AVIAN PROGRAM
2018
WILDLIFE RESEARCH SUMMARIES

JANUARY – DECEMBER 2018

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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 current wildlife research projects conducted by the Avian Research Section of Colorado Parks and Wildlife (CPW) during 2018. These research projects are long-term projects (2–10 years) in various stages of completion, each of which addresses applied questions to benefit the management of various bird species and wildlife habitats in Colorado. More technical and detailed reports of most of these projects can be accessed from the project principal investigator listed at the beginning of each summary, or on the CPW website at http://cpw.state.co.us/learn/Pages/ResearchBirds.aspx and http://cpw.state.co.us/learn/Pages/ResearchHabitat.aspx.

Current research projects in the Section address various aspects of the ecology and management of wildlife populations and the habitats that support them, human-wildlife interactions, and new approaches to field methods in wildlife management. This report includes summaries of 16 current projects addressing management-related information needs for a variety of species of conservation concern and game species and their habitats. Also included in this report is a listing of publications, presentations, workshops and participation on various committees and working groups by Avian Research staff during 2018. 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, U.S. Fish and Wildlife Service, U.S. Geological Survey, City of Fort Collins, Colowyo Coal Company L.P., EnCana Corp, ExxonMobil/XTO Energy, Marathon Oil, WPX Energy, Rocky Mountain Bird Observatory, and the private landowners who have provided access for research projects.

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Colorado Division of Parks and Wildlife
January – December 2018

TABLE OF CONTENTS
AVIAN WILDLIFE RESEARCH REPORTS

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Survival of Translocated Gunnison Sage-grouse

Period Covered: January 1, 2018 – December 31, 2018

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Translocations of individuals from one local population to another have been used frequently to manage North American grouse species (Baxter et al. 2008, Bell 2011, Bouzat et al. 1998, Gruber-Hadden et al. 2016, Hoffman et al. 2015, Mathews et al. 2016, Musil et al. 1993, Snyder et al. 1999, Stonehouse et al. 2015), with varied results. For sage-grouse (*Centrocercus*. spp), many translocations have failed or lacked enough data for an evaluation, with only three of the 56 efforts examined considered successful (Reese and Connelly, 1997). Baxter et al. (2008) recommended tracking several metrics to evaluate the success of sage-grouse translocation including annual survival rates, distance moved from release site, nesting propensity, nest survival, chick survival, flocking, and attendance at leks. Translocations are considered successful, according to Baxter et al. (2008), when translocated individuals were indistinguishable from resident birds in behavior and their demographic rates were comparable to or greater than resident birds.

The Gunnison sage-grouse (GUSG) is a sagebrush (*Artemisia spp*.) obligate whose range is limited to southwestern Colorado and southeastern Utah. Historically, the species is thought to have inhabited ~ 46,500 km^2 of sagebrush habitat in Colorado, Utah, New Mexico, and Arizona (Schroeder et al., 2004). Land-use changes in sagebrush habitat have reduced the species to just 8% of its historic range (Braun et al., 2014; Schroeder et al., 2004), and the species is listed as threatened under the federal Endangered Species Act (U.S. Fish and Wildlife Service 2014). A large (85-90% of the remaining birds) and stable population persisits the Gunnison Basin of Colorado, which is surrounded by seven much smaller satellite populations in Colorado and Utah: Poncha Pass, Cerro Summit-Cimarron-Sims Mesa, Crawford, Dove Creek, Monticello, Piñon Mesa, and San Miguel (U.S. Fish and Wildlife Service 2014). Natural migration between populations is low (Oyler-McCance et al. 2005).

In response to declining population sizes and low genetic diversity in satellite populations, Colorado Parks and Wildlife (CPW) began translocating individuals from the Gunnison Basin to satellite populations in 2000. Field crews used spot-lighting techniques (Giesen et al. 1982, Wakkinen et al. 1992) to trap GUSG. Spring trapping occurred during mid-March through early-May, and fall trapping occurred during early September through mid-October. In most cases, translocated birds were marked with transmitters and tracked following release. Plumage characteristics were used to determine sex and age (Dalke et al. 1963, Beck et al. 1975); each GUSG was classified as either an adult (second or later breeding season), yearling (first breeding season if captured in the spring), or juvenile. Although a preliminary summary indicated that 12-month survival rates of translocated GUSG can vary by population, ranging between 20 and 60% (U.S. Fish and Wildlife Service 2014), a detailed analysis of survival rates of translocated GUSG has not been conducted.

Several previous studies provide survival rate estimates of GUSG in their native population (i.e., not translocated). Apa (2004) examined survival in all seven Colorado populations; survival appeared to vary between the populations, however the sample sizes were too small to make definitive comparisons among the populations. Stiver et al. (2008) estimated one year survival in the San Miguel population. Survival estimates for GUSG ranged between 0.45–0.71 for females and 0.27–0.51 for males (Apa 2004, Stiver et al. 2008). Davis et al. (2015) estimated average annual survival for females was 0.61 (SE 0.06) and for males was 0.39 (SE 0.08). The effect of age was not a relatively strong effect on survival. Model averaged estimates of monthly survival were nearly identical for female adults and yearlings, and slightly higher, especially during the lekking period, for yearling males compared to adult males, although confidence intervals overlapped considerably. On average, males had a lower annual survival probability than females, which is consistent with many previous studies on greater sage-grouse (Zablan et al. 2003).

We compiled telemetry and observation data for GUSG translocated from the GB to the Crawford, Dove Creek, Pinyon Mesa, Poncha Pass, and San Miguel satellite populations. We used the nest survival module in Program MARK (White and Burnham 1999) to obtain preliminary estimates of survival for birds up to one year after release. We considered the following independent variables: population, sex, age (juvenile, yearling, adult), and season of release (fall, spring), as well a season*age interaction. Because movement data suggest it takes about 75 days for newly released GUSG to exhibit activity and movement patterns similar to native individuals, we also examined whether survival differed between the first 75 days and the remainder of the first year following release. Because field biologists were unable to determine the sex and age of every bird, we considered unknown age and sex as separate factor levels in some models but also fit models in which we pooled unknown individuals with each age and sex class. Additionally, we pooled juveniles and yearlings to investigate whether differences existed in their survival rates. For fall-released juveniles, we fit models in which they transitioned into the yearling age class six months into the encounter history. We used Akaike's Information Criterion adjusted for small sample size (AIC_c, Akaike 1973, Hurvich and Tsai 1989) to find the model that best explained the data.

Our top performing survival model included the variables Population and 75days (Table 1). In each population, estimates of daily survival rate were slightly lower during the first 75 days after release than during the remainder of the first year post-release. Survival of translocated GUSG during the first year after release was estimated as 0.657 (95% confidence interval = 0.527–0.772) in Crawford, 0.626 (0.448–0.786) in Dove Creek, 0.567 (0.462–0.670) in San Miguel, 0.468 (0.355–0.576) in Pinyon Mesa, and 0.426 (0.261–0.603) in Poncha Pass. In 2019, we will finalize models and submit a manuscript for publication.

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Table 1. Model selection results for survival of translocated Gunnison sage-grouse.

Model	**AICc**	**Delta AICc**	**AICc Weights**	**Num. Par**	**Deviance**
Population + 75day	1062.43	0.00	0.13	6	1050.4292
Population + Age + 75day	1062.71	0.28	0.12	7	1048.7085
Population + Sex + 75day	1062.76	0.33	0.11	7	1048.7547
Population + Age + Sex + 75day	1062.81	0.38	0.11	8	1046.8038
Age + 75day	1063.83	1.40	0.07	3	1057.8324
Age + Sex + 75day	1064.16	1.73	0.06	4	1056.1571
Population + Season + 75day	1064.41	1.98	0.05	7	1050.4122
Population + Season + Age + 75day	1064.61	2.18	0.04	8	1048.6067
75day	1064.68	2.25	0.04	2	1060.6794
Population + Season + Sex + 75day	1064.76	2.33	0.04	8	1048.7534
Population + Season + Age + Sex + 75day	1064.76	2.33	0.04	9	1046.7543
Season + Age + 75day	1065.14	2.71	0.03	4	1057.1426
Sex + 75day	1065.23	2.80	0.03	3	1059.2259
Season + Age + Sex + 75day	1065.74	3.31	0.03	5	1055.7378
Season + 75day	1066.24	3.81	0.02	3	1060.2409
Population + 75day + Age*Season	1066.53	4.10	0.02	9	1048.5314
Population + Sex + 75day + Age*Season	1066.70	4.27	0.02	10	1046.6989
Season + Sex + 75day	1067.00	4.57	0.01	4	1059.0009
75day + Age*Season	1067.00	4.57	0.01	5	1057.004
Sex + 75day + Age*Season	1067.65	5.22	0.01	6	1055.6498
Population + Age + Sex	1076.66	14.23	0.00	7	1062.6571
Population + Sex	1076.99	14.56	0.00	6	1064.9915
Population + Age	1077.13	14.70	0.00	6	1065.1333
Population	1077.14	14.71	0.00	5	1067.141
Age + Sex	1078.40	15.97	0.00	3	1072.4026
Age	1078.56	16.13	0.00	2	1074.5563
Population + Season + Age + Sex	1078.58	16.15	0.00	8	1062.5746
Population + Season + Age	1078.97	16.54	0.00	7	1064.9727
Population + Season + Sex	1078.98	16.55	0.00	7	1064.9815
Population + Season	1079.10	16.67	0.00	6	1067.0979
Season + Age	1079.82	17.39	0.00	3	1073.8172
Null	1079.87	17.44	0.00	1	1077.874
Season + Age + Sex	1079.98	17.55	0.00	4	1071.983
Sex	1080.02	17.58	0.00	2	1076.015
Population + Sex +Age*Season	1080.44	18.01	0.00	9	1062.438
Population + Age*Season	1080.82	18.39	0.00	8	1064.8181
Season	1081.39	18.96	0.00	2	1077.3858
Age*Season	1081.58	19.15	0.00	4	1073.5793
Season+Sex	1081.78	19.35	0.00	3	1075.7811
Sex + Age*Season	1081.81	19.38	0.00	5	1071.8105

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Greater sage–grouse response to surface mine mitigation

Period Covered: January 1, 2018 – December 31, 2018

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EXTENDED ABSTRACT

The greater sage–grouse (*Centrocercus urophasianus*) (GRSG) is a species of conservation concern because of historical population declines and range contraction (Schroeder et al. 2004, Connelly and Knick 2011). Intensive and extensive energy development within sagebrush (*Artemisia spp.*) communities in the western United States has raised specific concerns because of evidence linking demographic impacts to GRSG from active natural gas development (Lyon and Anderson 2003, Holloran 2005, Aldridge and Boyce 2007, Walker et al. 2007, Holloran et al. 2010, 2015). As such, significant financial resources have been allocated researching and mitigating the impact of fluid mineral development on GRSG. In contrast, there has been little attention towards investigating the response of GRSG to other forms of mineral extraction such as surface coal mine development (Manier et al. 2013). Most knowledge about the surface mine impacts has been gained from observational studies (Raphael and Maurer 1990) that rarely employ an impact study design (Green 1979, Buehler and Percy 2012).

Since most research assessing surface mining impacts to wildlife focus on reclamation and mitigation efforts, and there is significant potential for direct negative impacts (Buehler and Percy 2012), there has been considerable emphasis by industry and federal and state agencies to avoid, minimize, and mitigate impacts of energy development on GRSG (CDOW 2008). The effectiveness of these costly mitigation efforts is largely unknown. Industry and agencies that manage and regulate minimg need a better understanding of the efficacy of mitigation efforts.

In June 2016, the Bureau of Land Management (BLM) and the Office of Surface Mining Reclamation and Enforcement (OSMRE) finalized the "Colowyo Coal Mine Collom Permit Expansion Area Project Federal Mining Plan and Lease Modification Final Environmental Assessment" (EA) (Little Collom Expansion EA; USDI 2016). The avoidance measures were primarily focused on one active GRSG strutting ground (SG–4) (CPW, unpublished data). The avoidance and minimization measures were based on a different type (e.g. more dispersed fluid minerals) of energy development because information is lacking on coal surface mine impacts and mitigation measures. Because of the potential impacts, minimization and mitigation requirements were implemented in an attempt to avoid and minimize impacts to SG–4 (USDI 2016).

Our research will evaluate the efficacy of GRSG mitigation (avoidance and minimization) efforts implemented in the Little Collom Mine Expansion EA (Alternative B). The results of our study will provide the first approach to assess the response of male GRSG to coal surface mining mitigation efforts and if they effectively and successfully conserve the SG–4 strutting ground and breeding and summer habitat. The advanced notice and spatial containment of mining activities provided an opportunity to implement a BACI design that yields a higher level of management action certainty than traditional observational studies (Ratti and Garton 1994, Garton et al. 2005). With more management action certainty, managers will be better informed in making future disturbance specific mitigation recommendations in the face of disturbances associated with surface mine development or similar anthropogenic disturbance. The mitigation efficacy results from this research will help industry, state, and federal wildlife and habitat managers to conserve GRSG.

Our study area is located in Moffat County, Colorado (Fig. 1). The Axial Basin (AB) is approximately 736.7 km^2 consisting of rolling topography ranging from 1,800–2,350 m in elevation. The mine project area (MPA) is located in the largest (northwest) of 6 GRSG populations in northwestern Colorado (Fig. 2).

We captured grouse from 17 March – 15 April 2018, and trapped on or near 11 strutting grounds in the Axial Basin and 2 in the Danforth Hills. We captured a total of 162 sage-grouse, including 54 adult and 25 yearling males and 50 adult and 33 yearling females. Adult and yearling male greater sage-grouse mass ($\bar{x}$ ± SE) was 2,837.5 ± 33.5 g (*n* = 56) and 2,651.3 ± 127.7 g (*n* = 25) and adult and yearling female was 1,572.5 ± 14.9 g (*n* = 49) and 1,431.0 ± 24.6 g (*n* = 33), respectively. We fit captured birds with predesignated transmitter sample size allocations (Table 1).

From March through September 2018, for VHF-marked sage-grouse, we documented mortalities of 30 adult males, 10 yearling males, 23 adult females, and 10 yearling females post-release. The mortalities resulted in a 7-month adult and yearling VHF-marked male apparent survival rate ($\hat{S}$ ± SE) of 0.26 ± 0.07 (*n* = 41; 95% CI 0.13 - 0.40) and 0.35 ± 0.12 (*n* = 16; 95% CI 0.13 - 0.58), respectively (Fig. 3). The adult and yearling female apparent survival rates were 0.53 ± 0.07 (*n* = 50; 95% CI 0.38 - 0.66) and 0.70 ± 0.08 (*n* = 34; 95% CI 0.51 - 0.82) (Fig. 4). The 7-months survival rate for GPS-marked adult and yearling males was 0.15 ± 0.10 (*n* = 13; 95% CI 0.25 - 0.39) (Fig. 5) and 0.29 ± 0.17 (*n* = 7; 95% CI 0.04 - 0.61), respectively (Fig. 6)

We documented 56 nests with 39 and 17 nests from adult and yearling females, respectively. Two renests were documented and neither was successful. Adult female nest and female success was 61.5% (*n* = 24/39) and 64.9% (*n* = 24/37), and yearling nest and female success was 58.8% (*n* = 10/17). The overall mean movement from lek of capture to nest ($\bar{x}$ ± SE) was 2,893.3 ± 393.7 m (*n* = 54; range 346.3-14,732.8) while the treatment and control areas were 3,308.5 ± 651.4 m (*n* = 27; range 346.3-14,732.8) and 2,478.0 ± 476.9 m (*n* = 27; range 475.8-13035.9), respectively. Due to the skewed nature of the frequency distribution (Fig. 7), the median and 25% and 75% quartiles provide a better representation of the movement from capture lek central tendency. The overall median (25% and 75% quartiles) was 1,593.1 m (*n* = 54; 817.7, 4,133.9) while the treatment median was 2,206.3 m (*n* = 27; 943.3, 4829.2) and the control was 1,369.7 m (*n* = 27; 738.4, 3,032.5).

We deployed 10 dataloggers on 10 strutting grounds (Figs. 8, 9). Datalogger deployment occurred between 4 March and 23 June 2018, and varied by strutting ground. This resulted an average ($\bar{x}$ ± SE) of 72.1 ± 5.2 (*n* = 10; range 43-91) days of transmitter detections resulting in approximately 46,000 transmitter detections. We discontinued datalogger use when there were five consecutive days with no transmitter detections at a site.

Based on our preliminary analyses of male and female strutting ground visitation detections, VHF-marked adult and yearling males were detected attending from one to six strutting grounds during the breeding season, with many males attending two strutting grounds (Fig. 10). In contrast, one female was not detected by any of the dataloggers deployed on strutting grounds while one female was detected attending six different strutting grounds (Fig. 10). Many females attended two to three strutting grounds during the breeding season (Fig. 10).

The attendance by time of day of attendance was similar among all strutting grounds, and we provide an attendance pattern example with one male and female on a strutting ground. During the months of March, April, and May, males attended the strutting ground (either roosting or displaying) from approximately 1800 hours in the evening through 0900 in the morning (Fig. 11). There was some individual variation in the attendance in the early-evening and late-morning in March and May (Fig. 11). Although the female had a similar pattern of attendance (2000 – 0500 hours), she only attended the strutting ground in April (Fig. 12).

Our datalogger results suggest that adult males attended at higher rates than yearling males and adult and yearling females (Fig. 13). Attendance rates in April were followed by adult females, yearling males and yearling females (Fig. 13). Similar results were found in March, May, and June (Fig. 13).

We also conducted a preliminary evaluation of attendance rates in treatment and control sites. It appears that attendance was higher in control sites by all VHF-marked GRSG in March, April, and May (Fig. 14). When we evaluated attendance by strutting ground at treatment or control study areas, we found that the control sites generally had higher attendance rates overall for males and females. (Fig. 15).

With the placement of trail cameras, we documented more vehicles/day in the treatment area during the April/May and May time frames. The trend was reversed in the May/June and July/August time frames (Fig. 16).

Male strutting ground counts continue to decline (Fig. 17) from historic high numbers documented in 2016. Some indication of this decline maybe a partial reason for our low adult and yearling male 7-month apparent survival estimates. Currently our 7-month survival estimate is marginally lower than previously documented annual survival in Colorado. Our estimate of female 7-month survival appears equal to previously documented 7-month survival in the Axial Basin study area. In contrast, nest success was equal to or exceeded previous estimates.

Our datalogger information is preliminary, but shows promise for more substantial results. It is apparent that males and females visit as many as six strutting grounds during the breeding season, but future analysis is needed. In addition, male attendance is a typical focus in the morning hours, but attendance is relatively consistent from dusk through the nocturnal hours as well. We continue summarizing and quality checking our datalogger data. We encountered several issues with domestic livestock causing damage to datalogger antennae. In response, we have exchanged the rigid antennae with whip antennae to alleviate future issues.

Our vehicle counts using trail cameras is somewhat confounding. Although counts per day were consistently recorded early in the season, the change of two sites from cameras to observers changed count consistency. Thus, we urge caution in interpreting these results. We continue to conduct data quality control on the 2018 dataset, and are also conducting quality control on the 2001-2008 dataset that will provide invaluable information on pre-mine and existing mine development.

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Table 1. Proposed sample sizes for male and female greater sage-grouse marked in the control, treatment (impact) lek complexes and the impact lek (SG-4) before and after treatment (impact) and the number of males counted on leks in 2016 in Moffat county, Colorado, 2017-2019.

