AVIAN PROGRAM
2016
WILDLIFE RESEARCH SUMMARIES

OCTOBER 2015 – SEPTEMBER 2016

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 summaries of wildlife research projects conducted by the Avian Research Section of Colorado Parks and Wildlife (CPW) from October 2015 through September 2016. These research projects are of varying length (2–10 years) and 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 on the CPW website at http://cpw.state.co.us/learn/Pages/ResearchBirds.aspx for projects focused on avian ecology and management, at http://cpw.state.co.us/learn/Pages/ResearchHabitat.aspx for habitat research projects, or from the project principal investigators listed at the beginning of each summary.

Current research projects in the Section address various aspects of the ecology and management of wildlife populations and the habitats that support them, as well as evaluation and development of population monitoring methods. This report includes summaries of an on-going study designed to understand how Columbian sharp-tailed grouse respond to habitat treatments, new seasonal resource selection models for Gunnison sage-grouse in the Gunnison Basin, several continuing studies on greater sage-grouse, a pilot study to evaluate response of bobwhite quail to grazing management, an on-going study on measuring food production and bird use of different types of wetlands, a pilot study to measure grassland bird response to mid-contract management practices in the Conservation Reserve Program, a study to understand how avian communities associated with prairie dog colonies respond to plague management, a new study aimed at improving a CPW statewide raptor nest database and using the database to model population demographics and distribution, and several continuing experiments to evaluate techniques for restoring native plant communities for wildlife. An area of emphasis for current Avian Research projects is to measure avian responses to habitat treatments, in order to inform and improve habitat conservation programs. CPW Avian Research projects are directly addressing information needs for over over a dozen bird species of greatest conservation need (Tier 1 and 2) identified in the Colorado State Wildlife Action Plan.

Also included in this report is a listing of publications, presentations, workshops and participation on various committees and working groups by Avian Research staff from October 2015 through September 2016. Communicating research results and using their subject matter expertise to inform management and policy issues is a priority for CPW scientists.

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 the CPW Commission, statewide CPW personnel, Colorado State University, Bureau of Land Management, City of Fort Collins, EnCana Corp, ExxonMobil/XTO Energy, Marathon Oil, WPX Energy, Bird Conservancy of the Rockies, Playa Lakes Joint Venture, and the private landowners who have provided access for research projects.

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AVIAN RESEARCH STAFF

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Anthony D. Apa, Wildlife Researcher
Adam C. Behney, Wildlife Researcher
Reesa Yale Conrey, Wildlife Researcher
Danielle B. Johnston, Habitat Researcher
Mindy B. Rice, Spatial Ecologist
Brett L. Walker, Wildlife Researcher
Sandra Billings, Program Assistant

Colorado Division of Parks and Wildlife
October 2015 – September 2016

TABLE OF CONTENTS
AVIAN WILDLIFE RESEARCH REPORTS

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Columbian sharp-tailed grouse demographic response to habitat treatments

Period Covered: October 1, 2015 – September 30, 2016

Author: A. D. Apa, tony.apa@state.co.us, and R. E. Harris

Personnel: Jim Haskins and Bill deVergie, Area Wildlife Managers; Brad Petch, Senior Terrestrial Biologist; Trevor Balzer Sagebrush Habitat Coordinator; Kathy Griffin, Grouse Coordinator; Brian Holmes, and Jeff Yost, Terrestrial Biologists, Michael Warren, Energy Liaison; Becky Jones, Biologist-RMBO/NRCS/CPW

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

The Columbian sharp-tailed grouse (CSTG, *Tympanuchus phasianellus columbianus*) is one of six subspecies of sharp-tailed grouse in North America. Historically its distribution ranged from the northwest in British Columbia in the northwest to Colorado in the southwest. Isolated populations exist (or formally existed) in Washington, Idaho, Wyoming, Colorado, Montana (extirpated), Utah, Nevada (reintroduced) and Oregon (reintroduced), with CSTG currently occupying 10% of its former range. Habitat loss and degradation from anthropogenic activities are cited as the primary reasons for the decline in CSTG, with the conversion of native shrub plant communities to agricultural production being the most prevalent habitat impact. The United States Fish and Wildlife Service (USFWS) has been petitioned twice to list the CSTG for protections under the Endangered Species Act and concluded that the CSTG was not warranted for listing following both petitions. The ESA listing decision was, in part, not warranted because of CSTG range expansion facilitated by Conservation Reserve Program (CRP) in 1985 and subsequent reauthorizations. In Colorado a preponderance of plantings were seeded to intermediate wheatgrass (*Agropyron intermedium*), smooth brome (*Bromus inermis*), and occasionally included alfalfa (*Meticago sativa*). These mixes resulted in mature herbaceous stands of grass that provide marginal benefits to CSTG. In contrast, reclaimed mineland sites in northwest Colorado have been shown to be beneficial to CSTG and provide high quality spring-summer-fall habitat to CSTG when compared to CRP or native rangeland. Reclaimed mineland habitat provides sufficient quality to support favorable demographic rates for females when compared to CRP. Thus, based on past observational research, and that some existing CRP habitats are not occupied by CSTG, there is building evidence that habitat improvements could improve existing or expired CRP for CSTG. Ecological theory supporting habitat improvements in habitat quality through wildlife habitat enhancement and management has been a long established tenet of wildlife management, but the wildlife-habitat relationship is complex. CSTG provide an opportunity to evaluate demographic rates in relation to changes in habitat quality. CSTG are a highly productive, generalist species that have centralized breeding locations and have limited movements during the breeding season with relatively small home ranges.

Our overall research objective is to measure the demographic response of CSTG to improvements in habitat quality by increasing floristic horizontal and vertical structure and species richness in monotypic stands of non-native grasses. The goal of our research is to conduct treatments (habitat improvements) in two lek complexes (T1 and T2). A Before-After Control-Impact (BACI) design with paired controls is employed. Our study area is located in northwestern Colorado, in southwestern Routt and southeast Moffat counties. Our study area is predominantly (70%) privately owned by individuals or mining companies and is interspersed with Bureau of Land Management and State Land Board properties

(Fig. 1). Working cooperatively with the Northwest Region Terrestrial Habitat Coordinator (NWRTHC), we identified and finalized treatment areas working cooperatively with private landowners, the Natural Resources Conservation Service (NRCS), and the Farm Services Agency (FSA). Although we initially outlined treatments to be conducted in one year, FSA vegetation manipulation restrictions for mid-contract maintenance of the properties enrolled in CRP will prevent such an approach. Maintenance requirements differ for enrolled fields that are at a 65 ha threshold. For enrolled fields < 65 ha, we can only treat 50% of the field in year 1 and the remainder in year 2. For fields > 65 ha, we can only treat 33% of a field in year 1, 33% in year 2, and 33% must remain untreated. Thus, in Treatment Area 1 (Fig. 1), we will treat 140 ha in 2016 and 140 ha in 2017. In Treatment Area 2 (Fig. 1), we will treat 202 ha in 2016 and 202 ha in 2017. Although there are numerous vegetation manipulation approaches to reduce non-native grass cover and increase plant species richness, we identified the following protocol to implement habitat treatments. First, during late-summer (after nest hatch), we will initiate treatments with mechanical tillage equipment (off-set disc) to reduce viable non-native perennial grass cover and assist with seed-bed preparation. Second, approximately 2-4 weeks after mechanical tillage, we will treat sites with a chemical aerial application of Plateau® and glyphosate to reduce non-native perennial grass and limit annual and perennial grass seed germination. We may need to treat with a second application of glyphosate. Lastly, in late-fall, we will drill a seed mixture of native and non-native grasses, forbs, and shrubs (Table 1) with a no-till drill.

We captured female CSTG in the spring using walk-in funnel traps in the morning on dancing grounds. Trapping occurred on dancing grounds in three study sites in Moffat county (T1, T2, C3) and leks ranged in size from 10–45 males. We also trapped at dancing grounds at one study site in Routt county (C2) that ranged in size from 6–24 males. We fitted females with 15 g elastic necklace-mounted radio transmitter equipped with a 12-hour mortality circuit having an 8.5-month nominal battery life. We monitored movements every 1-3 days with hand-held Yagi antennas attached to a receiver. When monitoring revealed a successful hatch, we attempted to capture all chicks in the brood within 24 hours. We randomly selected 4 chicks per brood and fit a 0.55 g backpack style transmitter using sutures along the dorsal midline between the wings (Fig. 2). We captured juveniles when they reached 20-23 days of age at approximately two hours before sunrise while juveniles are brooding with the female. We removed chick transmitters and replaced them with a 2.4 g back-pack style juvenile transmitter (Fig. 3). We sampled vegetation at all nest and a sample of brood sites.

In 2016 we captured 105 female CSTG (78 adults: 27 yearlings) during 9 April–3 May (Fig. 4). We trapped on 8 dancing grounds in 4 study areas (Hayden; Big Elk 1: West Axial; Moffat County Road 53 and Temple; Iles Dome; Iles Dome 2, 3, and 4: Trapper; Trapper Mine 1, and 7). Adult and yearling female mass ($\bar{x}$ ± SE) was 671.3 ± 5.2 g (*n* = 78) and 620.8 ± 8.9 g (*n* = 27), respectively. Female mass appears to vary by study area (Fig. 5), by age, and spatially (Fig. 6). From April through September 2016, we documented 31 and 6 adult and yearling female mortalities resulting in a 6-month adult female survival rate of 0.52 ± 0.05 (*n* = 100; 95% CI 0.43-0.61) and a yearling survival rate of 0.49 ± 0.01 (*n* = 27; 95% CI 0.33-0.65) (Fig. 7). Female survival appeared similar between 2015 (0.62 ± 0.01 (*n* = 107; 95% CI 0.52-0.72) and 2016 (Fig. 8). We documented an overall nest initiation rate of 95% (*n* = 74/78) and 96% (*n* = 21/22) for adult and yearling females, respectively. We documented an overall 54.4% (*n* = 56/103) and 59% (n = 56/95) apparent nest and female success, respectively. Seven females renested once yielding 42.9% (n = 3/7) nest success and one female successfully nested on a second renest attempt. Female movement in 2016 from the lek of capture to nest averaged 2.42 ± 0.48 km (*n* = 94; range 0.17-35.0 km) (Fig. 9). Seventy percent (*n* = 66/84) of the nests were located within 2 km of the lek of capture (Fig. 9). We captured 391 chicks from 56 broods with an overall mean mass of 15.5 ± 0.1 g (range 11.8-3.1) and the average age of broods at chick capture was 2.4 ± 0.1 days (range 2-6 days). A majority of chicks (96%; *n* = 376/391) were captured 1-3 days post-hatch and included 93% (*n* = 52/56) of the broods. Thus, the mean mass for chicks from 1-3 days-of-age was 15.2 ± 0.1 g (range 11.8 - 20.0). There was a clear shift in chick mass with chicks being heavier in 2016 compared to 2015, and no chicks smaller than 12 g. We radio-marked 211 chicks resulting in an average number of chicks marked/brood of 3.8 chicks. We also PIT tagged 172 chicks. The average brood size at marking was 7.7 chicks (range

3-14). We recaptured and/or marked 119 juveniles that averaged 27 days post-hatch (range 18–53 days post-hatch). Juvenile mean mass was 112.0 ± 5.0 g (range 36.0-404.0 g). Nineteen of the juveniles were not previously marked.

At the writing of this report, data entry and proofing is continuing. Field data collection will continue in 2017.

Table 1. Plant scientific and common name and cultivar seeded in treatments in northwestern Colorado, 2016-2017.

Scientific Name	Common Name	Cultivar
Graminodes		
Dactylis glomerata	Orchard grass	Piaute
Leymus cinereus	Basin wildrye	Magnar/Trailhead
Poa secunda	Sandberg bluegrass	Sherman
Koeleria macrantha	Prairie Junegrass	Barkoel
Elymus lanceolatus ssp. lanceolatus	Thickspike wheatgrass	Critana
Achnatherum hymenoides	Indian ricegrass	
Elymus elymodies	Bottlebrush squirreltail	
Sporobolus crytandrus	Sand dropseed	
Forbs		
Sanguisorba minor	Small burnet	Delar
Onobrychis vicifolia	sainfoin	Eski/Melrose/Remont
Medicago sativa	Alfalfa	Falcata
Medicago sativa	Alfalfa	Ladak
Achillea millefolium	Western yarrow	
Linum lewisii	Lewis flax	Appar
Helianthus annuus	Common sunflower	
Cleome serrulata	Rocky Mountain beeplant	
Spaeralcea coccinea	Scarlet globemallow	
Shrubs		
Artemisia tridentata ssp. wyomingensis	Wyoming big sagebrush	
Artemisia tridentata ssp. tridentata	Basin big sagebrush	
Chrysothamus nauseosus	Rubber rabbitbrush	

Figure 1. Study area location of treatment (T) and control (C) sites and the number of males on 2 or more dancing grounds in Moffat and Routt counties, Colorado.

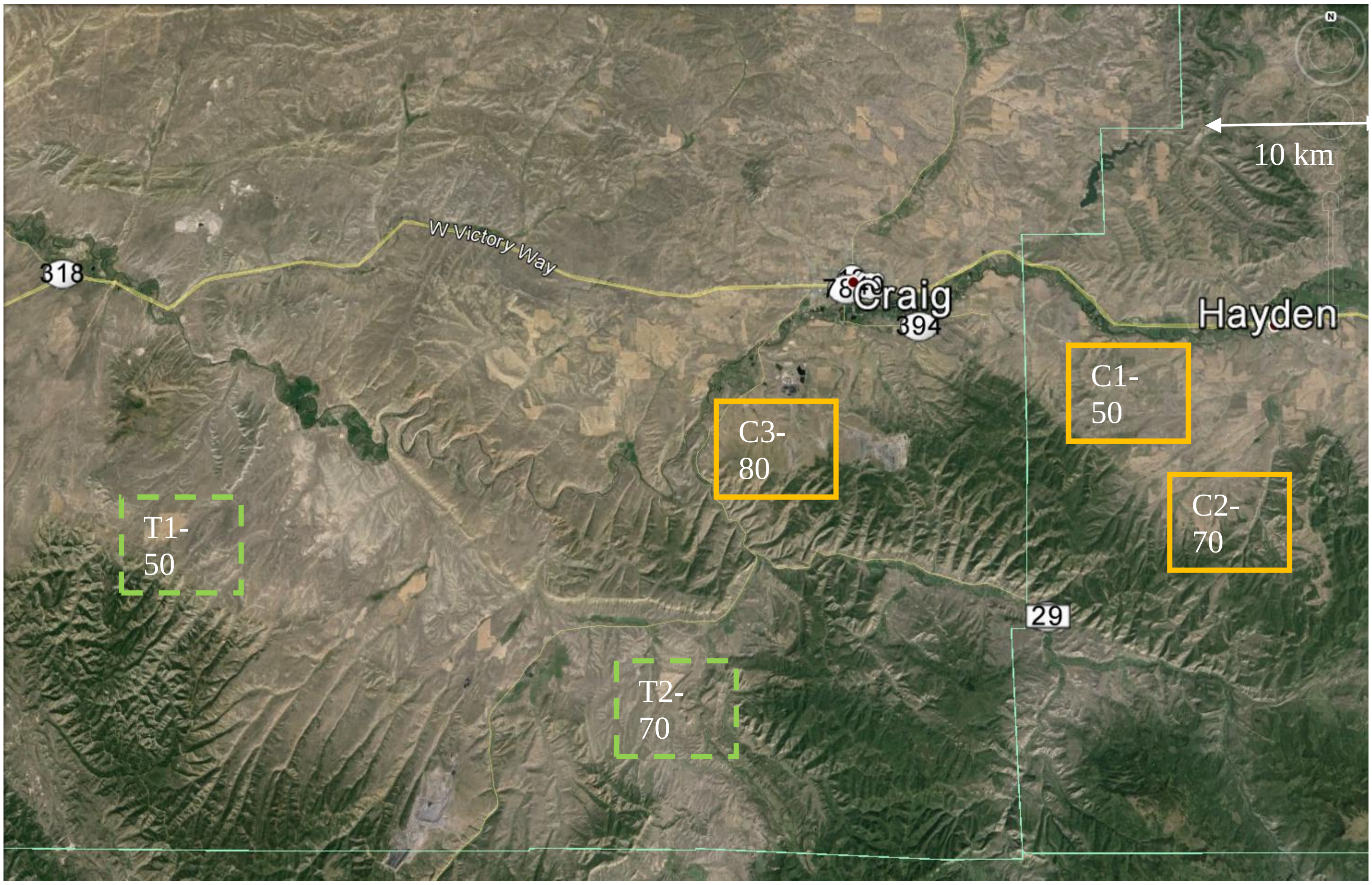


Figure 2. One day-old Columbian sharp-tailed grouse chick after being fitted with a 0.65 g VHF micro-transmitter.

