COLORADO PARKS & WILDLIFE

2021 Avian Research Summary Report

JANUARY 2021

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WILDLIFE RESEARCH SUMMARIES

JANUARY – DECEMBER 2021

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 2021. 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 2021, 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 10 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 Greater Sage-Grouse Conservation, Sagebrush Bird Conservation, Wildlife Habitat Conservation, Grassland Bird Conservation, Raptor Conservation, Quail Conservation, and Wetland Bird Conservation.

Also included in this report is a listing of publications produced during 2021, and presentations, workshops and participation on various committees and working groups by Avian Research staff during 2021. 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 technicians that will serve wildlife management in the future. Research collaborators include statewide CPW personnel, Colorado State University, University of Nebraska-Lincoln, Bureau of Land Management, U.S. Fish and Wildlife Service, U.S. Geological Survey, City of Fort Collins, Species Conservation Trust Fund, EnCana Corp, ExxonMobil/XTO Energy, Marathon Oil, WPX Energy, Conoco-Phillips, Rocky Mountain Bird Observatory, and the private landowners who have provided access for research projects.

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Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Greater sage-grouse conservation in the Parachute-Piceance-Roan Population in northwestern Colorado and the Hiawatha Regional Energy Development project in northwestern Colorado and southewestern Wyoming

Period Covered: January 1 – December 31, 2021

Principal Investigator: Brett L. Walker brett.walker@state.co.us

Project Collaborators: Bill deVergie, Brian Holmes, T. Knowles, H. Sauls

All information in this report is preliminary and subject to further evaluation. Information MAY NOT BE PUBLISHED OR QUOTED without permission of the principal investigator. Manipulation of these data beyond that contained in this report is discouraged.

ABSTRACT

1. Comparing Survival of Greater Sage-Grouse with VHF and GPS Transmitters in Northwestern Colorado and Southwestern Wyoming

Large-scale changes to sagebrush habitats throughout western North America have led to growing concern for conservation of greater sage-grouse (*Centrocercus urophasianus*) and widespread efforts to better understand sage-grouse demographic rates, movements, habitat selection, and responses to habitat manipulation and disturbance. Almost all current research projects use very high frequency (VHF) transmitters attached to a neck collar to radio-track individual sage-grouse because previous attempts using backpack-style transmitters appeared to increase vulnerability of birds to predation. However, recent technological advances have led to commercial production of 22-30 g, solar-powered, global positioning system (GPS) satellite transmitters that appear suitable for use with sage-grouse. GPS transmitters have several advantages over traditional VHF collars. They collect multiple locations per day at pre-programmed times, problems with accessing locations on the ground are eliminated, data are gathered remotely without disturbing the bird or its flock mates, and they provide extremely high-resolution data on survival, movements, habitat use, and timing of nest initiation. However, it remains unknown whether rump-mounted GPS transmitters influence survival or rates of nest initiation or survival of sage-grouse compared to VHF transmitters. I conducted a 1-year pilot study to compare demographic rates between greater sage-grouse with traditional VHF neck collars and rump-mounted solar GPS PTT transmitters in the proposed Hiawatha Regional Energy Development Project (HREDP) area in NW Colorado and SW Wyoming. We captured and attached 30-g, rump-mounted solar-powered GPS PTT satellite transmitters and VHF necklace collars on adult female sage-grouse in spring 2009 in and around the proposed HREDP. Survival of females with VHF ($n = 42$) and ($n = 50$) GPS transmitters was similar from spring 2009 through October 2009, but lower for GPS-marked females from October 2009 - March 2010, resulting in lower annual survival for GPS-marked females (0.556 ± 0.073 SE for VHF vs. 0.406 ± 0.068 SE for GPS). This finding prompted us to improve transmitter camouflage and padding, increase harness flexibility, modify our leg-loop fitting techniques, and recommend to other researchers to exercise caution in using rump-mounted GPS transmitters on females. Nest survival and transmitter GPS transmitter performance analyses will be completed and a manuscript submitted following completion of other, higher priority projects.

2. Using GPS satellite transmitters to estimate survival, detectability on leks, lek attendance, inter-lek movements, and breeding season habitat use of male greater sage-grouse in northwestern Colorado

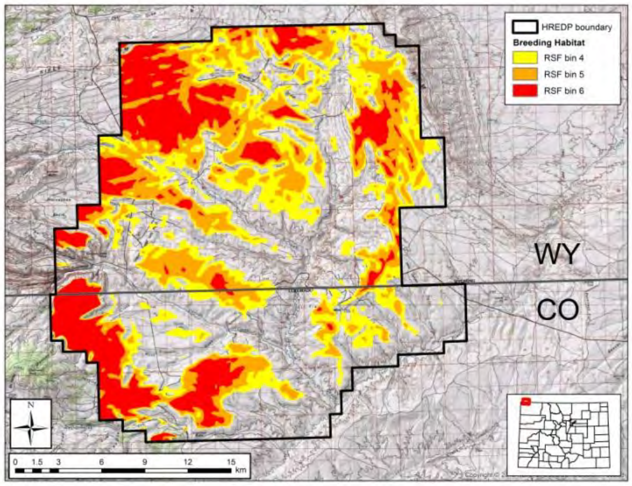
Implementing effective monitoring and mitigation strategies is crucial for conserving populations of sensitive wildlife species. Concern over the status of greater sage-grouse (*Centrocercus urophasianus*) populations has increased both range-wide and in Colorado due to historical population declines, range contraction, continued loss and degradation of sagebrush habitat, and the potential for listing the species under the Endangered Species Act. Despite untested assumptions, lek-count data continue to be widely used as an index of abundance by state and federal agencies to monitor sage-grouse populations. Lek locations are also commonly used as a surrogate to identify and protect important sage-grouse habitat. However, the use of lek counts and lek locations to monitor and manage sage-grouse populations is controversial because how closely lek-count data track actual changes in male abundance from year to year and how effective lek buffers are at reducing disturbance to male sage-grouse and the habitat they use during the breeding season are largely unknown. We deployed solar-powered GPS satellite transmitters on male greater sage-grouse to obtain data on male survival, lek attendance, inter-lek movements, and diurnal and nocturnal habitat use around leks and conducted double-observer lek counts to estimate detectability of males on leks during the breeding season in and around the Hiawatha Regional Energy Development project area in northwestern Colorado in spring from 2011-2014. In conjunction with Jessica Shyvers and Jon Runge, I developed a multi-state model to simultaneously estimate daily survival, lek attendance, and inter-lek movement rates of males during the breeding season and will use an unreconciled double-observer approach to estimate detectability of males attending leks. I will then use estimates of male survival, detectability of males on leks, lek attendance, inter-lek movement, and the proportion of leks known and counted during the breeding season to generate simulated lek-count data from simulated male populations to evaluate the reliability of current lek-based methods for monitoring population trends. I am using local convex hull (t-Locoh) and Brownian bridge movement models to identify space use in relation to known leks to evaluate the performance of lek buffers for conserving important greater sage-grouse seasonal habitats. Analyses for this project are ongoing.

3. Hiawatha Regional Energy Development Project and Greater Sage-grouse Conservation in Northwestern Colorado and Southwestern Wyoming. Phase I: Conservation planning maps and habitat selection

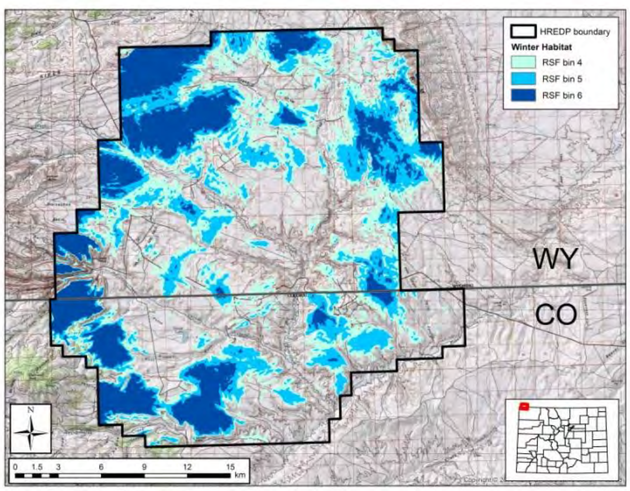
Increasing energy development within sagebrush habitat has led to concern for conservation of greater sage-grouse (*Centrocercus urophasianus*) populations, and both industry and regulatory agencies need better information on when and where sage-grouse occur to reduce impacts. Managers also lack landscape-scale habitat guidelines that identify the size and configuration of seasonal habitats required to support sage-grouse use. It is also essential to understand how sage-grouse in local populations select habitat in terms of the relative importance of local (i.e., micro-site) vs. landscape-scale habitat features. Understanding their response to different components of energy infrastructure is also essential for understanding and predicting the effects of specific development proposals. Resource selection functions (RSF) can be combined with geographic information system data to model habitat selection by sage-grouse in response to natural and anthropogenic habitat features at multiple scales and to map key seasonal habitats at high resolution over large areas. Multi-scale habitat use models, landscape-scale habitat guidelines, and high-resolution seasonal habitat-use maps will help streamline planning and mitigation for industry and facilitate sage-grouse conservation in areas with energy development. The proposed Hiawatha Regional Energy Development Project (HREDP) overlaps much of the known winter habitat and a portion of the documented nesting and brood-rearing habitat for the sage-grouse population that breeds in northwestern Colorado. Colorado Parks and Wildlife conducted a field study project tracking VHF females from December 2007 through July 2010. Objectives were to: (1) create validated, high-resolution conservation planning maps based on RSF models that delineate important seasonal sage-grouse habitats within the proposed HREDP boundary, (2) identify landscape-scale seasonal habitat guidelines, (3) evaluate the relative importance of local versus landscape-level habitat features (including vegetation, topography, and energy infrastructure) on sage-grouse wintering and (if possible) nesting habitat selection, and (4) assess whether historical energy development in the Hiawatha area influences current habitat selection. Field data collection was completed in July 2010. Preliminary seasonal RSF maps were completed in March 2010 (Fig. 1). However, analyses were limited by the extent of reliable classified land cover layers on either side of the Colorado-Wyoming state line. CPW's GIS section attempted to produce an improved classified land cover layer from 2010-2014, however, that effort was unsuccessful, so I opted to use the USGS Landfire vegetation layer instead. I completed mapping of annual energy infrastructure within 4 miles of the HREDP boundary from 2006-2015 in 2017. To meet objectives 1-3, I will first conduct RSF analyses and seasonal habitat mapping for the winter and breeding seasons using 2007-2010 VHF locations and micro-site vegetation data. Since field work for this project was completed, two additional, higher-resolution datasets have become available that would improve modeling of seasonal habitat. I plan to use two datasets of seasonal locations collected from GPS-marked females in 2009-2013 and GPS-marked males in 2012-2016 to conduct additional RSF analyses to assess habitat selection all three seasons in relation to vegetation cover, topography, and energy infrastructure to complement models based on VHF data. For objective 4, we found that historical and recent energy development within the HREDP were largely coincident (i.e., spatially correlated), so it would be impossible to distinguish the effects of historic vs. recent development on current habitat selection. So, to better assess the effect of historical well pads on likelihood of use by GRSG, we measured micro-site vegetation on abandoned and reclaimed well pads in summer 2010 for comparison against vegetation measured around well pads and around nests and wintering locations. Analyses for objectives 1-3 are ongoing, and analyses for objective 4 will be started after completion of other, higher priority projects.

Figure 1. Preliminary high-resolution (a) breeding and (b) winter habitat selection maps for greater sage-grouse in the Hiawatha Regional Energy Development project area based on vegetation and topography.

a) Breeding



b) Winter



4. Evaluation of alternative population monitoring strategies for greater sage-grouse (*Centrocercus urophasianus*) in the Parachute-Piceance-Roan population of northwestern Colorado

Accurate estimates of population size and population trends provide the scientific basis for managers to make appropriate recommendations regarding land-use, harvest regulations, and mitigation efforts for wildlife. When linked with environmental variables, robust monitoring also allows managers to examine wildlife responses to various stressors. However, many wildlife monitoring programs use population indices that may or may not meet assumptions required to accurately estimate population abundance or trends. For this reason, it is essential to evaluate alternative approaches to population monitoring. Lek counts are the primary index used by state wildlife agencies to monitor changes in greater sage-grouse (*Centrocercus urophasianus*) abundance over time, but they rely on untested assumptions about lek attendance, detectability, inter-lek movement, sex ratio, and proportion of leks counted. Given new methodological and statistical approaches to estimate abundance, it is worth comparing the performance of current lek-count approaches against other potential methods. Dual-frame sampling of leks and non-invasive genetic mark-recapture analyses based on winter fecal pellet sampling are two promising alternatives for estimating sage-grouse populations. The purpose of this study was to evaluate and compare the reliability and efficiency of dual-frame lek surveys, genetic mark-recapture, and standard lek counts for estimating population size and sex ratio in the Parachute-Piceance-Roan (PPR) population in northwest Colorado. Field data collection for this project finished in May 2014. Jessica Shyvers completed her dissertation in July 2017. We published dual-frame lek survey results in the Journal of Wildlife Management (Shyvers et al. 2018) and genetic mark-recapture results in Ibis (Shyvers et al. 2020). The sex ratio manuscript was resubmitted in November 2021 and is in review at Ibis. The manuscript on effective population size of the PPR population will be resubmitted in 2022. A manuscript on sex-biased winter flock composition and habitat use will also be submitted in 2022. This is the last annual report for this project.

5. Assessment of Greater Sage-grouse Response to Pinyon-Juniper Removal in the Parachute-Piceance-Roan Population in Western Colorado

Greater sage-grouse (*Centrocercus urophasianus*) in the Parachute-Piceance-Roan (PPR) region of western Colorado face at least two major potential stressors: projected habitat loss from energy development and a long-term decline in habitat suitability associated with pinyon-juniper (PJ) encroachment. Pinyon-juniper removal may be a useful mitigation tool to offset potential habitat losses associated with energy development. Although pinyon-juniper removal is commonly used to improve habitat for greater sage-grouse, until recently, few studies have quantified the timing or magnitude of how birds respond to treatments. Since 2008, Colorado Parks and Wildlife (CPW) has cooperated with industry and landowner partners to use pellet surveys to investigate the effectiveness of pinyon-juniper removal for restoring sage-grouse habitat in the PPR. In fall 2008, I established nine area-based study plots, arranged in three groups of three, with each group consisting of a Sagebrush-Control plot, an untreated PJ-Control plot, and a PJ-treatment plot. Treatments were completed on three of the 9 plots in 2010 and 2011. Pellet surveys in summer from 2009-2015 indicated that, as expected, the mean proportion of sample units containing pellets was consistently highest on sagebrush control plots and consistently lowest on plots with encroaching pinyon-juniper. The mean proportion of sample units containing pellets increased on 2 of 3 treated survey plots (Ryan Gulch and Upper Galloway) within 1-2 years after treatment. I established an additional 14 transect-based plots in fall 2010 and summer 2011, and two in summer 2014. We conducted pellet transects on these 16 plots each summer through 2015. As expected, the mean no. of pellet piles/km were low on the four PJ-Control plots for the duration of the study, low on PJ-Treatment plots prior to treatment, and higher on all four Sagebrush-Control transect plots (at least through 2014). However, the mean no. of pellet piles/km declined precipitously on 3 of 4 Sagebrush-Control transect plots in 2015. The mean no. of pellet piles/km was also high on the Lower Barnes transect plot 4-5 years post-treatment, but declined 6-8 years post-treatment. Mean no. of pellet piles/km remained low on treated transect plots for four years after pinyon-juniper removal with the exception of the Upper Bar D plot in 2014. We completed double-observer sampling on survey plots in 2013, 2014, and 2015 to estimate sample unit-level detectability, and we completed distance sampling on transect plots in 2014 and 2015 for generating distance-detection curves. Additional distance sampling data were collected on nearby plots as part of a separate project in 2016 and 2017 and will help estimate distance-detection curves. We established and conducted pre- and post-treatment surveys on two additional transect plots (Lower Galloway and Lower Ryan Gulch) in summer 2014 and 2015. Overall, estimates of the proportion of sample units with pellets (from survey plots) and the no. of pellet piles/km (from transect plots) varied substantially among Sagebrush-Control plots within years and among years within plots, which suggests substantial background variation in the no. of pellets deposited within suitable habitat. Sage-grouse response to pinyon-juniper removal (as measured by pellet surveys) also appeared to be inconsistent in the PPR, with pellet counts clearly increasing on only 2 of 8 treated plots within 4-5 years post-treatment. Analyses for this project are ongoing.

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, 2021

Principal Investigator: Brett L. Walker brett.walker@state.co.us

Project Collaborators: L. Rossi

All information in this report is preliminary and subject to further evaluation. Information MAY NOT BE PUBLISHED OR QUOTED without permission of the principal investigator. Manipulation of these data beyond that contained in this report is discouraged.

EXTENDED ABSTRACT

Discoveries of previously unknown populations continue to expand our knowledge of the breeding distribution, ecology, and conservation status of North American bird. The Brewer's Sparrow (*Spizella breweri*), a small, migratory songbird, has experienced long-term 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, reports have occasionally surfaced of Brewer's Sparrows being found in willow and krummholz habitats near treeline in Colorado's high country, including some well-known locations such as Mount Evans, Guanella Pass, Trail Ridge Road (Rocky Mountain NP), and the Flattops Wilderness. The identity of these birds remains unknown. 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. I identified eight possible explanations for the occurrence of Brewer's Sparrows in alpine areas. Birds could be: 1) previously unknown populations of *taverneri* nesting in typical habitat, 2) *breweri* nesting in atypical habitat, 3) *breweri* that first nested in sagebrush moving upslope to attempt subsequent nests in alpine willow/krummholz (i.e., itinerant breeding), 4) a zone of introgression between *breweri* and *taverneri*, 5) a third, undiscovered subspecies, 6) post-breeding, dispersing *breweri*, 7) post-breeding *taverneri* at molt-migration stopover sites, or 8) non-breeding birds (either *breweri* or *taverneri*). The objectives of this project are to determine the taxonomic identity and breeding status of Brewer's Sparrows reported from high-elevation, alpine sites in Colorado.