		BEFORE		AFTER	
		Year 2018[1]	Mine Development	Year 2019[1]	Total[1]
Females					
Control					
	Lek Complex	40/0		40/0	**80/0**
Treatment					
	Lek Complex	25/0		25/0	**50/0**
	Impact Lek	15/0		15/0	**30/0**
Males					
Control					
	Lek Complex (254 males)	25/10		25/10	**50/20**
Treatment					
	Lek Complex (256 males)	15/5		15/5	**30/10**
	Impact Lek (42 males)	10/5		10/5	**20/10**

[1]VHF/GPS-PTT sample size

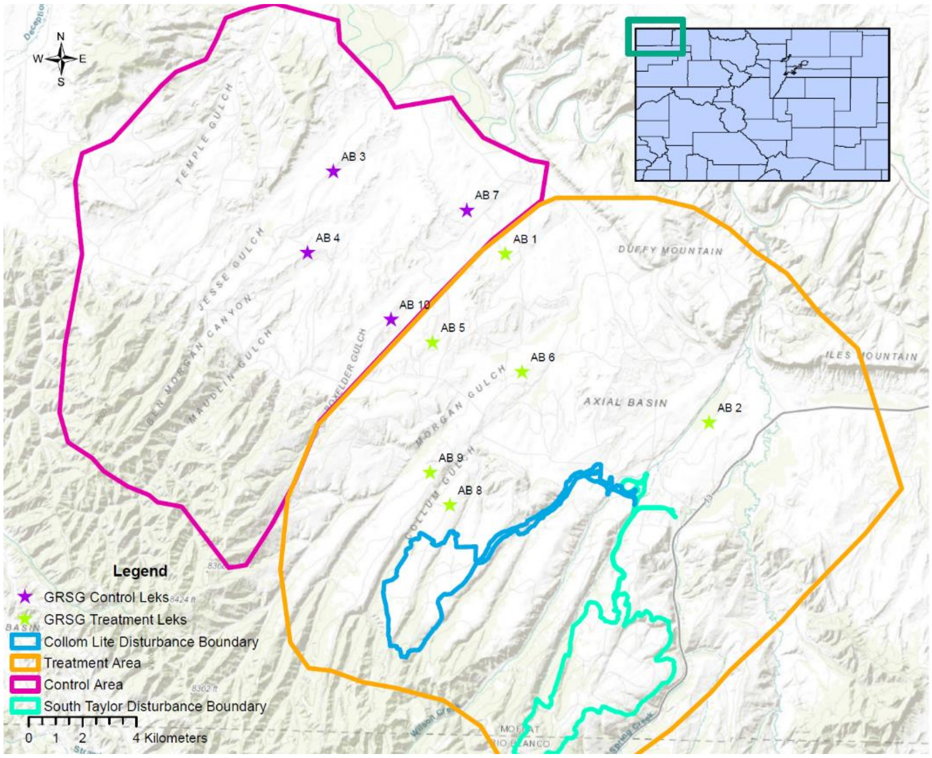

Figure 1. Study area location of treatment and control sites and greater sage-grouse strutting grounds in the Axial Basin area of Moffat County, Colorado.

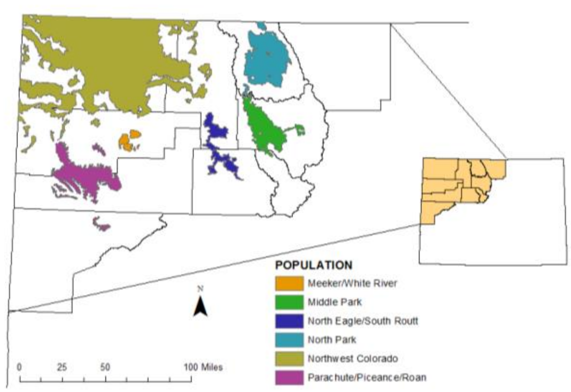

Figure 2. Greater sage-grouse populations identified by Colorado Parks and Wildlife (CDOW 2008) and county borders (black lines around populations) in northwestern Colorado.

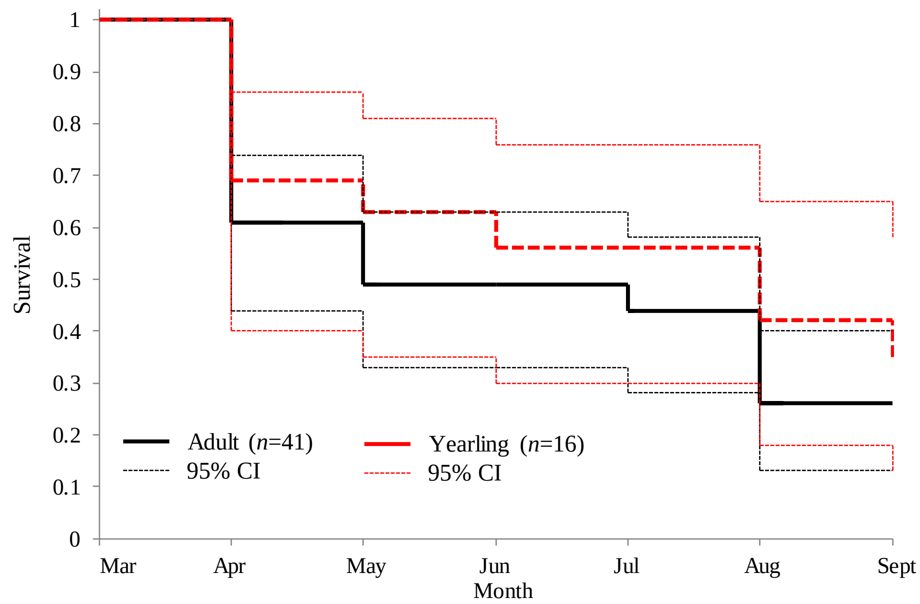

Figure 3. Kaplen-Meier product-limit monthly apparent survival rate with staggered entry for adult and yearling male greater sage-grouse from March-September in the Axial Basin of Moffat County Colorado, 2018.

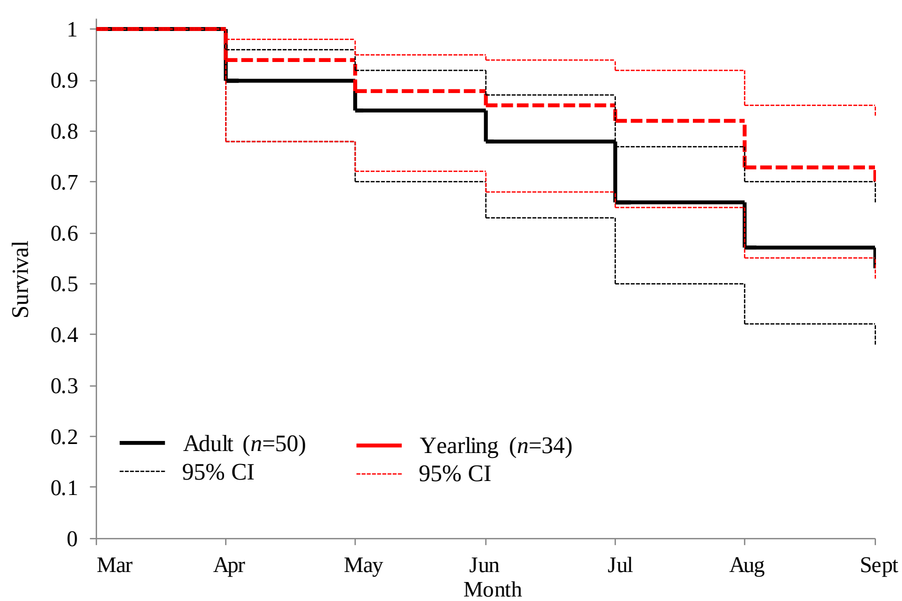

Figure 4. Kaplen-Meier product-limit monthly apparent survival rate with staggered entry for adult and yearling female greater sage-grouse from March-September in the Axial Basin of Moffat County Colorado, 2018.

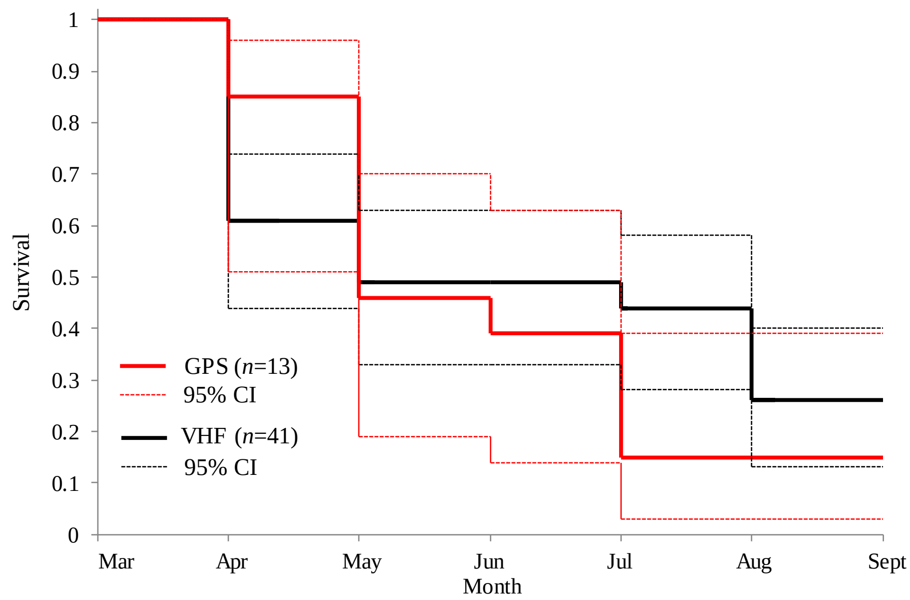

Figure 5. Kaplen-Meier product-limit monthly apparent survival rate with staggered entry for adult male greater sage-grouse marked with VHF or GPS/PTT rump-mounted transmitters from March-September in the Axial Basin of Moffat County Colorado, 2018.

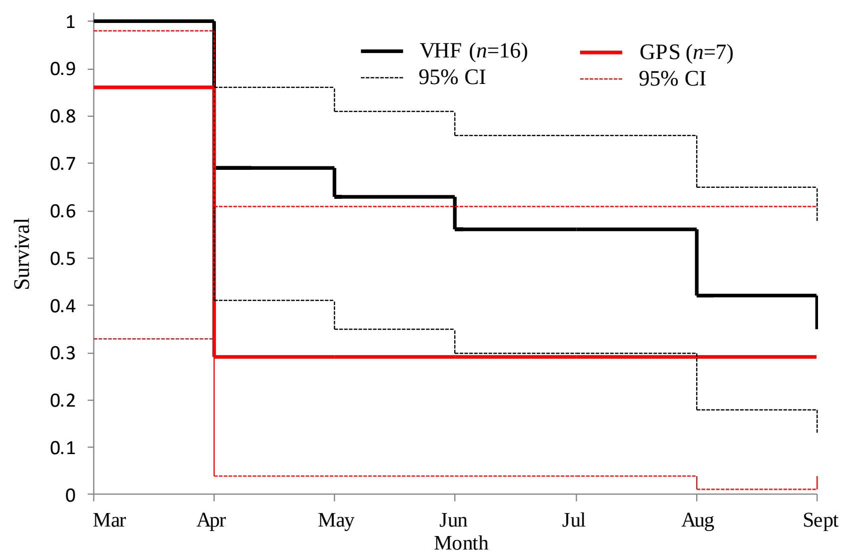

Figure 6. Kaplen-Meier product-limit monthly apparent survival rate with staggered entry for yearling male greater sage-grouse marked with VHF or GPS/PTT rump-mounted transmitters from March-September in the Axial Basin of Moffat County Colorado, 2018.

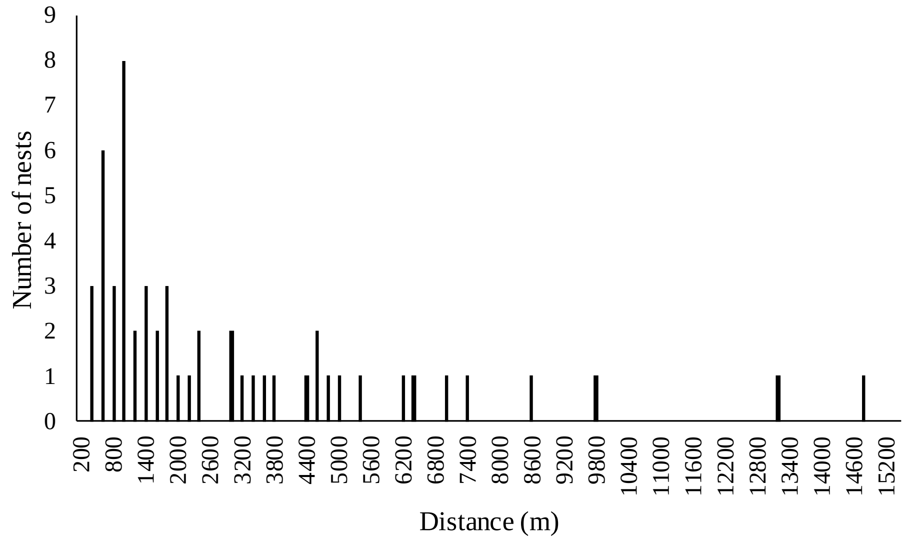

Figure 7. The distance moved by radio-marked female greater sage-grouse from the lek of capture to nest in the Axial Basin study area of Moffat County, Colorado, 2018.

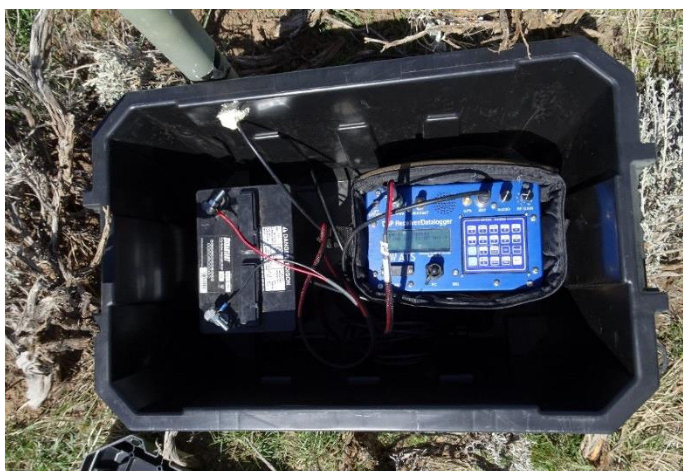

Figure 8. An Advanced Telemetry Systems datalogger connected to the 12-volt battery inside the waterproof box in the Axil Basin area of Moffat County, Colorado, 2018.

Figure 9. The datalogger setup in the waterproof box with the lid closed and camouflaged with sagebrush in the Axial Basin area of Moffat County, Colorado, 2018.

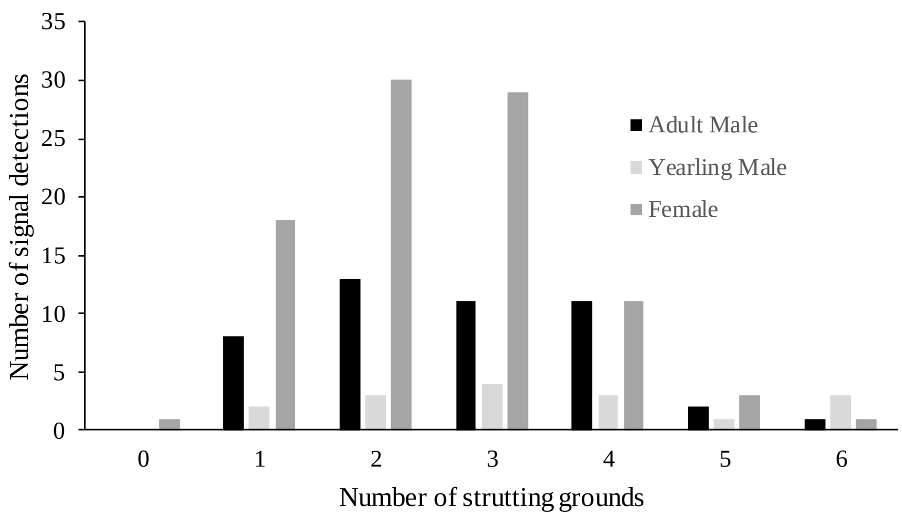

Figure 10. The number of individual VHF-marked yearling male, adult male, and female greater sage-grouse datalogger signal detections and the number of leks where those individuals were detected attending strutting grounds during the 2018 breeding season in the Axial Basin study area of Moffat County, Colorado.

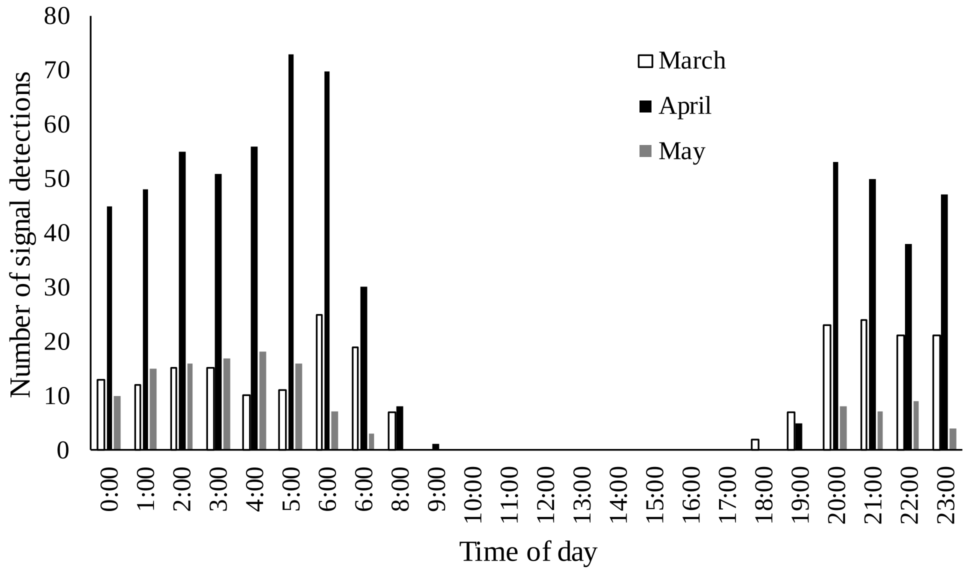

Figure 11. The number of datalogger signal detections of one VHF-marked male greater sage-grouse by time of day during the 2018 breeding season month on one strutting ground in the Axial Basin study area of Moffat County, Colorado.

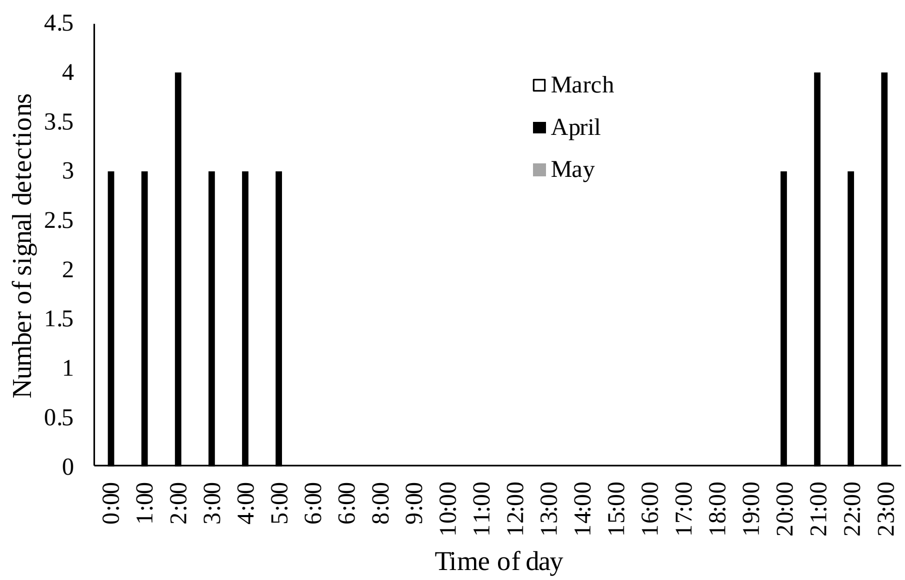

Figure 12. The number of datalogger signal detections of one VHF-marked female greater sage-grouse by time of day and breeding season month on one strutting ground during the 2018 breeding season in the Axial Basin study area of Moffat County, Colorado.