Figure 3. Twenty day-old Columbian sharp-tailed grouse juvenile fitted with a 3.9 g VHF micro-transmitter that replaces the chick transmitter seen in Figure 2.

Figure 4. Number of female Columbian sharp-tailed grouse captured by date in northwestern Colorado, 2014-2016.

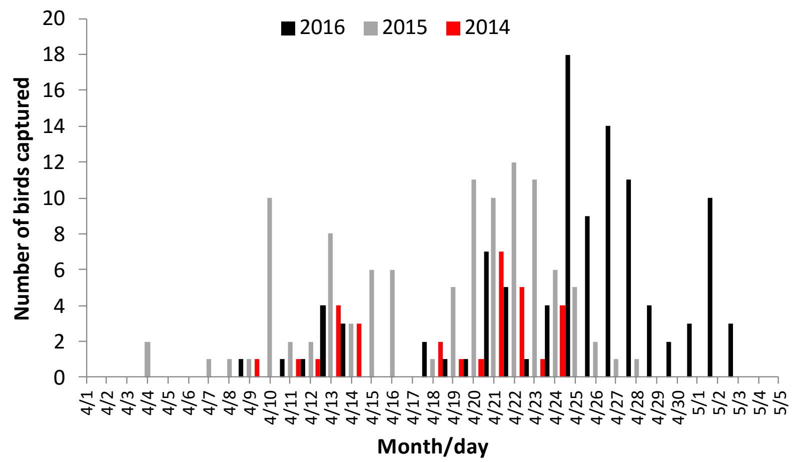


Figure 5. Mean mass (± SE) of female Columbian sharp-tailed grouse at 4 study areas in northwestern Colorado, 2016.

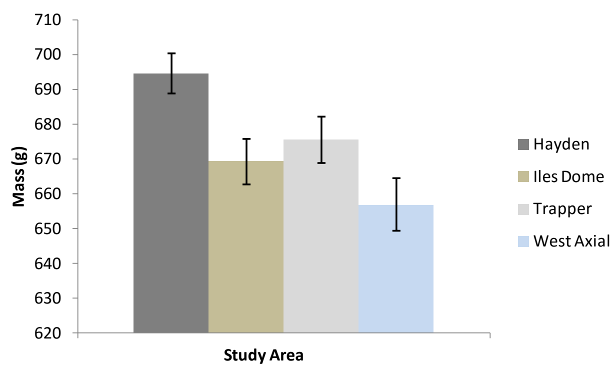


Figure 6. Mean mass (± SE) of female adult (A) and yearling (Y) Columbian sharp-tailed grouse at 4 study areas (HAY = Hayden; ID = Iles Dome; TRAP = Trapper; WA = West Axial) in northwestern Colorado, 2016.

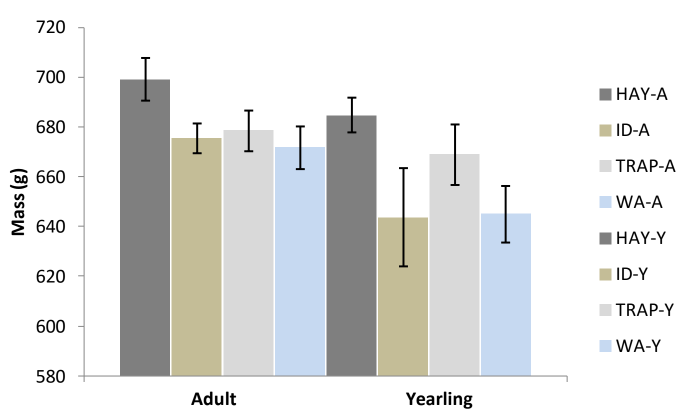


Figure 7. Kaplan-Meier product-limit monthly survival (± 95% CI) with staggered entry of adult (*n* = 100) and yearling (*n* = 27) female Columbian sharp-tailed grouse from April - September in northwest Colorado, 2016.

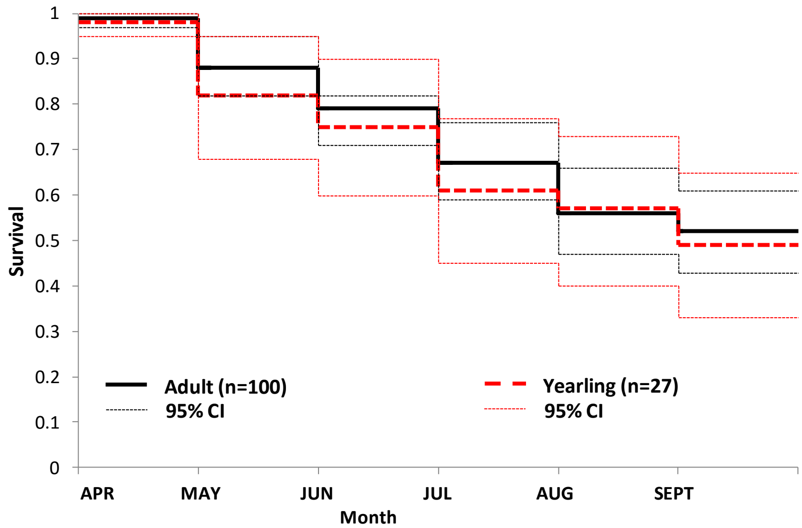


Figure 8. Kaplan-Meier product limit monthly survival with staggered entry of female Columbian sharp-tailed grouse from April – September in 2015 and 2016 pooled over 4 study areas, adults, and yearlings in northwestern Colorado, 2015-2016.

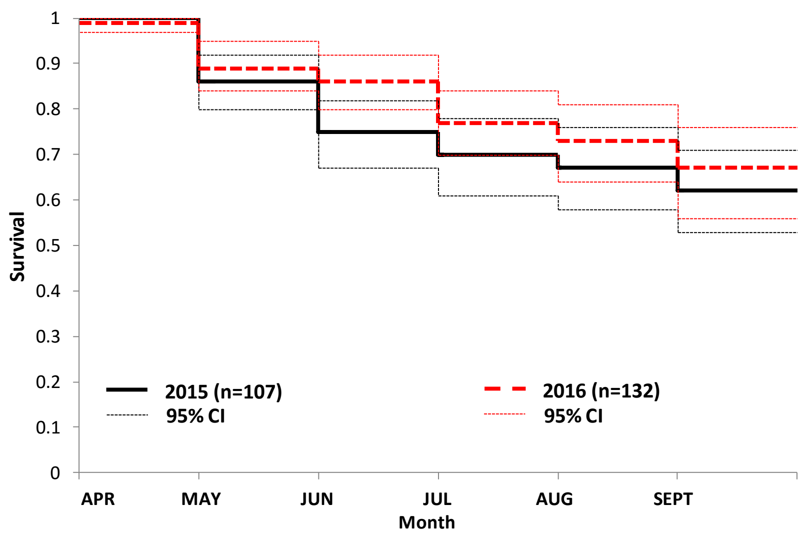
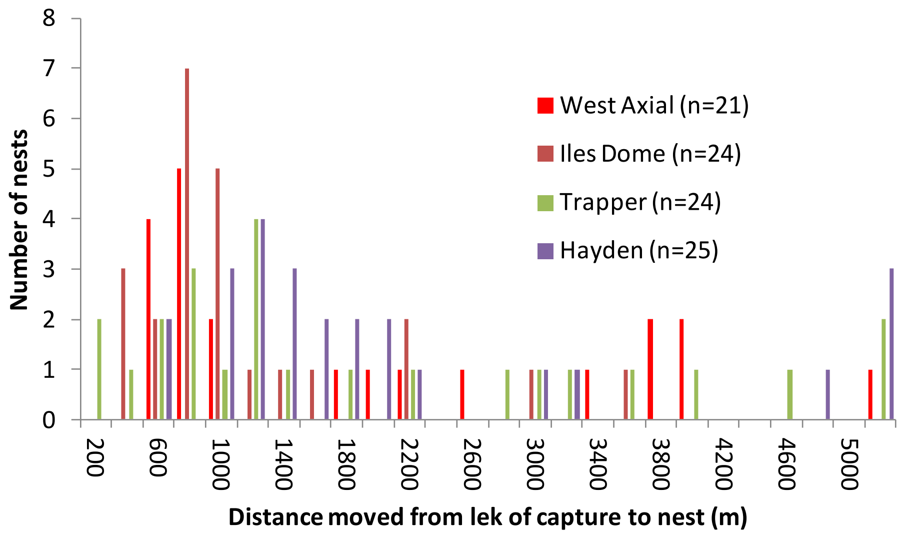


Figure 9. Frequency distribution of the number of Columbian sharp-tailed grouse nests by distance moved from the lek of capture by study area in northwestern Colorado, 2016.



Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Development of landscape scale resource selection models for the management of Gunnison sage-grouse in the Gunnison Basin population

Period Covered: October 1, 2015 – September 30, 2016

Principal Investigator: Mindy B. Rice and Anthony D. Apa, tony.apa@state.co.us

Project Collaborators: Michael Phillips, J Wenum

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Gunnison sage-grouse (*Centrocercus minimus*, GUSG) have declined substantially from their historical range and were listed as threatened by the U. S. Fish and Wildlife Service (USFWS) in November of 2014. GUSG are distributed into seven isolated populations in Colorado and one population, Gunnison Basin (GB) comprises 85-09% of all GUSG in the state. Concern over the small population size and isolated and fragmented nature of many of the smaller populations has led to interest in the habitat use of GUSG. Much of the information that has been used on GUSG habitat selection has come from studies pertaining to Greater Sage-grouse (*Centrocercus urophasianus*). Currently the USFWS have designated most of the GB as critical habitat, but there may be some variability to the quality and use of that critical habitat which could refine those maps for better management of the species. To successfully manage and understand the GUSG, we must identify the habitat that is most important to the birds using data driven models. Colorado Parks and Wildlife has collected radio-telemetry data from almost 200 birds from 2004-2010 which could be used to model habitat selection with a robust dataset specific to the GUSG in the GB.

We used radio-telemetry data from individual GUSG caught during the spring and fall periods 2004-2010. Following release, radiotelemetry locations of radio-marked individuals were estimated on the ground using hand-held Yagi antennas once every 1-3 days (from date of capture through September) to monitor status (dead or alive) and movement patterns. We were able to estimate resource selection models for the breeding (April to July 15) and summer seasons (July 16 to September). We used 3,936 locations from 188 GUSG for the breeding season model and 3,721 locations from 171 GUSG for the summer model. We buffered each use location by the average daily movements of 180.5 m in the breeding period and 223 m in the summer period. We generated 9,000 "available" locations across the entire GB and used the same seasonal buffers. Vegetation, topographical, and development variables were extracted for each buffer to be used in the analysis. Development variables included roads, subdivisions, trails, easements, and address points collected by Gunnison County. We used a generalized mixed linear model with a logistic link and a random effect for individual birds to model habitat use. We used all linear combinations of variables and model averaged over the 95% model set. We utilized an average prediction surface in ArcMap 10.1.

The breeding model indicated that GUSG were 2.24 times as likely to be located in sagebrush and 1.5 times as likely to be located in high densities of trails (Table 1). Being closer to subdivisions and easements and further from wetlands were also important predictors. Finally, GUSG are 1.49 more likely to not be located in forest. There were also smaller effects including being located in grassland, slightly higher elevations, in areas with higher water density, in areas with high road density and further from class 1 and 2 roads and further from address points (Table 1). The resulting prediction surface indicated that large swaths of sagebrush had a higher relative probability of GUSG presence and many of the drainages were avoided (Figure 1).

The summer model indicated that GUSG were 3.64 times as likely to be located in sagebrush, 2.41 times as likely to be located in irrigated agriculture, 1.41 times as likely to be in grassland, and 1.8 times as likely to be in alpine (Table 2). Being closer to subdivisions and easements and further from house address points were also important predictors. Finally, GUSG are 1.49 more likely to NOT be located in forest. GUSG are more likely to be in areas with high trail densities, low road densities, and high water densities. GUSG are also more likely to be closer to roads and slightly further from wetlands. They are also going to be located in higher elevations (Table 2). The resulting prediction surface indicated that GUSG used a more diverse set of habitats and tended to move into higher areas within the GB (Fig. 2).

Overall GUSG are dependent on large swaths of sagebrush although they tend to have more diverse selection during the summer when they utilize numerous habitats including grassland, irrigated agriculture, and alpine. They tend to be close to subdivisions and easements and in areas with high levels of trail density in both seasons. Overall, not all the human related variables were negatively impacting GUSG although it was dependent on the season. These models can be used to further refine the estimated critical habitat currently being used by USFWS as they reduce the amount of critical habitat in both seasons. In addition, these models provide information regarding two seasons in the GUSG life cycle and can be used to manage the population on the ground.

A manuscript summarizing this project has been submitted for publication in a peer-reviewed journal. Final, peer-reviewed distribution models will be provided to USFWS, CPW managers, and other collaborators for use in recovery planning for GUSG.

Table 1. Model averaged model coefficients, confidence intervals, and odds ratios for Gunnison sage-grouse during the breeding season in the Gunnison Basin of Colorado.

Variable	**β**	**SE**	**LCI**	**UCI**	**Odds ratio**
Intercept	- 1.671				
Sagebrush	0.805	0.065	0.712	0.899	2.24
Grassland	0.184	0.037	0.131	0.238	1.2
forest	- 0.396	0.081	- 0.513	- 0.279	0.67
elevation	0.095	0.039	0.039	0.151	1.10
distance to wetlands	0.517	0.029	0.479	0.554	1.68
water density	0.230	0.029	0.189	0.271	1.26
Road density	0.139	0.032	0.093	0.185	1.15
Distance to roads	0.103	0.032	0.056	0.149	1.11
Trail density	0.463	0.029	0.421	0.504	1.59
Distance to address points	0.309	0.034	0.260	0.358	1.36
Distance to subdivisions	- 0.536	0.049	- 0.607	- 0.495	0.58
Distance to easements	- 0.458	0.039	- 0.514	- 0.402	0.64

Table 2. Model averaged model coefficients, confidence intervals, and odds ratios for Gunnison sage-grouse during the summer season in the Gunnison Basin of Colorado.