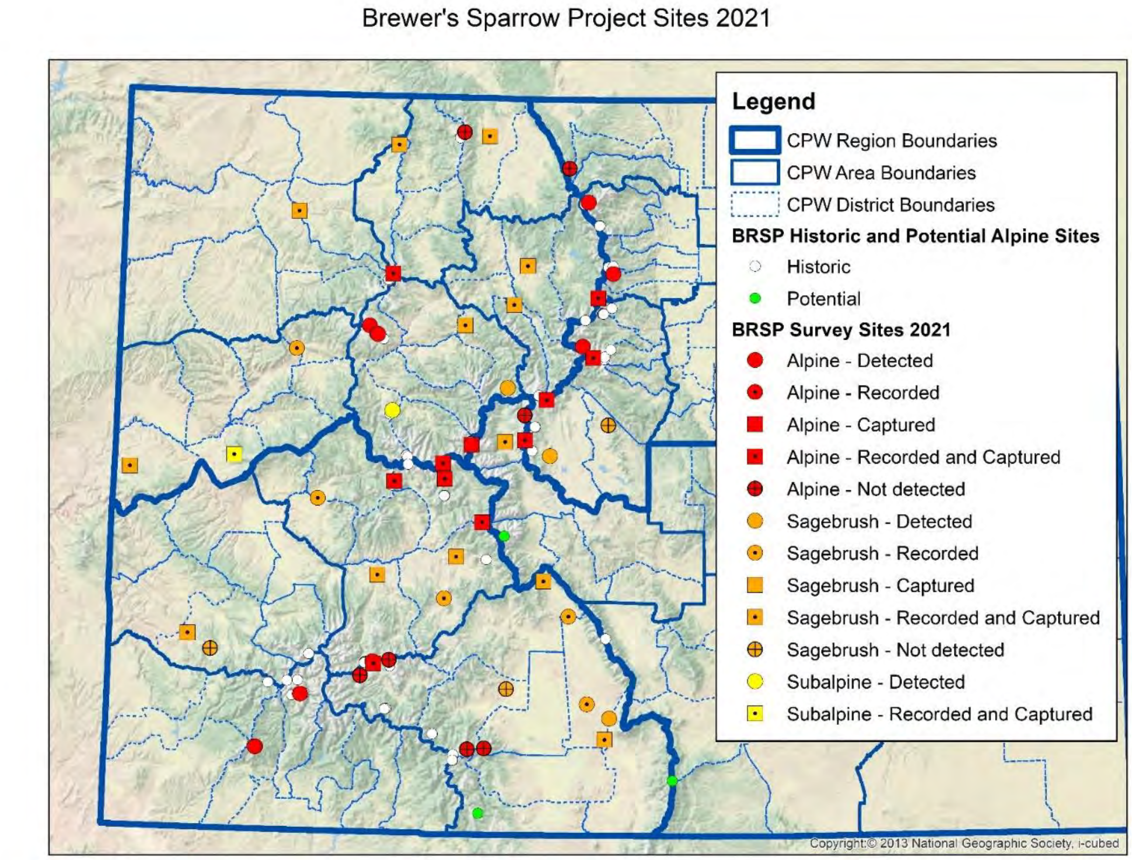
I compiled historical observations using data from the Rocky Mountain Bird Observatory (1999-2005), Bird Conservancy of the Rockies (2008-2020), eBird (1995-2020), and VertNet (1903-1995), along with reports from birders and U.S. Forest Service biologists. I identified 174 historic observations of Brewer's Sparrows at 52 sites in alpine or subalpine shrubs above 9,500 ft between 1 June and 15 July, and 5 additional potential sites with reasonable access based on habitat and elevation (Fig. 1). From 5 May – 2 July 2021, we visited 17 sites in low-elevation (~6,000-9,000 ft) sagebrush and 20 sites at high-elevation (~11,500-12,500 ft) alpine willow/krummholz to survey for Brewer's Sparrows. If present, we recorded and captured males; collected genetic, morphometric, and habitat data; and documented any evidence of breeding.

We located Brewer's Sparrows at 12 alpine sites we visited: Buck Mountain, Jarosa Mesa, Spring Creek Pass, Scarp Ridge, Taylor Pass, Italian Mountain, Cumberland Pass, Independence Pass, Hoosier Pass; Guanella Pass, Rollins Pass, and Devil's Causeway (Flattops). Despite the presence of suitable habitat, we did not detect Brewer's Sparrows at eight other alpine sites: Grayback Mountain, Blowout

Pass, Kitty Creek, Snow Mesa, Mosquito Pass, Swamp Park, Blue Lake, and Cameron Peak. Volunteers found Brewer's Sparrows at seven additional alpine sites: Kennebec Pass, Little Molas Lake, Crane Park, White Owl Lake, Kelso Mountain, Niwot Ridge, and Ute Trail (Rocky Mountain National Park) (Fig. 1). Kennebec Pass represents the southernmost known alpine site in the state. We recorded 194 short songs from ~182 males (128 in sagebrush, 48 in alpine, and 6 in subalpine), and captured and collected morphometric data and genetic samples from 82 males (39 sagebrush, 43 alpine). We also 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 timing of male arrival (starting ~ June 10) and the presence of numerous unpaired males and pairs at other occupied alpine sites indicate probable breeding.

We ruled out hypotheses 6-8 based on confirmation of breeding and the absence of prebasic molt in captured birds. Distinguishing among hypotheses 1-5 requires genetic data. Acoustic data were extracted from 194 songs but have not yet been analyzed. Genetic samples were sent to Dr. Andrew Jones at the Cleveland Museum of Natural History and are still being processed and analyzed. Confirmation of Brewer's Sparrows at several 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 suggest that Brewer's Sparrows are 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. We anticipate finding them as far south as the southern San Juan and Sangre de Cristo ranges and as far north as the Park and northern Medicine Bow ranges. The presence of Brewer's Sparrows in alpine areas throughout the state expands the species' known breeding distribution in Colorado. Distribution and habitat information needs to be updated in CPW's conservation assessment and species' status assessment in our State Wildlife Action Plan.

Figure 1. Sites investigated for Brewer's sparrows in 2021.



Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Effects of Esplanade herbicide at Bitterbrush State Wildlife Area

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

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

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

EXTENDED ABSTRACT

Cheatgrass invasion shortens fire cycles. At Bitterbrush State Wildlife Area (BBSWA), this dynamic is responsible for loss of extensive thickets of bitterbrush since the 1970s (Figure 1). Although bitterbrush is recovering in some areas, the rate of recovery has not been sufficient to outpace the rate of losses. We seek to find ways to control cheatgrass and improve the recovery rate of bitterbrush in order to restore habitat function for big game.

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 (Figure 2), but cheatgrass control has not resulted in any changes in bitterbrush cover, bitterbrush leader length, or cover of other perennials in 2020 or in 2021. Furthermore, we found evidence that indaziflam hindered bitterbrush germination.

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™ (ACF West Inc.). Bitterbrush and bottlebrush squirreltail seeds were sown within rodent-proof cages bordered by insect control barriers (Figure 3). We found in 2021 that both indaziflam and NutraFix severely curtailed bitterbrush and squirreltail germination (Figure 4).

The Yellow Experiment compared the impact of rodent control and insect control measures on bitterbrush seedlings in a crossed design. We found that rodent control improved seedling survival initially, but by midsummer, insect control had a larger effect on survival. We found extensive evidence of herbivory in our experiments and in wild bitterbrush seedlings (Figure 5). The most likely culprit is army cutworm.

In fall 2021 we planted a repeat of the Red and Yellow Experiments. This will allow us to see how indaziflam and NutraFix impact germination when there is a year lag between cheatgrass control and planting. The second iteration of the Yellow Experiment includes a treatment whereby some plots get added cheatgrass while others have cheatgrass weeded out. That treatment will be crossed with rodent control and insect control treatments, so we can determine how relatively important cheatgrass, rodent, and insect control are at determining success of bitterbrush establishment at BBSWA.

In fall 2021 we also planted two new experiments to test some management solutions for reducing rodent and insect impacts on bitterbrush establishment. In the Brown Experiment (so named because rodents are brown), we are testing several rodent-deterrent seed coatings which had been shown to be effective in the lab (Figure 6). In the White Experiment (so named for while plastic sprayers) we

are testing several methods of insect control, including an insecticidal seed coat and several spring-applied insecticides.

Both 2020 and 2021 had overall low cheatgrass cover. However, the fall 2021 cheatgrass crop appeared robust; cheatgrass cover in 2022 will likely be higher. Although we had not planned to monitor the indaziflam trial in 2022, we will monitor it for an extra year to determine if benefits of cheatgrass control are more evident in a 'better' cheatgrass year.

In 2021, we had good bitterbrush germination in plots which did not have cheatgrass control but which were protected from rodents and insects. 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.

Because indaziflam has such a detrimental effect on germination, but could be effective at breaking the cheatgrass/fire cycle, we make a preliminary recommendation that indaziflam be used for firebreaks but not to treat the entire landscape. The remainder of the data from this study will inform how long negative effects of indaziflam on bitterbrush germination persist, and how important cheatgrass control is in general when compared to other factors limiting bitterbrush establishment.

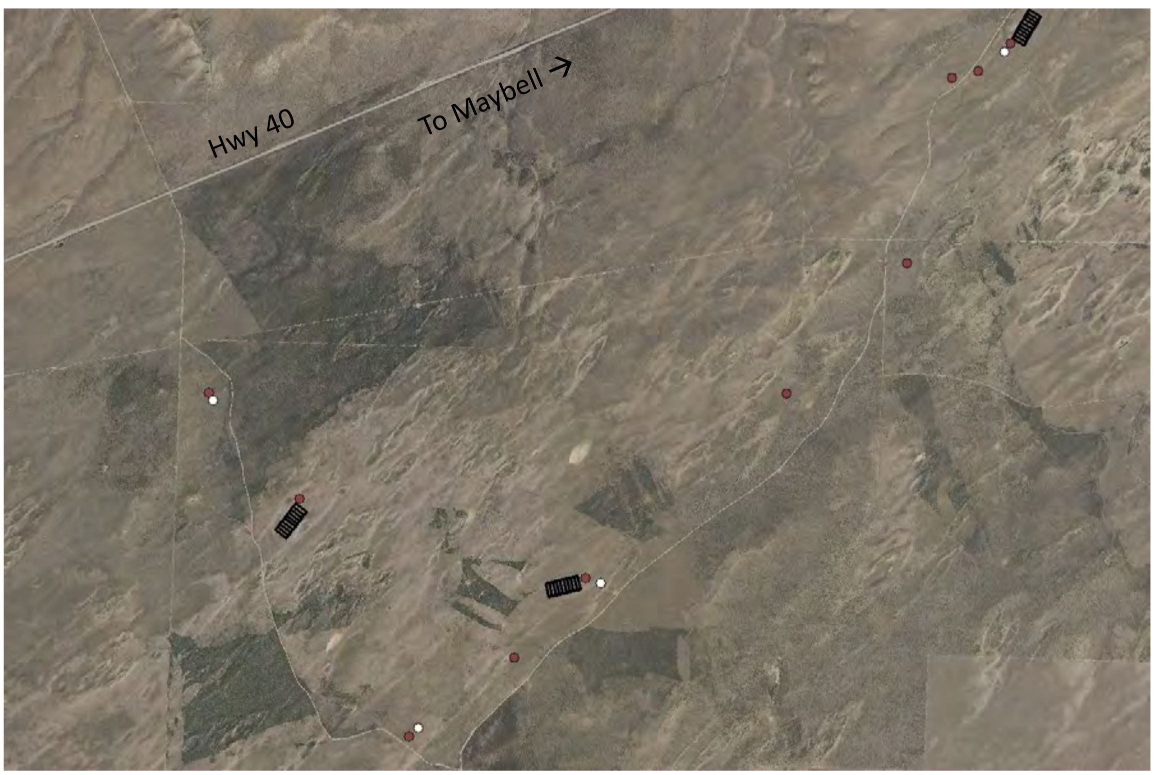


Figure 1. Remnant bitterbrush patches at Bitterbrush State Wildlife Area are visible in this aerial imagery from 2017. Indaziflam trial locations are in black, along with locations for two new experiments begun in fall 2021.

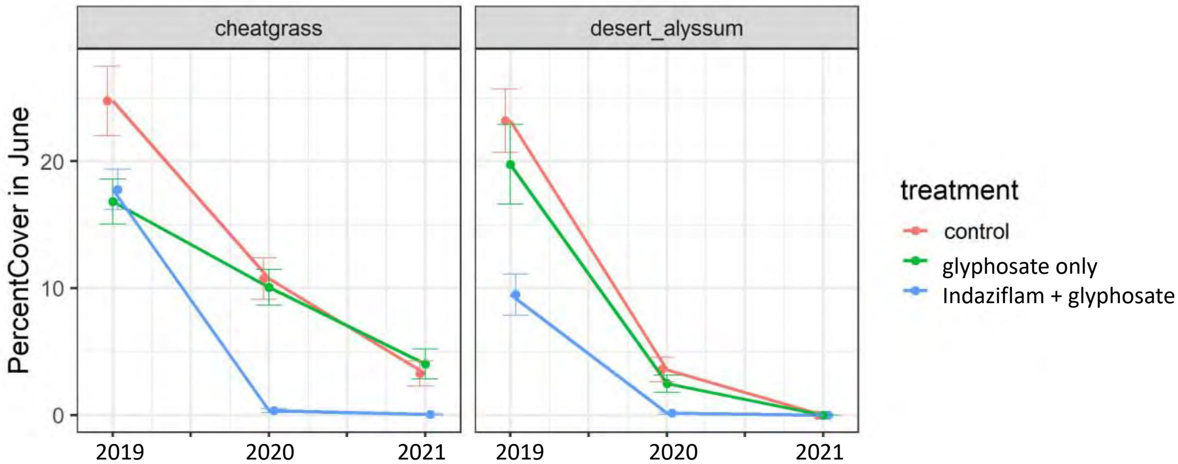


Figure 2. Cheatgrass and desert alyssum response to indaziflam + glyphosate, glyphosate only, and control treatments at Bitterbrush State Wildlife Area, 2019-2021. Overall, annual cover declined during this time period.

Figure 3. Schematic diagram of one replicate of the Red experiment. Rodents were excluded and insects controlled with collars of Tree Tanglefoot, a sticky resin. Indaziflam, NutraFix, and control were compared for bitterbrush and squirreltail seedlings.

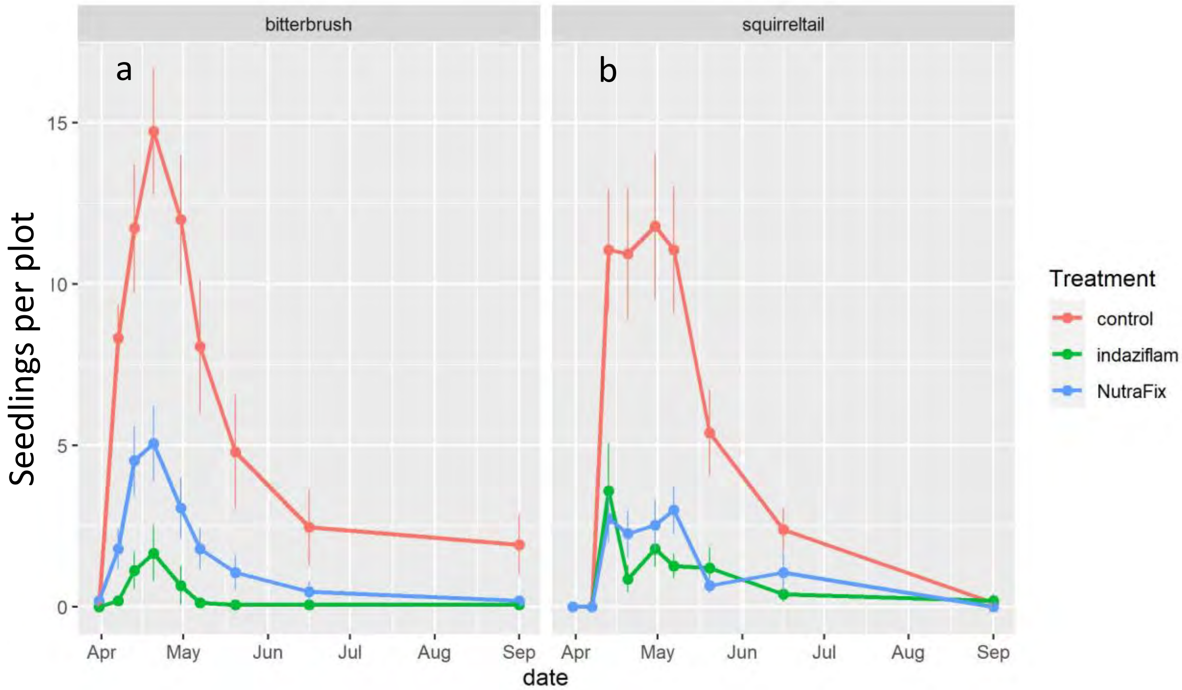


Figure 4. Bitterbrush (a) and squirreltail (b) seedlings in response to indaziflam and NutraFix treatments at Bitterbrush State Wildlife Area, spring 2021.

Figure 5. Naturally occurring groups of bitterbrush seedlings in early May (a) and late May (b) 2021.

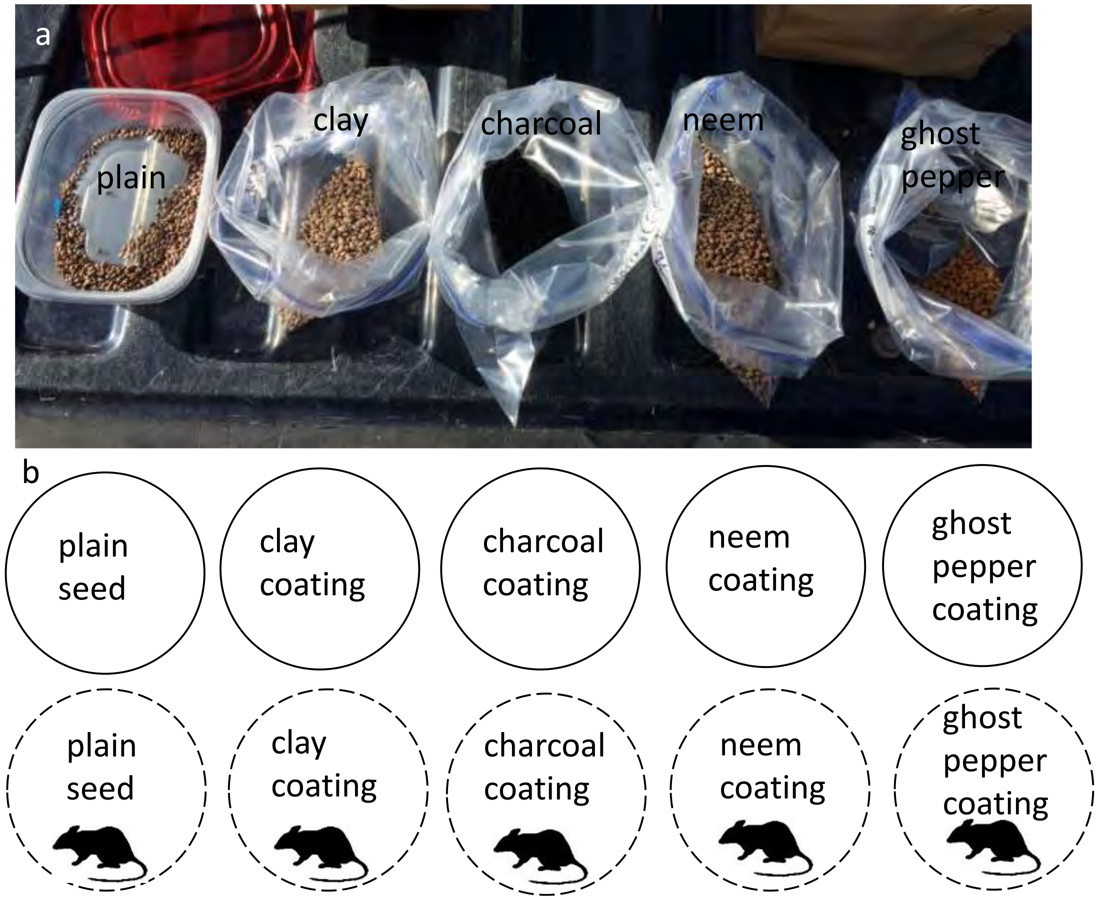


Figure 6. Coated seed (a) and schematic diagram (b) for the Brown Experiment. Seed coatings were crossed with cage type (open or closed). A no seed control (not pictured) was also included.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Pothole seeder demonstration studies

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

Principal Investigator: Danielle B. Johnston (Habitat Researcher, CPW)

Project Collaborators: Trevor Balzer (Habitat Coordinator, CPW), Jim Garner (Habitat Coordinator, CPW), Ivan Archer (Assistant Area Wildlife Manager, CPW), Derek Lovoi (Property Technician, CPW), Mark Hodges (Property Technician, CPW) , 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), Jon Moore (Ranch Manager, Mountain Island Ranch), Mary Conover (Owner, Mountain Island Ranch), Kenyon Fields (Mountain Island Ranch), Ken Holsinger (Ecologist, Bureau of Land Management)

EXTENDED ABSTRACT

Roughened surfaces have long been used to create microsites of higher soil moisture to aid plant establishment in arid environments. In addition, CPW research has indicated that seeding over a roughened surface can aid in cheatgrass (*Bromus tectorum*) control. The mechanism appears to involve slowing down the rate of seed dispersal, which hinders annual plants to a greater degree than perennial plants.

