, M. Smith, B. D. Snyder, and J. H. Gammonley. Bald eagles in our backyard: population trends, habitat use, and human impacts on Colorado's Front Range eagles. Oral presentation, Colorado Field Ornithologists meeting. Statewide (virtual), 13 November 2022.

Gammonley, J. H. Faculty Committee member for Ph.D. candidate Casey Setash, Colorado State University.

Gammonley, J. H. CPW Wetlands Program Application Review Team. February/March 2022.

Gammonley, J. H. Central Flyway Waterfowl, Webless Migratory Game Bird, and Central Management Unit Dove Technical Committee meetings (virtual), February 1-4, 2022.

Gammonley, J. H. August 4, 2022. The Northeast Duck Hunting Zone. Oral presentation, Northeast Sportspersons Caucus meeting, Johnstown, CO.

Gammonley, J. H. Central Flyway Technical Committee and Council meetings, South Padre Island, TX, September 11-16, 2022.

Gammonley, J. H. December 12, 2022. The Northeast Duck Zone Season. Oral presentation, CPW Northeast Region public meeting, Fort Collins, CO.

Johnston, D.B. February 7, 2022. Field tests of moisture-retaining restoration treatments. Oral presentation, Society for Range Management Annual Meeting. Albuquerque, NM.

Johnston, D. B., Lovoi, D., and I. Archer. February 24, 2022. Seeding with a pothole seeder. Oral presentation, RiversEdge West Restoration Workshop. Grand Junction, CO.

Johnston, D. B. April 5, 2022. Sagebrush from seed: what it takes. Oral presentation, Gunnison Sage-grouse Summit. Gunnison, CO.

Johnston, D. B. May 9, 2022. Cheatgrass control update: NutraFix, potholing, and indaziflam. Oral presentation (virtual), Conservation Days, Colorado Parks and Wildlife.

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.

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

Walker, B. L. Solving the mystery of Colorado's alpine Brewer's Sparrows. Grand Valley Audubon Society. May 16, 2022.