Variable	**β**	**SE**	**LCI**	**UCI**	**Odds ratio**
Intercept	- 1.580				
Sagebrush	1.292	0.058	1.209	1.376	3.64
Grassland	0.342	0.033	0.294	0.389	1.41
Irrigated agriculture	0.881	0.042	0.821	0.941	2.41
Alpine	0.592	0.032	0.547	0.638	1.81
elevation	0.238	0.039	0.182	0.295	1.27
distance to wetlands	0.072	0.026	0.035	0.110	1.07
water density	0.161	0.027	0.123	0.199	1.17
Road density	- 0.356	0.040	- 0.413	- 0.299	0.70
Distance to roads	- 0.294	0.032	- 0.340	- 0.249	0.75
Trail density	0.339	0.028	0.299	0.379	1.40
Distance to address points	0.377	0.034	0.328	0.427	1.46
Distance to subdivisions	- 0.655	0.040	- 0.713	- 0.597	0.52
Distance to easements	- 0.453	0.037	- 0.506	- 0.399	0.64

Figure 1. Relatively probability of Gunnison sage-grouse presence during the breeding season across the Gunnison basin using data from radio-telemetry data collected from 2004 until 2010.

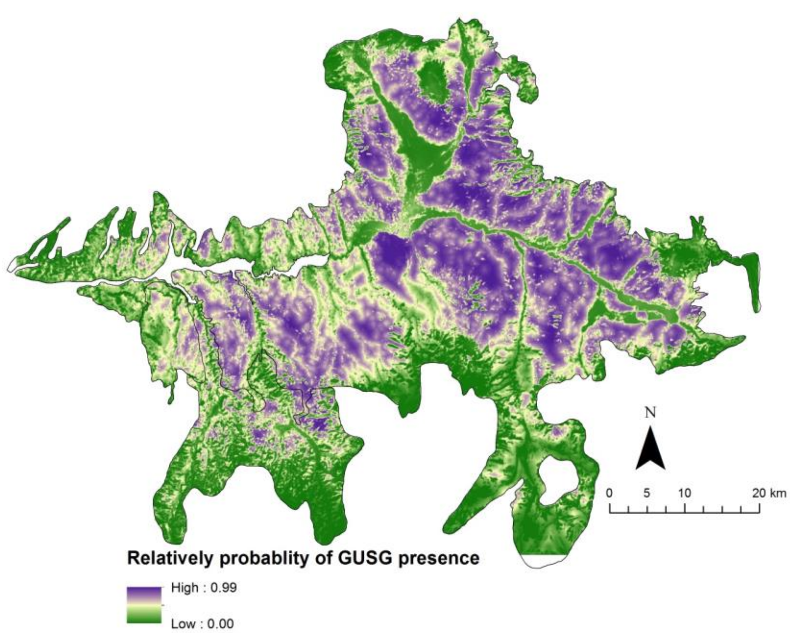
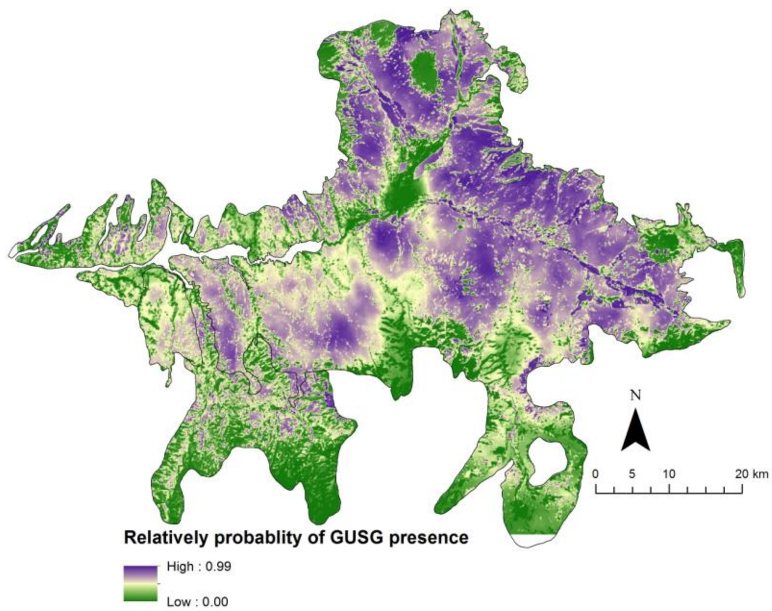


Figure 2. Relatively probability of Gunnison sage-grouse presence during the summer season across the Gunnison basin using data from radio-telemetry data collected from 2004 until 2010.



Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

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

Period Covered: October 1, 2015 – September 30, 2016

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

Project Collaborators: Brian Holmes, Brad Petch, Bill deVergie

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.

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 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. Colorado Parks and Wildlife deployed solar-powered GPS transmitters on male greater sage-grouse and conducted double-observer counts and resighting at leks to obtain data on male survival, lek attendance, inter-lek movements, detectability, and diurnal and nocturnal habitat use around leks during the breeding season in and near the Hiawatha Regional Energy Development project area in northwestern Colorado in spring from 2011-2014. These data will allow us to evaluate the reliability of current lek-based monitoring methods for providing information about sage-grouse population trends and the performance of lek buffers for conserving greater sage-grouse habitat. Analyses for this project are in progress.

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

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

Period Covered: October 1, 2015 – September 30, 2016

Author: B. L. Walker, brett.walker@state.co.us, CPW; J. S. Brauch, Colorado State University

Personnel: B. Holmes, B. Petch, W. deVergie, J. T. Romatzke

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Robust estimates of population size and population trends provide the scientific basis for managers to make appropriate and defensible recommendations regarding land-use decisions, harvest regulations, and mitigation efforts for wildlife. When linked with environmental variables, robust monitoring programs also allow managers to examine wildlife responses to various stressors. However, many wildlife monitoring programs continue to use population indices that may or may not meet the assumptions required to accurately estimate population abundance or trends. For this reason, it is essential to evaluate alternative approaches to population monitoring in terms of estimator precision, cost, practicality, and level of disturbance. 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 the availability of new methodological and statistical approaches to estimate abundance, it is worth comparing the performance of current lek-count approaches against other potential monitoring methods. Dual-frame sampling of leks by helicopter and non-invasive genetic mark-recapture analyses based on winter pellet sampling are two promising alternatives for monitoring trends in sage-grouse populations. The purpose of this study was to evaluate and compare the reliability and efficiency of dual-frame sampling of leks, genetic mark-recapture, and standard lek counts for estimating population size, trend, and sex ratio in the Parachute-Piceance-Roan (PPR) population in northwest Colorado. All field data collection for this project was completed in May 2014. For the dual-frame lek sampling analysis, we used occupancy modeling to account for imperfect detectability of leks in each sampling frame. We are currently finishing that analysis and preparing a manuscript for publication. Preliminary dual-frame results suggest that there are a substantial number of unknown leks in the population, a conclusion supported by the discovery of 44 new leks from 2012-2016 (25 of which have been confirmed active in ≥ 2 years). Dual-frame analysis also suggests that different proportions of occupied leks are counted in each year and this variation may bias estimates of population status, abundance, or trends based on lek-count data. For the genetic mark-recapture (GMR) analysis, we completed genetic analysis of all feather and pellet samples and used microsatellite data for six loci plus one sex locus to generate capture histories for individual birds. We conducted GMR analysis with closed population models in Program MARK to obtain preliminary abundance and sex ratio estimates for the PPR population over two consecutive winter seasons (2012-2013 and 2013-

2014). These preliminary results suggest a between-year population change similar in direction and magnitude to that reported in CPW lek-count data (summed maximum male count across leks). However, genetic data also indicated substantial variation in sex ratio between years. Annual variation in sex ratio may be an additional source of bias for estimates of population status, abundance, and trends based on lek-count data that rely on a constant sex ratio assumption.

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Evaluating lek-based monitoring and management strategies for greater sage-grouse in the Parachute-Piceance-Roan population of northwestern Colorado

Period Covered: October 1, 2015 – September 30, 2016

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

Project Collaborators: Bill deVergie, Stephanie Duckett, Brian Holmes, Brad Petch, J.T. Romatzke

Implementing effective monitoring and mitigation strategies is crucial for conserving populations of sensitive wildlife species. Concern over the status of greater sage-grouse populations has increased range-wide and in Colorado due to population declines, range contraction, loss and degradation of sagebrush habitat, and potential for listing the species under the Endangered Species Act. Despite untested assumptions, lek counts are widely used as an index of abundance by state agencies to monitor sage-grouse populations. Lek locations are also commonly used to identify and protect important sage-grouse habitat. However, the use of lek counts and locations to monitor and manage sage-grouse populations remains controversial because it is unknown how closely lek-count data track actual changes in male abundance from year to year or if lek buffers are effective at protecting habitat for male sage-grouse during the breeding season. Colorado Parks and Wildlife 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 the Parachute-Piceance-Roan population in northwestern Colorado in spring from 2012-2016. These data will allow us to evaluate whether current lek-based monitoring methods provide reliable information about sage-grouse population trends and whether current lek buffers are effective at protecting breeding males. We monitored 17 GPS males for all or part of the 1 September 2014 - 31 August 2015 period and 6 males for all or part of the 1 September 2015 – 31 May 2016 period. Analyses for this project are in progress.

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Assessment of greater sage-grouse response to pinyon-juniper removal in the Parachute-Piceance-Roan population of northwestern Colorado

Period Covered: October 1, 2015 – September 30, 2016

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

Project Collaborators: Bill deVergie, Brian Holmes, T. Knowles, Brad Petch

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.

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, no studies to date 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 investigate the effectiveness of pinyon-juniper removal for restoring sage-grouse habitat in the PPR. In fall 2008, I established nine “survey” 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 survey plots in 2010 and 2011. Pellet surveys in summer from 2009-2015 indicated that the mean proportion of sample units containing pellets was consistently highest on sagebrush control plots (range 0.197-0.449 across years), consistently lowest on plots with encroaching pinyon-juniper (range 0.007-0.048), and increased on 2 of 3 treated survey plots (Ryan Gulch and Upper Galloway) within 1-2 years after treatment. Fourteen transect plots were established in fall 2010 and summer 2011, and two were established in summer 2014. Transect plots were surveyed for pellets in summer though 2015. As expected, estimated mean pellet piles/km were low on the four PJ-Control plots for the duration of the study (range across years = 0.00-0.58 pellets/km) and on PJ-Treatment plots prior to treatment (mean = 0.03 pellet piles/km). Mean pellet piles/km were consistently higher on all four Sagebrush-Control transect plots through 2014 (range across years = 11.10 - 27.14 pellet piles/km), but declined precipitously on 3 of 4 Sagebrush-Control plots in 2015 (Magnolia Control, Upper Barnes Control, and Wagonroad Control). Pellet piles/km were also high on the Lower Barnes transect plot 4-5 years post-treatment (13.78-25.71 piles/km), but declined 6-8 years post-treatment (0.00-3.91 pellet piles/km). Mean pellet piles/km has generally remained low on treated transect plots for four years after pinyon-juniper removal (range across years = 0.00 - 2.86 pellet piles/km) with the exception of Upper Bar D in 2014 (8.96 pellet piles/km). Estimates of proportion of sample units with pellets (from survey plots) and of pellet piles/km (from transect plots) also varied substantially among Sagebrush-Control plots within years and among years within plots, which suggests there is substantial variation in pellets deposited within suitable habitat (i.e., over and above variation in counts due to observer bias). 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 to generate distance-detection curves, and those analyses are in progress. 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. Analyses for this project are in progress. However, to date, sage-grouse response to pinyon-juniper removal as measured by pellet surveys appears to be inconsistent, with pellet counts increasing on only 2 of 8 plots within 4-5 years post-treatment. A recent experimental pilot project suggests that sage-grouse may respond more strongly to both pinyon-juniper and serviceberry removal. We are developing a proposal to expand the current project to include pinyon-juniper and/or serviceberry treatments on existing and additional study plots starting in fall 2018.

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Pilot study to assess northern bobwhite response to short-duration intensive grazing on Tamarack State Wildlife Area

Period Covered: October 1, 2015 – September 30, 2016

Principal Investigators: Adam C. Behney, adam.behney@state.co.us

Project Collaborators: Trent Verquer, Ed Gorman, Jim Gammonley

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Widespread suppression of historic disturbance regimes has reduced heterogeneity in vegetation communities on which many wildlife rely for various life events and stages. Northern bobwhites (*Colinus virginianus*) require areas of thicker grass cover for nesting within close proximity to more open areas with bare ground and abundant food producing forbs for brood rearing and feeding. Altered or eliminated vegetation disturbance has been implicated in the rangewide decline of northern bobwhite populations. Lack of disturbance on state wildlife areas in Northeast Colorado has caused the vegetation to become uniformly dense and tall which is likely not meeting the needs of all parts of the northern bobwhite life cycle. Some type of disturbance is required to reduce the vegetation biomass and create some of the open structure on which bobwhites rely. Grazing represents one of the only options for disturbance at Tamarack State Wildlife Area and other similar riparian areas in northeast Colorado. Whereas unmanaged continuous grazing has been linked to degradation of bobwhite habitat quality, short-duration intensive grazing holds promise to reduce the vegetation biomass and rejuvenate the habitat to become more attractive to bobwhites.

The objective of this project is to assess the efficacy of using short-duration high-intensity grazing as a tool to improve northern bobwhite habitat. We will use a randomized block design in which we divide the study site into groups of four plots, one of which is grazed each year over a three-year period and one is a control (Fig. 1). Beginning in late winter each year, we will capture bobwhites using walk-in traps and affix necklace-style VHF radio transmitters on 50 females. We will locate each radio-marked bobwhite three times per week and determine nest sites by observing birds in the same location on subsequent days. When nests hatch we will continue to monitor broods and on day 14 post-hatch we will flush the brood, and weekly thereafter to count chicks and assess brood status. To assess nest and brood site selection, we will sample vegetation at nest and brood sites and paired random points to represent available habitat. The overall goal is to estimate adult, nest, and brood survival as well as nest and brood site selection in relation to grazing treatment and other general habitat characteristics.

In 2016, we conducted a pre-treatment pilot study to estimate general baseline demographics and habitat preferences of bobwhites at Tamarack. We captured and affixed radio transmitters on 26 female northern bobwhites in 2016. Overall survival from May through August was 0.63 ± 0.1. Estimated nest survival was 0.42 ± 0.19 based on 11 monitored nests.

Nest survival was positively affected by vegetation height (Fig. 2) and density (Fig. 3) around the nest. Bobwhite nest sites exhibited a greater percentage of grass cover than associated random sites (36.6 ± 11.5 % and 21.1 ± 6.7 %, respectively). We monitored six broods and survival to 21 days post-hatch was 0.65 ± 0.2. The results from this pilot study are generally consistent with previous research on northern bobwhites and provide a good baseline on which to build with grazing treatments beginning in 2017.

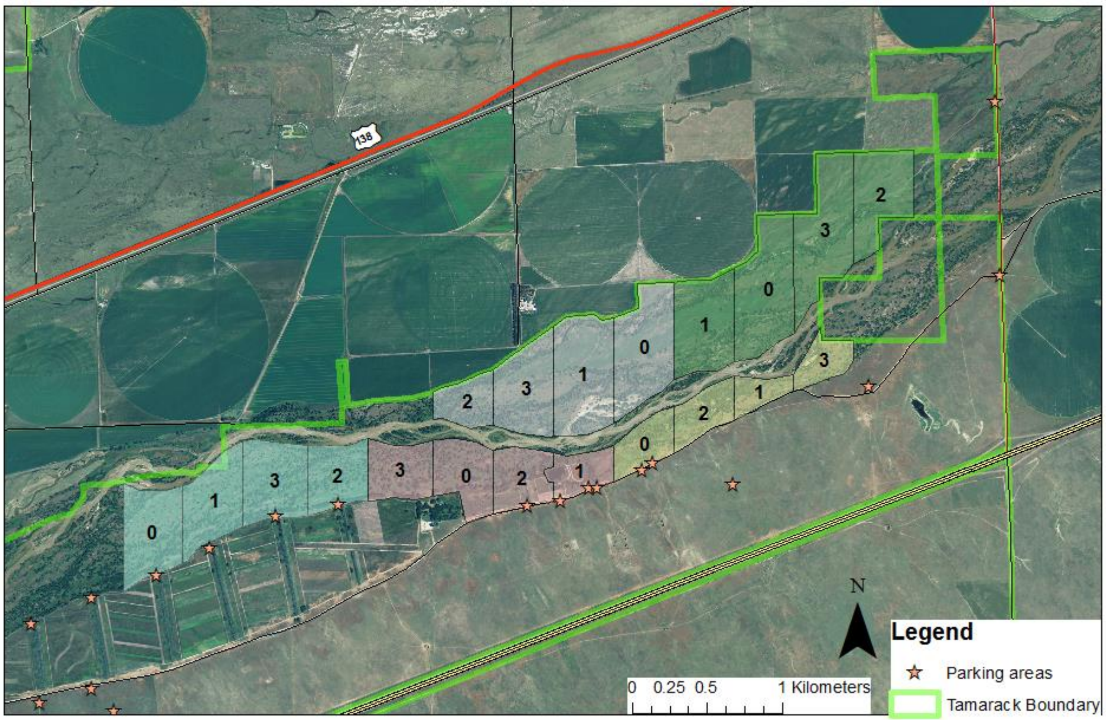

Figure 1. Proposed grazing treatment plot layout for the eastern portion of Tamarack State Wildlife Area. Numbers represent the year of treatment, zeros indicate control plots.