A new type of seeder, dubbed a pothole seeder, was designed and built to allow economical preparation of a roughened surface, and to drop seed over it in a single pass (Figure 1). This study documents the outcomes of four of the first projects to use the seeder. The projects were established 2018-20. All of the projects have dual management and research goals, and some incorporate complementary treatments and/or comparisons to other treatments. All include untreated control plots.

Figure 1. Pothole seeder

Conditions through most of the duration of this study have been extremely dry, with limited success from seeding efforts and low cheatgrass cover. Pothole seeding has proven beneficial for helping perennial grasses to establish. At two sites where pothole seeding was compared to drill seeding, seeded grasses were more plentiful with pothole seeding than with drill seeding (Figure 2). Two sites had enough cheatgrass for analysis; potholing was effective at controlling cheatgrass at one of these two. The potholing treatment was implemented differently at these two sites, with much greater depth of ground disturbance and depth of potholes at the site with effective cheatgrass control.

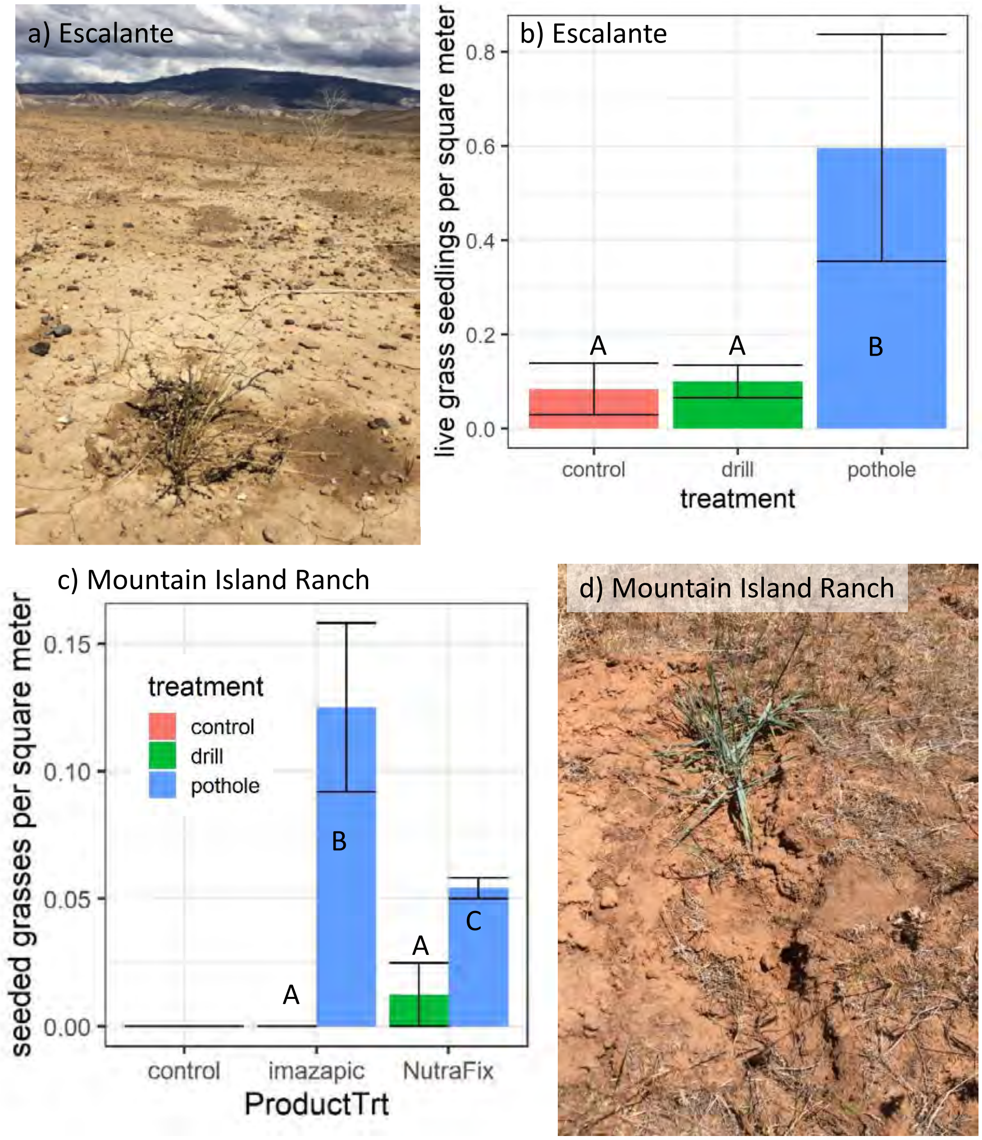


Figure 2. In spite of drought conditions, potholes helped perennial grasses to establish, at least sparsely, at most of our study sites. At Escalante (a-b), potholes helped grasses to survive at higher density than in drill seeded plots. At Mountain Island Ranch, potholes helped grasses to establish at higher density than in drill seeded plots, within both imazapic and NutraFix treatments. In b) and d), bars not sharing letters are significantly different at $\alpha = 0.05$. Error bars =SE.

The Escalante State Wildlife Area site receives about 213 mm (8 in) of annual precipitation and has saline and patchily hardpan soils. A project comparing pothole seeding to drill seeding was established in fall 2018. Although good grass establishment had occurred in both drill-seeded and pothole plots in 2019, by 2021 many grasses had died. Even so, grass density was higher in pothole plots than in drill seeded plots (Figure 2 a-b). No cheatgrass was present at the site in 2021.

The Nash Wash site is in Grand County, Utah and receives about 260 mm (10.5 in) of annual precipitation. A project comparing pothole seeding to drill seeding was established in fall 2019. Because of heavy cheatgrass cover, imazapic herbicide at a rate of 70 g ai/ha (4 oz/ac Plateau™) was applied prior to seeding. In 2021, seeded annual forbs such as Rocky Mountain beeplant and sunflower had lower density with pothole seeding than with drill seeding. Potholes greatly reduced cheatgrass density, and were more effective than imazapic herbicide.

The Mountain Island Ranch site in Mesa County receives 360 mm (14.2 in) of annual precipitation and has very sandy soils. A project was initiated in fall 2019. Due to heavy cover of cheatgrass and other undesirable annuals, weed control was applied to all plots prior to seeding, via either imazapic at 70 g ai/ha (4 oz/ac Plateau™) or NutraFix, a cheatgrass control fertilizer, at 373 kg/ha (333 lbs/ac). Weed control method was crossed with seeding method (pothole or drill) in a split-plot design. In 2021, NutraFix had the most notable effects on the plant community, with low density of weeds but also low density of seeded grasses. Seeded grass density was higher with potholing than with drill seeding within both imazapic plots and NutraFix plots (Figure 2c-d). Potholing did not have any effect on cheatgrass density at Mountain Island Ranch, nor did imazapic herbicide.

The Sims Mesa site in Montrose County receives about 280 mm (11 in) of annual precipitation with coarse, gravelly soils overlying a clay loam layer. The project site is a former plow-and-seed treatment which had been seeded with crested wheatgrass (*Agropyron cristatum*). To rehabilitate this potential Gunnison sage-grouse habitat, the Bureau of Land Management applied several herbicide treatments which killed most of the crested wheatgrass. Seven acres were pothole seeded in December 2020, with more acreage planned. In June 2021, the crested wheatgrass was recovering, unfortunately. Seeded grasses had established in early spring but only a few remained by June. Seeded grass density in June 2021 was higher with pothole seeding than in control plots.

Potholes allowed some seeded grasses to establish at 3 of the 4 sites studied, even given harsh drought conditions. The benefits of pitting/soil roughening, both for plant establishment and weed control, have recently been corroborated by a large independent study (Havrilla et al. 2020). Over the winter of 2020-2021, Derek Lovoi with the help of Scott Romatzke made necessary repairs and reinforcements to the discs and axles of the pothole seeder. The seeder performed well on a second, 15-acre project at Mountain Island Ranch. To our knowledge, CPW owns and operates the only machinery capable of economically producing this proven, beneficial treatment for plant establishment and weed control on arid sites in need of restoration. We plan to continue monitoring at Escalante, Nash Wash, Mountain Island Ranch, and Sims Mesa in 2022.

LITERATURE CITED

Havrilla, C. A., S. M. Munson, M. L. McCormick, K. M. Laushman, K. R. Balazs, and B. J. Butterfield. 2020. RestoreNet: An emerging restoration network reveals controls on seeding success across dryland ecosystems. Journal of Applied Ecology 57:2191-2202.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

NutraFix Rate Trials

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

Principal Investigator: Danielle B. Johnston (Habitat Researcher, CPW)

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

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 2021 revealed that NutraFix reduced cheatgrass cover by about a third when applied at the highest rate, with no discernable effects at the lower rates (Figure 2). This was result was consistent across sites even though baseline cheatgrass cover varied greatly by site (Figure 3). NutraFix also had some significant effects on other species, increasing salsify (*Tragopogon dubius*) cover at one site, reducing Indian ricegrass (*Achnatherum hymenoides*) cover at one site, and increasing sand sage (*Artemisia filifolia*) at the low rate at one site. 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.

We obtained soil samples in each plot in both spring and fall of 2021. These are awaiting analysis for nutrient cycling impacts by Tom Monaco's lab at the Agricultural Resource Service in Logan, Utah. Collaborators in Utah also set up 5 sites in 2020 and sampled them for vegetation and soils in 2021 using similar protocols as the Colorado sites. Vegetation response and soils will be monitored through 2023.

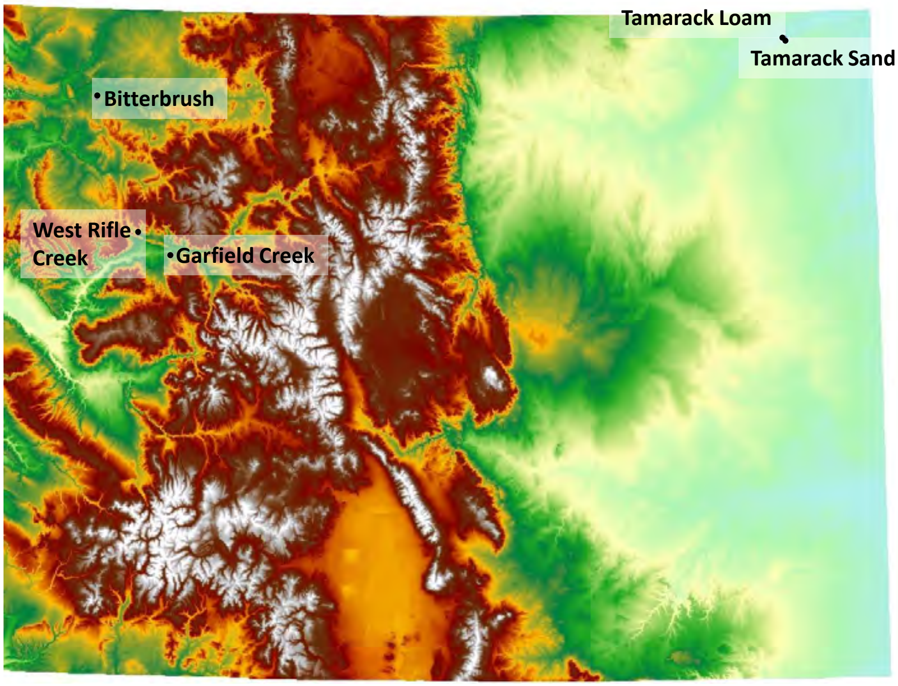


Figure 1. Locations for the five rate trial sites set up in 2020 in Colorado.

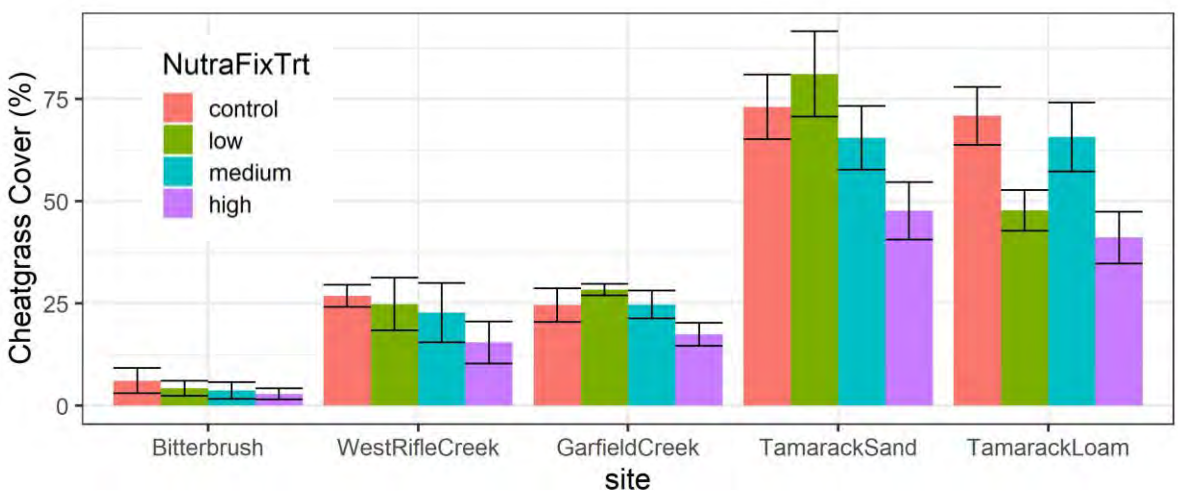


Figure 2. Cheatgrass cover in response to NutraFix applied at 3 rates at 5 sites. Error bars= SE.

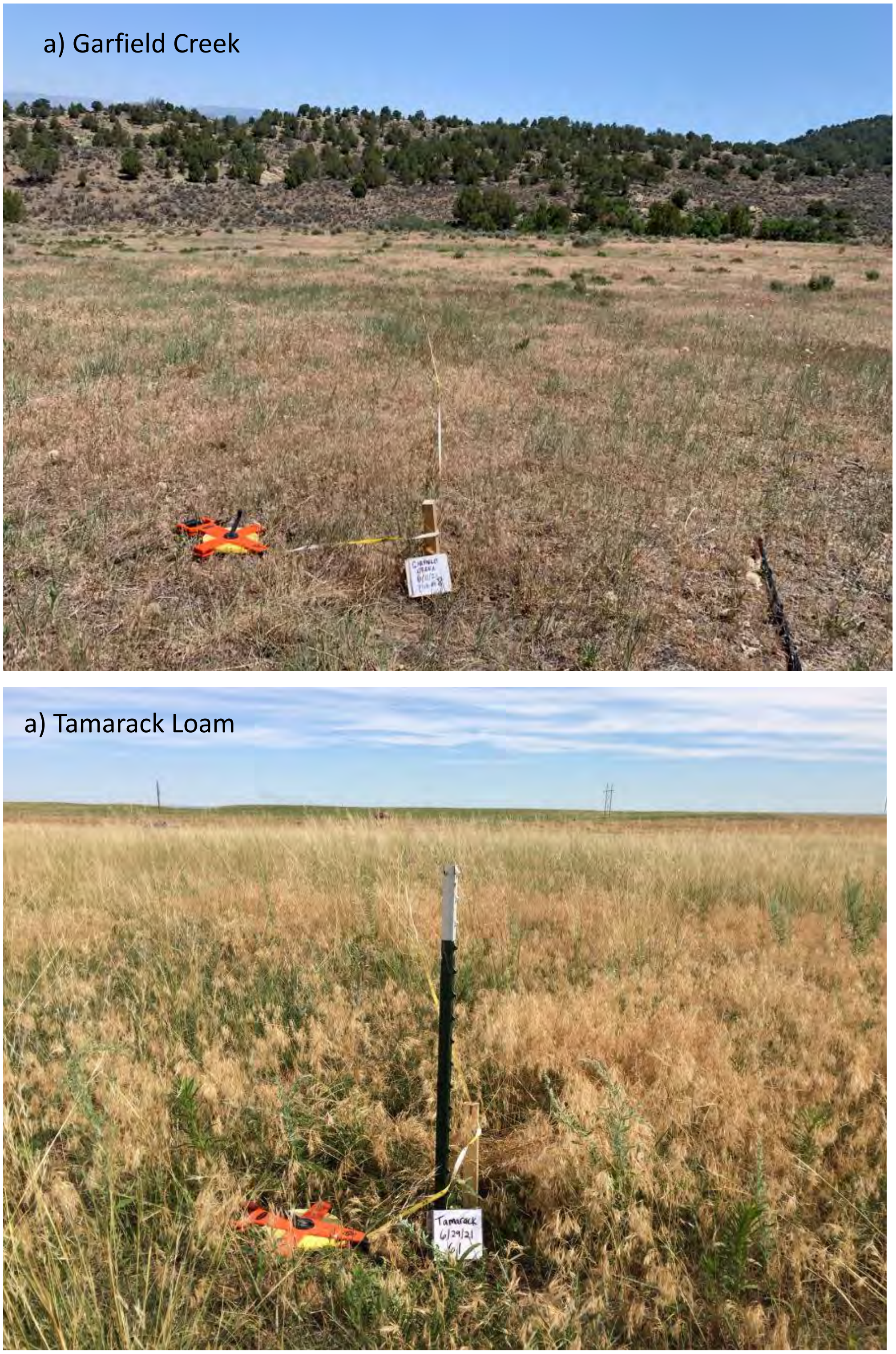


Figure 3. Both cheatgrass and more desirable vegetation were much less lush at the western slope sites such as Garfield Creek (a) than they were at the Tamarack sites (b) in 2021. Both a) and b) show the medium rate of 150 lbs/ac, which did not significantly reduce cheatgrass cover one year post-treatment.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Avian response to plague management on Colorado prairie dog colonies

Period Covered: January 1 – December 31, 2021

Principal Investigator: Reesa Yale Conrey, reesa.conrey@state.co.us

Project Collaborators: Dan Tripp, Jim Gammonley, Miranda Middleton, Cooper Mark, CPW; Erin Youngberg, 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.

All information in this report is preliminary and subject to further evaluation. Information MAY NOT BE PUBLISHED OR QUOTED without permission of the author. Manipulation of these data beyond that contained in this report is discouraged.

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 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.

Data collection over 7 years 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*).

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 adjacent to the Wyoming border, managed by the City of Fort Collins. 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). GUPD sites are managed by the Bureau of Land Management, U.S. Forest Service, National Park Service, U.S. Fish and Wildlife Service, and CPW. Study sites were grazed by cattle (and sheep in Baca NWR) and native grazers, especially prairie dogs, pronghorn (*Antilocapra americana*), jackrabbits (*Lepus* sp.), and cottontails (*Sylvilagus* sp.).

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, have had increasing prairie dog numbers since initially declining during the peak of the epizootic, while others, especially untreated areas, have 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. In contrast, we observed very little plague activity (two small colonies) at GUPD sites until 2017–2018.