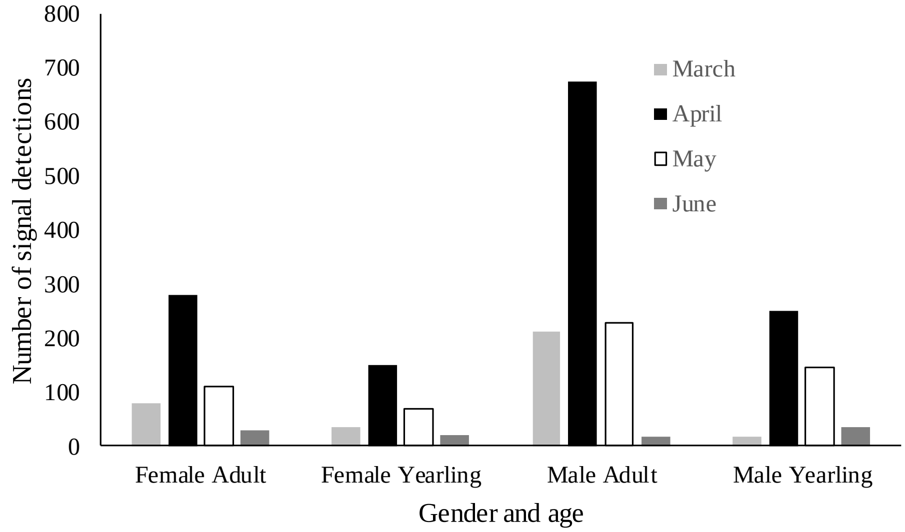

Figure 13. Number of daily datalogger signal detections of all VHF-marked greater sage-grouse by age and sex during the 2018 breeding season month in the Axial Basin study area in Moffat County Colorado.

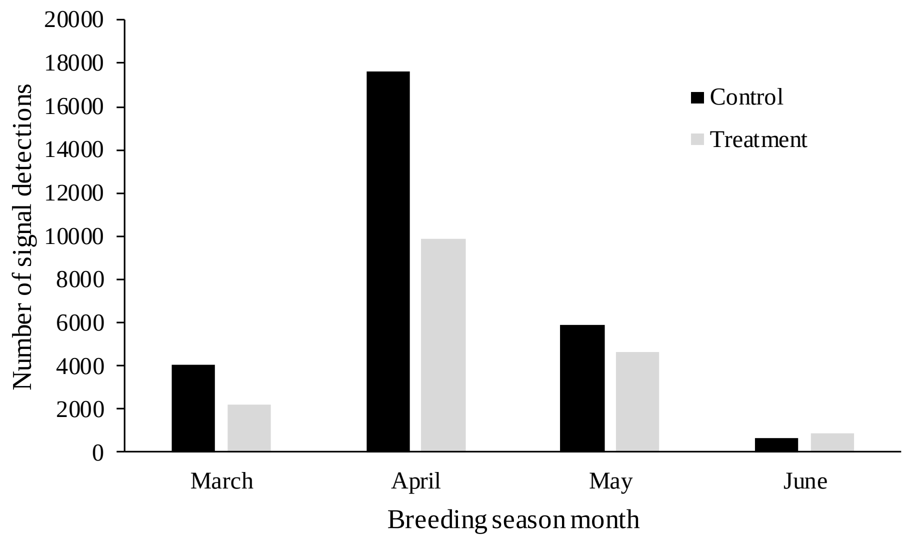

Figure 14. The total number of datalogger signal detections of all VHF-marked greater sage-grouse by month in treatment and control areas during the 2018 breeding season on 10 strutting grounds in the Axial Basin study area in Moffat County, Colorado.

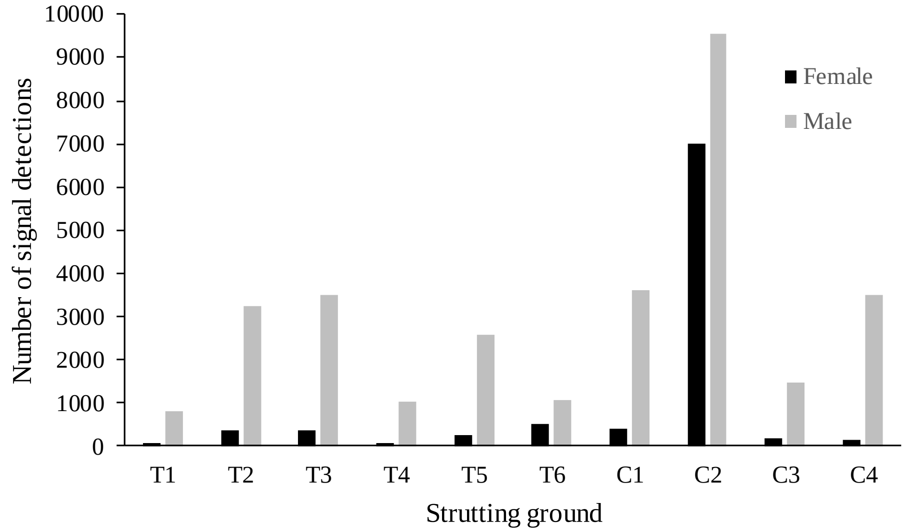

Figure 15. The total number of datalogger signal detections of VHF-marked male and female greater sage-grouse on 10 different strutting grounds (T=treatment, C=control) during the 2018 breeding season (March-June) in the Axial Basin study area in Moffat County, Colorado.

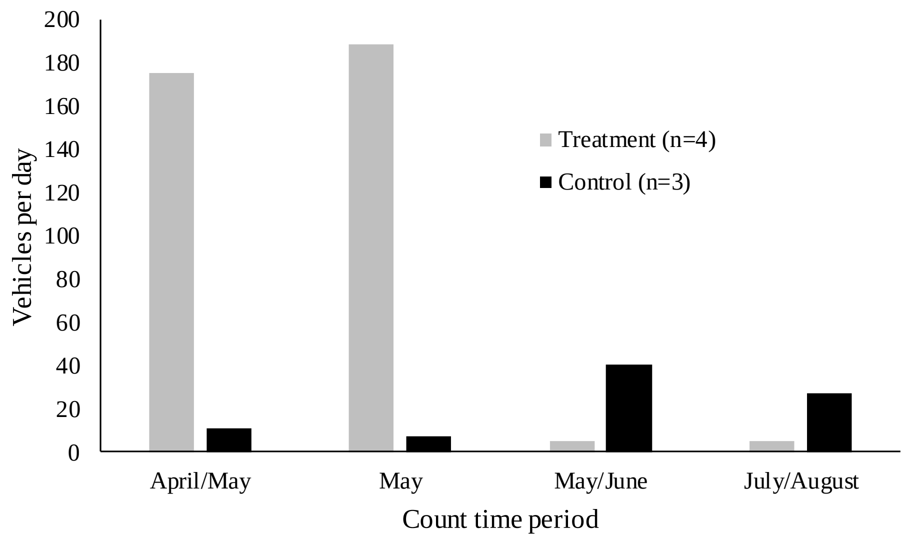

Figure 16. The number of vehicles per day detected by trail cameras or counted by observers on county or 2 track roads in treatment and control study areas during four sampling periods in the Axial Basin of Moffat County, Colorado, 2018. During the May/June and July/August observation periods, 2 trail camera sites in the treatment study area were discontinued and replaced by observers during briefer periods of time, thus influencing and reducing the total number of vehicles observed.

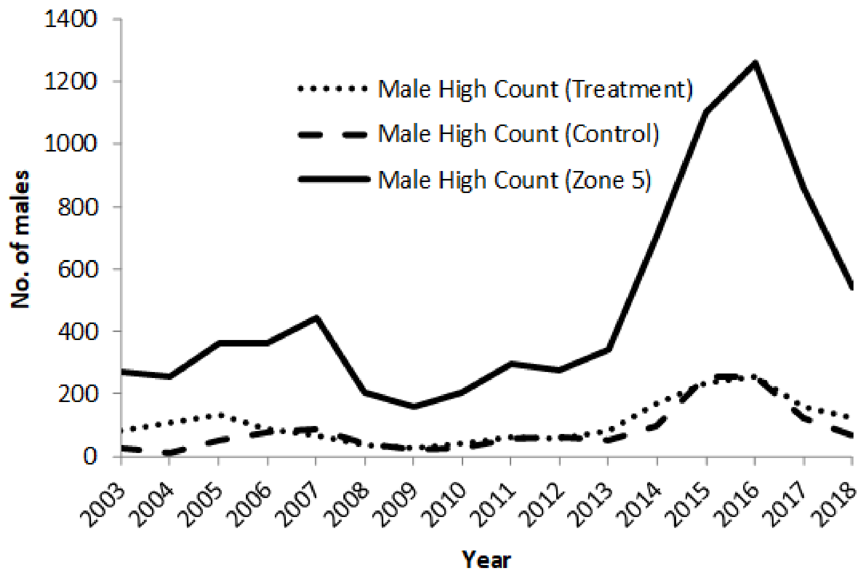

Figure 17. The male greater sage-grouse high count on strutting grounds in Population Management Zone 5, control area and treatment areas in the Axial Basin area of northwestern Colorado, 2003-2016.

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: January 1, 2018 – December 31, 2018

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.

ABSTRACT

Implementing effective monitoring and mitigation strategies is crucial for conserving populations of sensitive wildlife species. Concern over the status of greater sage-grouse (*Centrocercus urophasianus*) populations has increased both range-wide and in Colorado due to historical population declines, range contraction, continued loss and degradation of sagebrush habitat, and the potential for listing the species under the Endangered Species Act. Despite untested assumptions, lek-count data continue to be widely used as an index of abundance by state and federal agencies to monitor sage-grouse populations. Lek locations are also commonly used as a surrogate to identify and protect important sage-grouse habitat. However, the use of lek counts and lek locations to monitor and manage sage-grouse populations is controversial because how closely lek-count data track actual changes in male abundance from year to year and how effective lek buffers are at reducing disturbance to male sage-grouse and the habitat they use during the breeding season are largely unknown. We deployed solar-powered GPS satellite transmitters on male greater sage-grouse to obtain data on male survival, lek attendance, inter-lek movements, and diurnal and nocturnal habitat use around leks and conducted double-observer lek counts to estimate detectability of males on leks during the breeding season in and around the Hiawatha Regional Energy Development project area in northwestern Colorado in spring from 2011-2014. In conjunction with Jessica Shyvers and Jon Runge, I developed a multi-state model to simultaneously estimate daily survival, lek attendance, and inter-lek movement rates of males during the breeding season and will use an unreconciled double-observer approach to estimate detectability of males attending leks. I will then use estimates of male survival, detectability of males on leks, lek attendance, inter-lek movement, and the proportion of leks known and counted during the breeding season to generate simulated lek-count data from simulated male populations to evaluate the reliability of current lek-based methods for monitoring population trends. I am using local convex hull (t-Locoh) and Brownian bridge movement models to identify space use in relation to known leks to evaluate the performance of lek buffers for conserving important greater sage-grouse seasonal habitats. Analyses for this project are ongoing. I anticipate submitting publications on male space use, detectability, lek attendance, and inter-lek movements in 2019, and a publication on lek-count reliability in 2020.

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: January 1, 2018 – December 31, 2018

Principal Investigators: Brett L. Walker brett.walker@state.co.us, and Jessica S. Shyvers (Colorado State University)

Project Collaborators: Brian Holmes, Brad Petch, Bill deVergie, J. T. Romatzke, CPW; Barry Noon, Colorado State University

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ABSTRACT

Robust estimates of population size and population trends provide the scientific basis for managers to make appropriate recommendations regarding land-use, harvest regulations, and mitigation efforts for wildlife. When linked with environmental variables, robust monitoring programs also allow managers to examine wildlife responses to various stressors. However, many wildlife monitoring programs use population indices that may or may not meet assumptions required to accurately estimate population abundance or trends. For this reason, it is essential to evaluate alternative approaches to population monitoring. Lek counts are the primary index used by state wildlife agencies to monitor changes in greater sage-grouse (*Centrocercus urophasianus*) abundance over time, but they rely on untested assumptions about lek attendance, detectability, inter-lek movement, sex ratio, and proportion of leks counted. Given new methodological and statistical approaches to estimate abundance, it is worth comparing the performance of current lek-count approaches against other potential methods. Dual-frame sampling of leks and non-invasive genetic mark-recapture analyses based on winter fecal pellet sampling are two promising alternatives for estimating sage-grouse populations. The purpose of this study was to evaluate and compare the reliability and efficiency of dual-frame lek surveys, genetic mark-recapture, and standard lek counts for estimating population size and sex ratio in the Parachute-Piceance-Roan (PPR) population in northwest Colorado. Field data collection for this project finished in May 2014. Jessica Shyvers completed her dissertation in July 2017. We published the dual-frame lek survey manuscript in the Journal of Wildlife Management in August 2018. We submitted the genetic mark-recapture (GMR) analysis to Ibis in October 2018, received peer review comments back, and are currently revising the manuscript. We will submit the sex ratio paper to the journal Condor: Ornithological Applications in January 2019. This is the final annual report for this project.

Manuscripts:

Shyvers, J. E., B. L. Walker, and B. R. Noon. In prep. Estimating winter sex ratio and flock composition of greater sage-grouse (*Centrocercus urophasianus*) from non-invasive genetic mark-recapture analysis of fecal pellets in western Colorado. Condor: Ornithological Applications.

Shyvers, J. E., B. L. Walker, and B. R. Noon. In revision. Noninvasive genetic mark-recapture analysis to estimate pre-breeding population size of greater sage-grouse (*Centrocercus urophasianus*). Ibis.

Shyvers, J. E., B. L. Walker, and B. R. Noon. 2018. Dual-frame lek surveys for estimating sage-grouse populations. Journal of Wildlife Management. DOI: 10.1002/jwmg.2154.

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: January 1, 2018 – December 31, 2018

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

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

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ABSTRACT

Effective monitoring and mitigation strategies are crucial for conserving populations of sensitive wildlife species. Concern over the status of greater sage-grouse (*Centrocercus urophasianus*) populations has increased range-wide and in Colorado due to historical population declines, range contraction, continued loss and degradation of sagebrush habitat, and the potential for listing the species under the Endangered Species Act. Despite untested assumptions, lek-count data continue to be widely used as an index of abundance by state and federal agencies to monitor sage-grouse populations. Lek locations are also commonly used as a surrogate to identify and protect important sage-grouse habitat. However, the use of lek counts and lek locations to monitor populations is controversial because how closely lek-count data track actual changes in male abundance from year to year has never been tested. It is also unknown how effective lek buffers are at reducing disturbance to male sage-grouse and the habitats they use in each season. We deployed solar-powered GPS satellite transmitters on male greater sage-grouse to obtain data on male survival, lek attendance, inter-lek movements, and diurnal and nocturnal habitat use around leks and conducted double-observer lek counts to estimate detectability of males on leks during the breeding season in the Parachute-Piceance-Roan population in northwestern Colorado in spring from 2012-2016. I originally planned to use estimates of male survival, detectability of males on leks, lek attendance, inter-lek movement, and the proportion of leks known and counted during the breeding season to generate lek-count data from simulated male populations to evaluate the reliability of current lek-based methods for monitoring population trends. In conjunction with Jessica Shyvers and Jon Runge, I developed a multi-state model to simultaneously estimate daily survival, lek attendance, and inter-lek movement rates of males during the breeding season. That analysis is in progress with Jessica Shyvers as a collaborator. I anticipate submitting a publication on GPS male survival, lek attendance, and inter-lek movement in 2019. I am using local convex hull (t-Locoh) and Brownian bridge movement models to estimate space use in relation to leks to evaluate the performance of lek buffers for conserving important greater sage-grouse seasonal habitats. Male space use analyses are still in progress, and I anticipate submitting a publication in 2019.

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: January 1, 2018 – December 31, 2018

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

Project Collaborators: B. Holmes, B. Petch, T. Knowles, B. deVergie; H. Sauls and E. Hollowed (BLM-WRFO)

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ABSTRACT

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

within plots, which suggests substantial background variation in the no. of pellets deposited within suitable habitat. Sage-grouse response to pinyon-juniper removal (as measured by pellet surveys) also appeared to be inconsistent in the PPR, with pellet counts clearly increasing on only 2 of 8 treated plots within 4-5 years post-treatment. Analyses for this project are still in progress. A recent experimental pilot project conducted by Conoco-Phillips, with assistance from CPW, suggests that sage-grouse may respond more strongly to both pinyon-juniper and serviceberry removal. However, a proposal to expand that pilot study into a large-scale research project investigating pinyon-juniper and/or serviceberry treatments is on hold until access issues are resolved.

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Comparing survival of greater sage-grouse with VHF and GPS transmitters in northwestern Colorado and southwestern Wyoming

Period Covered: January 1, 2018 – December 31, 2018

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

Project Collaborators: B. Holmes, B. Petch, B. deVergie

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.

ABSTRACT

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

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

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

Period Covered: January 1, 2018 – December 31, 2018

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

Project Collaborators: B. Holmes, B. Petch, B. deVergie

ABSTRACT

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

modeling of seasonal habitat. I plan to use two datasets of seasonal locations collected from GPS-marked females in 2009-2013 and GPS-marked males in 2012-2016 to conduct additional RSF analyses to assess habitat selection all three seasons in relation to vegetation cover, topography, and energy infrastructure to complement models based on VHF data. For objective 4, we found that historical and recent energy development within the HREDP were largely coincident (i.e., spatially correlated), so it would be impossible to distinguish the effects of historic vs. recent development on current habitat selection. So, to better assess the effect of historical well pads on likelihood of use by GRSG, we measured micro-site vegetation on abandoned and reclaimed well pads in summer 2010 for comparison against vegetation measured around well pads and around nests and wintering locations. Analyses for objectives 1-3 are ongoing and should be submitted for publication in 2019, analyses for objective 4 will be completed after those for other, higher priority projects.

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Seasonal Habitat Mapping in the Parachute-Piceance-Roan Region of Western Colorado

Period Covered: January 1, 2018 – December 31, 2018

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

Project Collaborators: B. Holmes, D. Finley, S. Duckett, B. Petch, B. deVergie, J. T. Romatzke

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.

ABSTRACT

Large-scale changes to sagebrush habitats throughout western North America have led to growing concern for conservation of greater sage-grouse (*Centrocercus urophasianus*) and repeated petitions to list the species under the Endangered Species Act. Greater sage-grouse in the Parachute-Piceance-Roan (PPR) region of western Colorado face two major conservation issues: a long-term decline in habitat suitability associated with pinyon-juniper (PJ) encroachment, and potential impacts from rapidly increasing energy development. In 2006, Colorado Parks and Wildlife (CPW) and industry partners initiated a 3-year study to obtain baseline data on greater sage-grouse in the PPR. Using those data, we published validated multi-scale, season-specific, resource selection function (RSF) models for the PPR based on vegetation cover and topography (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). The second phase of the habitat selection study included examining the effects of energy infrastructure. To meet that second objective, I mapped annual changes in four major components of energy infrastructure (well pads, facilities, pipelines, and roads) as well as other landscape changes (e.g., habitat treatments, fires) from 2005-2015. I completed the infrastructure and landscape change mapping in 2017. Because of widespread interest in quantifying (and predicting) land cover changes associated with energy development for management agencies, I first plan to submit a paper describing a decade of infrastructure change within the PPR population. An additional higher-resolution dataset of seasonal locations collected from GPS-marked males in 2012-2016 as part of another project also became available and will be incorporated to help assess male and night-time seasonal habitat selection in relation to energy infrastructure. We encountered problems with GIS analysis that caused a major delay in generating landscape metrics for used and available locations and we were required to make additional revisions and corrections to used and available data following discovery of minor errors in telemetry datasets. I received all final revised landscape metrics for used and available locations from the GIS section in December 2018 and am now building used-available datasets and generating R code to run analyses testing seasonal habitat selection responses to different components of energy infrastructure. The analysis and manuscript will be completed and submitted for publication in 2019.

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Restoring habitat with super-absorbent polymer

Period Covered: January 1, 2018 – December 31, 2018

Author: Danielle Bilyeu Johnston danielle.bilyeu@state.co.us

Principal Investigators: Danielle Bilyeu Johnston, Cynthia Brown and Magda Garbowski, Colorado State University; Murphy Jacox, CPW

Project Collaborators: Murphy Jacox (Property Technician, Dry Creek Basin State Wildlife Area), Renzo Delpiccolo (Area Wildlife Manager)

EXTENDED ABSTRACT

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 (SAP) may buffer seeded species against negative impacts of precipitation fluctuations. In a prior CPW study, incorporating SAP into the soil at the time of seeding was found to reduce cheatgrass cover by up to 50% initially, and effects persisted for four years.