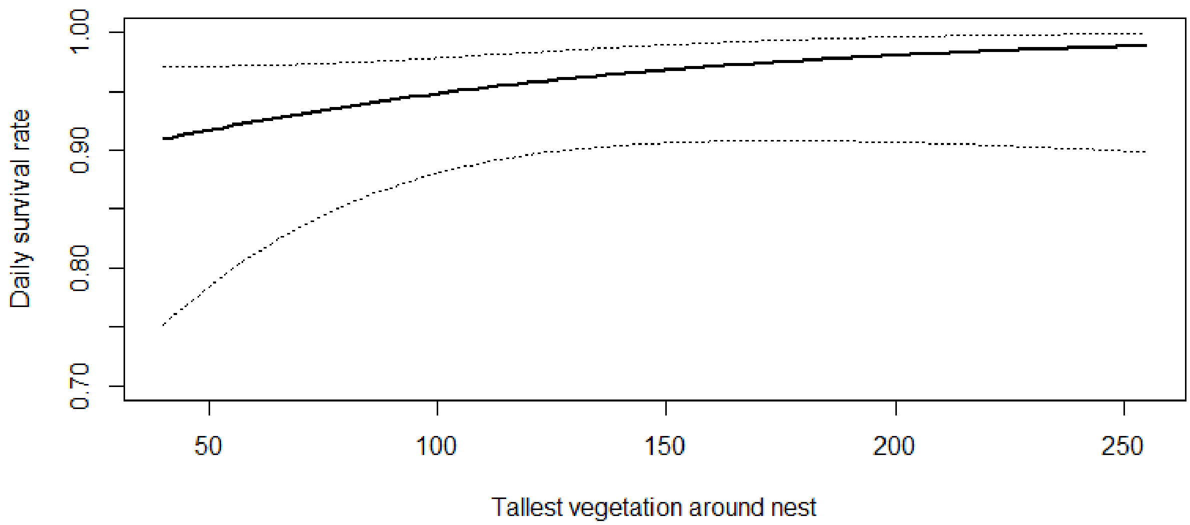

Figure 2. Model predicted values and 95% confidence interval of nest daily survival rate in relation to the tallest vegetation in 1 m^2 sample frame centered on nest.

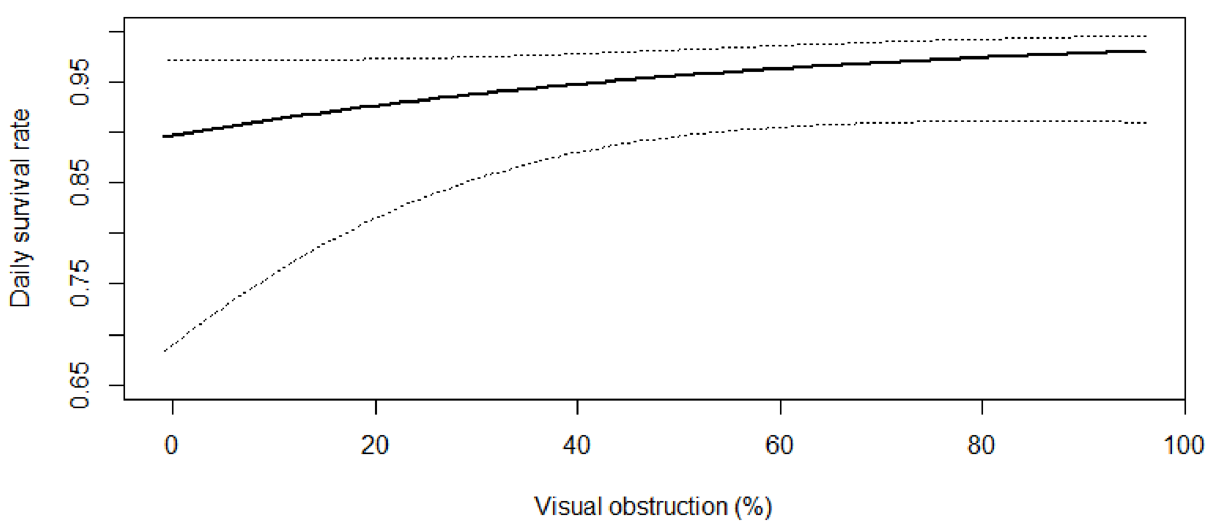

Figure 3. Model predicted values and 95% confidence interval of nest daily survival rate in relation to the visual obstruction measurement taken at the nest.

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Foraging ecology of nonbreeding ducks and other waterbirds in the South Platte River Basin

Period Covered: October 1, 2015 – September 30, 2016

Principal Investigators: Adam C. Behney, adam.behney@state.co.us

Project Collaborators: Brian Sullivan, Jim Gammonley

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.

Attracting and holding large populations of waterfowl are goals of habitat management for nonbreeding waterfowl. Currently, many habitat planners use bioenergetics approaches to guide habitat planning for nonbreeding waterfowl and shorebirds. In their simplest form, these bioenergetics models predict the amount of habitat needed to support a population goal based on the energy requirements of that goal and the productivity of the habitat. Many of these models assume that energy availability is the only factor affecting duck use of sites. However, recent evidence suggests that although energy availability is important for predicting wetland use by ducks, there are many other factors that influence duck use of sites and utility of those used sites. Therefore, more complex models have been developed but it is unclear how complex these models need to be and what specific factors should be incorporated into to accurately predict carrying capacity or habitat needs. Regardless of what form these models take, given the demonstrated importance of energy availability, estimates of food availability are necessary for the different wetland types in which nonbreeding ducks and shorebirds forage. Most dabbling and many diving ducks primarily consume benthic seeds during winter and migrations but transition to diets higher in invertebrates prior to nesting in spring. Shorebird diet consists of almost exclusively invertebrates.

The lower South Platte River corridor in northeastern Colorado (Fig. 1) is considered a waterfowl conservation priority area for migrating and wintering ducks and is important in terms of recreation. However, relatively little research has been conducted to determine the effectiveness of habitat management actions or food availability in the region. My first objective is to estimate duck and shorebird food abundance in various wetland types in the South Platte River basin throughout the nonbreeding season. Depletion of energy in wetlands is most likely a result of consumption by ducks and other wildlife or decomposition. Therefore, wetlands that exhibit the most depletion are also likely the most used during the nonbreeding season. Based on previous food availability research in other regions and the attractiveness of moist-soil units to ducks, we predict that moist soil units will produce the most energy and exhibit the greatest amount of energy depletion throughout the nonbreeding period. Secondly, we will assess the relationship between duck and shorebird use of wetlands, food abundance, and habitat structure characteristics in an effort to inform management treatments and better understand what form the energetic habitat planning models need to take. Sampling food availability for ducks and shorebirds in wetlands is very time-intensive. Therefore, my last objective is to evaluate a rapid visual assessment procedure to estimate duck habitat quality by comparing the calculated score with actual habitat quality metrics (i.e., food availability and duck use of sites).

During September–October (fall) 2015, we sampled 38 sites (Table 1), collecting a total of 264 core samples (avian food samples), and conducted a rapid habitat visual assessment procedure at each. During February – March (winter) and May-June (summer) 2016, we sampled 26 sites, collecting 182 core samples, and conducted the rapid assessment at all sites during both sampling occasions. To date, I've processed avian food samples from the fall 2015 and winter 2016 sampling occasions. During fall, moist soil wetlands contained the most energy per unit area (6472 DED/ha), followed by other emergent wetlands (6092.3 DED/ha), sloughs (2869 DED/ha), playas (2138 DED/ha), recharge ponds (913 DED/ha), and reservoirs (565 DED/ha). Depletion of energy from fall to winter was greatest in moist soil wetlands (lost 1129 DED/ha), followed by sloughs (lost 1072 DED/ha), playas (lost 794 DED/ha), emergent (lost 647 DED/ha), and reservoirs (lost 278 DED/ha). We conducted weekly bird counts at 22 sites during spring 2016 and these data are currently being analyzed. Rapid assessments were carried out at every sampling site during fall, winter, and spring. During fall and winter, moist soil units and emergent wetlands had the greatest habitat quality score. The rapid assessment procedures explained about 45% of the variability in energy availability of sites (Fig. 2) and about 68% of the variability in mean duck density on sites during spring (Fig 4.).

These estimates of food abundance can be directly incorporated into bioenergetic planning models for northeastern Colorado and based on energy depletion of sites and initial analyses of duck use, it appears that factors other than food availability are working to shape where ducks feed during the nonbreeding season. Furthermore, avian food sampling in wetlands is a very time intensive process and we demonstrate that a simple rapid assessment procedure is positively related to food biomass and duck use. However, depending on the desired accuracy of food availability estimates, the rapid visual assessment procedure we tested may not be sufficient.

Table 1. Number of sites sampled during each sampling period.

Site type	**Sept-Oct 2015**	**Feb-Mar 2016**	**May-Jun 2016**
Emergent[1]	6	5	5
Moist soil	8	4	4
Playa	5	2	2
Reservoir	6	5	5
Recharge pond	5	3	3
Slough	8	7	7

[1]At one emergent site in Sept-Oct 2015, only 5 core samples were collected.

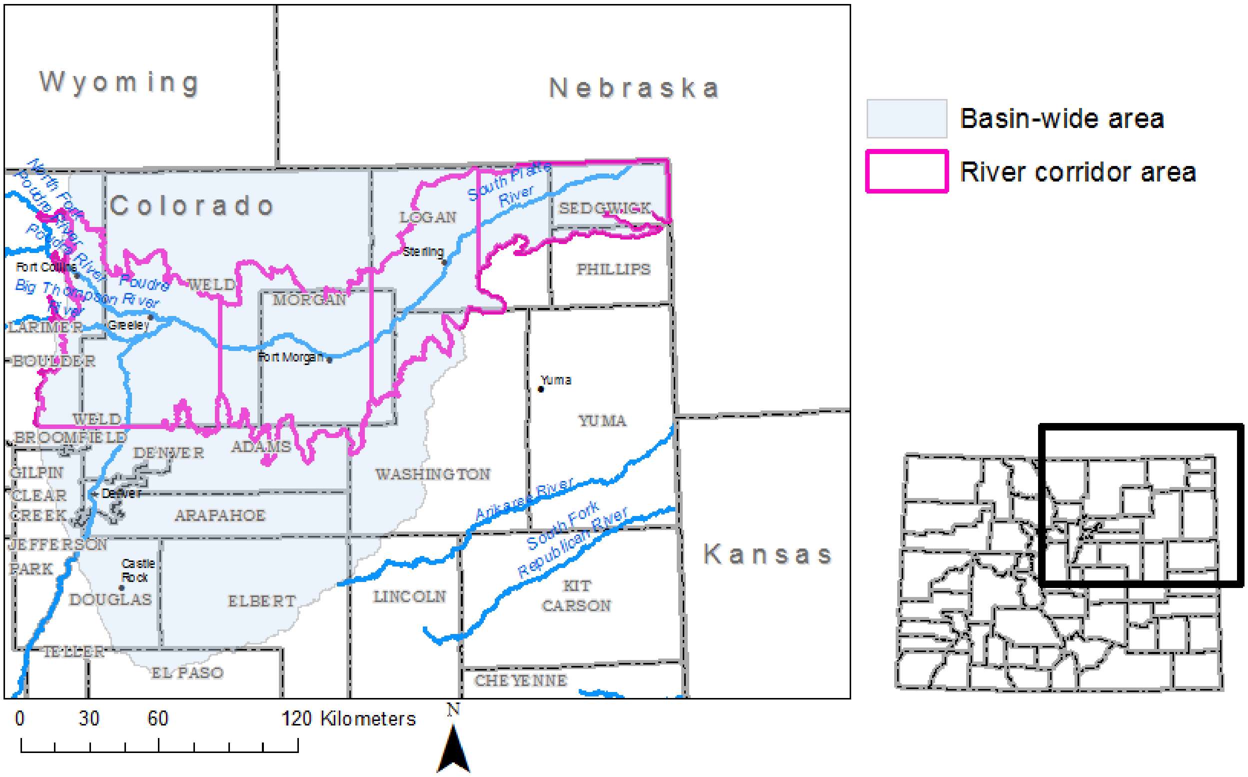

Figure 1. Study site along the South Platte River corridor in northeastern Colorado.

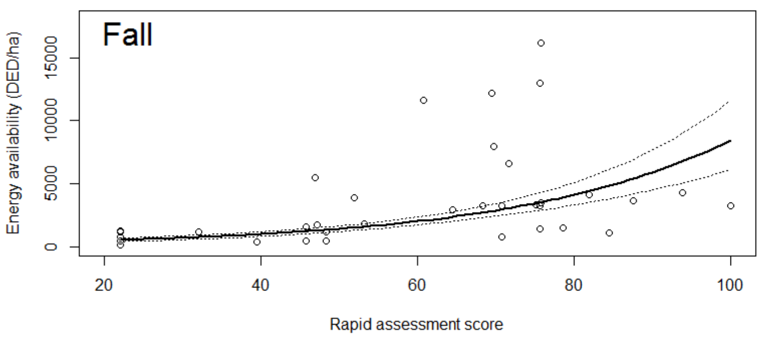

Figure 2. The relationship between rapid assessment score and energy availability (DED/ha) during fall (Sep-Oct) 2015 sampling. The solid line represents predicted values from a linear model using rapid assessment score to predict energy availability. Energy availability was natural log transformed in analysis to reduce heteroskedasticity but values were backtransformed in the figure. Dotted lines represent ± one standard error.

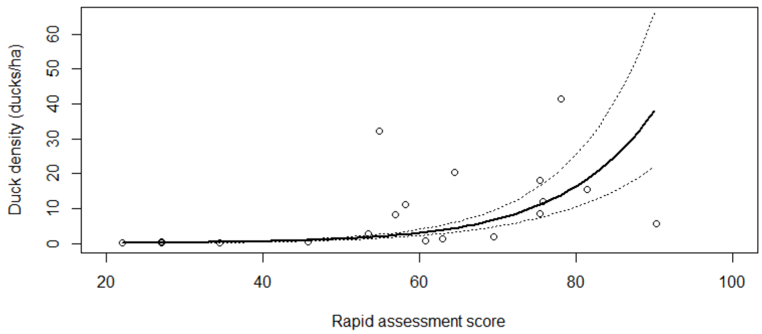

Figure 4. The relationship between rapid assessment score (winter 2016) and mean duck density (ducks/ha) during spring (Mar-Jun 2016). The solid line represents predicted values from a linear model using rapid assessment score to predict mean duck density. Duck density was natural log transformed in analysis to reduce heteroskedasticity but values were backtransformed in the figure. Dotted lines represent ± one standard error.