Research phases:

- 2013–2015: vaccine research (vaccine, insecticide, and placebo treatments) by CPW Wildlife Health. Plague epizootics occurred across much of the BTPD site but almost no plague at GUPD sites. We 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. Plague continued at some BTPD colonies. We sampled GUPD colonies (extant and extirpated) only in South Park, ahead of planned GUPD reintroductions (which then did not happen).
- 2017–2019: broader plague management by CPW Terrestrial staff at all GUPD study sites and some BTPD sites. Plague epizootics began in some GUPD sites in Woodland Park, Gunnison Basin, and then Baca NWR (new site in 2017), so we resumed on-colony (but not off-colony) work at GUPD sites. BTPD sites began a post-epizootic growth cycle.
- 2021–?: less intensive longer-term monitoring (e.g., point counts, vegetation transects, possible camera surveys) of species associated with prairie dogs at sites with varying levels of plague management. Requires collaboration internally and externally to monitor colony boundaries and changes in prairie dog activity caused by plague.

In 2021, we conducted avian point counts and sampled vegetation along transects on GUPD colonies in Gunnison Basin and Saguache Co. using the same point grid used in previous years. 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. We did point counts at ~120 locations and sampled vegetation at 1 – 2 transects per colony, depending on colony size. We plan to rotate through field sites, sampling each location every 3 years. This longer term monitoring is much less intensive than the earlier phase of this project; sampling in 2021 required the time of one technician for ~2 weeks, plus a few additional days to identify unknown plants and enter data.

In 2021, we also incorporated burrowing owl nest surveys into nest monitoring activities for a different raptor research project, monitoring priority diurnal raptors (mainly eagles) on the BTPD complex at SPNA and MSR. Time constraints precluded three repeat surveys on all colonies, but we surveyed any colony that had reliably supported owl nests in previous years. This extends a data set of burrowing owl nests that began in 2013 and has fluctuated widely over time, facilitating analyses of plague, climate, or other impacts on owls. These data are also expected to provide calibration for more rapid survey techniques by a new graduate student: Sarah Albright will be working with CPW Avian Research and Species Conservation on owl surveys across Colorado's BTPD range beginning in 2022.

Results from the main phase of this research that occurred from 2013 – 2019 showed that 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. Longer term monitoring will help to detect potential changes in the avian community caused by different types of plague management, as treated colonies no longer experience total extinction events and over time diverge from untreated areas.

Progress and completed project components in 2021:

- Avian point counts and vegetation transects completed on GUPD colonies in Gunnison Basin and Saguache Co.
- Burrowing owl nests monitored on BTPD colonies at SPNA & MSR.

Plans for 2022:

- Point counts on BTPD colonies at MSR while BCR does point counts at SPNA (which they will do every 3 years).
- Vegetation transects at MSR and SPNA colonies if time allows (BCR will do point counts but not vegetation transects).
- Burrowing owl nest monitoring at SPNA and MSR if time allows.

Plans for longer term:

- Track longer-term impacts of different plague management strategies on the community of wildlife associated with prairie dog colonies. Three-year rotation schedule:
    - GUPD in Gunnison Basin and Saguache Co.
    - BTPD in SPNA and MSR (Larimer and Weld Co.)
    - GUPD in Woodland Park and Baca NWR
- Cooperate with Terrestrial and Wildlife Health staff and external partners to continue monitoring colony boundaries and prairie dog/plague activity at research sites.
- Continue data analyses and preparation of manuscripts:
    - Changes in grassland bird densities at BTPD sites over two plague and recovery cycles (14+ years), co-authored with Bird Conservancy of the Rockies.
    - 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.

LITERATURE CITED

Antolin, M. F., P. Gober, B. Luce, D. E. Biggins, W. E. V. Pelt, D. B. Seery, M. Lockhart, and M. Ball. 2002. The influence of sylvatic plague on North American wildlife at the landscape level, with special emphasis on black-footed ferret and prairie dog conservation. Transactions of the 67th North American Wildlife and Natural Resources Conference 67: 104–127.

Ecke, D. H. and C. W. Johnson. 1952. Plague in Colorado and Texas. Part I. Plague in Colorado. Public Health Monograph No. 6. U. S. Government Printing Office, Washington D.C.

Tripp, D. W., Rocke, T. E., Runge, J. P., Abbott, R. C., and Miller, M. W. 2017. Burrow dusting or oral vaccination prevents plague-associated prairie dog colony collapse. EcoHealth 14:451-462.

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

Golden eagles in Colorado: monitoring methods and status evaluation

Period Covered: January 1 – December 31, 2021

Authors**:** Reesa Yale Conrey

Principle Investigators: R. Yale Conrey reesa.conrey@state.co.us, 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); A. Estep, M. Sherman, M. Cowardin, L. Carpenter, & 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 > 11,000 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, which will be even more prominent in decision making going forward, as 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. In addition, we are working in the SE Region 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 11,894 locations on 25 January 2022 (Table 1), having grown from 8,696 locations in 2016 due to increased sampling effort. Although the majority of nest locations (6,033 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 to 51% of the total at the end of 2021, due to increased sampling effort, especially at historic nest sites.

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. New revisions for 2021 included a field to differentiate the nest used for breeding from alternate structures within the territory, and a new disturbance field so that temporary sources of disturbance could be distinguished from habitat change or infrastructure.

As in previous years, not all data were incorporated into the statewide database by the requested deadline of 1 November and quality control is ongoing. When all the 2021 data are available, our goals are to assess fields left blank (where protocol revisions or training may be needed), calculate apparent nest success for species with adequate sample size, and summarize potential nest threats.

We 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 a new SCTF-funded raptor project that will continue through 2023 and focuses on GOEA in the SE Region of Colorado; 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. 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. 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 when the plane drew even with the nest. We also recorded bird species and structural characteristics (e.g., intact/dilapidated and tree species) whenever possible, plus time, weather, and altitude. As a result of these flights, we detected ~80 raptor nest structures, most of which were not previously included in the statewide database, in an area where only three bald eagle nests were being actively monitored. Analyses of detection probability and comparison of efficacy of distance sampling versus double-observer methods are ongoing. Flights were not possible in 2020 due to COVID-19 restrictions.

During 2021, we surveyed ~320 km (200 miles) of canyons and ~185 km (115 miles) of tributaries (riparian corridors) in SE Colorado (Fig. 1) 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: 31 March and 1 April for the rotor and 2 May and 5 May for the fixed-wing. Scheduling difficulties with the aircraft prevented the surveys from occurring closer together in time, but leaf-out was just starting in early May and this didn't appear to affect visibility. The rotor required much more refueling time (every 1.5 hours). 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; Fig. 1). 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 east in the morning and west in the afternoon, as the observer felt that strong sun at her back washed out the nests. Based on previous experience, she noted that cloudy days are not optimal either.

Distance sampling is not viable along linear features like canyons and rivers, because detection distance is limited by the width of the topographical feature. If multiple observers can ride in aircraft in future, then this method will be most efficient. 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 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 rather than canyons. Plains habitats, last surveyed in 2019, are much more easily surveyed by fixed-wing than tributaries because of the density of nesting substrate around riparian corridors.

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 hope to continue progress on statewide assessments of raptors in Colorado during 2022 by assessing the effect of additions made to data collection, flying a new area of SE Colorado (using multiple observers if COVID-19 protocols allow), and working creatively on ground-based methods. These might include a road-based survey protocol, use of imagery to guide surveys (e.g., looking for large trees in plains strata), and/or comparison of raptor data for this region in eBird vs. the statewide raptor nest database or CPW field surveys.

Progress and project components completed during 2021:

- Staff and volunteers statewide collected raptor nest data with a revised data form that distinguishes nests used for breeding from alternate nests and temporary disturbances from permanent infrastructure and habitat change.
- Publication on distribution models: Aagaard et al. (2021).
- Comparison of aerial nest surveys from helicopter vs. fixed-wing in canyon and tributary habitats.
- A subset of eagle nests was observed multiple times to estimate apparent nest survival and productivity.

Plans for 2022:

- Continue data queries and quality control as raptor nest data are submitted and incorporated into the statewide database. Calculate apparent nest survival rates and summarize threat data.
- Conduct additional aerial surveys in a different portion of the SE Region to locate previously unreported raptor nests while testing methods that account for detection probability.
- Develop targeted ground-based survey methods.

LITERATURE CITED

Aagaard, K., R. Y. Conrey, and J. H. Gammonley. 2021. Nest distribution of four priority raptor species in Colorado. Journal of Raptor Research 55:510–523.

Colorado Parks and Wildlife. 2015. State wildlife action plan: a strategy for conservation of wildlife in Colorado. Denver, Colorado.

Greenwood, J.J.D. 2007. Citizens, science and bird conservation. Journal of Ornithology 148 (Suppl 1): S77-S124.

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

B. Number of nest records for Golden Eagle in the CPW raptor nest database. Changes represent increased effort over the past three years 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

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

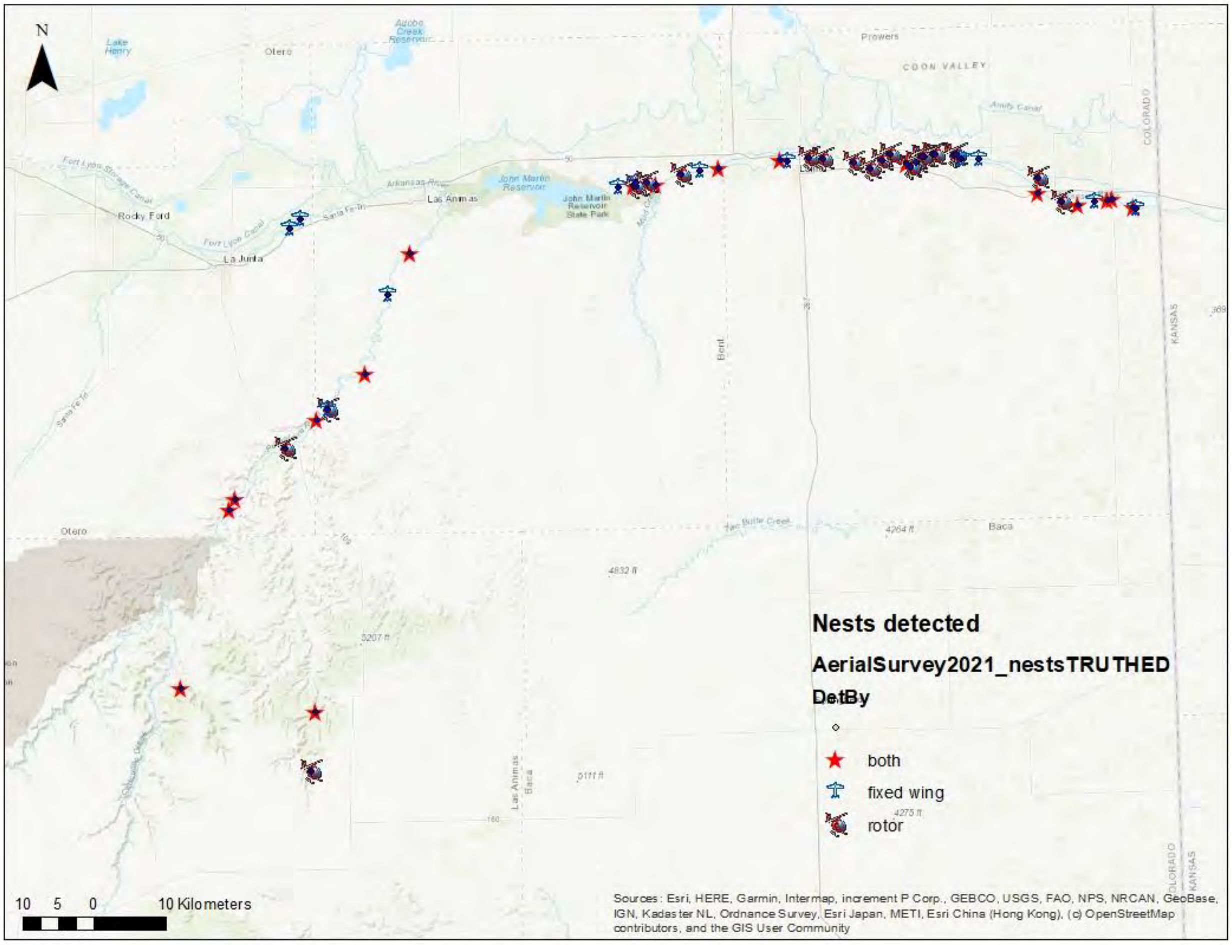


Figure 1. Raptor nests detected during flights over canyons and tributaries in SE Colorado during 2021. Rotor flights were 31 March – 1 April and fixed-wing flights were 2 May and 5 May. Symbology shows nests discovered using both methods vs. rotor-only or fixed-wing-only.

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, 2021

Authors**:** Reesa Yale Conrey

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

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 (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

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 commonly 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). By the end of the 1970s, there were only three known occupied bald eagle nests in Colorado and none in the Front Range (Craig 1998). Bald eagle populations declined in the early- to mid-20th century due to pesticides (primarily DDT), human persecution, and land conversion. Recovery began with the banning of DDT in 1972 and listing of bald eagles under the newly created Endangered Species Act in 1973.

Bald eagles have recovered from dramatic population declines and were removed from the federal threatened and endangered species list in 2007. A recent report showed that the number of breeding pairs of bald eagles in the contiguous United States has doubled over the past 10 years (USFWS 2020). However, 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 (residential, business, energy, etc.) and other forms of land use change regularly create concerns about impacts on bald eagles and particularly the loss of nest sites, and Colorado Parks and Wildlife (CPW) is required to provide consultation on land use issues affecting eagle nests. The U.S. Fish and Wildlife

Service is currently developing standards for allowing limited take of eagle nests (U.S. Fish and Wildlife Service 2016) and regularly seeks input from CPW on human-eagle issues.

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 approximately 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 response to various human activities and their proximity (Buehler 2020), making it challenging to develop disturbance mitigation recommendations that are both defensible and consistent. We predict that along the northern Front Range, nesting bald eagles that are regularly exposed to human activity are more tolerant of human activities and at closer distances than eagles using nest sites where human activities are limited. We also predict that impacts vary depending on the type of activity and whether the nest was built before or after the activity was initiated.

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, 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 (both accessed through CPW's SDE), static layers without temporal data. Wind, solar, and oil and gas data were available annually, but we summarized them by decade to match the timescale of the residential and commercial development layer, which is modeled based on housing units needed to support the human population, as measured by U.S. census 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 compared the index over time and at five different buffer distances from nests: 250 m, 500 m, 1 km, 5 km, and 10 km. 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 2021, 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. For all nests, observers determined if the nest was occupied, and whether the nest was destroyed (e.g., by a weather event or a nest tree falling down), failed, hatched successfully (at least one egg hatched), and whenever possible, fledged successfully (at least one young fledged). Occupied nests were observed multiple times (typically every two weeks or more frequently) to determine nest fate.

Preliminary results show that in 2021, 159 known bald eagle nests were monitored in the study area. Of these, 37 nests (23%) were destroyed prior to the 2021 nesting season, and an additional 27 nests (17%) were unoccupied (mainly alternate nests within occupied territories). Of the 95 occupied nests, 18 nests failed to hatch any nestlings (19%), including five nests that were destroyed during the nesting season. A total of 77 nests produced 161 nestlings, and 71 nests produced 141 fledged young (75% apparent nest success). Of successful nests, 23% produced one fledgling, 56% produced two fledglings, and 21% produced three fledglings (mean = 1.99 fledglings per successful nest).

We are estimating nest survival rates for bald eagles and determining what ecological and anthropogenic covariates are important predictors of nest survival. Prior to beginning this research project, we began a modeling effort using existing data with 163 nest attempts from 2012−2016. An additional 179 nests during those 5 years were not included, typically because the observer did not visit enough times or at the appropriate time to confirm nest fate. Preliminary results suggested that daily nest survival was best modeled by nest stage, maximum temperature in June, and time in season. Other covariates for land cover, roads, distance to water, monthly precipitation, location (Front Range vs. elsewhere), year, nest substrate, and disturbance were not supported. We expect that more of these covariates will be informative in new models built with more recent data, due to larger sample sizes and more frequent nest visits that prioritized collection of the information required for nest survival modeling.

The traditional nest survival model does not incorporate uncertainty in nest initiation or completion dates or nest stage (incubation of eggs vs. chick-rearing). Therefore, B. Kendall, our collaborator at USGS Colorado Cooperative Fish and Wildlife Research Unit, has begun development of a multi-event nest survival model that explicitly incorporates some types of uncertainty. Thus far, he has simulated 50 bald eagle nests with 2 – 3 visits each, calculating two survival parameters (one for each stage). This model produced unbiased estimates and reasonable precision, with higher precision for the nestling stage (which lasts longer) than the incubation stage and when nests were visited more frequently. We intend to use the 2021 bald eagle data to test how uncertainty in age or stage of nests and varying numbers of visits alters the accuracy and precision of estimates.

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 to us once per day when the bird is in proximity to cell phone towers (cell service areas). These transmitters are smaller and less expensive than tags that transmit signals to satellites, and because there are many cell phone towers throughout the study area, we expected GSM transmitters to be very effective. Continuous transmission, telemetry, and mortality signals are not enabled with these units, as these features are sacrificed for small unit size, frequent locations, and longevity. Transmitter data service with maximum fix settings provided one location every 2 hours during the night, every 15 minutes during the day when the eagle was not moving, and every 4 - 7 seconds when the eagle was flying ("flight mode").

We partnered with a consultant with decades of eagle trapping experience to lead our efforts to trap and mark eagles using methods approved by the CPW Institutional Animal Care and Use Committee (#05-2020). We attempted to capture one member per pair of eagles at active nest sites, using baited, padded leg-hold traps (Bloom et al. 2007) adjusted for safe eagle capture. Trap sets were under nearly constant observation by personnel in the field or via cellular-linked cameras that triggered when activity occurred near the bait, and captured eagles were immediately retrieved. Blood samples will be tested for toxic elements: lead, arsenic, cadmium, mercury, selenium, and thallium. We marked each captured eagle with a standard U.S. Geological Survey rivet leg band. Target eagles were fitted with a GPS/GSM transmitter using a break-away backpack style X-harness constructed of Teflon or Spectra ribbon straps (Fig. 3). The harnesses are designed to break down and 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).

The transmitters are programmed to run the maximum duty cycle that each will support (Fig. 4). Some units with lower battery performance are programmed for 30-second flight mode, and most units were switched to this interval in December 2021 due to lower solar energy. For units that won't support daily flight mode, we have programmed them whenever possible to run flight mode on Sundays and Wednesdays. Thus, we get very accurate flight paths on one weekend day and one weekday to test against human activity patterns. When units struggle, we have turned off flight mode and taken fixes every 15 minutes – 1 hour during daylight, transmitting data only on Mondays, Wednesdays, and Fridays.

As of 29 January 2021, we have tagged 20 bald eagles, with 17 transmitters still deployed (Fig. 3). We successfully trapped only two eagles in 2020, but pairs feeding older "teenaged" nestlings were more susceptible to trapping from mid-May to mid-August 2021. We are tagging fledged juveniles for comparison with more sedentary territorial adults, and we successfully deployed three transmitters on juveniles during summer 2021. Two adults captured in October 2020 and November 2021 were assumed to be the territory holders but later determined to be nonbreeding "floater" adults. Finally, USDA APHIS captured a 3.5 year eagle at Denver International Airport that we tagged. However, the majority of our sample has consisted of breeding adults, as originally planned. Our sample of tagged eagles consists of 16 adults (8 breeding males, 6 breeding females, 1 nonbreeding male, 1 nonbreeding female), 1 subadult (3.5 year old male), and 3 fledged juveniles (1 male, 2 females). We have had three mortalities among tagged eagles: one adult female and two hatch-year females.