Because SAP acts on existing soil moisture, its 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 that have contrasting precipitation patterns: a Colorado Eastern Slope site (Waverly Ranch, Larimer County), and a Colorado Western Slope site (Dry Creek Basin State Wildlife Area, San Miguel County). We quantify how SAP influences soil moisture through time at these locations, and how drought, cheatgrass presence, and SAP interact to influence plant community development.

Experiments were implemented in fall 2013 at the Eastern Slope site and summer 2014 at the Western Slope site (Figure 1), and responses were measured until 2017. In 2018, we have been preparing two manuscripts. The first is focused on seedling density, aboveground biomass, and belowground biomass, with an emphasis on the effects of SAP (abstract below).

> *Manuscript Abstract* (in preparation for *Restoration Ecology*): In the western United States, successful aridland restoration is often constrained by drought and invasion by *Bromus tectorum*. By increasing the water-holding capacity of soil and decreasing soil resource variability, superabsorbent polymers (SAP) may ameliorate the negative impacts of drought and *B. tectorum* on native species establishment. We

> established a full-factorial study to investigate the interactive effects of drought (66% reduction of ambient rainfall), *B. tectorum* seeding (BRTE, 465 seeds m^{-2}) and SAP (25 g m^{-2} incorporated into soil) on initial plant establishment and three-year above- and belowground biomass and allocation in restored plant communities at two sites in Colorado, one each on the Eastern and Western slopes. We observed an increase of over 100% in first-year seeded species establishment with SAP under ambient precipitation conditions (77.3 ± 104.1 plants m^{-2}) versus other treatments (range: 13.7 9 – 23.2 plants m^{-2}) at the Eastern Slope Site (Figure 2a). However, no SAP effects on seeded species biomass were detectable three years post-treatment (Figure 2b). Precipitation, BRTE, and SAP treatments interacted to influence all components of biomass as well as the root mass fraction, but results varied by site. Notably, at the Eastern Slope Site, negative effects of drought on belowground biomass seemed to be exacerbated by SAP resulting in lower root biomass in drought plots with SAP (61.66 ± 7.26 g m^{-2}) than in all other treatments (range: 83.67 – 91.56 g m^{-2}; Figure 3a). As SAP can interact with environmental variables to impact developing plant communities in both positive and negative ways they should be used with caution in aridland restoration.

In 2019 we will submit this manuscript for publication, and also prepare and submit manuscript containing percent vegetation cover data, with an emphasis on effects of drought and cheatgrass at contrasting sites.

Figure 1. Rainfall exclusion shelters induce artificial drought at the Western Slope site in 2014.

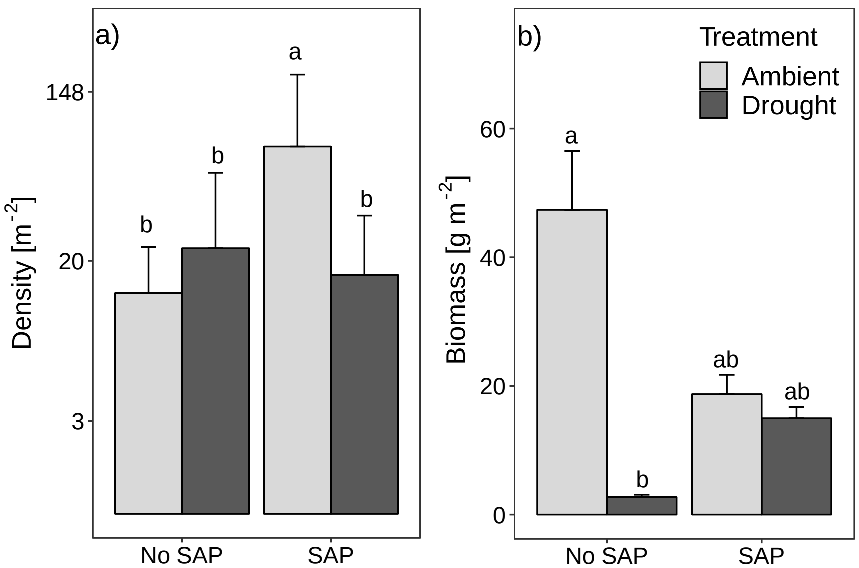


Figure 2: Eastern Slope Site a) 2014 seeded species seedling densities (log scale) and b) 2016 seeded species biomass under precipitation and super-absorbent polymer (SAP) treatments. Bars represent a) density and b) biomass means averaged over B. tectorum treatments. Error bars are standard error of the mean. Means with different lowercase letters above bars denote differences between treatments at the α = 0.05 level.

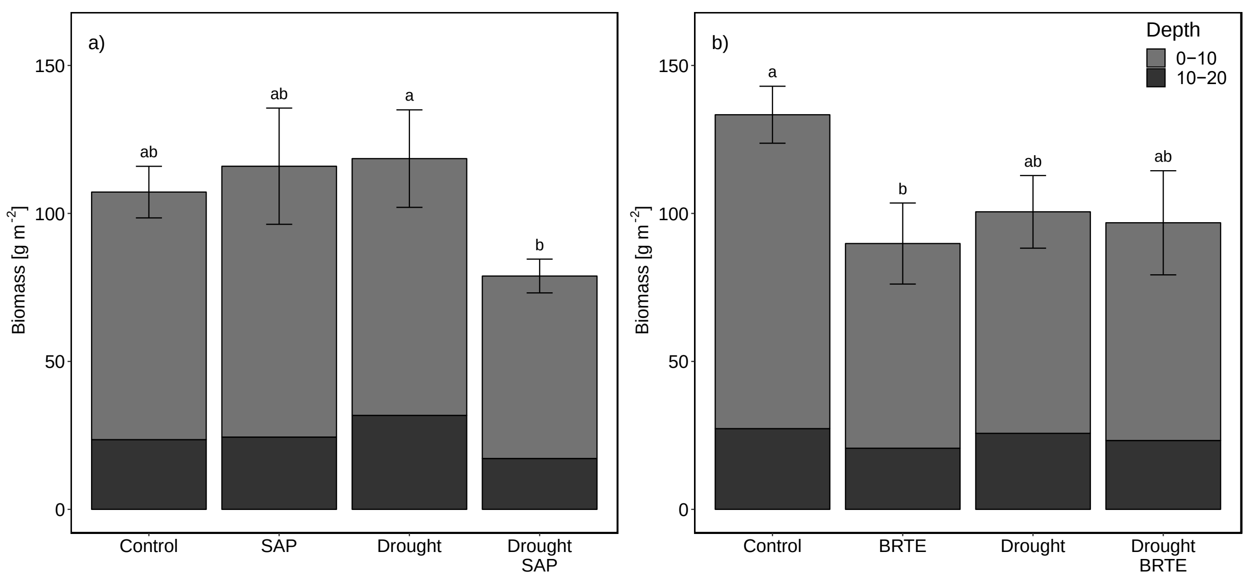


Figure 3: Eastern Slope Site 2016 belowground biomass under a) precipitation and super-absorbent polymer (SAP) treatments averaged over B. tectorum (BRTE) treatments and b) drought and BRTE treatments averaged over SAP treatments. Dark gray areas correspond to shallow (0-10cm) root biomass and light gray corresponds to deep (10-20cm) root biomass. Error bars are standard error of the mean for total belowground biomass. Means with different letters are statistically different at the α = 0.05 level.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Evaluating spatial patterns and processes of avian and mammalian wildlife populations

Period Covered: January 1, 2018 – December 31, 2018

Principal Investigator: Kevin Aagaard kevin.aagaard@state.co.us

Project Collaborators: Tony Apa, Trevor Balzer, Lance Carpenter, Reesa Conrey, Stephanie Durno, Darby Finley, Jim Gammonley, Dan Neubaum, Amy Seglund (CPW); Mindy Rice, Lief Weichmann (USFWS), Cameron Aldridge, Julie Heinrichs, Mike O'Donnell, Sara Oyler-McCance (USGS)

EXTENDED ABSTRACT

Evaluating wildlife location data provides substantial information for management. Location data reveal patterns of movement dynamics, species distribution (habitat suitability), and varying habitat use. Understanding these patterns and dynamics is critical for managing endangered and harvested species. Colorado Parks and Wildlife monitors myriad species of concern for conservation and hunting and thus needs to develop thorough and up-to-date assessments of the spatial patterns and processes of high-priority wildlife species. In collaboration with state wildlife biologists, avian researchers, big game managers, and federal counterparts, I have assisted in evaluating spatial data for several species and populations. Below, I list the active projects I am associated with, and briefly detail the objectives and current status of each.

- **Colorado Bat Distribution Model (with D. Neubaum)** – We compiled expected distribution models and range maps for 13 species of Colorado-resident bats species using location data of radio-tagged bats. A stated goal is to generate baseline expectations for bat distributions for comparative use in the event that white-nose syndrome (*Pseudogymnoascus destructans*) expands its range into Colorado. At present, distribution models have been created for each species (see Figure 1 for example, below). Future objectives include evaluating likely species movement corridors using landscape movement models.

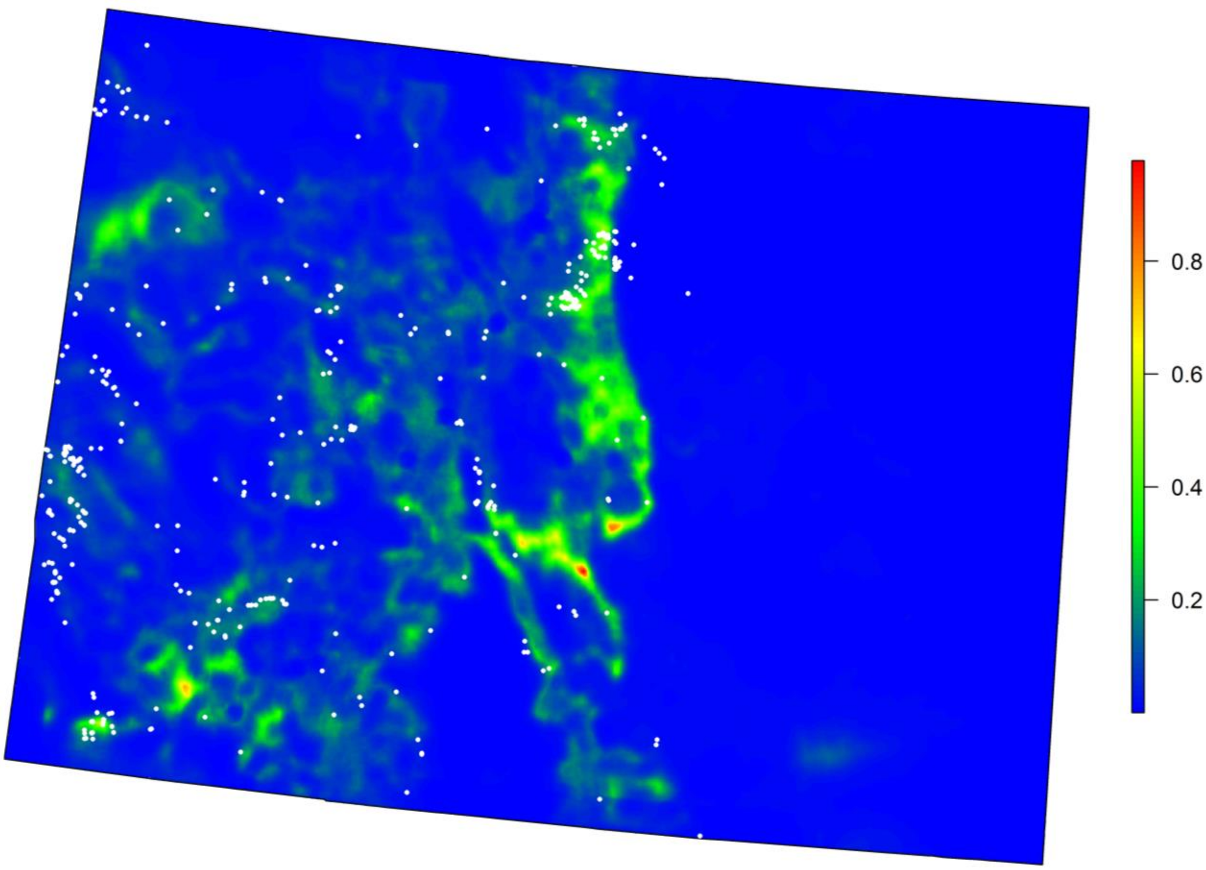


Figure 1. Example bat distribution model for long-legged myotis (*Myotis volans*). Warm (red) colors represent likely suitable habitat; cool (blue) colors represent unlikely suitable habitat. White points represent observed locations.

- **Mountain Goat Distribution Model (with L. Carpenter)** – Our focus is on mountain goat (*Oreamnos americanus*) populations in and around Mount Evans. The stated objectives are to determine differences in winter and summer habitat use, evaluate movement patterns of individuals, and to compare contemporary to historical habitat use patterns. We have completed distribution models for summer and winter seasons (Figure 2 A and B), and have analyzed estimated home-ranges for individuals tagged in the study (see Figure 3 for example).

  We are now working to compare results to historical distributions. We are using literature-derived location data for comparison. We are attempting to elicit the data from the author.

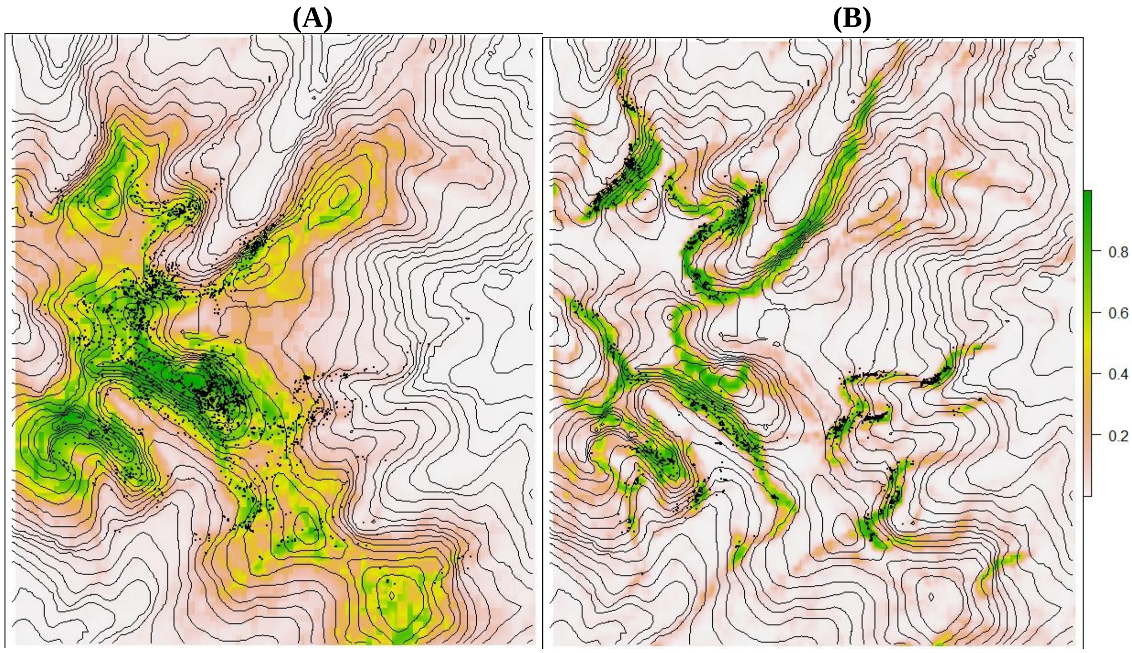
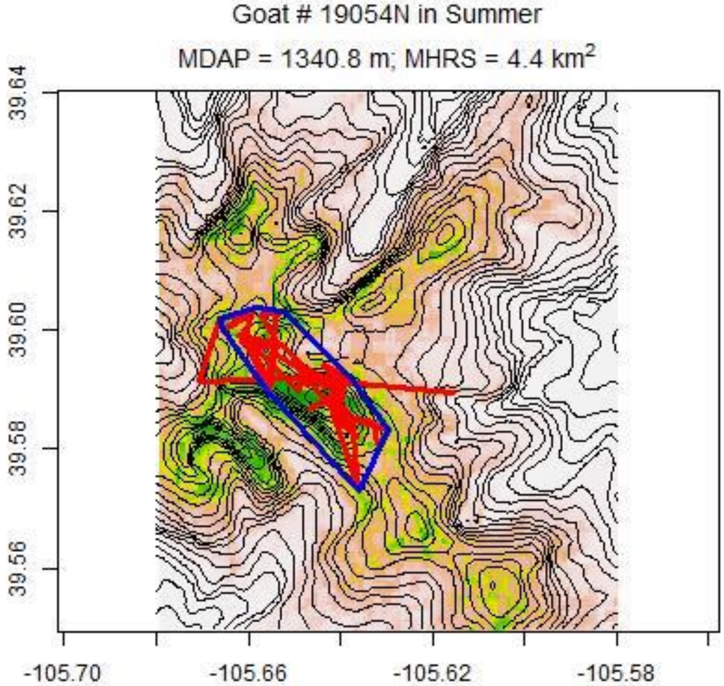


Figure 2. Expected summer (A) and winter (B) distribution models for Mt. Evans mountain goats. Elevation contours are provided for context. Green represents area of likely suitable habitat; white represents areas of unlikely suitable habitat. Black dots represent observed locations.


Goat # 19054N in Summer
MDAP = 1340.8 m; MHRS = 4.4 km2
39.64
39.62
39.60
39.58
39.56
-105.70
-105.66
-105.62
-105.58

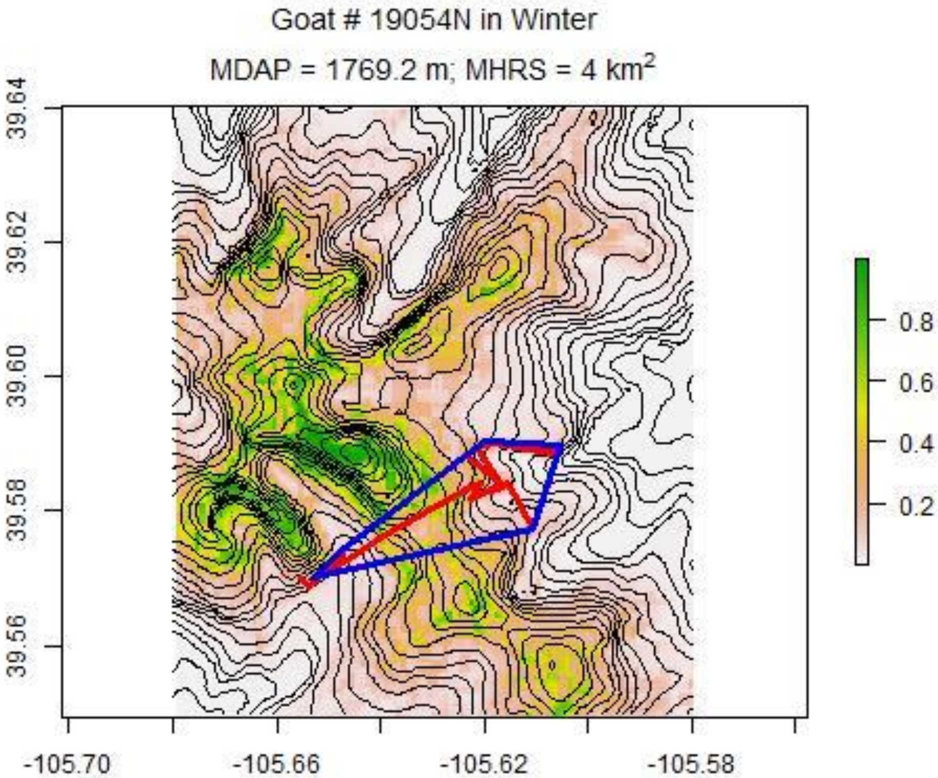

Goat # 19054N in Winter
MDAP = 1769.2 m; MHRS = 4 km2
39.64
39.62
39.60
39.58
39.56
-105.70
-105.66
-105.62
-105.58
0.8
0.6
0.4
0.2

Figure 3. Movement path and expected home range for Individual 19054N in the summer (top) and winter (bottom), both plotted over the predicted habitat suitability for the full year, with elevation contours. MDAP = Mean Distance Across Polygon; MHRS = Mean Home Range Size.