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Pilot study to evaluate avian response to conservation reserve program mid-contract management practices in northeastern Colorado

Period Covered: October 1, 2015 – September 30, 2016

Principal Investigators: Adam C. Behney, adam.behney@state.co.us

Project Collaborators: Trent Verquer, Ed Gorman, Jim Gammonley

The Conservation Reserve Program (CRP) is a government program in which landowners are paid to maintain grass cover on land that was, and would otherwise be, used for row-crop agriculture. Overall, the CRP has had many documented benefits to wildlife, specifically grassland birds, many of which are experiencing range-wide declines due to habitat loss and degradation. However, as CRP fields age with no disturbance, litter increases, bare ground decreases, vegetation density increases, and plant species and structural diversity decrease, which can reduce the value of CRP fields to certain bird species. Therefore, beginning in 2004, some type of "mid-contract management" was required on CRP fields. In northeastern Colorado this management typically consists of haying, disking, or disking and interseeding with forbs. Although there is some evidence that disking and interseeding can provide benefits to ring-necked pheasants (*Phasianus colchicus*; hereafter 'pheasants') in other regions, we lack a thorough understanding of how these various management practices affect pheasants and grassland dependent songbirds in northeastern Colorado. In an effort to provide guidance to managers and landowners regarding grassland management on CRP fields in northeastern Colorado, we will monitor the response of pheasants and songbirds to the three most common CRP mid-contract management practices (haying, disking, disking & interseeding).

I will randomly assign treatments to halves of each study field so each treatment is paired with a control. Beginning in late winter, we will capture pheasants on and around study fields using nightlighting techniques. All captured females will be fitted with a necklace-style radio transmitter and released at the capture site. We will locate all marked birds three times per week and determine nest sites by locations occurring in the same spot on multiple occasions. For successful nests, we will locate broods three times per week and flush broods at days 10 and 21 post-hatch to estimate brood survival. We will conduct vegetation samples at nest and brood flush sites as well as paired random points to assess factors affecting nest and brood survival and nest and brood site selection. We will conduct two rounds of songbird point counts at six points within each study field throughout the summer.

In 2016, we conducted a pre-treatment pilot study to gather baseline demographic information on pheasants and songbirds in the study area. We captured and monitored 34 female pheasants and surveyed songbirds on two occasions in six fields. Adult pheasant survival during the breeding season (four months) was low 0.29 ± 0.09 and 76% of the mortality occurred during May and June. Nest survival was influenced by whether nests were located in wheat fields (0.43

± 0.20) or CRP fields (0.33 ± 0.18). For nests in CRP fields, the amount of visual obstruction at the nest site positively influenced nest survival (Fig 2). Pheasants selected nest sites with a greater percentage of warm-season grasses (nest sites: 45.8 ± 8.3 %, random points: 27.3 ± 3.7 %). We were able to monitor eight pheasant broods, two of which survived to 10 days post-hatch and one survived to 21 days post-hatch. Estimates from a constant survival model predicted brood survival to 21 days post-hatch was 0.07 ± 0.07. Western meadowlarks were the most common bird detected during point counts, followed by grasshopper sparrows, and mourning doves.

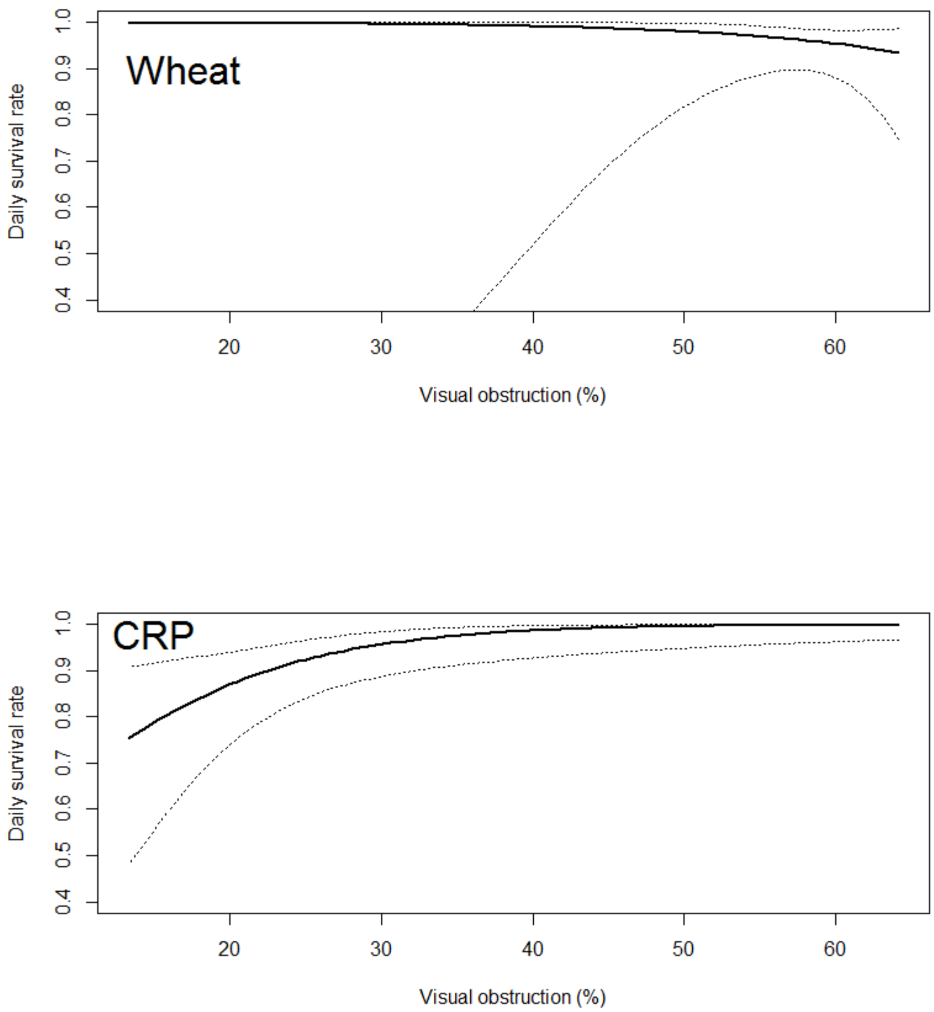

Figure 2. Model predicted values and 95% confidence interval of nest daily survival rate in relation to visual obstruction reading for nests in wheat (top) and Conservation Reserve Program (bottom) fields.

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Avian response to plague management on Colorado prairie dog colonies

Period Covered: October 1, 2015 – September 30, 2016

Principal Investigators: R. Yale Conrey, reesa.conrey@state.co.us, D. Tripp, J. Gammonley, CPW; A. Panjabi, E. Youngberg, Bird Conservancy of the Rockies (formerly Rocky Mountain Bird Observatory).

Project Collaborators: Miranda Middleton (CPW), Bird Conservancy of the Rockies (formerly Rocky Mountain Bird Observatory), City of Fort Collins Natural Areas and Utilities Programs, Michael Wunder and Allison Pierce (University of Colorado Denver), Bureau of Land Management (Cañon City office), and CPW wildlife managers, biologists, park rangers, and property technicians from Areas 1 and 4.

Range-wide declines in prairie dog (*Cynomys* sp.) populations have occurred, and the largest limiting factor in recent decades appears to be the high mortality and colony extirpation associated with plague (Antolin et al. 2002), caused by the bacterium *Yersinia pestis*. Prairie dog colonies support a diverse community of associated species, many of which are not susceptible to plague but may be indirectly affected. In order to conserve prairie dogs and species associated with their colonies, principally the black-footed ferret (*Mustela nigripes*), a plague vaccination program is being developed (Fig. 1a), which may also benefit a suite of species (Fig. 1b, d) listed in the Conservation Plan for Grassland Species in Colorado (Colorado Division of Wildlife 2003) and the Colorado Sagebrush Conservation Assessment and Strategy (Boyle and Reeder 2005). CPW is involved in a multi-state, multi-agency study of prairie dogs and associated small mammal species; the objective is to determine whether survival is enhanced by the experimental vaccine compared to use of placebo or insecticide to control fleas, an important vector of plague. They are also interested in how patterns of prairie dog abundance and occupancy change when plague epizootics occur in plots receiving different treatments. As an extension to this project, we initiated research in 2013 on the effects of plague management on avian species associated with prairie dog colonies, with particular focus on species of concern. Our main long-term objective is to determine whether areas treated to control plague differ from untreated areas in their avian communities. Shorter-term objectives are to 1) Determine how plague affects avian species and their predators associated with prairie dog colonies; 2) Determine whether avian species associations exist for colonies of Gunnison's prairie dogs (*C. gunnisoni*: GUPD); most evidence for associated species comes from black-tailed prairie dogs (*C. ludovicianus*: BTPD); 3) Determine whether insecticidal dusting influences bird density or nest survival; 4) Evaluate the importance of covariates such as weather and cattle grazing.

Study areas in 2013–2015 included BTPD colonies in north-central Colorado and GUPD colonies in west-central Colorado, but in 2016, we replaced the western Colorado location with South Park, a high elevation site in central Colorado. Study sites were dominated by short and mid-grasses, especially blue grama (*Bouteloua gracilis*). Our first three years of research (2013−2015) coincided with Wildlife Health's 3-year efficacy trials for an oral plague vaccine for prairie dogs (Fig. 1a). In Colorado, CPW Wildlife Health Program staff led by Dan Tripp surveyed colonies before and after bait distribution and conducted a mark-recapture study of prairie dogs and associated small mammal species. Treated areas were arranged in triplets with one vaccine, placebo, and dusted site per group; baited sites were assigned vaccine or placebo baits in a blind procedure. In 2016, CPW Wildlife Health did further research on bait distribution and design, but the vaccine was beginning to become a management tool, more broadly used in ferret reintroduction sites and in some high priority GUPD colonies. We continued work at our BTPD site in 2016, and with our collaborators from Bird Conservancy of the Rockies, we now have 11 years of point count data spanning two plague cycles. We completed three years of work comparing on- and off-colony study areas at GUPD sites in western Colorado, and in 2016 shifted our focus to South Park, an area with locally high densities of mountain plover (*Charadrius montanus*) and a possible reintroduction site for GUPD, which have been extirpated from some areas. South Park contains several small active GUPD colonies, and large areas of potentially suitable habitat with no prairie dogs. We continued to conduct avian point counts in 2016, and bird occupancy, density, and species composition will be estimated from these data. Summer and winter counts of diurnal raptors and early season passive and call-playback surveys of mountain plover (*Charadrius montanus*) and burrowing owls (*Athene cunicularia*: Fig. 1d) were used to sample high priority species that are rarely detected during point counts. We searched for nests of these species as well, but did not repeat the intensive passerine nest monitoring program of previous years. We continued to collect remote camera data, which will be used to estimate summer and winter on-colony occupancy rates for mammalian carnivores, including coyotes, badgers, and swift fox (Fig. 1e). Finally, we again quantified percent ground cover, visual obstruction (Fig. 1c), and species composition of vegetation at points, nests, and along randomly located transects.

Since fall 2013, plague epizootics have impacted ~80% of the BTPD study area. In September and October 2014 and 2015, black-footed ferrets were released in three BTPD study colonies. Precipitation (Fig. 2) has varied greatly during this study, particularly on BTPD sites, from slightly dry to very wet, compared to the 30-year average. At this point, all data analyses are preliminary. From 2013 – 2016, we detected 137 bird species during the breeding season. During BTPD colony surveys, at least three bird species (Brewer's blackbird *Euphagus cyanocephalus*, horned lark *Eremophila alpestris*, and vesper sparrow *Pooecetes gramineus*) appeared to have higher detection rates on active prairie dog colonies, while three species (European starling *Sturnus vulgaris*, grasshopper sparrow *Ammodramus savannarum,* and lark bunting *Calamospiza melanocorys*) appeared to have higher detection rates on colonies with extinct or severely reduced prairie dog populations following plague outbreaks (Table 1). Trend analysis from 2006−2016, which included two plague events, is ongoing with our collaborators. We documented 230 plant species over four years. Colonies contained a higher bare ground component with lower vegetation heights than off-colony sites, with shortgrasses dominant at BTPD sites, short and mid-grasses at GUPD sites in South Park, and a more even distribution of grasses, forbs, and shrubs at GUPD sites in western Colorado. Vegetation species composition was highly variable at BTPD sites over time, with increasing grasses and decreasing bare ground following an El Niño event associated with high rainfall during the growing season (Table 2, Fig. 2). We detected 18 raptor species during on- and off-colony counts. Burrowing owls, northern harriers *Circus cyaneus*, ferruginous hawks *Buteo regalis* (Fig. 1b), and rough-legged hawks *Buteo lagopus* were detected only on prairie dog colonies, and half the raptor species we observed used on-colony areas more than off-colony areas during our surveys, with the remainder appearing to show no preference or having low sample size (Table 3). Patterns in the raptor data on active colonies vs. plague-effected colonies have not yet been examined. Despite three rounds of nest searching for mountain plover in South Park, nests were found only in a known area of high density in James Mark Jones State Wildlife Area, which was monitored by our collaborators at University of Colorado − Denver. However, the number of burrowing owl nests at our BTPD site has doubled during each year of our study following an El Niño event and widespread plague, which may have created conditions with high prey and burrow availability in a landscape that continues to contain many active (if small) prairie dog colonies. Finally, in > 1.5 million remote camera photos, we have documented use of colonies by 8 species of mammalian carnivores, with decreased coyote activity and increased swift fox activity over the course of this study. Swift fox occurred only on BTPD colonies and badgers were more commonly detected there, while coyotes were equally common across all sites on BTPD and GUPD colonies. These species are known nest predators with large home ranges and carry fleas that could potentially move plague across a broad area.

This was the fourth year of data collection on this project, and it will likely take additional years of monitoring to detect potential changes in the avian community caused by different types of plague management, as treated colonies no longer experience extinction events. Regardless of the efficacy of plague vaccine versus insecticide in reducing plague impacts, the vaccine will continue to be an important tool due to cost/benefit of its use and increasing evidence that fleas are evolving resistance to deltamethrin. Preliminary data suggest that bird densities do vary according to the status of prairie dogs on a colony, with differences between active colonies and those with extirpated or severely reduced prairie dog populations following plague outbreaks. Vegetation surveys have also identified differences between on- and off-colony areas. Raptor and camera data collection will continue through winter 2016/2017. During the 2017 breeding season, we hope to continue collecting point count, raptor count, and vegetation data on BTPD colonies with different activity levels, following the extensive 2013−2015 plague outbreak. Beyond that, there are several possibilities for continued research. The GUPD reintroduction planned for South Park is on hold until new funding is obtained; our avian work on GUPD sites may similarly go on hiatus. We may work more in ferret reintroduction sites, on private lands, or in a new location with little or no plague management (such as Pawnee National Grassland) for comparison with our current BTPD site north of Fort Collins.

CODE	SPECIES	Use Rate		TOTAL
		A	R + E	COUNT
BRBL	Brewer's Blackbird	**0.249**	0.069	257
HOLA	Horned Lark	**4.642**	3.899	6764
VESP	Vesper Sparrow	**0.324**	0.135	369
BARS	Barn Swallow	0.122	0.122	192
BRSP	Brewer's Sparrow	0.101	0.089	150
CORA	Common Raven	0.120	0.114	185
MCLO	McCown's Longspur	1.379	1.544	2301
RWBL	Red-Winged Blackbird	0.395	0.330	574
WEME	Western Meadowlark	2.566	2.812	4235
EUST	European Starling	0.070	**0.123**	151
GRSP	Grasshopper Sparrow	0.173	**0.290**	361
LARB	Lark Bunting	2.231	**2.797**	3948

Table 1. Bird use rates for the most common species detected during avian point counts on BTPD colonies (Larimer and Weld Co.) with varying prairie dog activity status: Active (A), Reduced (R) after a plague event, and Extinct (E). Use rate was calculated by dividing the number of detections by the total number of points surveyed. The first three species were more common on active colonies, those in the middle showed no preference, and the last three species were more common on reduced or extinct colonies. Data reported here do not yet account for probability of detection or the location of individual birds inside or outside of treatment area boundaries.