One preliminary finding is that territorial adults that breed in the Front Range are resident year-round. Some individuals have taken a hiatus (days to weeks) from their territories in late summer or early fall. These individuals (mostly females) have moved west into the mountains or north into Wyoming. Other territorial adults almost never go farther than 5 km from their nests (Fig. 4). In contrast, all non-breeding eagles have ranged widely through Colorado and Wyoming, sometimes spending 1 – 2 months in an area before moving on. The nonbreeding adult female went as far north as South Dakota in early fall. All tagged juveniles moved north into southern Wyoming after dispersal. One juvenile female reached the US-Canada border in 5 days and in another 5 days was at the north end of Lake Winnipeg, halfway through the provinces of Manitoba and Saskatchewan. All surviving nonbreeding eagles eventually returned to the Colorado Front Range for the winter, except that the juvenile female who returned from Canada was wintering in Nebraska when she died in January 2022.

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. Anecdotal examination of the location data suggests that eagles nesting outside of urban or suburban areas appear to use similar areas for foraging and skirt highly developed areas, while eagles nesting within metropolitan areas forage mainly in natural areas and reservoirs occurring within that urban environment. We plan to examine these patterns with more formal analyses over the coming years, including development of a method to assess land use at foraging sites that are heavily used by tagged eagles.

During 2021, we provided information to numerous partners and publicized the research project through a press release (https://cpw.state.co.us/aboutus/Pages/News-Release-Details.aspx?NewsID=7858), podcast, video, interviews with news organizations (e.g., https://www.rmpbs.org/blogs/news/colorados-bald-eagle-population-is-booming-in-urban-areas-the-state-is-trying-to-figure-out-why/), and multiple social media posts to CPW's Facebook page and Twitter feed. R. Conrey also gave presentations to Denver Audubon, Fort Collins Audubon, CPW's Wildlife and Habitat Roundtable, State Parks raptor volunteers, and BCR Bald Eagle Watch volunteers. We have had numerous communications about bald eagles and our research with the interested public, private landowners, city and county employees, volunteers, and agency staff within and outside of CPW.

We will continue to annually monitor nesting activity and land use patterns at all known nests through the 2024 nesting season. Miranda Middleton, who has worked as a technician on this project from its inception, is beginning a Master's thesis at Colorado State University to conduct spatial analyses of marked eagle movements compared to land use. We will continue to monitor the 17 eagles currently tagged and attempt to mark 10 or more additional eagles in 2022. We will develop a database to house telemetry data, which is currently stored on CTT's data portal and on computer hard drives. We will analyze data and prepare reports and manuscripts for publication in 2025. 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 2021:

- Monitored 95 occupied bald eagle nests on the Front Range with multiple visits per site.
- Captured and attached transmitters to 18 more eagles, for total sample size of 20 eagles marked.
- Monitored tags, altering duty cycles as needed to maximize locations while preserving battery life.
- Reworked the human development index for eagle nest sites.
- Coordinated with many partners, landowners, and others to access nest sites and provide information.
- Revised statewide raptor monitoring protocols to clarify occupied vs. alternate nest structures and distinguish temporary disturbances from permanent infrastructure.

Plans for 2022:

- Monitor all occupied bald eagle nests on the Front Range at least every two weeks.
- Deploy tags on 10 or more eagles, redeploying tags recovered from mortalities.
- Continue to evaluate movement data and space use by transmittered birds.
- Develop method for evaluating land cover and use at foraging sites heavily used by marked birds.
- Develop database for GPS/GSM data from tagged birds.
- Continue spatial analysis on land use metrics.
- Co-advise new graduate student.
- Continue coordination and information sharing with partners and media.

LITERATURE CITED

Bloom, P. H., W. S. Clark, and J. F. Kidd. 2007. Capture techniques. Pages 193-220 *in* D. M. Bird and K. L. Bildstein, editors. Raptor research and management techniques. Raptor Research Foundation. https://www.raptorresearchfoundation.org/publications/techniques-manual/

Buehler, D. A. 2020. Bald Eagle (*Haliaeetus leucocephalus*), version 1.0. In Birds of the World (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.baleag.01

Colorado Parks and Wildlife. 2015. State wildlife action plan: a strategy for conservation of wildlife in Colorado. Denver, Colorado.

Colorado Parks and Wildlife. 2020. Recommended buffer zones and seasonal restrictions for Colorado raptors. Colorado Division of Wildlife. https://cpw.state.co.us/Documents/WildlifeSpecies/LivingWithWildlife/Raptor-Buffer-Guidelines.pdf

Craig, G. R. 1979. Bald and golden eagle nesting studies. Project report, Colorado Division of Wildlife, Denver, CO.

Craig, G. R. 1998. Bald eagle nest site protection and enhancement program. Project report, Colorado Division of Wildlife, Denver, CO.

Sushinsky, J. R. 2020. Mapping land-use and land-cover change in Colorado (1970-2019). Technical report to Colorado Parks and Wildlife, Denver, CO.

U.S. Fish and Wildlife Service. 2007. National bald eagle management guidelines. Division of Migratory Bird Management, Washington D.C., USA.

U.S. Fish and Wildlife Service. 2016. Bald and golden eagles: population demographics and estimation of sustainable take in the United States, 2016 update. Division of Migratory Bird Management, Washington D.C., USA.

U.S. Fish and Wildlife Service. 2020. Final report: Bald eagle population size: 2020 update. Division of Migratory Bird Management, Washington D.C., USA.

Wickersham, J. L. 2016. Bald eagle (*Haliaeetus leucocephalus*). Pages 172-173 *in* L. E. Wickersham, editor. The second Colorado breeding bird atlas. Colorado Bird Atlas Partnership and Colorado Parks and Wildlife, Denver, Colorado.

Figure 1. Number of observed occupied bald eagle nests, 1975–2020, 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. Many 2021 records had not yet been reported as of 30 January 2022, so 2021 data were not included.

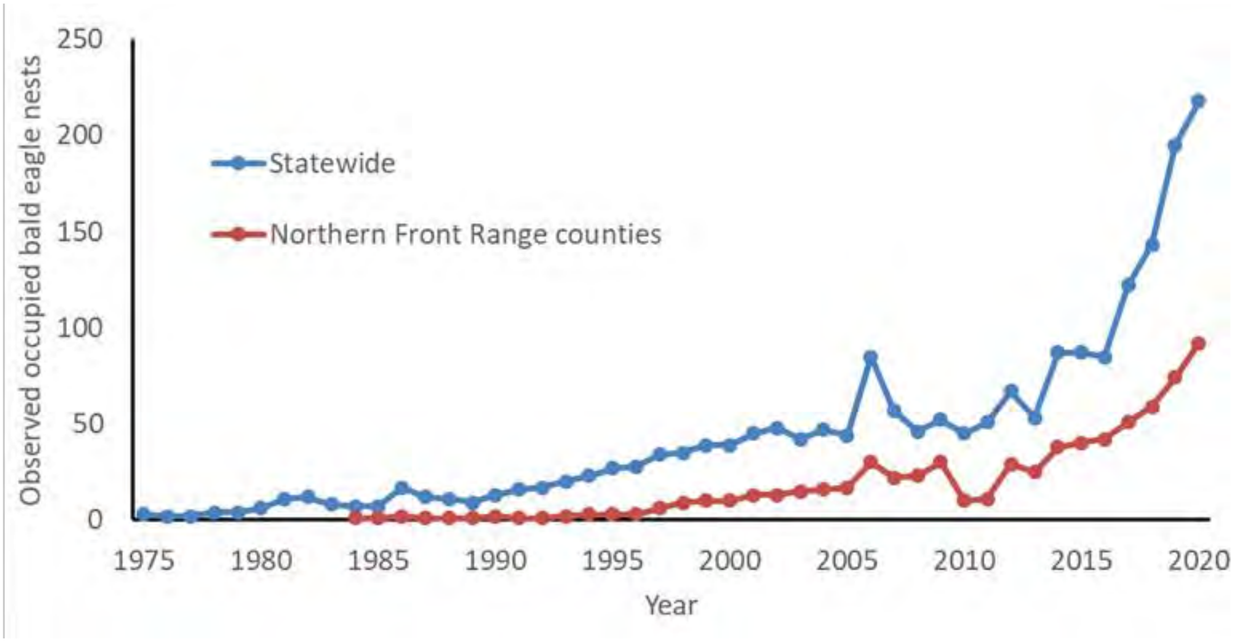


Figure 2. Development index values at bald eagle nests in the Front Range of Colorado. Development layers included oil and gas, solar and wind energy, transmission lines, trails, roads, and residential and commercial development. The index was created by summing the unweighted distance layers from each 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.

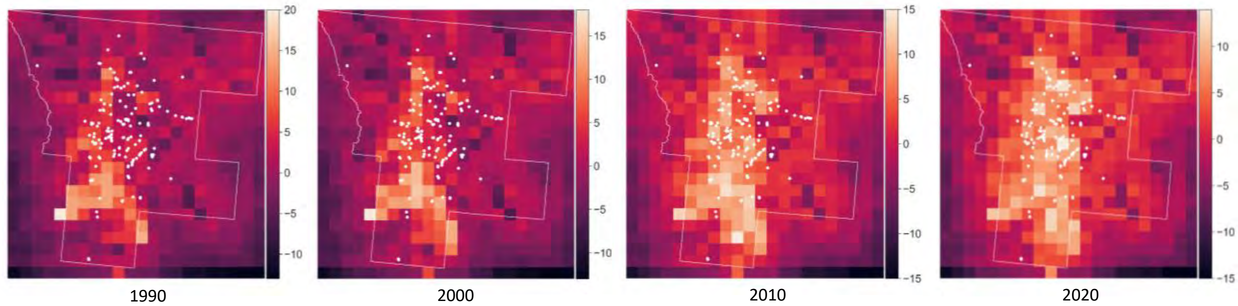
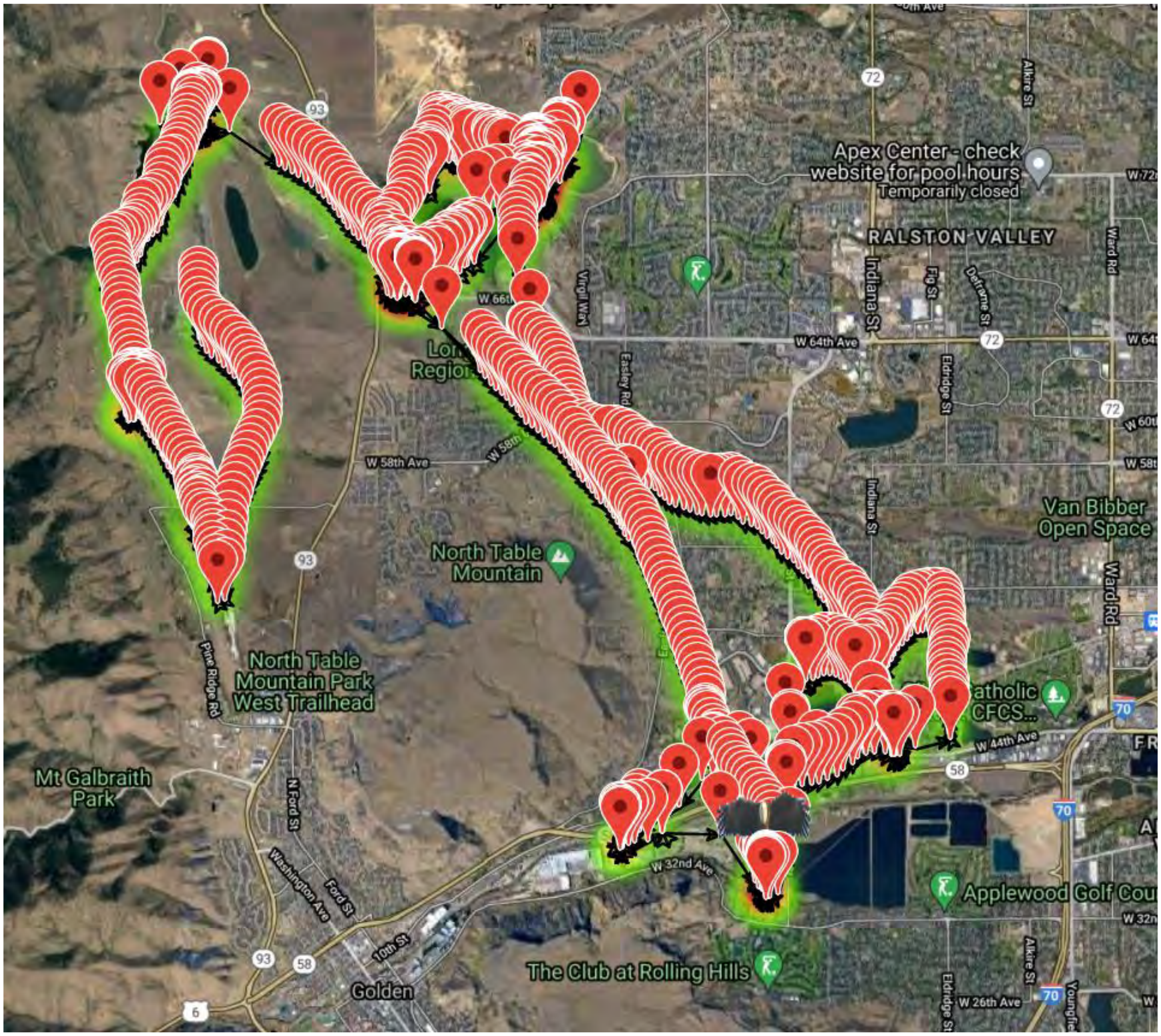


Figure 3. Bald eagles tagged during 2021 in the Front Range of Colorado. Photo credits: Mike Lockhart, Wildlands Photography and Bio-consulting.

Figure 4. Example of locations collected with GPS/GSM transmitter set to maximum duty cycle, taking fixes every 4 – 5 seconds during flight. Locations over 2.5 days from an adult male bald eagle with a territory in metro Denver, Colorado, in late August after successful fledging of eaglets.



Colorado Parks and Wildlife

WILDLIFE WILIDLIFE RESEARCH PROJECT SUMMARY

Nonbreeding season survival and habitat use of northern bobwhite

AUTHOR: Adam C. Behney, Joseph Wolske

PROJECT PERSONNEL: Jim Gammonley, Larkin Powell

Period Covered: January 2021 – December 2021

All information in this report is preliminary and subject to further evaluation. Information MAY NOT BE PUBLISHED OR QUOTED without permission of the author. Manipulation of these data beyond that contained in this report is discouraged.

Northern bobwhites (*Colinus virginianus*) have experienced rangewide population declines (Brennan 1991, Brennan 1994, Brennan and Kuvlesky 2005) and are listed as a tier 2 species of conservation concern in Colorado (Colorado Parks and Wildlife 2015). Although bobwhites are a popular gamebird and heavily hunted in many states, only about 1,800 hunters hunted bobwhites in Colorado in 2012, harvesting an estimated 3,811 birds (Colorado Parks and Wildlife 2012). For comparison, 44,885 hunters harvested 199,661 quail in Kansas in 2012 (Kansas Department of Wildlife, Parks, and Tourism 2015). On Tamarack State Wildlife Area in Northeast Colorado, harvest was as high as 699 quail in 1982 and as low as six in 2014 (Colorado Parks and Wildlife, unpublished data), suggesting high variation in population abundance.

Identifying the vital rates to which population growth rate is limited by, or sensitive to, can help guide management actions aimed to affect population size. For bobwhites, many studies have suggested that populations are most sensitive to changes in reproductive characteristics (Roseberry 1974, Klimstra and Roseberry 1975, DeMaso et al. 2011). However, recent studies have suggested that some populations can be sensitive to adult nonbreeding season survival. Folk et al. (2007) suggested a dependency on location; in the North, population growth rate was most sensitive to nonbreeding season survival in the earliest age class, whereas fertility was most influential in the South. In a metaanalyses using data from all over the United States, Sandercock et al. (2008) found that rate of population change was most sensitive to winter survival of adults. Winter survival varies dramatically among studies, regions, and years and based on 21 studies, Sandercock et al. (2008) report 6-month winter survival ranging from 0.52 to 0.04. Over 5 years, Snyder (1978) found Fall-Winter mortality ranged from 42 to 87 %. In order to assess population limiting factors, demographic data must be available for all life-stages. As part of a research project looking at quail response to grazing treatments, we have four years of very detailed bobwhite demographic data during the breeding season, including nesting probability, adult survival, nest survival, and brood survival on Tamarack State Wildlife Area in northeastern Colorado. However, we do not have any current information on nonbreeding season survival or habitat selection, which would be necessary for future population analyses.

In northeastern Colorado, bobwhites are generally limited to river bottom riparian areas where there is abundant woody cover (Snyder 1978). Woody cover is important for protection from snow (Roseberry et al. 1964) and predators (Perkins et al. 2014). However, in southeastern Colorado, bobwhites are regularly found in sandsage (*Artemisia filifolia*) rangelands far from riverbottom riparian areas. They are sometimes associated with additional woody cover (e.g., dead trees abandoned homesteads) but also in areas with no woody cover other than sandsage (T. Verquer, personal observation). The reason for this discrepancy in habitat use between the Northeast and Southeast is unknown but based on the frequent bobwhite use of structure in the southeast sandsage rangelands, we predict that adding structure to northeast rangelands would facilitate use by bobwhites. Tamarack State Wildlife Area in Northeast

Colorado is typical for the region; bobwhites are regularly observed in the riverbottom riparian area but are rarely observed in the upland rangelands (A. Behney, unpublished data). Approximately 2700 ha of upland rangeland exist at Tamarack State Wildlife Area. If woody cover is limiting the value of upland rangelands to bobwhites at Tamarack than increasing woody cover should facilitate expansion of bobwhite range into the uplands. Facilitating use of uplands by bobwhites at Tamarack would create additional opportunity for hunters and potentially a more satisfactory hunting experience because they would not be concentrated in the riverbottom riparian area.

Shrubs (e.g., American plum [*Prunus Americana*]) are commonly planted in areas lacking woody cover to provide quail habitat (Hiller et al. 2007, Pierce et al. 2016). However, shrubs take a few years after planting to reach a size that is valuable for quail (Abbott 2003). Artificial structure has been used successfully to establish quail habitat (Webb and Guthery 1983, Boyer et al. 1989, Abbott 2003). These artificial structures consist of steel T-posts or some other structure to which cedar (*Juniperus virginiana*) or other branches can be attached. If bobwhites are observed using artificial structure, it would suggest that planting shrubs would be a valuable method to increase usable space for bobwhites into upland rangelands.

The specific objectives of this project are to:

1. Estimate survival rates during the nonbreeding season (Oct – Mar).
2. Assess habitat selection and movement characteristics during the nonbreeding season.
3. Document use of artificial woody cover placed in upland rangelands.

METHODS

Capture and marking

We captured bobwhites using baited walk-in traps (Smith et al. 1981). All captured bobwhites received a numbered, aluminum leg band. On a subsample, we affixed ≤ 6.5 g necklace-style VHF radio transmitters equipped with an 8-hour mortality sensor (American Wildlife Enterprises, Monticello, FL), which have been used frequently for bobwhites (Burger et al. 1995, DeMaso et al. 1997, Taylor et al. 1999*a*). We did not deploy transmitters on quail weighing less than 130 g to keep the transmitter mass less than 5% of the bird's body mass. Terhune et al. (2007) concluded that 6 g necklace style transmitters affixed on bobwhites weighing ≥ 132 g had no effect on survival. Furthermore, bobwhites fitted with these transmitters during our previous study (A. Behney, unpublished data) exhibited demographic characteristics consistent with other published estimates.