- **Raptor Nesting Distribution Model (with R. Conrey and J. Gammonley) --** We used nesting location data to assess suitable nesting habitat for four raptor species in Colorado (golden eagle, bald eagle, prairie falcon, ferruginous hawk). These data come from the CPW SDE SAM Raptor Nesting database. There are 29,317 recorded nest observations in the database, 11,535 of which are for our focal species, and 3,522 (of 1,396 unique nests) of which are from observations of occupied nests in the last 10 years.

  We used landscape layers relating to land cover classes (linear distance to water features, linear distance to cliffs/bluffs/rocky outcrops, herbaceous grassland, cottonwood, mixed forest, shrubland/scrub-steppe grassland, riverine/riparian, cultivated areas, developed areas, and linear distance to roads), topography (elevation, local elevational difference, and topographic ruggedness index [TRI]), and temperature (degree-days above 5°C). We also included layers that indicate prairie dog range and prairie dog colonies for black-tailed prairie dogs, Gunnison's prairie dogs, and white-tailed prairie dogs.

  We supply the predicted use surface for each species, wherein white areas are more suitable locations (i.e., Pr[use] ~ 1) and black areas are less suitable locations (i.e., Pr[use] ~ 0) in Figure 4.

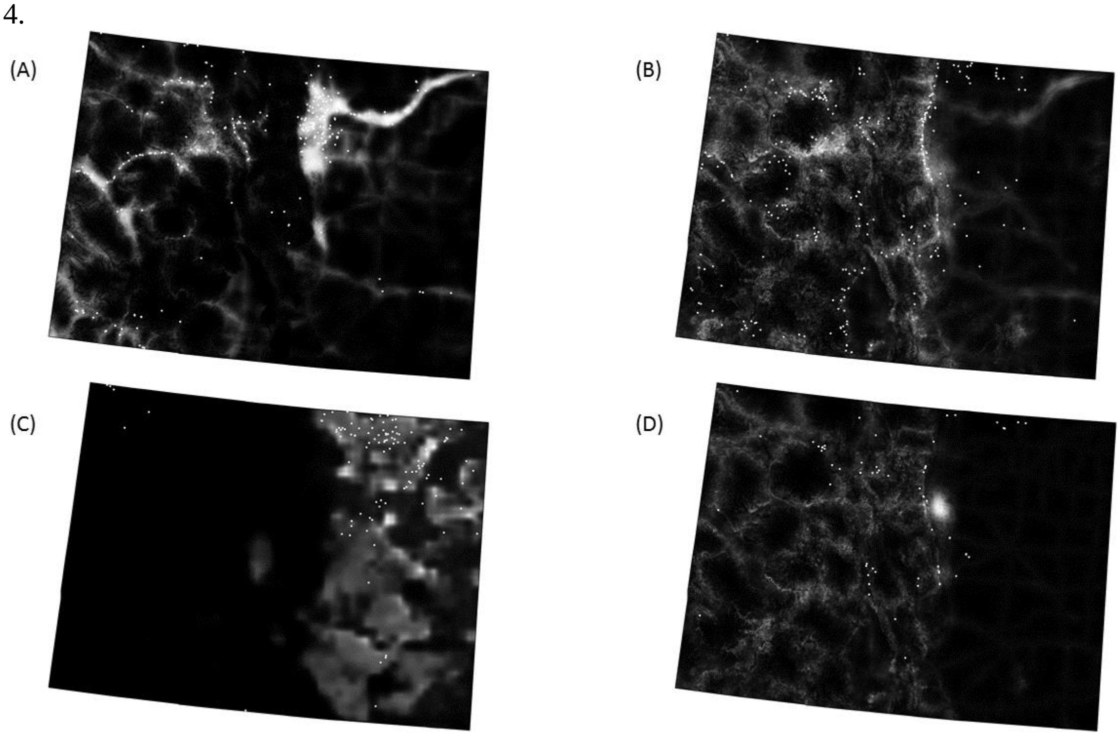


Figure 4. Expected suitable nesting habitat for (A) bald eagle; (B) golden eagle; (C) ferruginous hawk; and (D) prairie falcon in Colorado. White represents likely suitable habitat, black represents unlikely suitable habitat. White points represent observed nest locations.

- **White-tailed Ptarmigan Habitat Use and Movement Models (with A. Seglund)** – To evaluate habitat use of white-tailed ptarmigan habitat use throughout Colorado, we used observed location data and landscape layers relating to elevation, temperature, precipitation, topographic ruggedness (or, terrain roughness), land-cover/land-use type (mixed tundra, meadow tundra, prostrate shrub tundra, bare ground tundra, exposed rock, shrub dominated wetland/riparian, graminoid/forb dominated wetland, and mesic/upland shrub; all taken from Colorado GAP). We used these layers because they were from pertinent time scales relative to when the observed data were collected, and because we sought to optimize the resolution of our input layers to capture the scale of habitat use demonstrated by the ptarmigan. We used 3,379 locations of white-tailed ptarmigan. There were 2,950 locations in the summer and 429 locations in the winter. For the contemporary (CO-GAP) data, in both populations and across both season, the posterior credible interval estimates for all covariates included 0, and thus we cannot say any particular covariate served as a significant predictor of white-tailed ptarmigan occurrence. Similarly, for the forecasted (USGS EROS) data, in both populations and across both season, the posterior credible interval estimates for all covariates included 0.

- **Gunnison Sage-grouse Habitat-use Model (with T. Apa, L. Wiechman [USFWS], M. Rice [USFWS], J. Heinrichs [USGS], M. O'Donnell [USGS], C. Aldridge [USGS], S. Oyler-McCance [USGS])** – We are working with members of the U. S. Fish and Wildlife Service and U. S. Geological Survey to develop management-focused habitat-use models (resource selection function, RSF) for Gunnison sage-grouse (*Centrocercus minimus*) populations. We have developed the landscape habitat covariate layers for use in the RSF and have developed the distributional models. We are working with area biologists and wildlife managers to identify which covariates in certain contexts (populations and seasons) are the most useful from a management perspective.

- **Big-game Data Analysis (with D. Finley and T. Balzer)** – This is an on-going effort to model movement patterns of some big-game species (e.g., mule deer, *Odocoileus hemionus*; elk, *Cervus canadensis*) within Colorado. We plan to use Brownian-bridge movement models to evaluate movement corridors for Colorado big-game species. Preliminary data analysis is underway to generate a work flow to create the models.

- **Grand Mesa Moose Habitat Suitability Model (with S. Durno) –** We used moose telemetry data to assess suitable habitat in and around the Grand Valley in Colorado (DAU M5). There are 21,603 recorded locations in the dataset. We restrict the modeled landscape to only that area outside of elk and mule deer winter range. This yielded a dataset of 21,563 moose locations. We used landscape layers relating to land cover classes (agriculture, alpine tundra, grassland, montane shrubland, montane woodland, pinyon-juniper woodland, riparian/wetland/water, rock/disturbed soil, semi-desert shrubland, subalpine forest meadow, and urban areas; digitized 1993-1997 from Landsat Thematic Mapper imagery, ground-truthed 2000-2004) and topography (elevation and topographic ruggedness index [TRI]). To account for potential longitudinal bias we included a variable related to the easting value to account for eastward or westward preference; we refer to this as the longitudinal index.

  Moose showed weak association with the selected covariates, suggesting that they behave as generalists in this habitat. We present the predicted probability of use surface in Figure 5. The best performing model contained land cover types related to the percent cover-per pixel of: agriculture, grassland, montane shrubland, montane woodland forest, pinyon-juniper woodland, semi-desert shrubland, urban; it contained the topographic features elevation and TRI; and it contained a longitudinal index. In the case of both elevation and longitudinal index the 95% credible intervals (CI) overlapped 0, indicating a lack of statistical significance. The adjusted-R^2 value was 0.411, and no other model had a BIC score within five units.

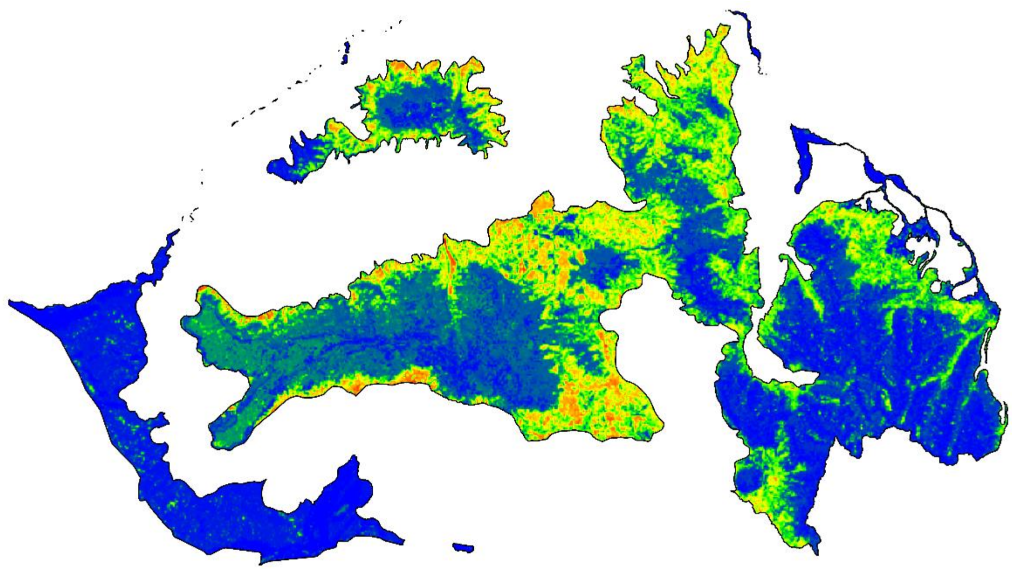


Figure 5. Predicted surface using the best performing model. Blue indicates low probability of use, red indicates high probability of use.

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Avian response to plague management on Colorado prairie dog colonies

Period Covered: January 1 – December 31, 2018

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

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

EXTENDED ABSTRACT

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

Here we briefly summarize research activities during 2013-2018 on both BTPD and GUPD sites and describe plans for the upcoming final year (2019) of this phase of research. We provided detailed results in previous years' annual reports, and will provide full summaries after the conclusion of the 2019 field season. However, more detailed results and site-specific bird, plant, and mammalian species lists are available to partners who request them. Research is ongoing, so all results should be considered preliminary.

Data collection over six years has included avian point counts; summer and winter raptor surveys; burrowing owl surveys and nest monitoring; monitoring of all raptor nests located opportunistically; remote camera data targeting mammalian carnivores; and percent ground cover, visual obstruction, and species composition of vegetation at points, nests, and along randomly located transects. In prior years, we also monitored passerine nests and surveyed for mountain plover (*Charadrius montanus*). From 2013 through 2018, we have completed approximately 3700 point counts, 1800 30-min. raptor surveys, and 600 vegetation transects (~13 stops/transect); monitored 700 bird nests; and collected 3 million photos from remote cameras.

Study areas include BTPD colonies in north-central Colorado and GUPD colonies in western and central Colorado. BTPD study colonies are dominated by short and mid-grasses (especially blue grama *Bouteloua gracilis* and buffalograss *B. dactyloides*) and located in Larimer and Weld counties adjacent to the Wyoming border, managed by the City of Fort Collins. GUPD study colonies are dominated by sagebrush (especially big sagebrush *Artemisia tridentata*) mixed with other shrubs and grasses and located in the Gunnison Basin (Gunnison County), northwest Saguache County, Woodland Park area (Teller County), South Park (Park County), and Baca National Wildlife Refuge (Saguache County). GUPD sites are managed by the Bureau of Land Management, U.S. Forest Service, National Park Service, U.S. Fish and Wildlife Service, and CPW. Study sites were grazed by cattle (and sheep in Baca NWR) and native grazers, especially prairie dogs, pronghorn (*Antilocapra americana*), jackrabbits (*Lepus* sp.), and cottontails (*Sylvilagus* sp.).

Over a 3-year period starting in fall 2013, plague epizootics occurred over ~75-80% of the BTPD study area. Some colonies, particularly those receiving dust or vaccine, have had increasing prairie dog numbers since initially declining during the peak of the epizootic, while others, especially untreated areas, have continued at severely reduced acreage (Tripp et al. 2017). Precipitation has varied greatly over the six years of this study, from slightly dry to very wet, compared to the 30-year average. This plague cycle began during a dry period but peaked during two wet years. In contrast, we observed very little plague activity (two small colonies) at GUPD sites until the 2017 field season, when epizootics began at several colonies. The 2018 season was our first opportunity to collect data on post-plague communities on GUPD colonies.

To summarize the planned phases of this research project:

- Phase 1 (2013-2015) featured active vaccine research (vaccine, insecticide, and placebo treatments) by CPW Wildlife Health, and plague epizootics across much of the BTPD site but almost *no* plague at GUPD sites. We did extensive avian field work at BTPD sites, on and off GUPD colonies, nest searching at all sites, and deployed cameras to record mammalian activity.
- Phase 1.5 (2016) featured the early use of plague vaccine as a management tool for CPW. Plague continued at some BTPD colonies. Because we could not address all of ourresearch goals at GUPD sites without plague, we discontinued avian work in Woodland Park and Gunnison Basin. We started work on GUPD colonies (extant and extirpated) in South Park, ahead of planned GUPD reintroductions (which subsequently were not completed).
- Phase 2 (2017-2019) features broader plague management by CPW Species Conservation at all our GUPD sites and some BTPD sites. Plague epizootics began in some GUPD sites in Woodland Park, Gunnison Basin, and then Baca NWR (new site in 2017), so we resumed on-colony (but not off-colony) work at GUPD sites. BTPD sites began a post-epizootic growth cycle.
- Phase 3 (2020-?) will feature less intensive, longer-term monitoring (e.g., point counts) of avian species associated with prairie dogs at sites with varying levels of plague management. This may eventually involve more external collaborations with partners at unmanaged sites.

At BTPD colonies, we detected more Brewer's blackbirds (*Euphagus cyanocephalus*), vesper sparrows (*Pooecetes gramineus*), and horned larks (*Eremophila alpestris*) during point counts in active colonies, and more grasshopper sparrows (*Ammodramus savannarum*) and lark buntings (*Calamospiza melanocorys*) in colonies impacted by plague (which intersected with wet years). Grasses were taller and plant cover generally higher following epizootics, which likely contributed to higher densities of species that prefer taller vegetation structure and lower densities of those that prefer shorter stature vegetation. In both summer and winter raptor counts, during which we recorded time spent within colonies, ferruginous hawks showed the strongest preference for foraging on active vs. post-plague colonies, with a use rate six times higher on active colonies. American kestrels (*Falco sparverius*) and golden eagles (*Aquila* *chrysaetos*) had use rates 2 – 4 times higher on active colonies. In contrast, burrowing owls, which are known to be associated with BTPD colonies (e.g., Butts & Lewis 1982, Tipton et al. 2008) and were by far the most commonly detected raptor in our summer surveys, had use rates ~2.5 times higher on post-plague colonies. Although seemingly counterintuitive, this confirms results from Conrey (2010), who found high densities of burrowing owls nesting on post-plague colonies where small numbers of BTPD occurred. Across raptor species, the pattern of higher use of active vs. post-plague colonies was stronger in winter than in summer. We plan additional analyses of bird data, with the inclusion of covariates related to colony characteristics, weather, vegetation, and for raptors, alternative prey such as lagomorphs.

Badgers and coyotes had 20-30% lower usage of BTPD colonies following plague events. Swift fox showed the opposite pattern, but prairie dog activity had a weaker effect on fox occupancy, and this species may be responding more strongly to coyotes, which prey upon swift fox (Kamler et al. 2003, Karki et al. 2006). Occupancy models containing prairie dog activity had 99.9% of model weight for coyotes and badgers and 82.7% for swift fox. Detection rates for all three species were higher when more cameras were deployed and during August-April, compared to May-July. Coyotes and badgers appear to respond negatively to plague in prairie dogs, which dramatically reduces abundance of an important prey item. Future analyses of camera data will incorporate additional years of data and more covariates and may include multi-species models (allowing coyote-fox interaction) and relative abundance models.

A new aspect of the camera work in 2018 included field tests of the new Reconyx professional series camera against the older model that CPW has used for many years. The Reconyx HyperFire 2 Professional Covert IR (HP2X) camera has replaced the PC800 HyperFire Professional IR camera, which is no longer available. Both Avian and Mammals Research now own both models, and it was important to know how to mix (or not) the two camera models when designing field studies. Our preliminary results suggest that even with "legacy" settings (for motion sensitivity and infrared range) intended to make the two models perform similarly, the new cameras always perform better, achieving more detections for all species (especially small-bodied species). Taking BTPD as an example, during one 3-week interval, the old model got 30 photos, the new model with legacy settings got 87 photos, and the new model with optimum settings got 145 photos. Recognizing that camera model will need to be added as a covariate on detection probability regardless, it makes sense to use the new model with optimum settings, mixing them carefully and proportionally with the old model cameras so that results remain unbiased (i.e., don't use all old cameras in Treatment A and new cameras in Treatment B).

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

Collaborations and Products

CPW is involved in several collaborations related to this research. Bird Conservancy of the Rockies began collecting data at our BTPD site in 2006 and is sharing these data, with a goal of analyzing point count data over two full plague and recovery cycles over 13+ years. We have collaborated on point count data collection since 2013. David Augustine (USDA Agricultural Research Service) has provided bird and vegetation transect data on and off GUPD and WTPD colonies that were collected by Bruce Baker (emeritus, USGS Fort Collins Science Center). These data may be useful in expanding inference of species associations with GUPD colonies. D. Augustine, Ana Davidson (Colorado Natural Heritage Program), and possibly others in future may also collaborate on questions related to mesocarnivore use of prairie dog colonies using remote camera data. Tangential to this research, R. Conrey is serving on the graduate committee of M.S. student Tyler Michels at the University of Colorado Denver. He is working with Dr. Mike Wunder on habitat use (via GPS tags) of mountain plover breeding on the Pawnee National Grassland and a multi-species occupancy analysis of mountain plover, burrowing owl, and swift fox. Finally, we have contributed photos and participated in discussions of collaborative efforts that aim to develop machine learning tools for species identification in photo ID (along with CPW Mammals Research, CPW Species Conservation, and outside organizations such as USDA APHIS and American Museum of Natural History).

Expected products over the next several years include manuscripts related to avian and mammalian carnivore species associated with prairie dog colonies:

1) We will work with Bird Conservancy of the Rockies to analyze grassland bird densities at our BTPD site over two plague and recovery cycles (13+ years).
2) We have three years of avian point counts, raptor surveys, and vegetation transects on and off GUPD colonies that might be combined with B. Baker's data to examine associations with GUPD colonies, which are less well-understood than those with BTPD.
3) We will estimate the relationship of grassland bird nest survival to plague, climate, and other variables.
4) We will run more complex occupancy models for mammalian carnivores associated with colonies, expanding upon the results for active and plague-affected colonies presented here.
5) We will examine raptor use of active and plague-affected BTPD and GUPD colonies.
6) Additional possibilities for analysis include comparisons of vegetation height and ground cover across active and plague-affected colonies, along with weather and land management variables. In addition, remote camera data contain information about the relationship of other species with prairie dogs, including lagomorphs and pronghorn, which could be explored.

Two products from 2018 include a short publication in the America's Grasslands Conference proceedings, and a time lapse video showcasing diverse wildlife at a prairie dog burrow (posted publicly January 2019):

- Conrey, R. Y., D. W. Tripp, E. N. Youngberg, and A. O. Panjabi. 2018. Bird and mammalian carnivore response to plague in prairie dog colonies. Pages 48-50 *in* Knuffman, L., ed. America's Grasslands Conference: United for Conservation. Proceedings of the 4th Biennial Conference on the Conservation of America's Grasslands. November 14-16, 2017, Fort Worth, TX. Washington, DC: National Wildlife Federation.
- https://www.youtube.com/watch?v=CpJYrZ2MMJk
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Tipton, H. C., V. J. Dreitz, and P. F. Doherty, Jr. 2008. Occupancy of mountain plover and burrowing owl in Colorado. Journal of Wildlife Management 72:1001–1006.