% Cover	2013	2014	2015	2016
Grass	36.7	55.9	55.7	71.0
Litter	27.2	8.7	14.3	11.9
Bare	22.8	19.4	13.3	7.5
Forb	3.9	8.3	9	4.8

Table 2. Ground cover percentages for dominant vegetation types from 2013 – 2016 for BTPD sites (Larimer and Weld Co.) in north central Colorado.

Species	BTPD in	GUPD in	GUPD out	TOTAL min
American Kestrel	2.26	2.30	1.47	539
Burrowing Owl	23.02	0.45	0.00	2756
Common Raven	3.23	17.50	16.70	2881
Ferruginous Hawk	2.21	0.03	0.00	264
Golden Eagle	1.09	1.79	2.08	414
Loggerhead Shrike	0.00	0.78	0.21	69
Northern Goshawk	0.00	0.00	0.38	30
Northern Harrier	0.46	0.48	0.00	86
Prairie Falcon	0.52	0.33	0.04	86
Rough-legged Hawk	0.24	0.09	0.00	35
Red-tailed Hawk	1.34	5.46	3.04	766
Sharp-shinned Hawk	0.00	0.19	0.21	30
Swainson’s Hawk	4.80	0.45	0.52	639
Turkey Vulture	6.07	2.66	1.85	1044
TOTAL min	11840	6690	7950	26480

Table 3. Raptor use of vaccine project areas at BTPD and GUPD sites, on and off prairie dog colonies in 2013 – 2016. Use was quantified as time spent in project areas, and use rate = 100*(use minutes/total minutes) in BTPD, in GUPD, and off GUPD colonies. Data include breeding counts (late April – August) at all sites and wintering counts (November – early March) at BTPD sites. Species with small sample sizes are not shown: American crow, bald eagle, Cooper’s hawk, and osprey (2 min each).

Figure 1. Photos from BTPD and GUPD sites during 2013 – 2016. 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.

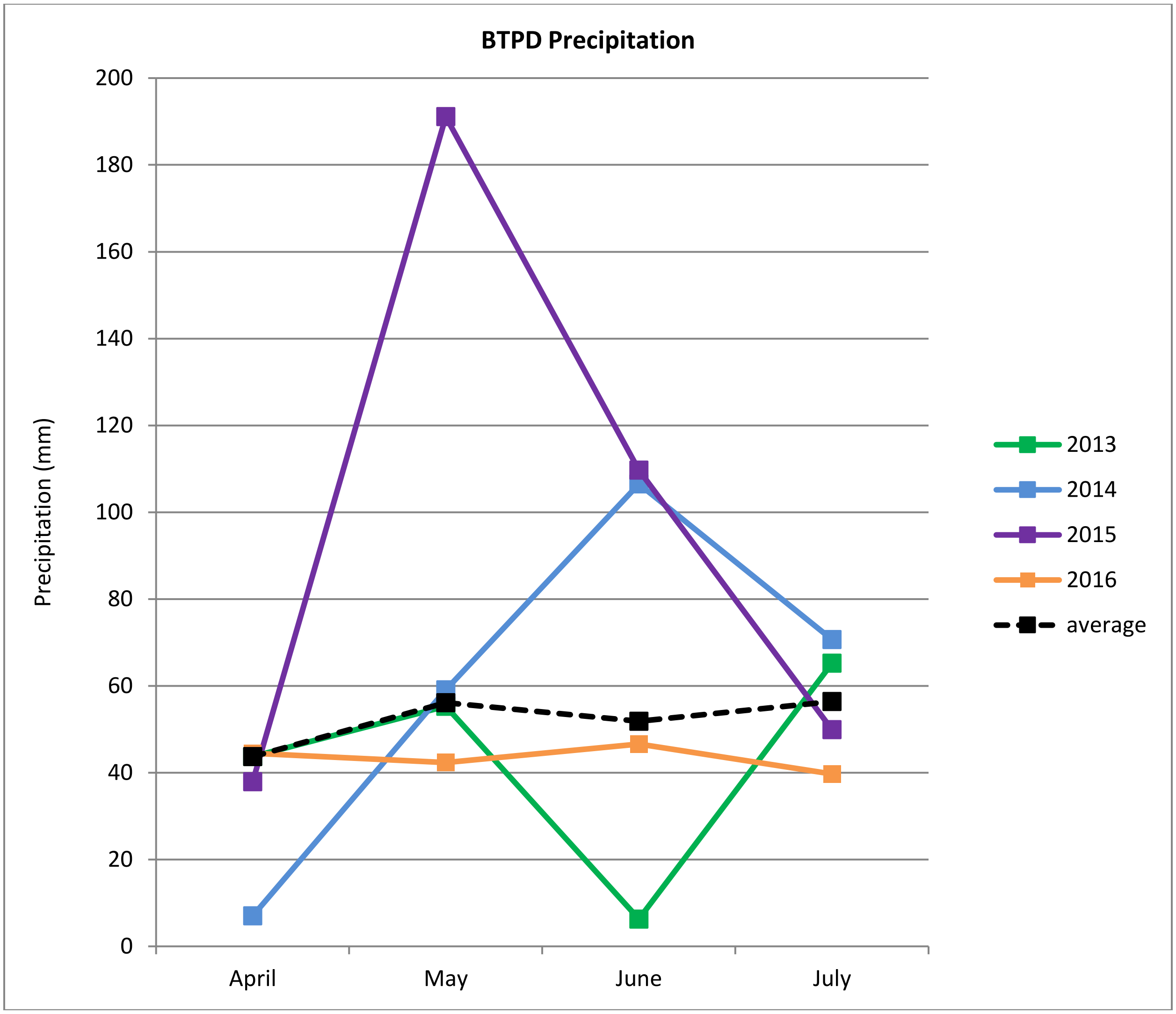

Figure 2. Monthly precipitation at BTPD (Larimer and Weld Co.) sites from 2013 – 2016, including the 30-year average. Data were taken from the nearest weather station.

WILIDLIFE RESEARCH PROJECT SUMMARY

Raptor data integration, species distribution, and suggestions for monitoring

Period Covered: October 1, 2015 – September 30, 2016

Author**:** R. Yale Conrey, reesa.conrey@state.co.us

Principle Investigators: R. Yale Conrey, J. Gammonley, CPW; J. DeCoste, W. Kendall, Colorado State University

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

CPW biologists, GIS group, Species Conservation staff, and Parks staff: especially R. Sacco (GIS Unit); Senior Terrestrial Biologists, M. Sherman, A. Estep, M. Cowardin, N. Seward (Terrestrial); D. Klute, L. Rossi (Species Conservation); J. Thompson (Resource Stewardship).

Where they exist, raptor monitoring databases have generated important insights into various aspects of raptor ecology, and can provide a sound foundation for specific management priorities for individual species or within the larger context of managing targeted habitats and ecosystems (Greenwood 2007). CPW has a statewide raptor nest database, developed by Bob Sacco (GIS Unit), which currently contains records for ~9,000 nest records going back to the 1970s. Currently, the nest database is primarily being used by CPW at a site-specific scale in the oil and gas comment process (CO House Bill 1298) and other local-scale land use input. The potential of this database to assess raptor populations at regional or statewide scales, and the field protocols used to provide records for this database, have not been thoroughly assessed. Other data sources have potential to contribute to our understanding of Colorado raptors, including eBird, Breeding Bird Survey, and Colorado Breeding Bird Atlas. By exploring the possibility of integrating these various datasets, we hope to generate a more comprehensive picture of raptor abundance and occupancy across the state, with the eventual goal being to provide a more concrete understanding of raptor population trends for management purposes.

We are focusing on breeding populations of bald eagles (*Haliaeetus leucocephalus*: BAEA), golden eagles (*Aquila chrysaetos*: GOEA), prairie falcons (*Falco mexicanus*: PRFA), and ferruginous hawks (*Buteo regalis*: FEHA). GOEA are a Tier 1 Species of Greatest Conservation Need in Colorado, while the other three species are on the Tier 2 list and BAEA and FEHA are species of Special Concern. We are first focusing on GOEA and BAEA, partly because we have more nest records (GOEA) and better quality data, with repeat visits to nests that allow nest survival analysis (BAEA). In addition, GOEA are a species of conservation concern due to declining populations rangewide and their sensitivity to human activity and energy development. BAEA are a species of management concern due to the recent attention to nest take, contention over revised federal regulations, and the frequency with which BAEA nest in areas with rapidly accelerating housing development.

Research objectives are to 1) Assess and improve the data available in CPW's raptor nest database; 2) Build distribution models for our highest priority raptor species, evaluating the importance of ecological and anthropogenic covariates; 3) Estimate nest survival for bald eagles, evaluating the importance of ecological and anthropogenic covariates; 4) Evaluate the potential for integrating other data sources, such as eBird, Breeding Bird Survey, and Colorado Breeding Bird Atlas; 5) Make recommendations for a state-wide raptor monitoring protocol.

The first step in this research project was to assess the data available in CPW's raptor nest database. This database contains locations and nest site occupancy information for 29 species of raptors from 1975 to present. Most of the nest data have been collected opportunistically, and known nest sites are resurveyed at a much higher rate than new areas are surveyed. For a nest site to be considered active during CPW consultation for HB 1298, it must be known to have been occupied sometime within the past 5 years. Although some sites are visited yearly, others are therefore visited only when they have reached the end of their 5-year window, and most nest sites have a listed status of undetermined or unknown (many of these are historic nests that have not been visited within the past 5 years). More detailed information is sometimes available for nests, but this information is typically summarized into annual records by GIS staff who enter and maintain the data.

There has been a special effort to monitor BAEA through multiple visits per known nest location per year, making these data suitable for modeling of daily nest survival. Aside from estimating daily and annual nest survival rates, the goals of this model are to determine what ecological and anthropogenic covariates are important predictors of nest survival and to provide a comparison of the outputs, usefulness, and monitoring methods suitable for nest survival modeling versus distribution modeling. The nesting cycle averages 18 weeks (or 126 days) from egg laying until fledging: incubation begins with the first egg and lasts 5 weeks while the nestling period ranges from 8 – 14 weeks, averaging 12 – 13 weeks. In Colorado, egg laying usually begins in late January to early February, hatching occurs in early March, and young eagles can fledge anytime between early June and August.

Modeling of daily nest survival requires the following data from each nest: 1) date when the nest was found; 2) the last day the nest was checked when alive; 3) the last day the nest was checked; and 4) the fate of the nest (0=successful, 1=failed). For spatial covariates to be calculated, an accurate location was also required. Covariates are listed in Table 1 along with the data source and citations supporting their inclusion. J. DeCoste is calculating spatial covariates using ArcGIS spatial analysis tools and running nest survival models in Program MARK,which uses maximum likelihood methods to estimate nest survival as a known fate data type. Model selection will be based on AICc values. We expect to complete the BAEA nest survival model by the end of 2016, but protocols and coding will be well documented so that the model can be updated in future as more nest and covariate data become available.

The goal of distribution modeling is to determine what variables predict breeding locations and to map areas with high to low probability of use for mitigation planning and future survey design. The next phase of this research project will include distribution modeling for GOEA and BAEA. For GOEA, we will collaborate with U.S. Fish and Wildlife Service's Western Golden Eagle Team (WGET), which has completed some ecoregional models and is currently working on a High Plains model. Models for PRFA and FEHA will follow, data permitting.

It is our objective to make recommendations for future monitoring guidelines that can be consistently applied state-wide. We plan to use the distribution maps that result from this research to stratify the state of Colorado into appropriate survey regions. Ideally, monitoring guidelines will include a time of year for surveys, how often various regions will be visited, and a means to record survey effort and both presence (new and existing nests) and absence data. In addition, we hope to provide some guidance on the amount of effort that should be allocated to surveys for new nests, versus return visits to known nest sites, and how to prioritize survey effort by raptor species and spatial location.

The CPW raptor nest database contained 9479 nest records for 8696 locations, as of 7 November 2016 (Table 2). This included 1477 active nests known to be occupied within the past 5 years. The majority of nest locations (6127 nests, 70% of the total) have an unknown or undetermined status, meaning that the site has not been visited in at least 5 years or that an observer was unable to determine the status of the nest. There are 12 species with at least 100 nest records, and 27% of records are for nests occupied by an unknown species. We made an agency-wide and inter-agency request for additional nest data to maximize sample size prior to our analyses, which likely contributed to the 20% increase (1730 nests) over 2 years. Our bald eagle nest survival model currently has an input file containing 121 nest attempts at 79 locations from 2012−16: 45 nest sites are on the Front Range and 34 are on the Western Slope. An additional 105 nests were not included, and the most common reason for exclusion was that the observer did not visit enough times or at the appropriate time to confirm nest fate.

Modeling efforts are still in progress. This was intended as a 2-year research project, ending 31 December 2017, although it will take additional years to implement and evaluate the monitoring recommendations that result from our work and from discussions among CPW employees and our partners working on raptors. However, some useful information has been gleaned from data quality control, calculation of covariates, and initial runs of the bald eagle nest survival model. First, nest survival models require more intensive survey data than do distribution models, because at least two, and frequently more visits are required during the nesting season. One visit must occur during the incubation or nestling phases, in which nesting activity can be confirmed by sighting eggs or nestlings, or at least by sighting an adult sitting on the nest who is presumably incubating or brooding. One visit must occur shortly before or after the presumed fledging date to confirm the fate of the nest, where successful nests have at least one fully feathered juvenile leaving the nest and failed nests have none. For all purposes, observers should reserve the value of zero to represent true zero, as opposed to a placeholder or indication of an unknown or inapplicable value. Finally, 70% of nest locations in the database have a status of unknown or undetermined (Table 2). These sites have much less value for modeling or HB 1298 purposes than have nests with any of the other status designations, so some effort should be allocated to re-visiting these sites.

SPECIES	NUMBER OF NESTS				
	Active	Inactive	Destroyed	Unk/Undeter	Total*
Bald Eagle	194	18	56	152	437
Golden Eagle	103	71	80	1630	1978
Ferruginous Hawk	63	3	29	325	436
Prairie Falcon	25	13	1	163	215
Total All Species	1477	474	618	6127	9479

Table 2. Nest counts for Colorado raptors included in the CPW raptor nest database as queried on 7 November 2016. 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). 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. Counts of active, inactive, destroyed, unknown, and undetermined nests are for the last raptor species occupying a nest site. *Total nest numbers exceed the summation of those in specific status categories due to nest sites that have changed species or have missing data.

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Restoring energy fields for wildlife

Period Covered: October 1, 2015 – September 30, 201

Principal Investigators: Danielle Bilyeu Johnston, danielle.bilyeu@state.co.us

Project Collaborator: Bill deVergie, J.T. Romatzke, J.C. Rivale, and Ron Velarde (CPW); Phillip L. Chapman (Colorado State University)

Healthy sagebrush-steppe areas of western Colorado are characterized by a diverse mixture of shrubs, forbs, and grasses. Restoring such habitats following oil and gas disturbances is often difficult because of the variety of impacted precipitation zones and the threat of weed invasion. An area of particular concern is the Piceance Basin gas field because of its value to mule deer (*Odocoileus hemionus*), greater sage-grouse (*Centrocercus urophasianus*), and other wildlife. In 2008, 2009, and 2012, a series of six experiments was implemented on simulated well pads and pipelines covering the wide range of precipitation and ecological conditions represented in the Piceance Basin gas field.