Survival

We attempted to assess status (live or dead) of all radio-marked bobwhites one or two times each week from October – March. Upon notice of a dead quail (mortality signal from transmitter), we retrieved the transmitter and assessed cause of mortality (mammal, avian, hunter cripple, etc.).

Habitat Selection

To assess habitat selection, we homed in on each quail weekly or biweekly to get an exact location. We attempted to get a precise location without disturbing the bird so as to not bias its microhabitat use by causing it to seek cover as observers approach. We circled the bird and pinpoint its location using landmarks (e.g., trees, brush piles, etc.) from different angles based on the direction of the signal. After a location was determined, we immediately went to that location and sampled vegetation as well as at four random points in the same general habitat type within 200 m of the used location (i.e., within the distance bobwhites typically move in a day; Taylor et al. 1999*a*, Taylor et al. 1999*b*). At each used and random point we visually estimated the percent cover of bare ground, litter, and each species of vegetation within a 1 m^2 sampling frame. We also noted the lowest decimeter visible on a 2.5 cm diameter pole, read from 4 m in four directions, 90° apart, from 1 m above the ground (Robel et al. 1970).

Artificial Structures

In late summer/early fall 2019, we created five lines of artificial structures approximately 300 m long running from the riverbottom where quail currently inhabit straight out into the upland rangelands. Artificial structures will consist of t-posts or large cable spools to which we will attach cedar boughs or some other woody debris. The lines of structures will be ~3 m wide and ~1.5 m tall.

Once every two weeks we walked all artificial structure lines, beating the cover with sticks to flush out any quail that were using it. We noted of any quail sign (tracks or droppings) in or around the cover or if radio-marked quail were located in or around the artificial structure. Searches in cover will be exhaustive and invasive so we can assume that any quail in the artificial cover were detected (detection probability = 1). We also searched five areas where artificial cover was not been deployed (i.e., control sites). These control sites were approximately the same size as the artificial cover and randomly placed in the same general area.

RESULTS

Capture

Using walk-in traps we had 159 capture events, catching 123 individuals during 2019 (first capture season), and had 48 capture events with 43 individuals in 2020 (second capture season). 10 additional quail were captured via nightlighting in the second season. We had 25 birds and 3 birds that were lighter than the allowable weight to be fitted with transmitters in the first and second season, respectively. We radio tagged 98 individuals (43 females and 55 males) and 49 individuals (20 females and 29 males) in the first and second season, respectively.

Survival

We included 157 bobwhites in our survival analysis. Individuals that were tagged in September but did not survive until the start of the nonbreeding season (October 1) were excluded. In addition to the 98 birds tagged during our first season we included 11 birds that still had functional collars from the previous breeding season study. The fates of birds in the first season are as follows: 18 survivals, 73 mortalities, 13 missing birds with unknown fates, and 5 transmitters deployed in the spring had the battery die. 5 birds with transmitters and one with only a band were harvested by hunters. During the second season: 0 survivals, 46 mortalities, 2 missing with unknown fates and one defective collar with unknown fate. 5 birds with transmitters were harvested by hunters.

We used known-fate models in program MARK to assess variation in seasonal and weekly survival with time trend, age, sex, and body mass at capture as covariates. The population of bobwhites was substantially lower during the second year of our study, and survival varied between years. For both seasons (2019-2020 and 2020-2021), we found that a time trend grouping weeks into three periods explained variation in survival (wi = 0.774 and wi = 0.622, respectively). Nonbreeding season survival in the 2020-2021 season (26 weeks) was $\hat{S} = 0.243$ (95 % CI = 0.165 - 0.342). Survival was much lower during the second season (2020-2021) with $\hat{S} = 0.093$ (95 % CI = 0.031 – 0.250). We did not find evidence that sex, age, or body mass influenced survival in either year of our study. Our nonbreeding season survival estimate is the first for bobwhite in Colorado, and regional seasonal estimates from Kansas, Iowa, and Illinois range from 0.04 to 0.37.

Locations/Movements

In the first season we performed 5,678 status checks, 4,293 of those being homing locations and 1,074 status checks, 698 homing or triangulations in the second season. We found the bobwhites to be flightier and more skittish during the non-breeding season leading us to use larger homing circles. This may have caused a slight drop in the accuracy of our locations but minimized our disturbance of the birds. Some coveys frequently crossed the river into areas inaccessible by ATV or truck. To reach them we crossed the river in waders during the first season. During the second season we opted to triangulate birds in inaccessible areas, only crossing the river to flush birds for habitat use samples as needed.

Over the course of study 17 birds went missing from Tamarack SWA. These birds were extensively searched for multiple times and listened for daily while locating birds still known to be on property. On 13 January 2020 we performed an aerial telemetry flight over the riverbottom between Sterling and Sedgewick in attempt to locate missing birds. Two were located giving mortality signals, one near Iliff and one near Sterling, the latter being found ~27km from the point it was captured.

We found an average daily distance moved of 215.6 meters. We used a mixed effects model to investigate variation in daily movement. We used a daily weather index score that incorporates minimum and maximum temperatures and snowfall and snow depth to get an overall estimate of the severity of weather on a given day. Our highest ranked model was our daily weather index score + season of study model ($w_i = 0.999$) showing that bobwhites moved less on days when there was more snow and temperatures were lower. Sex, age, capture weight, day length, day of year and season of study were used to create models as additional covariates, but only the top-ranked model (weather index + season) was ranked better than the null (no effect) model.

We used fixed kernel density estimation (KDE) to generate seasonal home ranges for each collared bobwhite with >30 (n = 67) locations by producing a utilization distribution (UD) (Worton 1989). We defined seasonal home range as the 95% UD for each individual. We found the average to be 52.3 hectares with a minimum of 7.3 ha and a max of 267.4 ha. Seasonal range values for each individual will be used in future analyses investigating possible relationships between range size and survival, as well as range size and average daily movement.

Artificial Structures

No bobwhites or bobwhite signs were found during the searches of the artificial structures. One bobwhite was found using the structure during a daily homing location, although, we located bobwhite in the sandhills within a quarter mile of the structures multiple times, suggesting that may have been a chance occurrence.

Next Steps

Field work for this project was completed in 2021. Survival and movement analyses are complete. Habitat selection analyses are ongoing and should be completed during spring 2022. A final thesis is scheduled to be finished in spring 2022.

LITERATURE CITED

Abbott, C. W. 2003. Transplanting northern bobwhite (*Colinus virginianus*) in the Southern High Plains of Texas. Thesis, Texas Tech University, Lubbock, TX, USA.

Boyer, D. A. 1989. Evaluation of feeders, waterers, and shelters for use in bobwhite management. Thesis, Texas A & M University, Kingsville, TX, USA.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544-555.

Brennan, L. A. 1994. Broad-scale population declines in four species of North American quail: an examination of possible causes. Pages 44-50 *in* W. W. Covington and L. S. DeBano, Technical Coordinators. Sustainable ecological systems: implementing an ecological approach to land management. U.S. Forest Service General Technical Report RM-247.

Brennan, L. A. and W. P. Kuvlesky, Jr. 2005. North American grassland birds: an unfolding conservation crisis? Journal of Wildlife Management 69:1-13.

Burnham, K. P. and D. R. Anderson. 2002. Model selection and multi-model inference: a practical information-theoretic approach. Springer-Verlag, New York, USA.

Colorado Parks and Wildlife. 2012. 2011/2012 Small game harvest report. https://cpw.state.co.us/thingstodo/Pages/SmallGameStatistics.aspx

Colorado Parks and Wildlife. 2015. State Wildlife Action Plan. https://cpw.state.co.us/aboutus/Pages/StateWildlifeActionPlan.aspx

DeMaso, S. J., W.E. Grant, F. Hernandez, L. A. Brennan, N. J. Silvy, X. B. Wu, and F. C. Bryant. 2011. A population model to simulate northern bobwhite population dynamics in southern Texas. Journal of Wildlife Management 75:319-332.

Elff, M. 2018. mclogit: mixed conditional logit models. R package version 0.6.1.

Folk, T. H., R. R. Holmes, and J. B. Grand. 2007. Variation in northern bobwhite demography along two temporal scales. Population Ecology 49:211-219.

Hiller, T. L., F. S. Guthery, A. R. Rybak, S. D. Fuhlendorf, S. G. Smith, W. H. Puckett, Jr., R. A. Baker. 2007. Management implications of cover selection data: northern bobwhite example. Journal of Wildlife Management 71:195-201.

Kansas Department of Wildlife, Parks, and Tourism. 2015. Small game hunter activity survey – 2014.

Klimstra, W. D. and J. L. Roseberry. 1975. Nesting ecology of the bobwhite in southern Illinois. Wildlife Monographs 41.

Perkins, R., C. Boal, D. Rollins, and R. M. Perez. 2014. Northern bobwhite predator avoidance behavior in response to varying types of threat. Journal of Wildlife Management 78:1272-1281.

Pierce, R. A., B. White, and P. Graham. 2016. Habitat management practices for bobwhite quail. University of Missouri Extension.

Pollock, K. H., C. T. Moore, W. R. Davidson, F. E. Kellogg, and G. L. Doster. 1989. Survival rates of bobwhite quail based on band recovery analyses. Journal of Wildlife Management 53:1:6.

R Core Team. 2018. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hurlbert. 1970. Relationship between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-297.

Roseberry, J. L. 1964. Some responses of bobwhites to snow cover in Southern Illinois. Journal of Wildlife Management 28:244-249.

Roseberry, J. L. 1974. Relationship between selected population phenomena and annual bobwhite age ratios. Journal of Wildlife Management 38:665-673.

Sandercock, B. K., W. E. Jensen, C. K. Williams, R. D. Applegate. 2008. Demographic sensitivity of population change in northern bobwhite. Journal of Wildlife Management 72:970-982.

Smith, H. D., F. A. Stormer, and R. D. Godfrey, Jr. 1981. A collapsible quail trap. United States Forest Service Research Note RM-400, Lubbock, USA.

Snyder, W. D. 1978. The bobwhite in eastern Colorado. Technical Publication 32 (O. B. Cope, Ed.). Colorado Division of Wildlife.

Taylor, J. S., K. E. Church, and D. H. Rusch. 1999*a*. Microhabitat selection by nesting and brood-rearing northern bobwhite in Kansas. Journal of Wildlife Management 63:686-694.

Taylor, J. S., K. E. Church, D. H. Rusch, and J. R. Cary. 1999*b*. Macrohabitat effects on summer survival, movements, and clutch success of northern bobwhite in Kansas. Journal of Wildlife Management 63:675-685.

Terhune, T. M., D. C. Sisson, J. B. Grand, and H. L. Stribling. 2007. Factors influencing survival of radiotagged and banded northern bobwhites in Georgia. Journal of Wildlife Management 71:1288-1297.

Webb, W. M. and F. S. Guthery. 1982. Response of bobwhite to habitat management in northwest Texas. Wildlife Society Bulletin 10:142-146.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

TITLE: Estimates and determinants of duck production in North Park, Colorado

AUTHORS: Adam C. Behney, James H. Gammonley, and Casey M. Setash

Period Covered: 1 January 2021 – 31 December 2021

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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

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.During the 2021 field season, we surveyed 117 individual wetlands for breeding ducks.

We conducted 147 dependent double observer surveys on basin wetlands in 2021. Out of 2,086 duck detections during these surveys, 36 were missed by the primary observer. The most parsimonious model of detection probability allowed detectability to vary among observers (two groups: obs A, B, C vs. obs D) and linearly with group size (Table 1). Detection probability was 0.993 and 0.974 for the two levels of observer held constant at mean group size. Detectability increased with group size ($\beta_{group} = 0.28 \pm 0.15$). We conducted 113 independent double observer surveys on riparian areas, irrigation ditches, and hay fields. Out of 258 duck detections, 20 were missed by an observer. The best model of detection probability allowed detectability to vary among habitat types, species (3 groups: small dabbling duck, larger dabbling duck, diving duck), and linearly with group size (Table 2). Estimated detection probabilities were generally high, ranging from 0.91 to 1.00 (Fig. 1). Detectability decreased with group size ($\beta_{group} = -0.59 \pm 0.18$).

At 5 large reservoirs, we conducted 3 rounds of duck counts between 23-Apr and 15-Jun. Duck abundance decreased throughout the survey period (Fig. 2). We conducted duck pair counts on 68 basin wetlands, 18 hay meadows, 13 riparian transects, and 13 irrigation ditch transects from 22-Apr until 18-Jun. Summed across all sites, we observed 3,765 total indicated breeding pairs, including 1,049 gadwall, 648 mallards, 501 northern shovelers, 322 American wigeon, 319 lesser scaup, and 182 cinnamon teal. We modeled pair abundance separately for these species in addition to all ducks combined. For all ducks combined, gadwall, mallards, and cinnamon teal, a cubic effect of day was the most parsimonious time trend model (Table 3). For northern shovelers, a linear time trend was best and for lesser scaup, a quadratic time trend was best; whereas, the null model outperformed any time trend for American wigeon (Table 3). Total pair abundance across species was relatively stable throughout the breeding season but decreased in June, while individual species temporal trends were more variable (Figure 3). We then added vegetation variables to the best time trend model. For all ducks combined, as well as for gadwall, mallard, cinnamon teal, and northern shoveler individually, percent open water was the best habitat variable and was positively related to pair abundance (Table 3, Figure 4). For American wigeon and lesser scaup, scrub/shrub vegetation was best and negatively related to pair abundance (Table 3, Figure 4).The number of indicated breeding pairs was greatest on wetlands with more open water.

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 2019-2021. We therefore located nests associated with flood irrigation to evaluate the importance or impact of flood irrigation on nesting waterfowl.

We searched 131 plots across three privately-owned ranches, Arapahoe National Wildlife Refuge, Lake John State Wildlife Area, and Hebron Slough Waterfowl Area within areas that were managed via flood irrigation. Plots ranged from 0.45-123.55 ha ($\bar{x}$ = 8.58 ha) and we rope-dragged on foot, with ATVs, or searched systematically on foot to locate duck nests. Plots consisted of flooded and dry hay meadows (*n*=18), flooded and dry uncut/nongrazed meadows interspersed with shrubs (*n*=75), expanses of shrub/scrub (primarily greasewood and basin sagebrush; *n*=3)), irrigation ditches (*n*=6), reservoir perimeters (*n*=4), and the perimeter of riparian areas (*n*=23). Preliminary results indicate that the top three observed nesting species (mallards, gadwall, and cinnamon teal) all selected nest sites with high visual obstruction (i.e., high vegetation density surrounding the nest), indicating that tall, dense ground vegetation may be important for nesting ducks. We did not detect an effect of the other measured covariates (e.g., percent of each of the following at the nest site: litter, grass, forbs, shrubs, sedges, or rushes) on where each of these three species selected nest sites.

We located 40 nests of six species throughout the 2021 breeding season. A large portion (82.5%, *n*=33) of these nests were located on Arapahoe NWR while 15% (*n*=6) were associated with working lands and 2.5% (*n*=1) were located at Lake John State Wildlife Area. Over the four years the study has been taking place, nest density has been highest in different habitat types each year. Typically riparian areas (mean = 1.09 nests/ha), irrigation ditches (mean = 0.58 nests/ha), and graminoid meadows (mean = 0.42 nests/ha) have exhibited the highest density of nests across all years. Nest density was highest in riparian areas (3.14 nests/ha) in 2021, followed by hay meadows (0.31 nests/ha), irrigation ditches (0.33 nests/ha), graminoid meadows interspersed by shrubs (0.15 nests/ha), purely graminoid meadows (0.13 nests/ha), and shrub-scrub habitat (0 nests/ha). Future analyses will explore how nest density is impacted by local weather conditions and whether that might explain the disparity between densities within the same habitat type across years. Only six nests successfully hatched at least one duckling in 2021, and most nests were depredated by nest predators (e.g., common raven, coyote, etc.). Nest survival did not vary by habitat type and averaged 0.28 (SE = 0.17) across species and habitats.

We deployed cameras at six duck nests during summer 2021. Five of the six nests failed and one was successful. Of the five failed nests, we were able to capture pictures of ravens depredating three. We were not able to identify what depredated the remaining two nests.

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 199 independent double observer surveys for broods. Out of 1,394 duckling detections 518 were missed by an observer. The only model of brood detection probability to outperform the null model included wetland type (AIC_c weight = 1). Detection ± SE was greatest in hay meadows (1.0 ± 0.00), followed by riparian (0.98 ± 0.02), basin (0.77 ± 0.01), and reservoirs (0.70 ± 0.04). We observed broods of 12 duck species with gadwall being the most common followed by mallard, and cinnamon teal. Summed across surveys and sites we observed 1459 ducklings (267 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, and northern shovelers. For all ducks combined, date in quadratic form was the best temporal trend of duckling abundance, which peaked in early August (Table 4, Figure 5). Percent of the site that was flooded positively influenced duckling abundance; whereas, percent herbaceous vegetation negatively impacted abundance (Figure 6). For gadwall, a cubic time trend was best, whereas for mallards a quadratic trend, and for northern shovelers, the null model was best (Table 4). Gadwall duckling abundance peaked in late July, decreased, and then increased again in mid-August; whereas, mallard duckling abundance had a more gradual peak in late July (Figure 7). Percent herbaceous vegetation was the best habitat variable predicting mallard duckling presence (Table 4). Percent submergent vegetation was best in predicting gadwall and northern shoveler duckling presence (Table 4). The probability of mallard duckling being present on a site decreased with percent herbaceous vegetation (Figure 8). Gadwall and northern shoveler duckling presence increased with percent submergent vegetation on a site (Figure 8). Mean brood-pair ratio was greatest for cinnamon teal and least for lesser scaup (Table 5). Overall mean ± SD brood-pair ratio was 0.15 ± 0.37 and duckling pair ratio was 0.86 ± 2.24 (Table 5).

Duck Banding

We trapped ducks on Arapaho NWR and Hebron Waterfowl Area 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 and airboat and spotlights on one site during one night. We marked ducks with standard U.S. Geological Survey (USGS) legbands and released them at their capture sites. In coordination with a CSU research project, we also marked 2 mallards captured in swim-in traps, and one mallard captured on its nest, with Ecotone Kite-L GPS-GSM transmitters (12-14 g). 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 (30 July – 10 September) we banded 608 ducks of 7 species (Table 6). Given the relatively dry conditions and poor production in 2021, we captured and banded relatively few total ducks, and very few local and hatch year ducks. Our pre-season trapping effort was comprised of 294 trap-days with baited swim-in traps (95% of the banded sample), and 1 night of spotlighting from an airboat (5% of the banded sample). Mallards comprised the majority (82%) of our banded sample. We captured gadwall (6% of the banded sample) primarily (92%) with spot-lighting. We banded 25 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, 100 ducks we banded in 2018, 91 ducks we banded in 2019, 140 ducks we banded in 2020, and 21 ducks we banded in 2021 (total = 352) had been harvested by hunters and reported to the USGS Bird Banding Laboratory, including 297 mallards, 32 gadwall, 5 cinnamon teal, 4 unidentified teal (likely cinnamon teal), 3 green-winged teal, 4 wigeon, 3 shoveler, 2 redhead, and 2 canvasback. Among mallards, juveniles and adult males have been harvested at higher rates than adult females (Table 7). Most mallards (72.6%) were harvested in Colorado, in 34 different counties (Table 8). Mallards banded in North Park during 2018-2021 were also harvested in 12 other states, including 50 different counties, and the province of Alberta in Canada (Table 8).

Future Work – We plan to continue annual field work through 2023.

LITERATURE CITED

Gollop, J. B., and W. H. Marshall. 1954. A guide for aging duck broods in the field. Mississippi Flyway Council Technical Section, Minneapolis, Minnesota, USA.