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

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

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Raptor data integration, species distribution, and suggestions for monitoring

Period Covered: January 1 – December 31, 2018

Authors**:** Reesa Yale Conrey reesa.conrey@state.co.us, and Kevin Aagaard kevin.aagaard@state.co.us

Principle Investigators: R. Yale Conrey, K. Aagaard, J. Gammonley, CPW; J. DeCoste*, W. Kendall, Colorado Cooperative Fish & Wildlife Research Unit (*currently, City of Boulder Parks and Recreation)

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

EXTENDED ABSTRACT

Raptor monitoring databases have generated important insights into various aspects of raptor ecology and can provide a sound foundation for management of individual species or within the larger context of managing targeted habitats (Greenwood 2007). CPW has a statewide raptor nest database developed by R. Sacco (GIS Unit), which currently contains records for > 9,700 nest locations of 30 species 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 consultation process (Colorado 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. We hope to generate a comprehensive picture of raptor distribution across the state and illustrate how a better structured statewide survey could provide a more concrete understanding of raptor population trends for management purposes.

We are focusing on breeding populations of four species: bald eagles (*Haliaeetus leucocephalus*: BAEA), golden eagles (*Aquila chrysaetos*: GOEA), ferruginous hawks (*Buteo regalis*: FEHA), and prairie falcons (*Falco mexicanus*: PRFA). 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. BAEA are a species of management concern due to the recent attention to nest take, contention over regulations, and their tendency to nest in areas with rapidly accelerating housing development. Consultation on these species is mandated by HB 1298.

Research objectives are to: 1) Assess and improve the data available in CPW's raptor nest database; 2) Estimate nest survival for bald eagles, evaluating the importance of ecological and anthropogenic

covariates, and offering a comparison of distribution vs. productivity objectives; 3) Build distribution models for our highest priority raptor species, evaluating the importance of ecological and anthropogenic covariates and identifying priority areas for future surveys; 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. Most of the nest data have been collected opportunistically, and known nest sites are resurveyed at a 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, 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. More detailed information (e.g., biweekly observations) is available for some nests.

The CPW raptor nest database contained nest records for 9717 locations of 28 (most recently occupying) raptor species, as of 8 January 2019 (Table 1). (Two additional species, American crow and Mississippi kite are not currently reported because the crow nest sites have since been occupied by other species, and the kite nest has not been occupied within the past 5 years). This included 1846 active nests known to be occupied within the past 5 years. The majority of nest locations (6300 nests, 65% of the total) have an unknown or undetermined status. In general, diurnal species are better represented than nocturnal species (owls), and those with nests in taller structures (e.g., trees, cliffs) are better represented than ground-nesters. There are 12 species with at least 100 nest records in the database: bald eagle, burrowing owl, Cooper's hawk, ferruginous hawk, golden eagle, great horned owl, northern goshawk, osprey, peregrine falcon, prairie falcon, red-tailed hawk, and Swainson's hawk. In contrast, there are eight species (American crow, boreal owl, Chihuahuan raven, eastern screech-owl, merlin, Mexican spotted owl, Mississippi kite, and northern pygmy-owl) with just 1 – 2 records in the database and one species (short-eared owl) known to breed in Colorado but with no records in the database. Twenty-six percent of records are 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 27% increase (2342 nests) over the first 3 years. Although 409 new nest locations were added in the past 11 months since the last query, the proportion of nests with undetermined or unknown status also increased from 64 – 65%.

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. Our bald eagle nest survival model currently has an input file containing 163 nest attempts at 86 locations from 2012−2016; 54 nest sites are on the Front Range and 32 are on the Western Slope. An additional 179 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. Preliminary results suggest daily nest survival is best modeled by nest stage, maximum temperature in June, and time in season. Other covariates for land cover, roads, distance to water, monthly precipitation, location (Front Range vs. elsewhere), and year were not supported. We did not have enough data from nest observers to properly analyze the effects of nest substrate (live tree, dead tree, or other) or disturbance (traffic, recreation, etc.).

Results for BAEA will be finalized and nest success estimates available after we complete quality contol on the input data. Extra effort is required in the field and in follow-up data management to get information that will produce productivity estimates versus distribution estimates. First, nest survival models require more intensive survey data than do distribution models, because at least two (but these estimates would have poor precision), and frequently more visits are required. 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 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. In addition, observers must note the presence of eggs, nestlings, or fledglings, or at least make careful observations of adult behavior that can reveal nest activity (e.g., incubation, bringing food to the nest, etc.). Instead of just one record per year, there are multiple records to enter and proof, and productivity observations may need to be added as a separate data type in the database.

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 statewide species assessment, mitigation planning, and future survey design. During this phase of the project, we have evaluated the potential for presence-only data, collected opportunistically over several decades for other purposes, to be used for distribution modelling. The sample of known nests used in these models included all occupied nests (during years when occupancy was confirmed) between 2008–2018. Of the 1,396 recorded nests there were 699 for bald eagle, 459 for golden eagle, 133 for ferruginous hawk, and 105 for prairie falcon. We ran generalized linear mixed models (GLMMs) for each species using *R2jags* in R, comparing used locations to a sample of available locations statewide. We used landscape layers relating to land cover classes (linear distance to water features, linear distance to cliffs/bluffs/rocky outcrops, herbaceous grassland, cottonwood, mixed forest, shrubland/scrub-steppe grassland, riverine/riparian, cultivated areas, developed areas, and linear distance to roads), topography (elevation, local elevational difference, and topographic ruggedness index [TRI]), and temperature (degree-days above 5°C). We also included layers that indicate prairie dog range and prairie dog colonies for black-tailed prairie dogs, Gunnison's prairie dogs, and white-tailed prairie dogs. Many of these layers were used in the construction of golden eagle nesting habitat suitability model for Wyoming (for the Western Golden Eagle Team, Collopy et al. 2017).

The maps of breeding habitat distribution (Figure 1) that resulted from the GLMM revealed some commonalities among species, with the most distinct result occurring for a grassland species, the ferruginous hawk. Bald eagle, golden eagle, and prairie falcon distribution were all influenced by terrain roughness: a negative predictor for bald eagle and a positive predictor for golden eagle and prairie falcon. Terrain roughness index was among the most important covariates in our candidate set for golden eagle and prairie falcon, and both species also showed a positive association with shrub-scrub cover. The resulting distribution maps for these two species, which often nest on cliffs or bluffs in open terrain, are fairly similar (Figure 1B and 1D). Cultivated land cover was also an important predictor of raptor use: negative for prairie falcon and positive for the other three species. Herbaceous grassland was a positive predictor of golden eagle, prairie falcon, and ferruginous hawk distribution but not of bald eagle distribution. Bald eagle distribution was also influenced by water and cottonwood cover, with most nests occurring along the Platte, Colorado, and Yampa Rivers, and smaller numbers of nests (and probability of predicted nest occurrence) along other rivers and reservoirs (Figure 1A).

The current dataset with opportunistic sampling also supported a positive relationship with roads and developed land cover (urban and suburban areas) for all species except ferruginous hawk (Figure 1). An overlay of known nests, predicted distribution, and roads showed considerable overlap, which highlights the potential benefits of a future sampling approach to surveys, rather than relying exclusively on opportunistic sampling with associated roads bias. The distribution maps for eagles and prairie falcon showed hot spots along Colorado's Front Range (Figure 1), a rapidly developing area that is an interface between mountains and plains, and longitudinal index was the strongest predictor of bald eagle distribution in our candidate set.

The model predicted relatively low probability of use for nesting bald eagle, golden eagle, and prairie falcon, with only a few hot spots for nesting across Colorado (Figure 1A, B, D). We expect to get better discernment in future, with more nest data and the inclusion of points where nests were *not* detected (the current model uses presence-only data). In contrast, the model predicted a relatively high probability of use for ferruginous hawk across the entire eastern plains (Figure 1C), with fewer predictors compared to the other three species. Ferruginous hawk use was positively related to herbaceous grassland, cultivated areas, and prairie dog range but negatively related to forest cover. The current dataset from 2008–2018 contained very few occupied ferruginous hawk nests on the western slope (although many were occupied in previous decades and revisiting these sites may be a future priority); therefore, predicted distribution is almost exclusively east of the Rockies (Figure 1C). For all species, land cover covariates were exclusively supported at the scale of 1 km and 10 km buffer distances, with no support for intermediate spatial scales.

The models had relatively good discriminatory ability (i.e., they were able to distinguish between used and available areas accurately): AUC values for all species were ≥ 0.8. Model performance was better for the habitat specialist bald eagle and ferruginous hawk than the more generalist golden eagle or prairie falcon. For all species except golden eagle, the standardized coefficient estimate of the intercept parameter was the furthest from 0, which indicates that a high degree of the variation in probability of occurrence was not explained by any of the covariates in our model set. The data in the CPW database were not collected with the intention of creating a distribution model. As more raptor data are collected, covariate layers are updated, and sampling protocols are revised, we expect model performance to improve.

L. Rossi, Statewide Bird Conservation Coordinator, organized a well-attended meeting in September 2018 with statewide representation by Terrestrial, Research, and Regional staff at which we reached broad agreement on several fronts related to raptor monitoring. Avian Research presented the preliminary results and recommendations discussed above. Several objectives were identified, including local land use planning, maintaining or recovering statewide raptor populations, and public engagement. It was agreed that the statewide database with its HB1298 objectives should be maintained and expanded, and that we should explore the costs and benefits of monitoring programs geared toward estimation of raptor population trend, abundance, and productivity (and how citizen science data such as eBird might be incorporated). Golden eagles were chosen as the top priority species; therefore, Avian Research and Species Conservation proposed a 3-year golden eagle pilot project for the Species Conservation Trust Fund that is expected to produce deliverables on all those fronts by the end of 2023.

Over the next year, we will continue to refine our models of nest survival and distribution, explore potential integration of eBird and COBBA data, and work with CPW staff and partners to better design a more structured state-wide raptor survey protocol. We will provide some assistance in the Northwest and Southwest regions in re-visiting nest locations with unknown status and other high priority nest sites. We are working with Terrestrial staff to propose sampling and survey protocols that incorporate areas farther from roads, note absences, and at a subset of locations, produce estimates of probability of detection: these issues currently preclude estimation of statewide abundance or population trend for any Colorado raptor. This may require higher dependence on volunteer and citizen science data and some changes to the structure of our database. It will also require continued articulation of CPW goals for raptor monitoring and priorities for raptor conservation and management.

We have several recommendations for collecting nest visit data that will maximize the usefulness and integrity of the data. If only one survey of a given area is possible, it should occur during the typical egglaying or incubation phase when adult activity can be confirmed and before nest failures cause adults to abandon their nests or leaf-out obscures views. 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, 65% of nest locations in the database have a status of unknown or undetermined. 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.

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Table 1. Number of nest site records for Colorado raptors, queried on 8 January 2019. 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. Nest counts are for the last raptor species occupying a site.

SPECIES	NUMBER OF NESTS				
	Active	Inactive	Destroyed	Unk/Undeter	Total
Bald Eagle	215	13	96	149	473
Golden Eagle	166	191	107	1571	2035
Ferruginous Hawk	58	2	31	337	428
Prairie Falcon	32	14	2	165	213
Total: 28 Species	1824	736	857	6300	9717

Figure 1A. Predicted relative probability surface for bald eagle in Colorado based on occupied nest locations from 2008–2018. Warm colors (red-orange-yellow) are more suitable locations (Pr[use] ~ 1) and cool colors (blue, purple, gray) are less suitable locations (Pr[use] ~ 0).

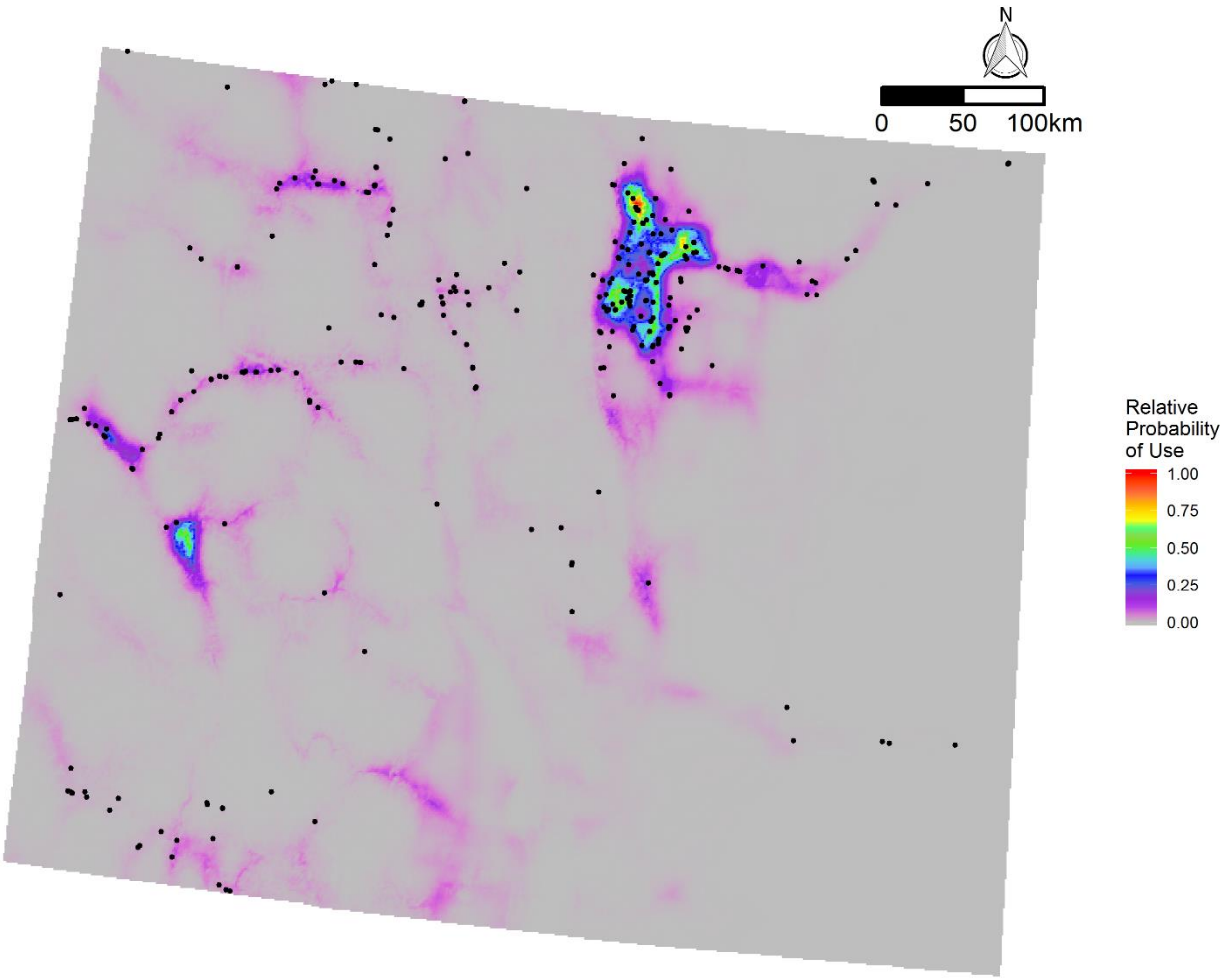


Figure 1B. Predicted relative probability surface for golden eagle in Colorado based on occupied nest locations from 2008–2018.

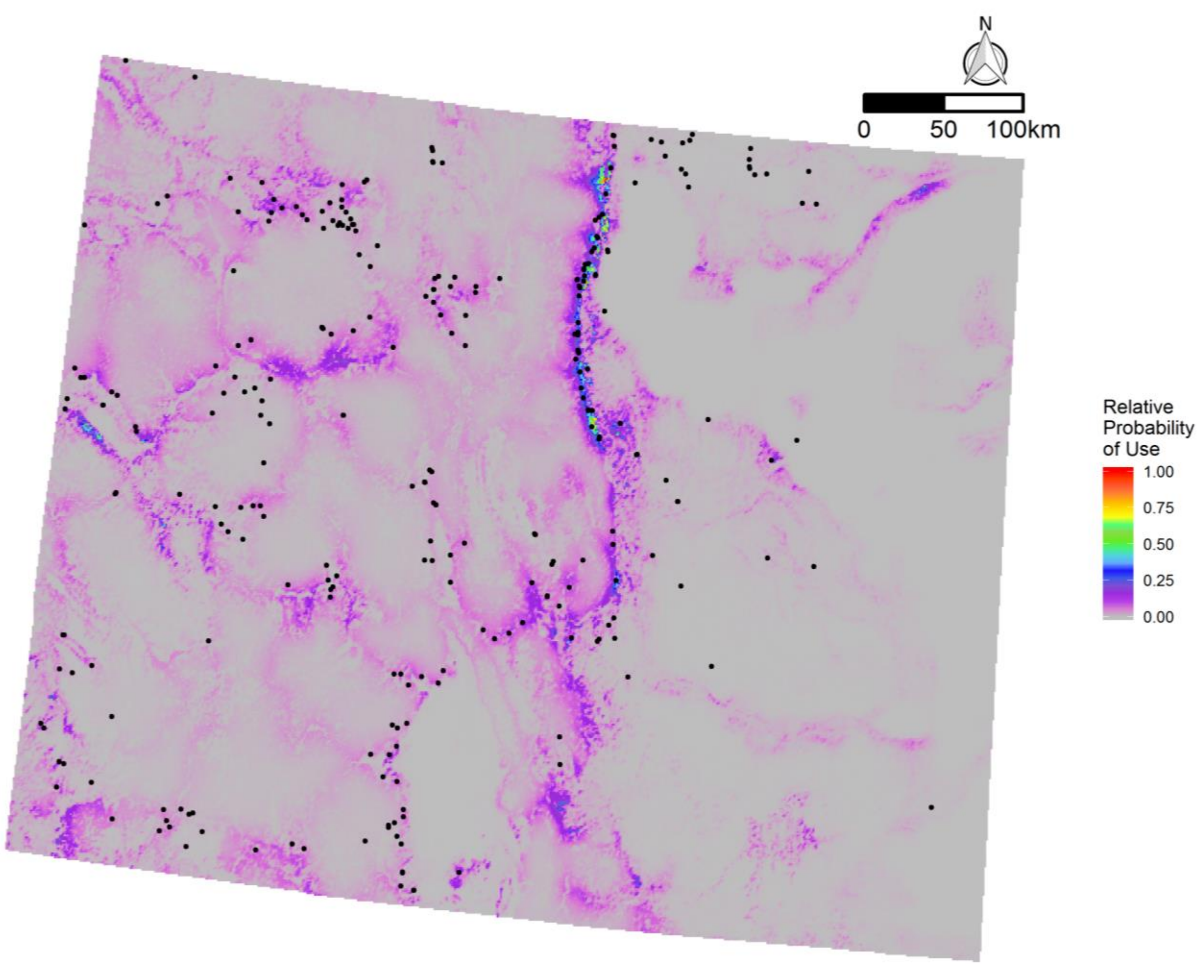


Figure 1C. Predicted relative probability surface for ferruginous hawk in Colorado based on occupied nest locations from 2008–2018.