The experiments conducted at lower elevations emphasize weed control, particularly that of cheatgrass (*Bromus tectorum*), which presents a serious obstacle to effective reclamation (Knapp 1996, Chambers et al. 2007, Reisner et al. 2013). The four lower elevation experiments are the Pipeline experiment (implemented at six sites ranging from 1561 to 2216 m in elevation), the Competition and Competition 2 Experiments (implemented at two sites of elevations 2004 and 2216 m), and the Gulley experiment (implemented at four sites ranging from 1561 to 2084 m in elevation). The remaining two experiments, conducted at high or middle elevations, emphasized maximizing plant diversity. The Mountain Top experiment was implemented at the four highest elevation sites, ranging from 2342 to 2676 m. The Strategy Choice experiment was implemented at four moderate elevation sites ranging from 1662 to 2216 m.

Sites were prepared in 2008 by simulating pipeline disturbances and well pad disturbances. These two disturbance types differ in the length of time topsoil is stored, an important variable for restoration. The Pipeline Experiment was implemented in 2008, three weeks after the disturbances. All other experiments were implemented on well pad disturbances. These experiments were implemented in 2009 immediately after the well pads were reclaimed, except for the Competition 2 Experiment, which was implemented in 2012. Results and analysis for at least 3 post-treatment years for all experiments is now available, either within this report or via the included links to publications.

Although the complexity of elevation, soil type, and prior land use history make finding general recommendations for improving restoration for wildlife challenging, a general theme did emerge over the seven years these six experiments have been studied. This general theme is the importance of controlling weed seed propagule pressure. Propagule pressure is the number of weed seeds per area per unit of time. Even the experiments that were not explicitly designed to address propagule pressure ultimately provided lessons about its importance, and what we can do about controlling it. This corroborates research in other ecosystems which has demonstrated that controlling propagule pressure is more important than other factors managers might try to influence, such species diversity, herbivory, or abiotic conditions (Von Holle and Simberloff 2005, Eschtruth and Battles 2009).

In the Pipeline Experiment, we learned that in limited circumstances, pipeline disturbances can reduce cheatgrass density compared to unimpacted areas (Johnston 2015). When combined with Plateau ® (ammonium salt of imazapic) herbicide, enough cheatgrass control can be achieved to allow establishment of big sagebrush (*Artemisia tridentata*). While Plateau is a useful herbicide, using it alone is sometimes ineffective because applying it at high enough rates to get sufficient cheatgrass control results in unacceptable injury to desirable plants (Owen et al. 2011). By causing cheatgrass seeds to be buried too deeply to germinate, ground disturbances can work additively with herbicides to reduce cheatgrass propagule pressure. The timing of the disturbance is important. We quantified the seasonality of cheatgrass propagule pressure using seed traps (Appendix 1). Most cheatgrass seeds arrive between May and June, but seeds continued to arrive until September. The disturbances in the Pipeline Experiment occurred in September, which maximized burial of seeds from the prior growing season. A disturbance earlier in the growing season may not be as helpful for limiting cheatgrass.

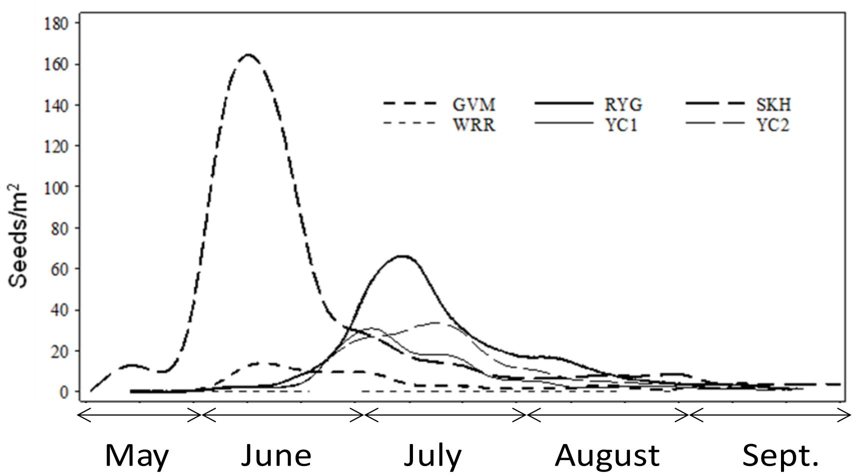

Figure 1. Propagule pressure of cheatgrass seeds between May and September in undisturbed locations near 6 sites: GVM, RYG, SKH, WRR, YC1, and YC2, which varied in elevation from 1561-2216 m (5120-7268 ft.) and cheatgrass cover from 0% to 70%. Data are averages over 3 years, 2009-11

In the Competition and Competition 2 Experiments, cheatgrass propagule pressure was intentionally controlled in order to look for other factors that may limit cheatgrass during restoration. These experiments had mixed results. We focused on abiotic manipulations which might exploit cheatgrass's weaknesses: lower competitive ability under higher, more stable soil moisture (Chambers et al. 2007, Bradley 2009), and inability to germinate through compacted soils (Thill et al. 1979, Beckstead and Augspurger 2004). In the Competition Experiment, the treatments were super-absorbent polymer (SAP) application (to increase water retention), a soil binding agent designed to increase water infiltration (DirtGlue ®), and compaction with a heavy roller. Rolling was not helpful. SAP increased initial perennial grass density and reduced subsequent cheatgrass cover at one of two sites, and the binding agent increased perennial grass density and reduced cheatgrass cover at one of two sites. Because the binding agent application was more expensive, the Competition 2 Experiment focused on SAP. In Competition 2, SAP had beneficial effects at one site (increasing perennial grass cover and reducing cheatgrass), but detrimental effects at the other site, causing a five-fold increase in cheatgrass. The limitations on cheatgrass germination and the nature of competitive interactions between cheatgrass and desirable perennial plants appears to be a complex interaction of site conditions, treatment timing, and treatment choice. Right now, clear management recommendations on how to use SAP or binding agent are not available, although this may be improved through further study.

The Gulley Experiment focused on identifying which sources of propagule pressure are important to control: the seed bank, new seeds entering from the surrounding landscape, or both. The treatments were application of Plateau herbicide at 140 g ai/ha (8 oz/ac) just prior to seeding, fallowing for one year with the broad-spectrum pre-emergent herbicide Pendulum™ (pendamethilin, BASF Corporation), and surrounding plots with seed dispersal barriers of aluminum window screen. The barriers had slight effects which were entirely positive: lower annual forb cover at some sites where Russian thistle (*Salsola tragus*) was dominant, and higher perennial grass and forb cover. The herbicide treatments were a lesson in the dangers of over application. The pendamethilin treatment was especially detrimental. Both herbicides in combination so suppressed perennial vegetation that by four years post-treatment, there was a trend for higher cheatgrass cover where both had been applied, in spite of both herbicides effectively controlling cheatgrass in the initial years of the experiment. The barriers did not reduce cheatgrass cover, possibly because cheatgrass seeds passed under the barriers or blew over them. The Mountain Top and Strategy Choice Experiments examined a treatment that had more success at reducing cheatgrass cover.

The Mountain Top Experiment was initially designed to address how to maximize plant diversity in restoration. This is critical because restored areas are often dominated by grasses, even after decades of recovery. Unexpectedly, this experiment also demonstrated that high elevation sites in Piceance are vulnerable to cheatgrass invasion, and revealed a useful technique for combating that invasion. The treatments were: seeding (17.8 kg/ha PLS native species including 60% grass or no seed), soil surface (roughened with 50 cm-deep holes or flat), and brush mulch replacement (0.024 m^3/m^2 or no brush). Unseeded plots were initially dominated by annual forbs, while seeded plots were dominated by perennial grasses. After five years, unseeded plot annual forb cover had declined to 10%, perennial grass cover had increased to 24% (about two-thirds of that of seeded plots), and perennial forb cover was 6.8% (about one-third that of seeded plots). Cover of shrubs (mostly big sagebrush, *Artemisia tridentata*) in unseeded plots was 26% (almost double that of seeded plots), highlighting the degree to which competition by seeded species can slow the recovery of sagebrush. Brush mulch benefitted shrubs, perennial grasses, and perennial forbs, and also slightly reduced annual forbs. Contrary to expectations, the rough soil surface did not have any large effects on cover of perennial grasses, forbs, or shrubs, but it did have an effect on cheatgrass. By five years post-treatment, cheatgrass had become established in unseeded plots at two sites, especially Scandard. At Scandard, the rough surface reduced unseeded plot cheatgrass cover from 13% to 3% (Figure MountainTop 5). We hypothesize that cheatgrass seeds become entrapped in the bottom of holes, limiting their spatial distribution, and forcing them to compete under wetter conditions under which they are less competitive.

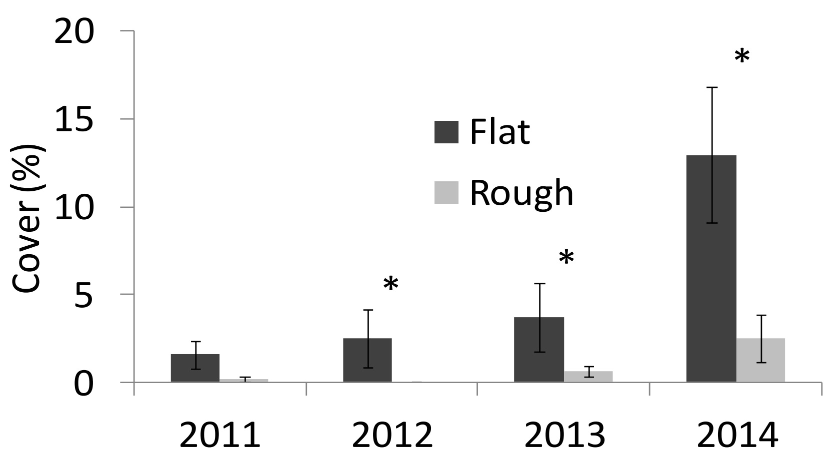

Figure 2. Percent cover of annual grass (*Bromus tectorum*) in response to a rough versus flat soil surface in unseeded plots at Scandard Ridge 2- 5 years post-disturbance. Error bars are SE. Stars denote significant differences at $\alpha = 0.05$.

The Strategy Choice Experiment also included a rough vs. flat soil surface treatment, although in this experiment the rough surface was always applied with brush (and broadcast seeded), while the flat surface was always applied with straw mulch (and primarily drill-seeded). The Strategy Choice Experiment was conducted at middle elevations where the threat of weed invasion was moderate or ambiguous, in order to find optimal strategies in uncertain circumstances. The other treatments included Plateau (8 oz/ac vs. none) and a seed mix treatment. There were two seed mixes compared: one that had about equal numbers of forb, shrub, and grass seeds, and one that was about 75% forbs, 17% shrubs, and only 8% grass. Cheatgrass established at two of the four sites, one each with high (GVM) and low (MTN) cheatgrass propagule pressure. The Plateau treatment successfully controlled cheatgrass, but caused an increase in annual forbs, and had either neutral or negative effects on perennials. At GVM, the rough surface augmented the effect of Plateau, reducing cheatgrass biomass six-fold. At MTN, the rough surface reduced cheatgrass biomass 10-fold in the absence of Plateau and reduced weedy annual forbs 100-fold in the presence of Plateau. Across sites, there was no difference in cheatgrass due to seed mix, and forb and shrub biomass were higher with the high-forb mix.

Looking across the Mountain Top and Strategy Choice experiments, the rough surface helped control cheatgrass at three of four sites where cheatgrass became established. The one site where it had no effect, the Sprague site in Mountain Top, had only sparse and patchy cheatgrass. As an extension of this project, we implemented a rough surface treatment along with a light (4 oz/ac) Plateau application to 7 acres at Horsethief SWA, and successfully turned a cheatgrass near-monoculture into a diverse stand of grasses, forbs, and shrubs (Johnston 2014). Weedy species, almost by definition, produce large numbers of rapidly dispersing seeds to quickly exploit any open or disturbed areas. From prior research we know that holes entrap many kinds of seeds (Chambers 2000), and that cheatgrass seeds disperse 10 to 50-fold farther over bare soils than in intact ecosystems (Kelrick 1991, Johnston 2011, Monty et al. 2013). Our research supports the conclusion that landscapes which permit rapid seed dispersal foster weeds; landscapes which slow seed dispersal favor less weedy species.

Altered seed dispersal is one reason why cheatgrass responds so well to fire. Even though a fire may kill 97% of cheatgrass seeds (Humphrey and Schupp 2001), fire also removes vegetation, which allows cheatgrass seeds to travel farther (Monty et al. 2013). The few surviving seeds grow in the absence of competition, which enables them to produce 40 times more seed than they might have within a dense stand (Hulbert 1955). These seeds disperse readily over the burned surface, producing a second generation of plants which are also relatively free from competition. By two years after the fire, cheatgrass is fully recovered from the 97% reduction (Humphrey and Schupp 2001). A rough soil surface can entrap seeds near the parent plant, preventing the growth of isolated, highly productive cheatgrass plants. This may slow the cheatgrass recovery cycle enough for perennial plants to establish. A rough soil surface is a practical tool managers can use to limit cheatgrass and other weedy invasives after disturbances including fire and development.

The two experiments which addressed seeding practices demonstrate the costs of including too much grass seed in seed mixes: forb and shrub growth is delayed. Including at least a little grass in seed mixes is probably wise, as research has shown that the best competitors for invasive species are native species of the same functional group (i.e. grasses compete best with grass, and forbs with forbs) (Fargione et al. 2003). Even so, the high-forb seed mix performed well at the GVM site, which had high cheatgrass propagule pressure. The recent investments made by CPW through the Uncompagre Project to make additional forb species available at low cost are critical, and additional resources should be devoted to this task.

Results of Plateau application in this series of experiments are mixed, generating beneficial results in one experiment (Pipeline), mixed results in another experiment (Gulley), and largely detrimental results a third experiment (Strategy Choice). Successful use of this herbicide requires accurately applying a light rate, focusing on areas with cheatgrass cover prior to disturbance, and combining Plateau with other measures to reduce cheatgrass propagule pressure, such as a rough soil surface or a well-timed ground disturbance.

Restoring oil and gas disturbances to fully functional, diverse wildlife habitat in northwestern Colorado is possible. Making use of a higher proportion of forbs and shrubs in seed mixes, considering the timing of weed seed dispersal, combining herbicides with other factors to reduce weed propagule pressure, and seeding over a rough soil surface are strategies which can be used over a wide range of elevations and ecological conditions to the benefit of wildlife.

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Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Restoring habitat with super-absorbent polymer

Period Covered: September 1, 2014 – August 31, 2015

Principal Investigators: Danielle Bilyeu Johnston, danielle.bilyeu@state.co.us

Project Collaborator: Cynthia Brown and Magda Garbowski, Colorado State University; Murphy Jacox

In the western United States, successful restoration of degraded habitat is often hindered by invasion of exotic species and unfavorable climatic conditions. Cheatgrass (*Bromus tectorum* L.) is an especially aggressive competitor on disturbed lands and poses threats to restoration, including outcompeting desirable species, altering soil nutrient cycles, reducing species diversity, and decreasing the quality of forage and wildlife habitat. In addition, uncertainties of future climate and precipitation changes make planning for and implementing restorations difficult. With their ability to absorb moisture when soils are wet and slowly release it over time, superabsorbent polymers (SAPs) may buffer seeded species against negative impacts of precipitation fluctuations. In a prior CPW study (Johnston 2012), incorporating SAPs into the soil at the time of seeding was found to reduce cheatgrass cover by up to 50%, possibly by shifting the timing of soil moisture availability in a way that favors perennial plants.