Huggins, R. M. 1989. On the statistical analysis of capture experiments. Biometrika 76:133–140.

Huggins, R. M. 1991. Some practical aspects of a conditional likelihood approach to capture experiments. Biometrics 47:725–732.

Mauser, D. M., J. G. Mensik. 1992. A portable trap for ducks. The Wildlife Society Bulletin, 20:299-302.

Nichols, J. D., J. E. Hines, J. R. Sauer, F. W. Fallon, J. E. Fallon, P. J. Heglund. 2000. A double-observer approach for estimating detection probability and abundance from point counts. The Auk, 117:393-408.

Pagano, A. M. and T. W. Arnold. 2009. Detection probabilities for ground-based breeding waterfowl surveys. The Journal of Wildlife Management, 73:392-398.

Pagano, A. M., C. L. Amundson, M. R. Pieron, T. W. Arnold, and T. C. Kimmel. 2014. Using sigtability-adjusted brood-pair ratios to estimate waterfowl productivity. Wildlife Society Bulletin, 38:566-573.

Table 1. Model selection results for duck detection probability on basin wetlands using dependent double observer sampling in North Park, Colorado during 2021.

Model	**k**	**ΔAIC_c**	**w_i**
Observer (2 levels) + group size	3	0.0	1.0
Observer (2 levels)	2	6.2	0.0
Group size	2	11.3	0.0
Null	1	16.8	0.0
Species (2 levels: dab vs. div)	2	18.0	0.0
Species (3 levels: big dab vs. small dab vs. div)	3	19.9	0.0
Social category	4	21.2	0.0
Species (17 levels: all species separately)	17	22.4	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 2021.

Model	**k**	**ΔAIC_c**	**w_i**
Habitat type + species (3 levels) + group size	7	0.0	0.8
Habitat type + species (3 levels) + group size + observer	10	3.0	0.2
Habitat type + species (3 levels)	6	9.8	0.0
Habitat type	4	12.6	0.0
Species (3 levels)	3	19.8	0.0
Observer	4	20.9	0.0
Species (2 levels)	2	22.2	0.0
Null	1	23.5	0.0
Species (14 levels)	14	34.7	0.0

Table 3. Model selection results for indicated breeding pairs/survey based on date and vegetation characteristics of sites in North Park, Colorado during the 2021 breeding season. Vegetation variables were added to the best time trend model. K indicates the number of parameters estimated in the model and w_i indicates the model weight.

Species	Model	k	ΔAIC_c	w_i
All ducks				
	Date (cubic) + open water	6	0.0	1.00
	Date (cubic) + shrub/scrub	6	19.8	0.00
	Date (cubic) + bare ground	6	35.8	0.00
	Date (cubic) + herbaceous emergent	6	156.1	0.00
	Date (cubic)	5	175.5	0.00
	Date (cubic) + robust emergent	6	175.7	0.00
	Date (quadratic)	4	176.0	0.00
	Null	2	176.6	0.00
	Date (linear)	3	178.5	0.00
Gadwall				
	Date (cubic) + open water	6	0.0	1.00
	Date (cubic) + bare ground	6	67.0	0.00
	Date (cubic) + herbaceous emergent	6	85.6	0.00
	Date (cubic)	5	90.8	0.00
	Date (cubic) + shrub/scrub	6	91.8	0.00
	Date (cubic) + robust emergent	6	92.2	0.00
	Date (quadratic)	4	97.4	0.00
	Date (linear)	3	114.6	0.00
	Null	2	127.6	0.00
Mallard				
	Date (cubic) + open water	6	0.0	1.00
	Date (cubic) + bare ground	6	41.2	0.00
	Date (cubic)	5	51.3	0.00
	Date (cubic) + herbaceous emergent	6	52.3	0.00
	Date (cubic) + shrub/scrub	6	53.0	0.00
	Date (cubic) + robust emergent	6	53.2	0.00
	Null	2	96.6	0.00
	Date (linear)	3	98.4	0.00
	Date (quadratic)	4	100.3	0.00
Northern shoveler				
	Date (linear) + open water	4	0.0	1.00
	Date (linear) + bare ground	4	16.0	0.00
	Date (linear)	3	17.8	0.00
	Date (linear) + herbaceous emergent	4	18.5	0.00

Date (linear) + shrub/scrub	4	18.6	0.00
Date (linear) + robust emergent	4	18.7	0.00
Date (cubic)	5	19.0	0.00
Date (quadratic)	4	19.4	0.00
Null	2	63.5	0.00
American wigeon			
Shrub/scrub	3	0.0	1.00
Open water	3	54.8	0.00
Bare ground	3	74.3	0.00
Robust emergent	3	89.3	0.00
Herbaceous emergent	3	91.4	0.00
Null	2	92.5	0.00
Date (linear)	3	93.5	0.00
Date (quadratic)	4	95.3	0.00
Date (cubic)	5	97.4	0.00
Lesser scaup			
Date (quadratic) + shrub/scrub	7	0.0	0.92
Date (quadratic) + bare ground	7	5.0	0.08
Date (quadratic) + open water	7	58.1	0.00
Date (quadratic)	4	84.4	0.00
Date (quadratic) + robust emergent	7	84.8	0.00
Date (cubic)	5	86.4	0.00
Date (quadratic) + herbaceous emergent	7	86.4	0.00
Date (linear)	3	109.2	0.00
Null	2	257.0	0.00
Cinnamon teal			
Date (cubic) + open water	6	0.0	0.99
Date (cubic) + robust emergent	6	10.3	0.01
Date (cubic) + herbaceous emergent	6	13.1	0.00
Date (cubic)	5	14.3	0.00
Date (quadratic)	4	14.8	0.00
Date (cubic) + shrub/scrub	6	16.3	0.00
Date (cubic) + bare ground	6	16.4	0.00
Date (linear)	3	26.5	0.00
Null	2	35.6	0.00

Table 4. Model selection results for duckling abundance and brood presence based on date and vegetation characteristics of sites in North Park, Colorado during the 2021 breeding season. For all ducks, we modeled duckling abundance; whereas, for gadwall, mallard, and northern shoveler, we modeled brood presence. Vegetation variables were added to the best time trend model. K indicates the number of parameters estimated in the model and w_i indicates the model weight.

Species	Model	k	ΔAIC_c	w_i
All ducks				
	Date (quadratic) + per. flooded + per. herbaceous	7	0.0	0.81
	Date (quadratic) + per. flooded	6	2.9	0.19
	Date (quadratic) + per. herbaceous	6	11.8	0.00
	Date (quadratic)	5	16.2	0.00
	Date (quadratic) + per. robust emergent	6	16.4	0.00
	Date (quadratic) + per. emergent	6	18.0	0.00
	Date (quadratic) + per. submergent	6	18.1	0.00
	Date (cubic)	6	18.1	0.00
	Date (quadratic) + per. shrub/scrub	6	18.2	0.00
	Date (linear)	4	18.5	0.00
	Null	3	21.1	0.00
Gadwall				
	Date (cubic) + per. submergent	7	0.0	0.88
	Date (cubic) + per. emergent	7	5.9	0.05
	Date (cubic) + per. flooded	7	7.5	0.02
	Date (cubic)	6	7.6	0.02
	Date (quadratic)	5	7.7	0.02
	Date (cubic) + per. herbaceous	7	7.8	0.02
	Date (linear)	4	16.4	0.00
	Null	3	23.8	0.00
Mallard				
	Date (quadratic) + per. herbaceous	6	0.0	0.32
	Date (quadratic) + per. flooded	6	0.5	0.25
	Date (quadratic) + per. shrub/scrub	6	1.6	0.14
	Date (quadratic) + per. submergent	6	2.5	0.09
	Date (quadratic)	5	3.6	0.05
	Date (linear)	4	4.4	0.04
	Date (quadratic) + per. robust emergent	6	4.8	0.03
	Date (cubic)	6	4.8	0.03
	Null	3	5.0	0.03
	Date (quadratic) + per. emergent	6	5.4	0.02
Northern shoveler				
	Per. submergent	4	0.0	0.38
	Null	3	2.1	0.13

Per. emergent	4	2.5	0.11
Per. flooded	4	3.0	0.08
Per. shrub/scrub	4	3.3	0.07
Per. herbaceous	4	3.3	0.07
Date (linear)	4	4.0	0.05
Per. robust emergent	4	4.1	0.05
Date (quadratic)	5	4.9	0.03
Date (cubic)	6	5.6	0.02

Table 5. Brood and duckling-pair ratios with associated standard deviation and minimum and maximum values across sites in North Park, Colorado during 2021.

	Brood-pair ratio				Duckling-pair ratio			
Species group	Mean	SD	Min	Max	Mean	SD	Min	Max
Cinnamon teal	0.15	0.29	0.0	1.0	0.76	1.55	0.0	8.0
Mallard	0.08	0.19	0.0	1.0	0.49	1.13	0.0	4.75
Gadwall	0.11	0.24	0.0	1.0	0.58	1.33	0.0	5.67
Lesser scaup	0.02	0.06	0.0	0.4	0.09	0.37	0.0	2.6
Northern shoveler	0.13	0.39	0.0	2.0	0.61	1.83	0.0	10.0
All ducks	0.15	0.37	0.0	2.0	0.86	2.24	0.0	12.5

Table 6. Numbers of ducks banded in North Park during pre-season capture efforts in 2021. 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	95	306	38	57	0	0	496
Gadwall	11	25	1	1	0	0	36
Cinnamon/blue-winged teal[a]	9	12	2	2	0	0	25
Green-winged teal	1	32	1	1	3	3	41
American wigeon	1	0	0	0	0	0	1
Northern pintail	4	0	2	0	0	0	6
Total	121	376	44	61	3	3	608

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

Table 7. Numbers of mallards banded in North Park during 2018-2021 in different age and sex cohorts and reported shot by hunters during hunting seasons through December 31, 2021.

Banded cohort	Band year	Number banded	Number harvested (% of banded sample)			
			2018-2019	2019-2020	2020-2021	2021-2022
AHY male	2018	168	10 (6.0%)	11 (6.5%)	5 (3.0%)	0
	2019	234	-	24 (10.3%)	8 (3.4%)	3 (1.3%)
	2020	246	-	-	16 (6.5%)	7 (2.8%)
	2021	306	-	-	-	12 (3.9%)
AHY female	2018	69	1 (1.4%)	2 (2.9%)	0	0
	2019	104	-	4 (3.8 %)	1 (1.0%)	1 (1.0%)
	2020	108	-	-	10 (9.3%)	2 (1.9%)
	2021	95	-	-	-	1 (1.1%)
HY male	2018	221	29 (13.1%)	13 (5.9%)	2 (0.9%)	2 (0.9%)
	2019	109	-	12 (11.0%)	6 (5.5%)	0
	2020	266	-	-	25 (9.4%)	14 (5.3%)
	2021	57	-	-	-	5 (8.8%)
HY female	2018	131	13 (9.9%)	5 (3.8%)	0	0
	2019	73	-	3 (4.1%)	1 (1.4%)	0
	2020	200	-	-	24 (12.0%)	4 (2.0%)
	2021	38	-	-	-	1 (2.6%)
L male	2018	12	1 (8.3%)	0	0	0
	2019	7	-	1 (14.3%)	0	0
	2020	25	-	-	5 (20.0%)	0
	2021	0	-	-	-	-
L female	2018	14	2 (14.3%)	0	0	0
	2019	11	-	1 (9.1)	0	0
	2020	28	-	-	3 (10.7%)	0
	2021	0	-	-	-	-
Total	2018	615	56 (9.1%)	31 (5.0%)	7 (0.7%)	2 (0.3%)
	2019	538	-	45 (8.4%)	16 (3.0%)	4 (0.7%)
	2020	873	-	-	83 (9.5%)	27 (3.1%)
	2021	496	-	-	-	19 (3.8%)

Table 8. 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, 2018-2021, reported by hunters through December 31, 2021.

State	County	Direct recoveries	Indirect recoveries
Colorado	Total	161 (78.2)	54 (61.7)
	Adams	3 (1.5)	2 (2.2)
	Alamosa	5 (2.4)	1 (1.1)
	Bent	2 (1.0)	1 (1.1)
	Boulder	4 (1.9)	2 (2.2)
	Chaffee	1 (0.5)	0
	Conejos	1 (0.5)	1 (1.1)
	Costilla	2 (1.0)	0
	Delta	0	1 (1.1)
	Dolores	0	1 (1.1)
	Douglas	1 (0.5)	0
	Eagle	7 (3.4)	0
	El Paso	1 (0.5)	0
	Fremont	1 (0.5)	1 (1.1)
	Garfield	1 (0.5)	0
	Grand	10 (4.9)	4 (4.4)
	Gunnison	1 (0.5)	0
	Jackson	54 (26.2)	6 (6.7)
	La Plata	1 (0.5)	1 (1.1)
	Larimer	3 (1.5)	1 (1.1)
	Las Animas	3 (1.5)	1 (1.1)
	Logan	0	2 (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)	2 (2.2)
	Park	5 (2.4)	3
	Pitkin	1 (0.5)	0
	Prowers	1 (0.5)	0
	Pueblo	7 (3.4)	1 (1.1)
	Rio Grande	4 (1.9)	1 (1.1)
	Routt	4 (1.9)	1 (1.1)
	Saguache	6 (2.9)	1 (1.1)
	Summit	1 (0.5)	0
	Weld	18 (8.7)	14 (15.6)
Arizona	Total	2 (1.0)	0
	Coconino	1 (0.5)	0
	Maricopa	1 (0.5)	0
Kansas	Total	2 (1.0)	2 (2.2)
	Barton	1 (0.5)	0
	Hamilton	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)	0
	Yellowstone	1 (0.5)	0
Nebraska	Total	3 (1.5)	3 (3.3)
	Garden	1 (0.5)	0
	Keith	1 (0.5)	0
	Lincoln	1 (0.5)	1 (1.1)
	Morrill	0	1 (1.1)
	Scotts Bluff	0	1 (1.1)
New Mexico	Total	25 (12.1)	10 (11.1)
	Bernalillo	1 (0.5)	0
	Chaves	2	0
	Dona Ana	1 (0.5)	0
	Mora	0	1 (1.1)
	Rio Arriba	1 (0.5)	0
	Roosevelt	1 (0.5)	0
	San Juan	1 (0.5)	2 (2.2)
	Sandoval	0	1 (1.1)
	Santa Fe	1 (0.5)	0
	Sierra	2 (1.0)	1 (1.1)
	Socorro	7 (3.4)	4
	Taos	1 (0.5)	0
	Valencia	7 (3.4)	1 (1.1)
Nevada	Total	0	1 (1.1)
	Lyon	0	1 (1.1)
Oklahoma	Total	2 (1.0)	5 (5.6)
	Caddo	0	1 (1.1)
	Carnegie	0	1 (1.1)
	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	2 (1.0)	3 (3.3)
	Davis	0	1 (1.1)
	Duchesne	1 (0.5)	0
	Salt Lake	0	1 (1.1)
	Uintah	1 (0.5)	0
	Weber	0	1 (1.1)
Wyoming	Total	1 (0.5)	4 (2.1)
	Albany	1 (0.5)	2 (2.2)
	Lincoln	0	1 (1.1)
	Sublette	0	1 (1.1)
Canada	Total	0	1 (1.1)
	Alberta	0	1 (1.1)
Total recoveries		206	90

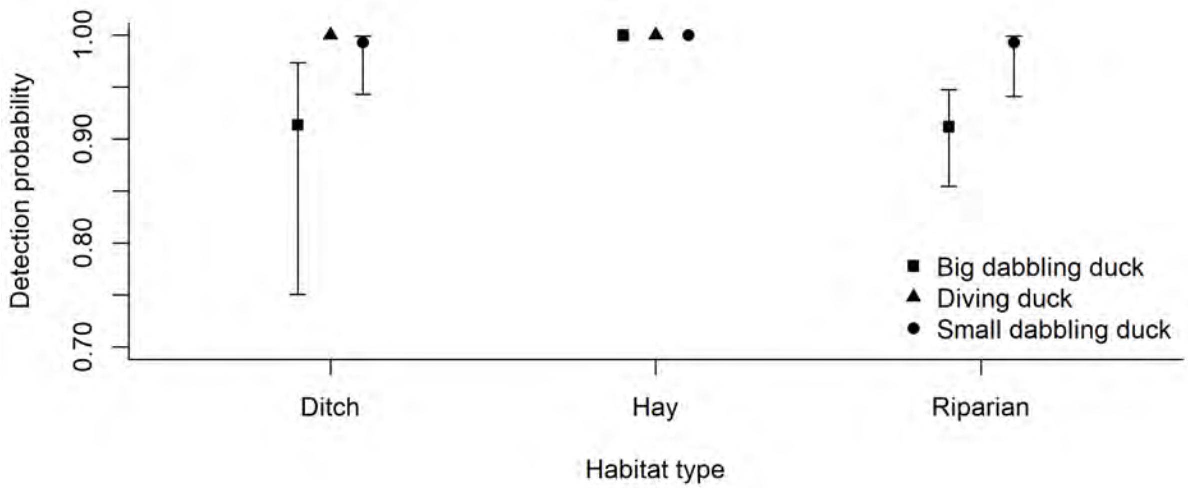

Figure 1. Estimated duck detection probability based on independent double observer surveys at ditches, riparian areas, and hay fields for big dabbling ducks, small dabbling ducks, and diving ducks in North Park, Colorado during 2021.

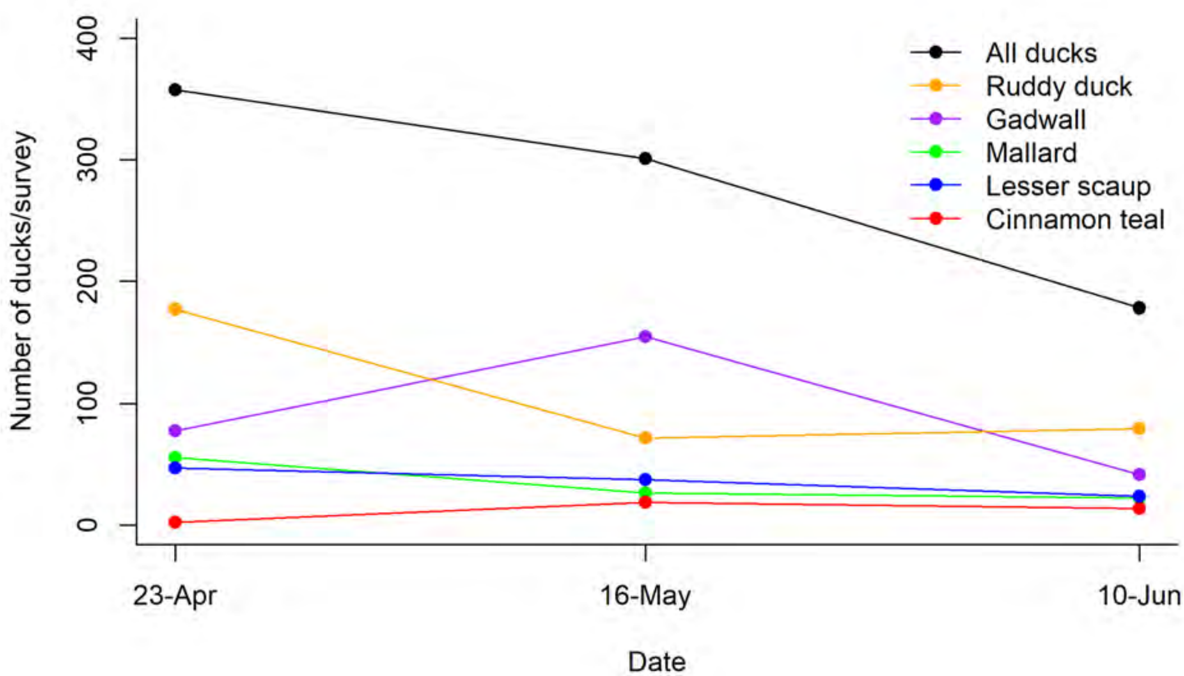

Figure 2. Number of ducks detected per survey for three surveys throughout the 2021 duck breeding season at five large reservoirs in North Park, Colorado.