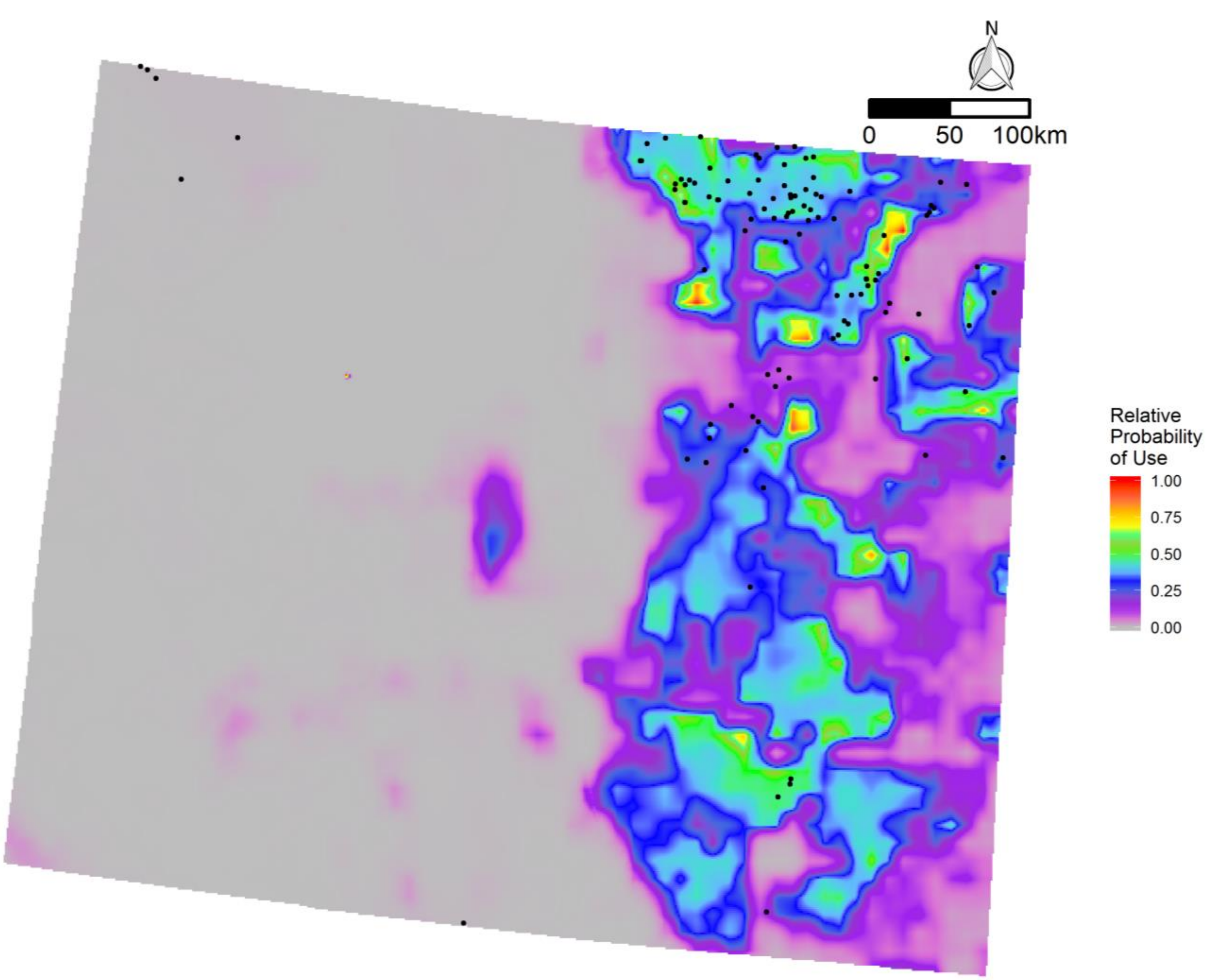
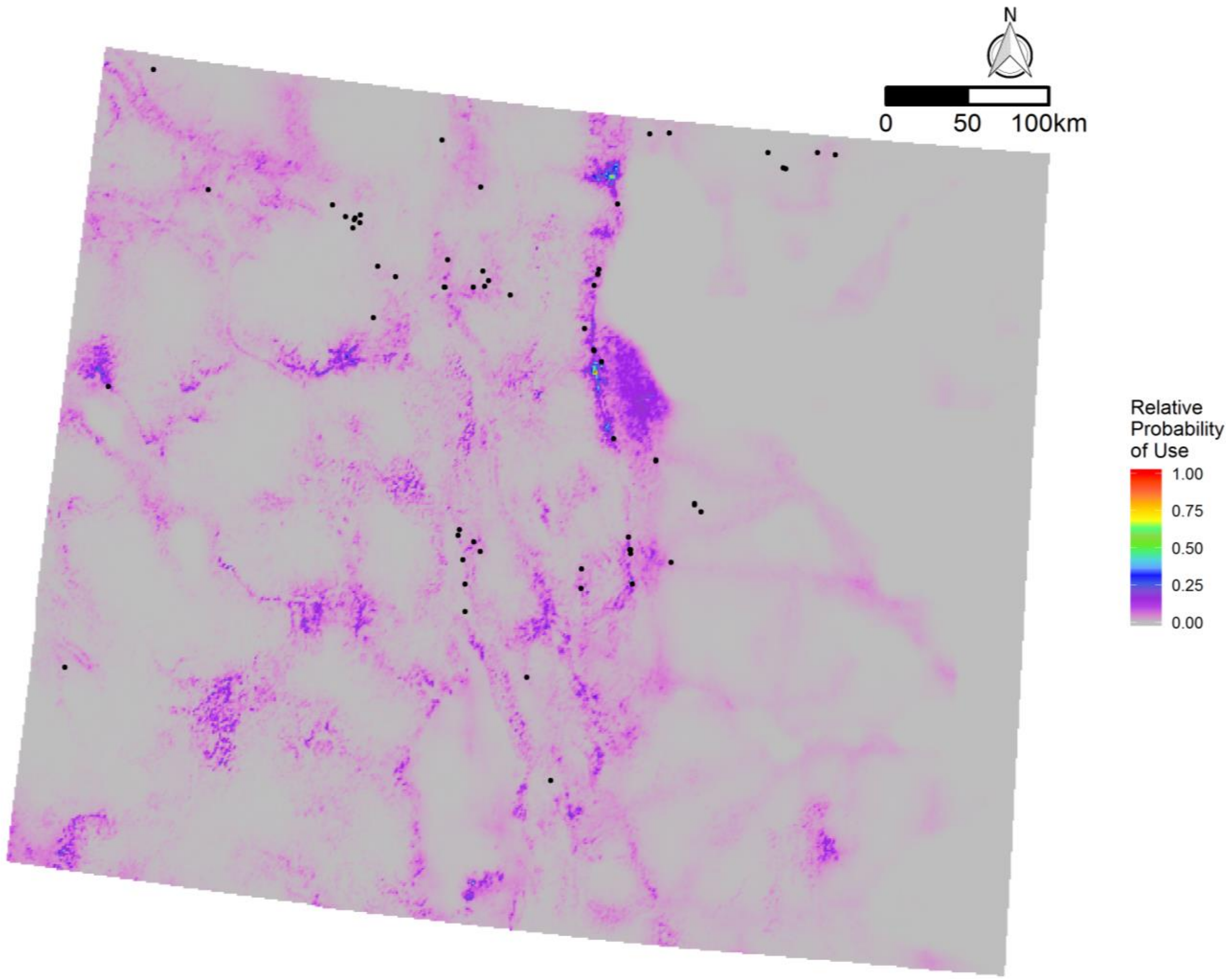


Figure 1D. Predicted relative probability surface for prairie falcon in Colorado based on occupied nest locations from 2008–2018.



Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Northern bobwhite response to short-duration intensive grazing on Tamarack State Wildlife Area

Period Covered: January 1, 2018 – December 31, 2018

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

Project Personnel: Trent Verquer, Ed Gorman, 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.

EXTENDED ABSTRACT

Widespread suppression of historic disturbance regimes have reduced heterogeneity in vegetation communities on which many wildlife rely for various life events and stages. Northern bobwhites 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 objectives of this project are to assess the efficacy of using short-duration high-intensity grazing as a tool to improve northern bobwhite habitat. We used a randomized block design in which we divided the study site into groups of four plots; a different plot was grazed each year over a three-year period and one plot was a control (Fig. 1). Beginning in late winter each year, we captured bobwhites using walk-in traps and deployed necklace-style VHF radio transmitters and GPS transmitters, which were set to record a location every 1–4 hours. We located each radio-marked bobwhite three times per week and determined nest sites by observing birds in the same location on subsequent days. When nests hatched we continued to monitor broods and on day 14 post-hatch we flushed the brood, and weekly thereafter to count chicks and assess brood status. To assess nest and brood site selection, we sampled vegetation at nest and brood sites and four associated random points to represent available habitat around the nest or brood site. The overall goals were 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 2018, we were able to graze seven plots in late winter/early spring. Directly after grazing, there were substantial differences in vegetation characteristics between grazed and control plots (lower height, density, percent grass, and more bare ground). However, by late summer, there was little difference, if any, remaining between grazed and control plots (Fig. 2). We deployed 67 VHF radio transmitters on northern bobwhites and collected 2905 locations. Overall adult survival from April through September

was 0.34 ± 0.07. Estimated nest survival was 0.38 for female incubated nests (*n* = 23) and 0.03 for male incubated nests (*n* = 8). Nest survival was negatively affected by percent litter around the nest. Bobwhite nest sites exhibited a greater percentage of grass cover and less bare ground than associated random sites (Fig. 3). Two nests were in plots grazed in 2018, one in a plot grazed in 2017, four in control plots, and four in plots scheduled for grazing in 2019. We monitored 12 broods and survival to 30 days post-hatch declined substantially with date. For a nest hatched on 30 June, 30-day brood survival was 0.932 and for a nest hatched on 13 September, 30-day brood survival was 0.352. Broods selected sites with more visual obstruction than associated random points. Four brood sites were in control plots, eight were in plots grazed in 2018, three were in plots grazed in 2017, and the rest were not in plots. Moving forward, we will attempt to gather a larger sample of nests and broods and/or create greater differences between grazed and control plots in order to more concretely document any effects of grazing on bobwhite demographic parameters. We are currently working with the field staff at Tamarack State Wildlife Area to prepare for the third and final year of grazing treatments to begin in early 2019.

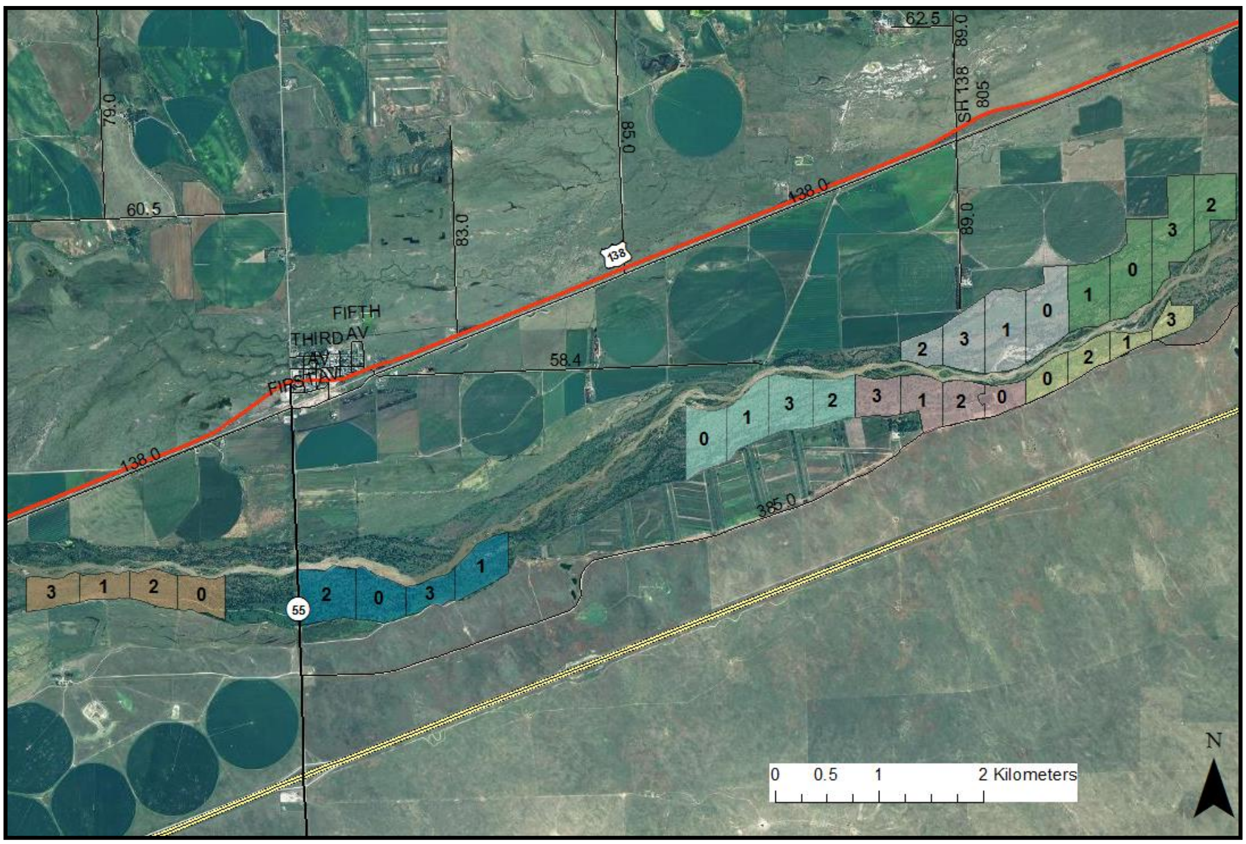


Figure 1. Grazing treatment plot layout for Tamarack State Wildlife Area. Numbers represent the year of treatment, zeros indicate control plots.

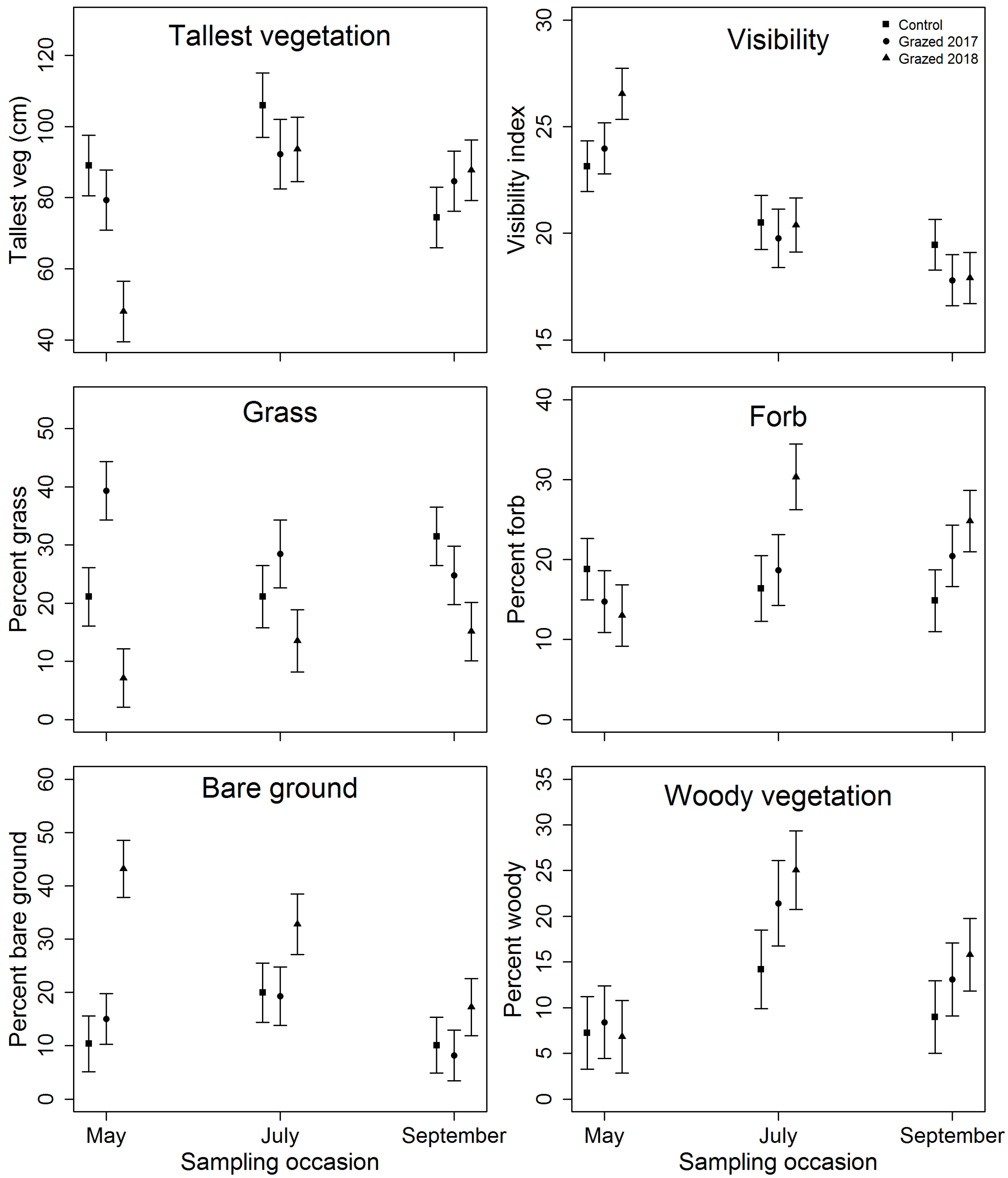


Figure 2. Vegetation characteristics at random points in grazed and control plots during three sampling occasions at Tamarack State Wildlife Area. Error bars represent one standard error

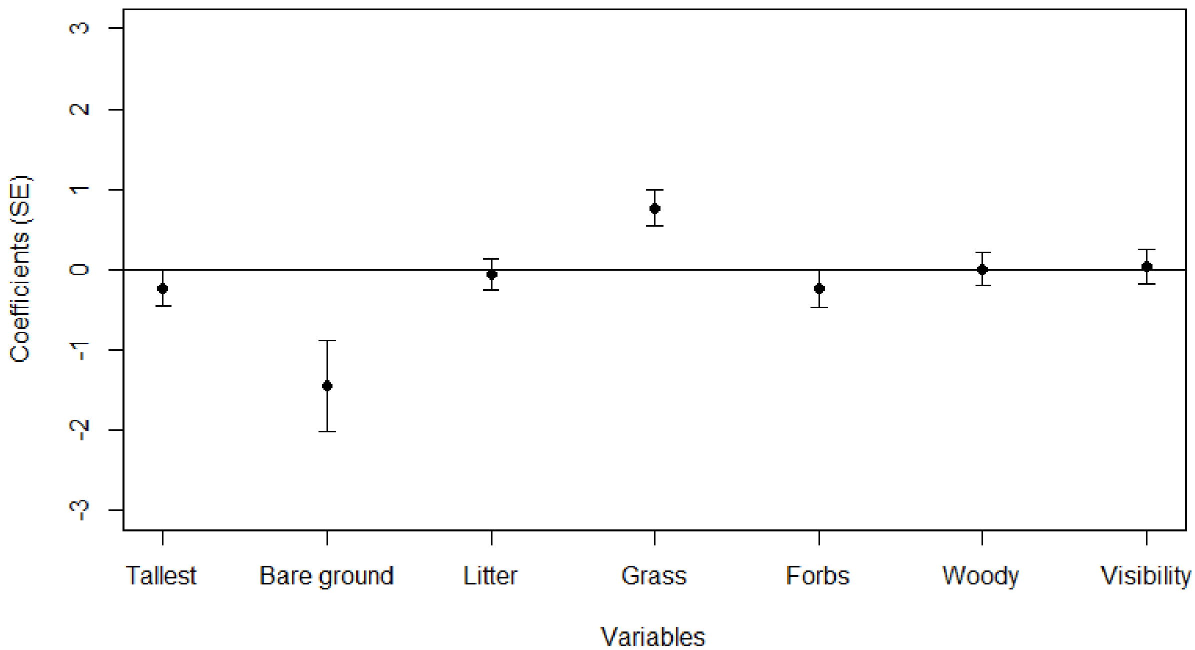


Figure 3. Standardized coefficients ± SE from discrete choice models predicting nest site selection of northern bobwhites at Tamarack State Wildlife Area in 2018. Positive values indicate selection for a variable and negative values indicate selection against a variable. All coefficients are from single variable models

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

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

Period Covered: January 1, 2018 – December 31, 2018

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

Project Personnel: Brian Sullivan, Jim Gammonley

EXTENDED ABSTRACT

Attracting and holding large populations are goals of habitat management for nonbreeding waterfowl (Soulliere et al. 2007). Currently, many habitat planners use bioenergetics approaches to guide habitat planning for nonbreeding waterfowl and shorebirds (Central Valley Joint Venture 2006, Soulliere et al. 2007, Playa Lakes Joint Venture 2008). 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 (Brasher 2010, O'Shaughnessy 2014, Behney 2014). Therefore, more complex models have been developed (Sutherland and Allport 1994, Miller et al. 2014) 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 habitats 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 (Hitchcock 2009, Tidwell et al. 2013) and shorebirds primarily consume invertebrates (Davis and Smith 1998).