Because SAPs act on existing soil moisture, their effectiveness is likely to depend on precipitation factors, such as total annual precipitation, seasonal timing, and size of precipitation events. In this study, we assess the repeatability of the prior study in two additional locations which have contrasting precipitation patterns: a Colorado front range site (Waverly Ranch, Larimer County), and a Colorado western slope site (Dry Creek Basin State Wildlife Area, San Miguel County, Figure 1). We quantify how SAPs influence soil moisture through time at these locations, and how drought, cheatgrass presence, and SAPs interact to influence plant community development. At the Dry Creek Basin site, we also contrast broadcast versus pelleted application methods.

We implemented the experiment by preparing research areas, seeding a native seed mix, and applying drought, SAPs, and cheatgrass treatments in a factorial design (drought: exclusion of 66% of ambient rainfall or ambient rainfall; cheatgrass presence: 465 seeds m^{-2} or none; SAP: 26 g m^{-2} or none). Drought was imposed via construction of rainfall diversion shelters, and treatments were completed in fall 2013 at Waverly and summer 2014 at Dry Creek. Seedling density was monitored in the first growing season at each site, while plant cover was the primary metric in subsequent years. Soil moisture (both sites) and first-year soil available nitrogen (NH_3^-, $NH4^{+;}$ Dry Creek only) were also assessed. This report contains results and analysis of first-year data: 2014 at Waverly and 2015 at Dry Creek. Plant cover data from 2015 and 2016 at Waverly and 2016 at Dry Creek will be analyzed for a future report.

Drought had a large effect at both Waverly and Dry Creek. By the end of the first growing season, seeded or native species seedling densities and soil moisture were lower in drought plots at both sites. At Waverly, SAP addition increased density of seeded species, but only in plots with ambient precipitation (Figure 9). Cheatgrass density was low at Waverly and no effects of cheatgrass addition were found. In contrast, cheatgrass established well at Dry Creek and had a large impact on seeded plants and soil moisture, while SAP had no effect. At Dry Creek, seeded annual densities were highest in mid-summer in ambient precipitation plots without cheatgrass. Cheatgrass and rainfall treatments interacted in an interesting manner to influence soil moisture at Dry Creek. At 30 cm depth, soil moisture was by far lowest in plots with ambient precipitation and cheatgrass. Apparently, a stand of cheatgrass can reduce deep soil moisture to a greater degree than a 66% reduction in rainfall.

The effectiveness of SAP at Dry Creek was not improved by pelleted application. Overall, seeded species establishment was lower when seeds were applied in pellets than when they were broadcast, regardless of whether or not SAP was included in the pellets. Seeds within pellets germinated well in the greenhouse; therefore, we suspect that germinating seedlings from pellets may have had difficulty transitioning from the pellet to the surrounding soil.

Other reasons for the lack of SAP effect at Dry Creek include insufficient application rate and insufficient soil moisture. The rate used in this study, 0.045% by weight (257 kg/ha) costs approximately \$1,900 ha^{-1} (\$800/ ac). Higher application rates are often used in greenhouse settings, but are impractical for the large areas relevant to dryland plant community restoration. SAP was most effective under ambient precipitation at Waverly, which likely had the highest spring soil moisture of any plots in this study. Prior studies have found SAPs to be more effective under drier conditions, but these studies did not examine soils as dry as those in this study. We may have found a lower limit of soil moisture for which SAP application is beneficial. Testing localized SAP application, either in drill seeded rows or pellets, under higher soil moisture conditions, is warranted.

Overall the effects of SAP on plant emergence, soil resources, and cheatgrass establishment were site and precipitation dependent. Soil moisture, soil texture, or other site-specific factors are likely also responsible for differences between the results of this study and the prior CPW effort. Finding conflicting results at different sites is not uncommon in restoration ecology. Further monitoring, assessment at additional sites, modeling exercises, and synthesis can improve the quality of management recommendations. Developing restoration treatments and techniques that ameliorate the negative impacts of drought and invasive species is fundamental to restoring resilient wildlife habitats.

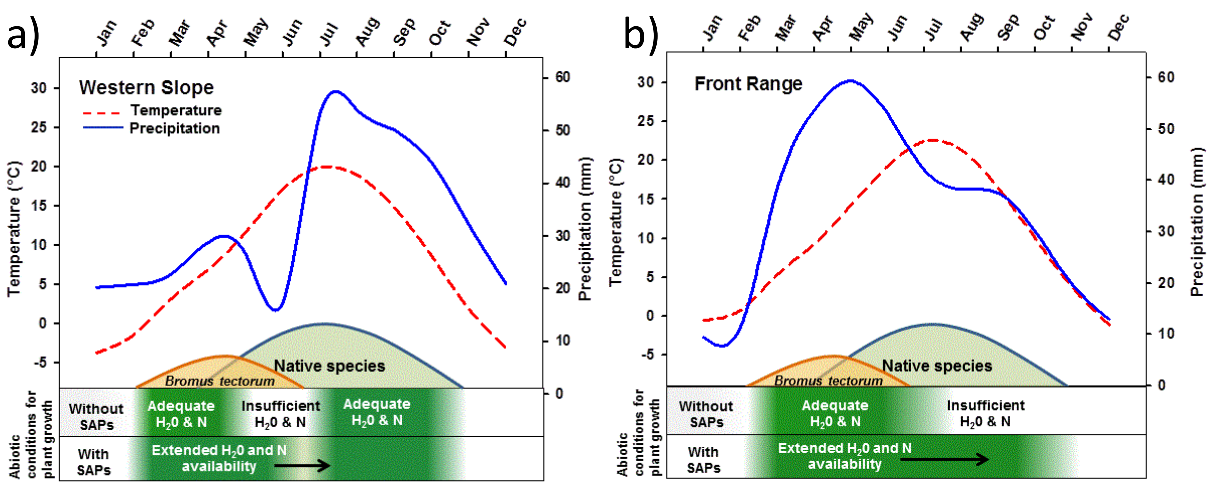

Figure 1. Thirty-year average temperature and precipitation for the Western Slope (Dry Creek State Wildlife Area, San Miguel County, CO) and Front Range (Waverly, CO) study sites. **a) Western Slope.** Water availability is suitable for plant growth in the early spring when soils are moist after snow melt, but the majority of precipitation falls in late summer and early fall as part of the North American Monsoon. Seedlings are especially vulnerable during the warmest and driest months of the growing season (April-July) when rainfall events are small and intermittent and evaporative demand is high. SAPs may ameliorate the negative impacts of periodic drought by extending water availability during this resource limited period until late summer monsoonal precipitation commences. **b) Front Range.** Water is most often sufficient for plant growth during the spring. Seedlings are most vulnerable in the summer (mid-June – mid-September), when rain events are small and intermittent and evaporative demand is high due

to warm temperatures. SAPs may extend water and nutrient availability through these harsh months, promoting seedling survival.

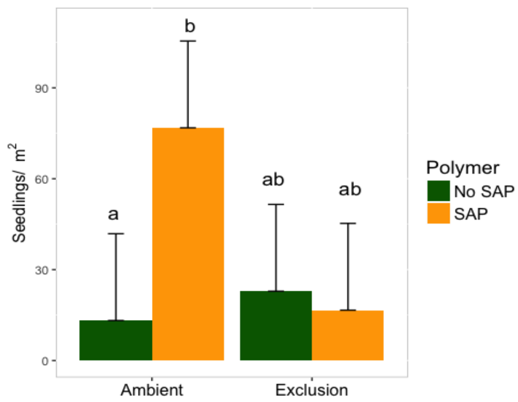

Figure 9. 2014 seedling densities of seeded species at Waverly. Data are averaged over *B. tectorum* treatments. Bars are means of untransformed data ± standard error of the mean. Letters denote significant differences between means of transformed data ($p < 0.1$).

Publications, presentations, workshops and committee involvement by Avian Research staff
October 2015 – September 2016

PUBLICATIONS

Apa, A. D., and L. A. Wiechman. 2016. Captive-breeding of captive and wild-reared Gunnison sage-grouse. Zoo Biology 35:70-75.

Apa, A. D., K. P. Reese, and T. R. Thompson. *Accepted.* Juvenile survival, recruitment of greater sage-grouse in northwestern Colorado. Journal of Wildlife Management.

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Walker, B. L., A. D. Apa, and K. Eichhoff. 2016. Mapping and prioritizing seasonal habitats for greater sage-grouse in northwestern Colorado. Journal of Wildlife Management 80:63-77.

Hoffman, R. W., and **B. L. Walker**. 2016. Grouse capture, handling, marking, monitoring, and translocation guidelines. Unpublished report. Colorado Parks and Wildlife Animal Care and Use Committee. Fort Collins, USA. 80 p.

Decker, K., A. Pocewicz, S. Harju, M. Holloran, M. Fink, T. Toombs, and **D. B. Johnston**. *In review*. Landscape disturbance models consistently explain variation in ecological integrity across large landscapes. Ecosphere.

Johnston, D. B. *In review.* Rough microtopography and coarse litter replacement promote shrubland recovery under threat of annual grass invasion. Journal of Applied Ecology.

Stephens, G. J., **D. B. Johnston**, J. L. Jonas, and M. W. Paschke. 2016. Understory responses to mechanical treatment of pinyon-juniper in northwestern Colorado. Rangeland Ecology & Management 69:351-359.

PRESENTATIONS, WORKSHOPS, AND COMMITTEES

Apa, A. D. Faculty Committee for M.S. degree candidate Rachel Harris, University of Wisconsin, Madison.

Apa, A.D. Technical support, CPW Northwest Region ruffed grouse transplant project.

Apa, A. D., and **B. L. Walker.** CPW science support, Associated Counties of Northwest Colorado greater sage-grouse mapping project.

Behney, A. C., R. O'Shaughnessy, M. W. Eichholz, and J. D. Stafford. Worth the reward? An experimental assessment of risk-taking behavior in foraging ducks, North American Duck Symposium, Annapolis, MD, February 5, 2016.

Behney, A. C. Duck behavior, energetics, and wetland conservation planning. Colorado State University Department of Fish, Wildlife, and Conservation Biology Graduate Faculty Seminar Series, Fort Collins, CO, February 26, 2016.

Behney, A. C. Avian response to habitat management in northeast Colorado. Colorado Cattlemen's Association Annual Convention, Colorado Springs, CO, June 13, 2016.

Behney, A. C., R. Y. Conrey, and **B. L. Walker**. CPW Animal Care and Use Committee. Meeting September 14, 2016.

Conrey, R. Y. Great Plains Landscape Conservation Cooperative technical committee. Meetings: Fort Collins, CO, February 8-9, 206; Fort Collins, CO, September 20-22, 2016.

Conrey, R. Y. Burrowing owl presentation. Audubon Society of Greater Denver's HOOTenanny, Littleton, CO, September 24, 2016 (poster and activity table, 338+ attendees).

Gammonley, J. H. Central Flyway Waterfowl, Webless Migratory Game Bird, and Central Management Unit Dove Technical Committees. Meetings: Denver, CO, October 6-9, 2015; Colorado Springs, CO, March 1-4, 2016; Pittsburgh, PA, March 15, 2016; Steamboat Springs, CO, September 17-23, 2016.

Gammonley, J. H. Class lecture: waterfowl management. Fish and Wildlife 375 (Paul Doherty, professor), Colorado State University, February 10, 2016.

Gammonley, J. H. Central Flyway wing bee, Hartford, KS, February 16-29, 2016.

Gammonley, J. H. CPW raptor database project overview. Statewide Bureau of Land Management biologists meeting, Silt, CO, April 14, 2016.

Gammonley, J. H. Mid-Continent Mallard Adaptive Harvest Management Committee workshop, Kansas City, MO, June 7-9, 2016.

Gammonley, J. H. Joint meeting of the North American Waterfowl Management Plan Update Steering Committee and Interim Integration Committee, Minneapolis, MN, July 12-14, 2016.

Gammonley, J. H. Waterfowl life cycle needs and habitats. Avian Habitat Project Development Strategies meeting, sponsored by the Desert Rivers Collaborative, August 25, 2016.

Gammonley, J. H. Search committee for James C. Kennedy endowed chair in waterfowl and wetland ecology at Colorado State University. April-November 2016.

Johnston, D. B. Faculty Committee for Ph.D candidate Magda Garbowski, Colorado State University, Fort Collins.

Johnston, D. B. Colorado Habitat Exchange Science Team. Meetings (conference calls): October 17, 2015; November 11, 2015; November 24, 2015; December 8, 2015; December 16, 2015; January 5, 2015; January 26, 2016; February 4, 2016; February 18, 2016; March 29, 2016; April 13, 2016.

Johnston, D. B. Forage production of habitat treatments for mule deer. Annual Piceance Basin Research Cooperator's Research Update Meeting, Grand Junction, CO, October 29, 2015.

Johnston, D. B. Pothole Seeding Update. Annual Piceance Basin Research Cooperator's Research Update Meeting, Grand Junction, CO, October 29, 2015.

Johnston, D. B., G. S. Stephens, and M. Paschke. Evaluating mechanical treatment techniques for vegetation control. Habitat Partnership Program 2015 Statewide Meeting, Grand Junction, CO, December 2, 2015.

Johnston, D. B. Habitat meeting. Brown's Park National Wildlife Refuge, CO, January 19, 2016.

Johnston, D. B. Field lecture and tour: Rangeland restoration at Horsethief State Wildlife Area. Tamarisk Coalition 13th Annual Research and Management Conference, Fruita, CO, February 11, 2016.

Johnston, D. B., P. L. Chapman, C. S. Brown, and A. Monty. Manipulating seed dispersal to benefit restoration. The Fourth Gunnison Sage-Grouse Summit, Gunnison, CO, March 10, 2016.

Garbowski, M. and **D. B. Johnston**. Field lecture and tour: Restoring habitat with super-absobent polymer. Area 18 meeting, Dry Creek Basin State Wildlife Area, CO, April 20, 2016.

Johnston, D. B. Field lecture and tour: Habitat mitigation for oil and gas impacts. Colorado State University Restoration Case Studies course (Mark Paschke, professor). Silt, CO. August 17, 2016.

Johnston, D. B. Science team history, current status, and future direction. Colorado Habitat Exchange Oversight Committee meeting. Denver, CO. September 1, 2016.

Walker, B. L. Faculty Committee for Ph.D candidate Jessica Brauch, Colorado State University, Fort Collins.

Walker, B. L. Parachute-Piceance-Roan greater sage-grouse research update. Annual research cooperator's meeting. Grand Junction, CO. October 28, 2016

Brauch, J. E., **B. L. Walker**, S. J. Oyler-McCance, J. A. Fike, and B. R. Noon. Evaluation of population monitoring strategies for greater sage-grouse in NW Colorado: genetic mark-recapture as an alternative to traditional lek counts. North American Ornithological Congress, Washington, D.C. August 18, 2016 (Best Poster Award).

Walker, B. L. Mapping and prioritizing seasonal habitats for greater sage-grouse in the PPR population in NW Colorado. Western Section of The Wildlife Society annual meeting. Pomona, CA. February 25, 2016.

Walker, B. L. Mapping, prioritizing, and increasing seasonal habitats for greater sage-grouse in the PPR population in NW Colorado. Colorado Chapter of The Wildlife Society annual meeting. Colorado Springs, CO. February 5, 2016.

Walker, B. L. Evaluation of population monitoring strategies for greater sage-grouse (*Centrocercus urophasianus*) in northwestern Colorado: genetic mark-recapture as an alternative to traditional lek counts. Colorado Chapter of The Wildlife Society annual meeting. Colorado Springs, CO. February 5, 2016.

Walker, B. L. Board Member, NW Region Representative, Colorado Chapter of The Wildlife Society (2013-present).