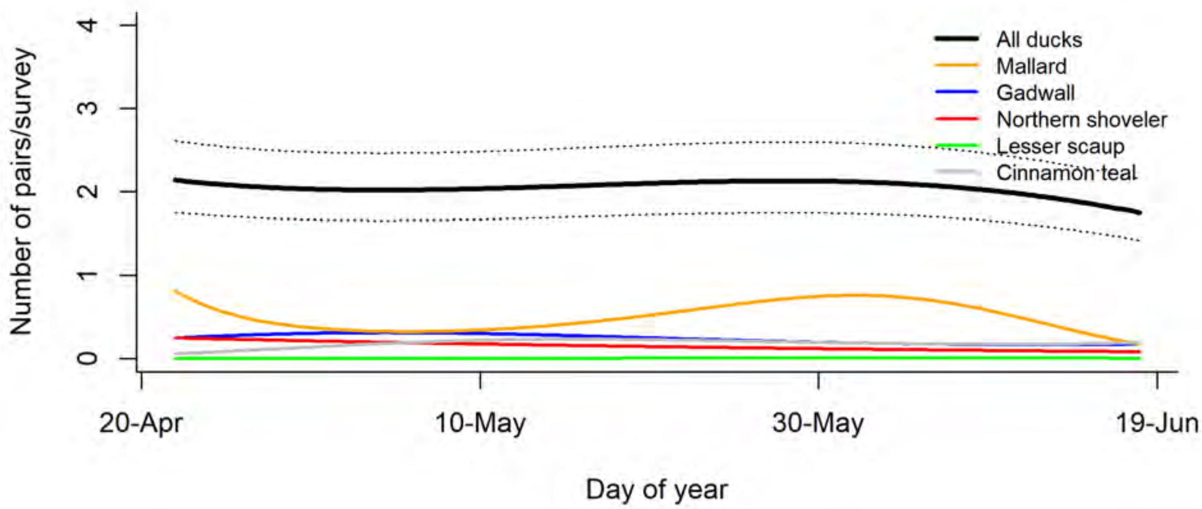

Figure 3. Number of indicated breeding pairs per survey for all ducks and select species throughout the 2021 duck breeding season in North Park, Colorado. Dotted lines indicate ± 1 SE.

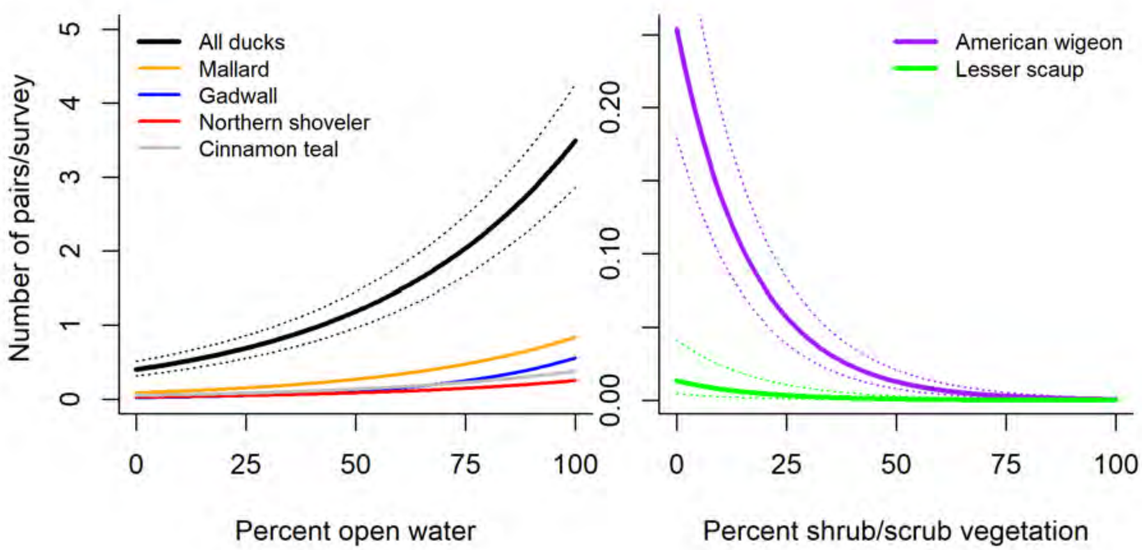

Figure 4. Effects of open water and shrub/scrub vegetation on duck indicated breeding pair abundance in North Park, Colorado during 2021. Dotted lines indicate ± 1 SE.

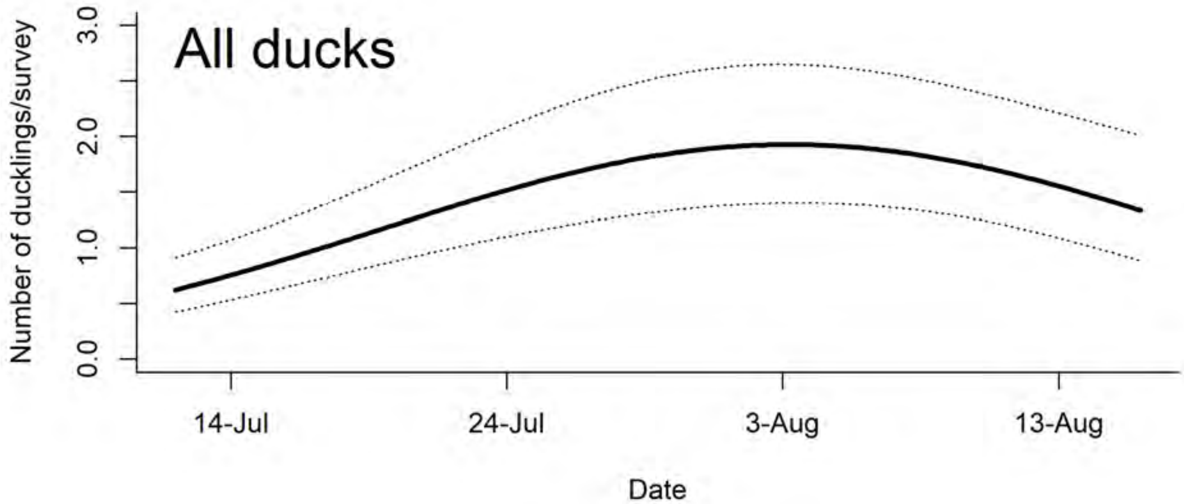

Figure 5. Model-estimated time-trend of duck brood abundance for all ducks combined throughout the 2021 breeding season in North Park, Colorado. Dotted lines indicate ± 1 SE.

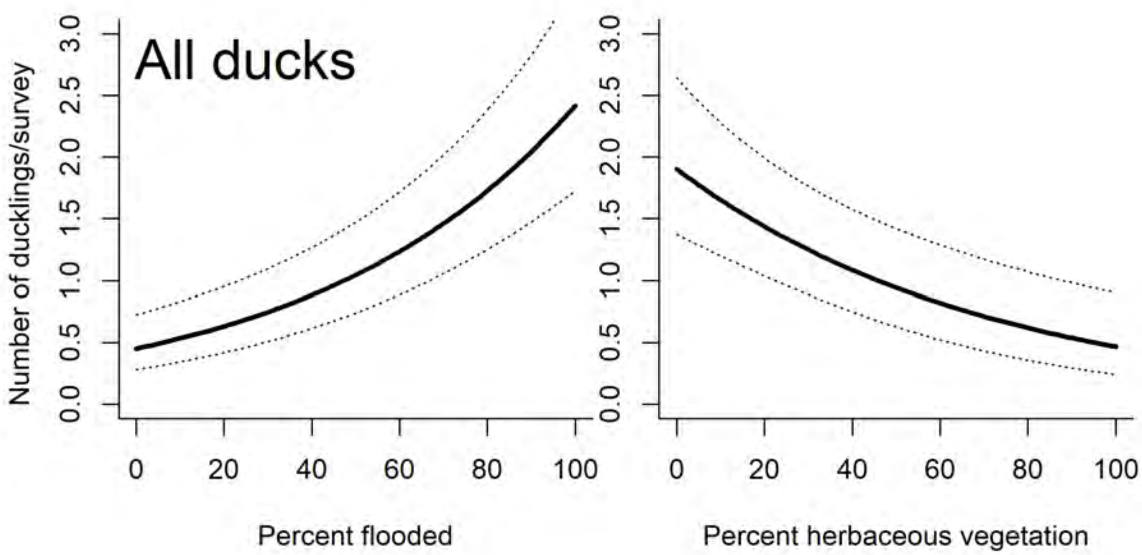

Figure 6. Model-estimated effects of the percent of a site that was flooded and covered with herbaceous vegetation on duckling abundance for all species combined in North Park, Colorado during 2021. Dotted lines indicate ± 1 SE.

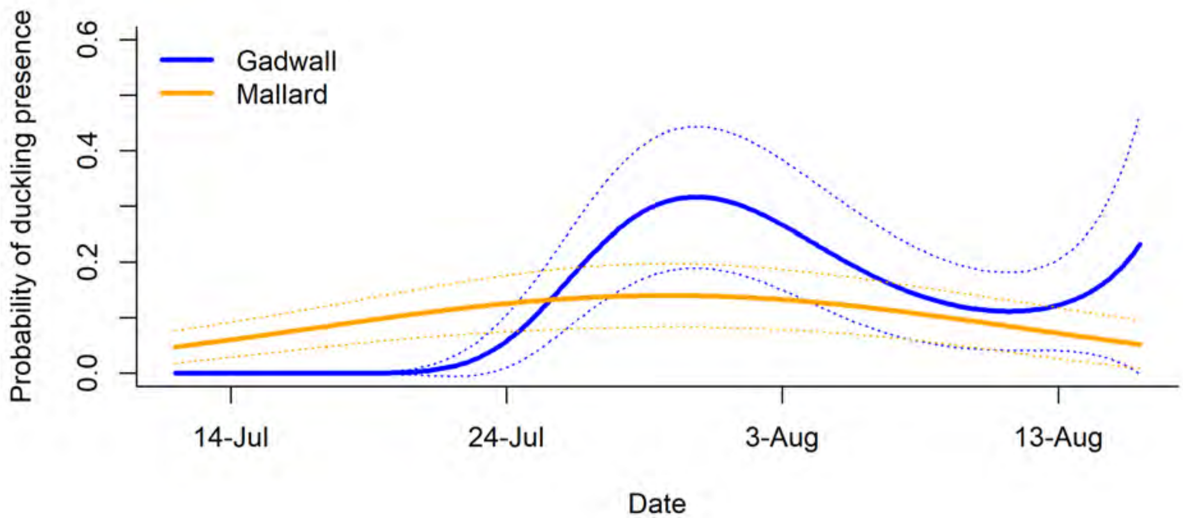

Figure 7. Model-estimated probability of duckling presence by date for gadwall and mallard across the 2021 breeding season in North Park, Colorado. Dotted lines indicate ± 1 SE.

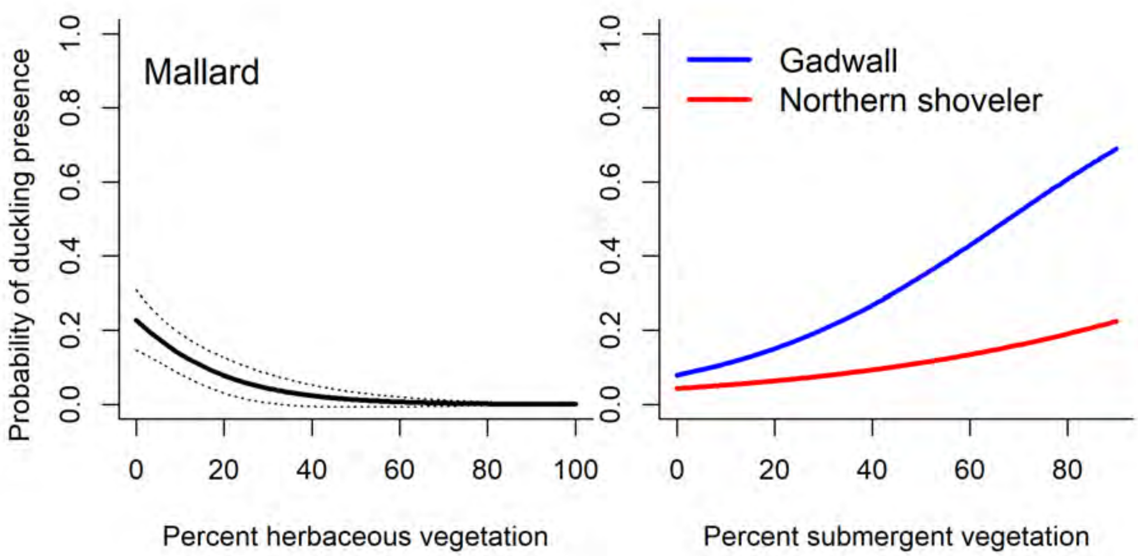

Figure 8. Model-estimated effects of herbaceous and submergent vegetation on mallard, gadwall, and northern shoveler duckling presence at sites in North Park, Colorado during 2021. Dotted lines indicate ± 1 SE.

Publications, presentations, workshops and committee involvement by Avian Research staff
January – December 2021

PUBLICATIONS

Aagaard, K., R. Y. Conrey, and J. H. Gammonley. 2021. Spatial analysis of the nesting distribution of four priority raptor species in Colorado. Journal of Raptor Research 55:510-523.

Apa, A. D., **K. Aagaard**, M. B. Rice, E. Phillips, D. Neubaum, N. Seward, J. R. Stiver, and S. Wait. 2021. Species distribution models for a threatened species: the Gunnison sage-grouse. Wildlife Research 48:609-624.

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

Behney, A. C. 2021. High-intensity short-duration grazing during spring is not an effective habitat management tool for Northern Bobwhite in Colorado. Ornithological Applications 123:1-17.

Donnelly, J. P., S. L. King, J. Knetter, **J. H. Gammonley**, V. J. Dreitz, B. A. Grisham, M. C. Nowak, and D. P. Collins. 2021. Migratory efficiency sustains connectivity across agroecological networks supporting sandhill crane migration. Ecosphere 12(6):e03543. 10.1002/ecs2.3543

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

Garbowski, M., **D. B. Johnston**, and C. S. Brown. 2021. Cultivars of popular restoration grass developed for drought do not have higher drought resistance and do not differ in drought-related traits from other accessions. Restoration Ecology 29 e13415

Kocina, M, and **K. Aagaard**. 2021. A review of home range sizes of four raptor species of regional conservation concern. Western North American Naturalist 81: https://scholarsarchive.byu.edu/wnan/vol81/iss1/8

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.

Walker, B. L., and M. A. Schroeder. 2021. Atypical primary molts and plumages in greater sage-grouse: implications for age classification. Wildlife Biology: wlb.00855

PRESENTATIONS, WORKSHOPS, AND COMMITTEES

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

Apa, A. D. CPW science support, CPW Terrestrial greater sage-grouse transplant project.

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

Behney, A. C. Faculty co-advisor for M.S. degree candidate Joseph Wolske, University of Nebraska-Lincoln.

Behney, A. C. Pacific Flyway Study Committee Work Meeting. January 2021.

Behney, A. C. Pacific Flyway Study Committee Business Meeting. February 2021.

Behney, A. C. Pacific Flyway Study Committee Meeting. August 2021.

Behney, A. C. 2021. Using duck energetics to guide wetland restoration. University of Nebraska-LincolnSchool of Natural Resources Seminar.

Behney, A. C. 2021. Grazing as a tool to manage northern bobwhite habitat at the northwest edge of their range. Annual meeting of The Wildlife Society.

Wolske, J. M., L. A. Powell, and **A. C. Behney**. 2021. Nonbreeding season survival and movement of northern bobwhites in northeast Colorado. Annual meeting of The Wildlife Society.

Behney, A. C. 2021. Northern bobwhite breeding movements, survival, and the cost of reproduction. Annual meeting of the American Ornithological Society.

Behney, A. C. 2021. High-intensity short-duration grazing during spring is not an effective habitat management tool for northern bobwhites in Colorado. Annual meeting of the Colorado Chapter of The Wildlife Society.

Conrey, R. Y. Faculty Committee member for M.S. candidate Sarah Albright, 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. CPW Front Range Bald Eagle Study. Presented as part of Bird Conservancy of the Rockies Bald Eagle Watch, Annual Volunteer Training. Statewide (virtual), 23 January 2021.

Conrey, R. Y., **K. Aagaard**, M. Smith, B. D. Snyder, J**. H. Gammonley**, and M. M. Middleton. Bald eagles in our backyard: population trends, habitat use, and human impacts on Colorado's Front Range eagles. Denver Audubon, Lois Webster Fund Annual Program. Denver, CO (virtual), 3 May 2021.

Conrey, R. Y., M. Smith, B. D. Snyder, **J. H. Gammonley**, and M. M. Middleton. Bald eagles in our backyard: population trends, habitat use, and human impacts on Colorado's Front Range eagles. CPW Wildlife Habitat Roundtable. Statewide (virtual), 26 August 2021.

Conrey, R. Y., M. Smith, B. D. Snyder, **J. H. Gammonley**, and L. Rossi. Bald eagles in our backyard: population trends, habitat use, and human impacts on Colorado's Front Range eagles. Colorado State Parks, Annual Meeting of Raptor Monitoring Volunteer Program. Denver, CO (in person/hybrid), 7 November 2021.

Conrey, R. Y., M. Smith, B. D. Snyder, **J. H. Gammonley**, and M. M. Middleton. Bald eagles in our backyard: population trends, habitat use, and human impacts on Colorado's Front Range eagles. Meeting of Fort Collins Audubon. Fort Collins, CO (in person/hybrid), 11 November 2021.

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

Gammonley, J. H. Central Flyway Waterfowl, Webless Migratory Game Bird, and Central Management Unit Dove Technical Committee meetings (virtual), February 9-11, 2021.

Gammonley, J. H. Central Flyway Waterfowl Technical Committee and Council meetings, Angel Fire, NM, August 22-26, 2021.

Johnston, D. B. Piceance Basin Restoration for Wildlife, Uinta Sage-grouse Working Group (Virtual), February 9, 2021.

Johnston, D. B. How you chop matters: plant and mule deer responses to tree removal by three methods, Society for Range Management Annual Meeting (Virtual), February 17, 2021.

Johnston, D. B. Piceance Basin Restoration for Wildlife, WAFWA Sage and Columbian Sharp-tail Grouse Workshop, (Virtual), June 22, 2021.

Johnston, D. B. Bitterbrush SWA Habitat Research Update, CPW Terrestrial Section Annual Meeting, Winter Park, August 25, 2021.

Johnston, D. B., Lovoi, D., and S. Romatzke. Horsetheif SWA and pothole seeder field tour, Colorado Chapter of the Society for Range Management Annual Meeting, Fruita, CO, October 6, 2021.

Johnston, D. B. 125 Stories Committee, 125th Anniversary of CPW. Meetings held June- November. Contributed 5 stories.

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

Rossi, L., **R. Y. Conrey**, and R. Sacco. SCON Coordination Meeting: Raptor Monitoring. CPW Species Conservation Annual Coordination Meeting. Statewide (virtual), 22 February 2021.

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