The lower South Platte River corridor in northeastern Colorado (Fig. 1) is considered a waterfowl conservation priority area for migrating and wintering ducks (Colorado Parks and Wildlife 2011) and is important in terms of recreation (Runge and Gammonley 2012). However, relatively little research has been conducted to determine the effectiveness of habitat management actions or food availability in the region. My first objective was to estimate duck and shorebird food and energy availability in various water feature types in the South Platte River basin throughout the nonbreeding season. As a way to assess how much of the food is actually available for exploitation by ducks, I also estimated the percentage of water features that were shallow enough to facilitate feeding by dabbling ducks. Based on previous food availability research in other regions and the attractiveness of moist-soil units to ducks, I predict that actively managed emergent wetlands will produce the most energy and exhibit the greatest amount of energy depletion throughout the nonbreeding period. Secondly, I assessed the relationship between duck and shorebird use of sites, 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 water features is very time-intensive. Therefore, my last objective was to evaluate a rapid visual assessment procedure to estimate duck habitat

quality (Ortega 2013) by comparing the calculated score with actual habitat quality metrics (i.e., food availability and duck use of sites).

Over two years, I sampled during September – October (fall), February – March (winter), and May (summer), collecting a total of 1265 core samples (avian food samples) at 44 sites (each site was not sampled during each occasion), and conducted rapid habitat visual assessments at each site. From February through March both years, I counted ducks at a subsample of sites to examine patterns of duck distribution.

I found that emergent wetlands contained the greatest food and energy density, followed by playas and sloughs, and reservoirs contained little food or energy (Fig. 2). Fall depletion of energy was greatest in actively managed emergent wetlands and spring depletion was greatest in sloughs and passively managed emergent wetlands (Fig. 3). Mean percentage of passively managed emergent wetlands, actively managed emergent wetlands, small reservoirs, large reservoirs, and sloughs shallower than 50 cm was 37, 77, 10, 4, and 83%, respectively. Duck use of sites was most affected (positively) by energy availability and area of the site but also increased with nearness of large reservoirs and at sites further East (Fig. 4). The rapid assessment procedures explained about 45% of the variability in energy availability of sites (Fig. 5) and about 68% of the variability in mean duck density on sites durinbbbbg spring (Fig. 6).

These estimates of energy availability can be directly incorporated into energetic carrying capacity models for northeastern Colorado. My results show that although energy density is important in predicting duck use of sites, it is not the only factor affecting duck habitat use. If the other variables I found to be important (size, distance to reservoir, easting) could be included in habitat planning strategies, then habitat acquisition and restoration could be conducted more effectively. Avian food sampling in water features is a very time intensive process and I 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 I tested may not be sufficient. In 2019, I will complete analyses of results and submit a manuscript for publication.

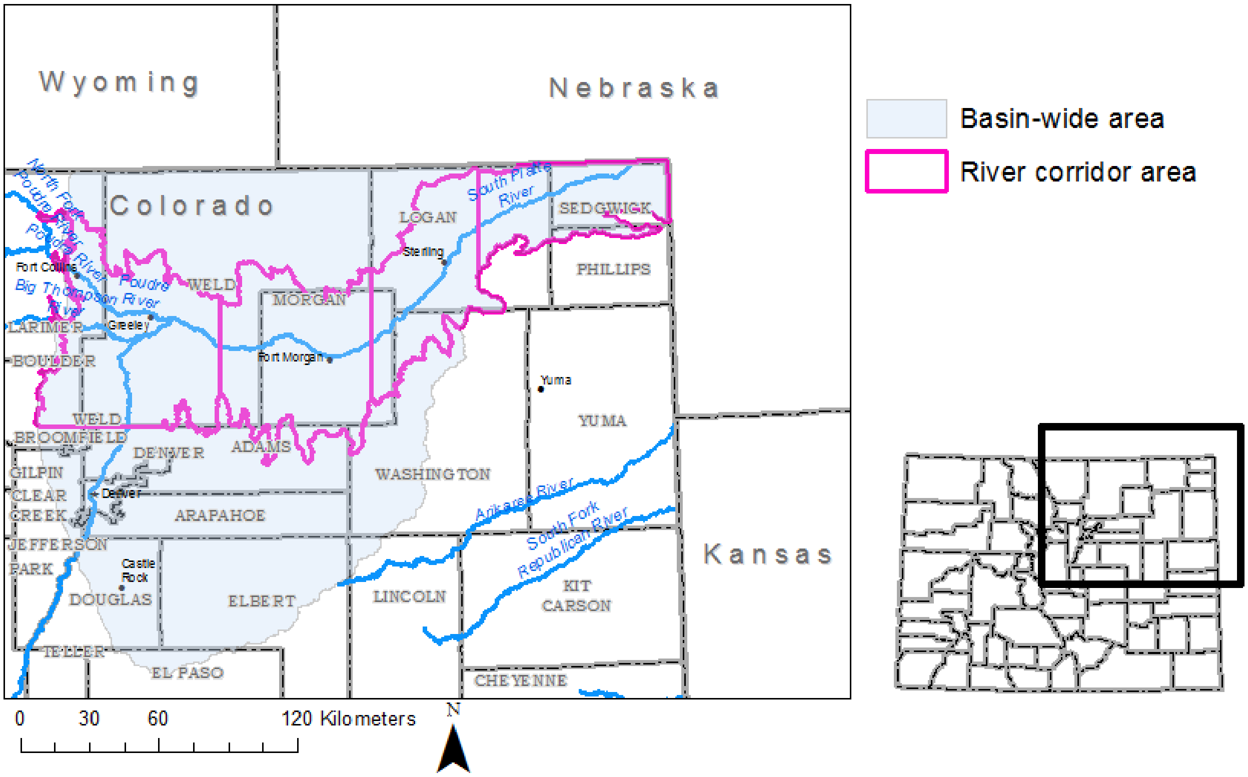


Figure 1. Study site along the South Platte River corridor in northeastern Colorado.

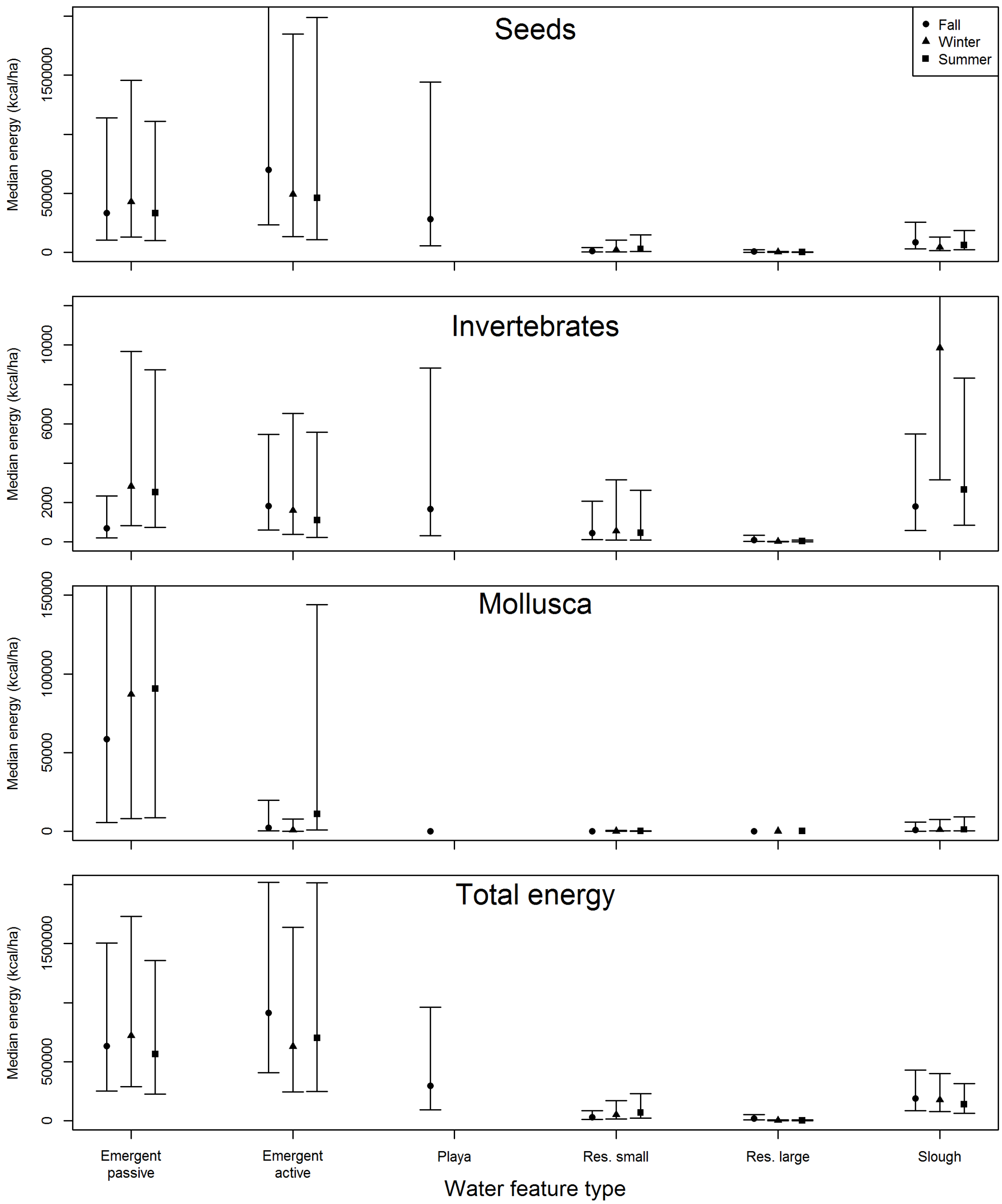


Figure 2. Model predicted median energy (kcal/ha) of seeds, invertebrates (excluding mollusca), mollusca, and total food at three sampling occasions and six types of water features in northeastern Colorado, 2015 to 2017. Error bars represent Bayesian 95% credible intervals.

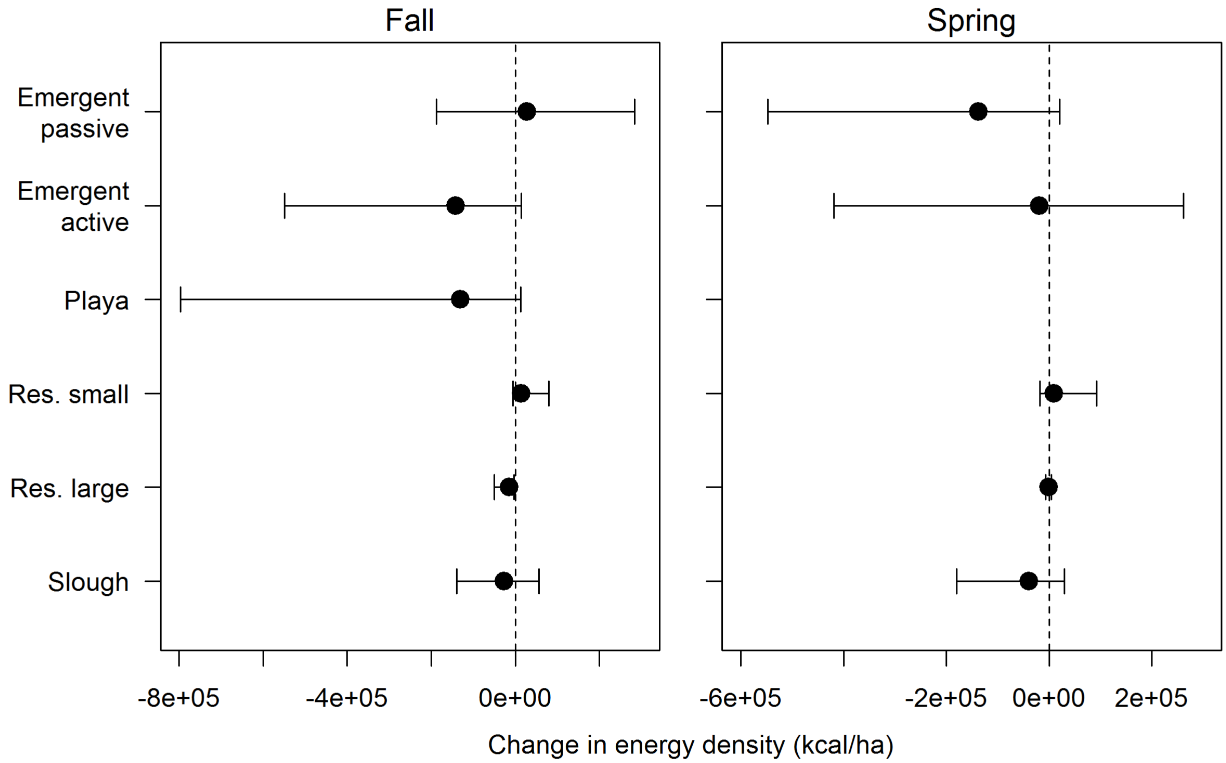


Figure 3. Model predicted energy (kcal/ha) depletion during fall and spring periods for six types of water features in Northeast Colorado, 2015 to 2017. Error bars represent Bayesian 95% credible intervals.

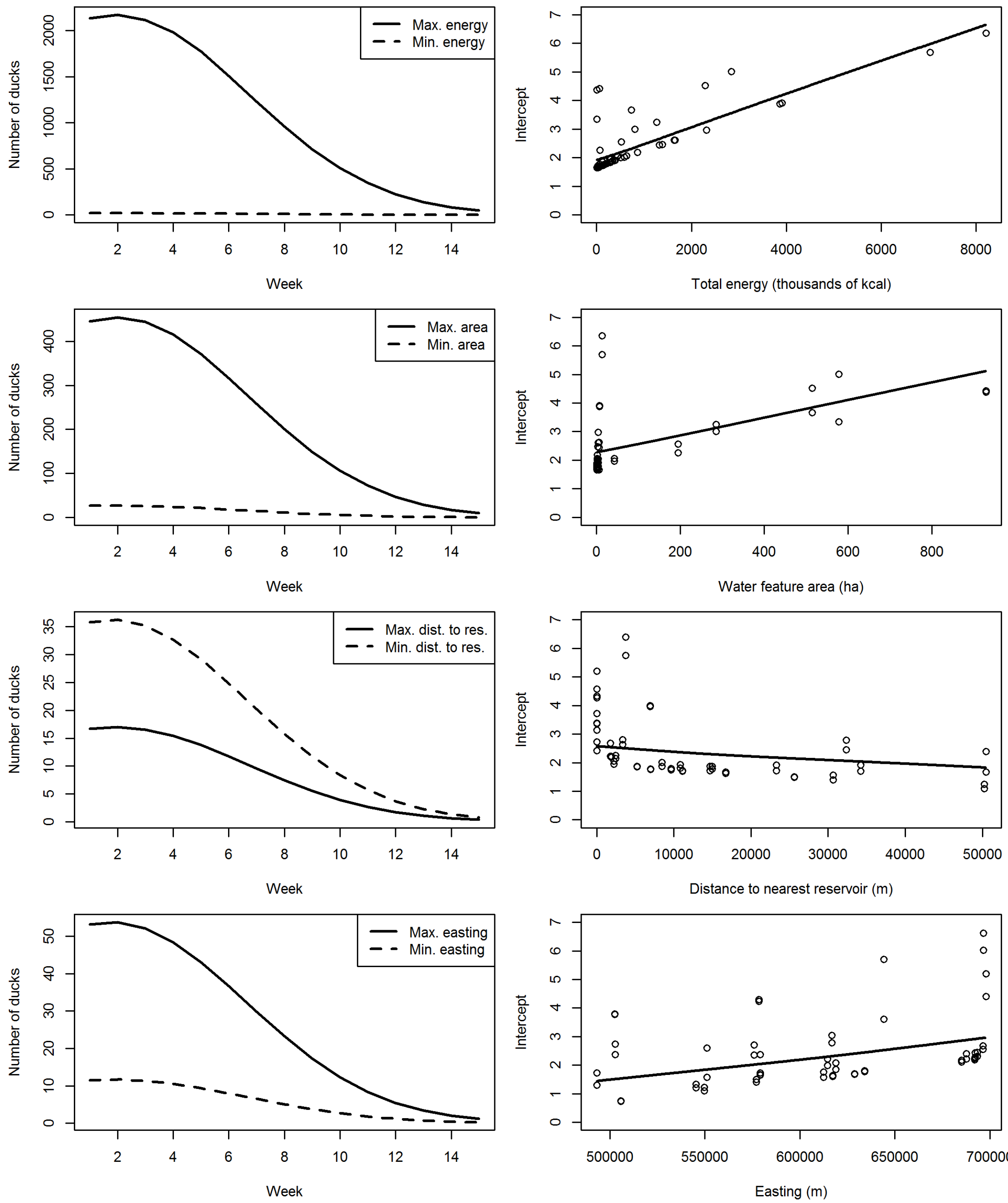


Figure 4. Model predicted number of ducks observed at a site throughout the spring given the maximum or minimum value of site level predictor variables (left column). Week one corresponds to 17-March of 2016 and 2017. The intercept in the model was allowed to vary by site and site-level predictors were used to explain variation in the intercept (right column). Model predicted values of the intercept are shown with the solid line and circles represent each site's intercept and value of predictor variable. The top row shows the effects of total energy at a site that is found at water depths less than 50 cm and was taken from

the model including energy + size as site-level predictors. The second row shows the effects of total area of the water feature and was also taken from the model including energy + size as site-level predictors. The third row shows the effects of distance to the nearest reservoir and was taken from the model including energy + size + distance to reservoir. The bottom row shows the effect of each site's easting coordinate and was taken from the model including energy + size + easting as site-level predictors.

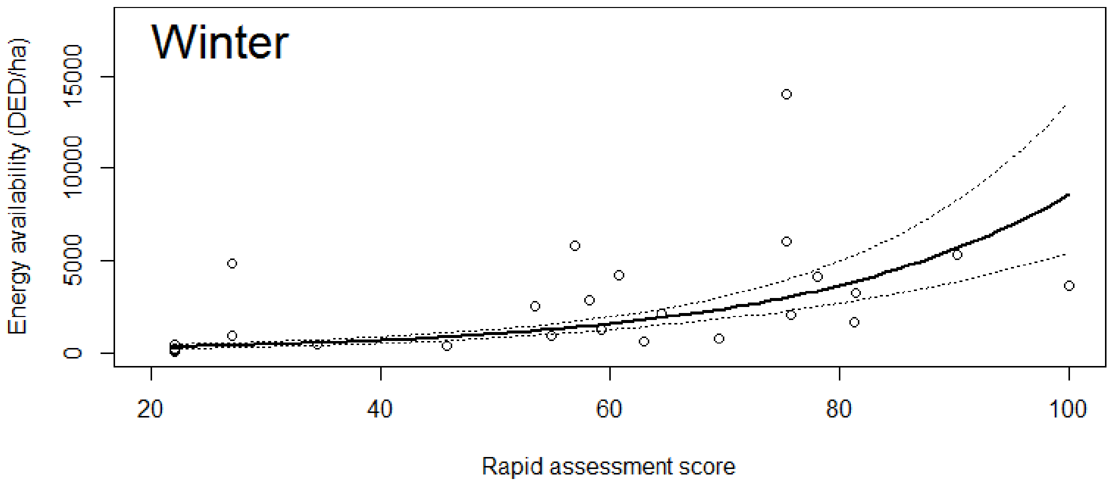


Figure 5. The relationship between rapid assessment score and energy availability (DED/ha) during winter (Feb-Mar) 2016 sampling. The solid line represents predicted values from a linear model using rapid assessment score to predict energy availability. Energy availability was natural log transformed in analysis to reduce heteroskedasticity but values were backtransformed in the figure. Dotted lines represent ± one standard error.

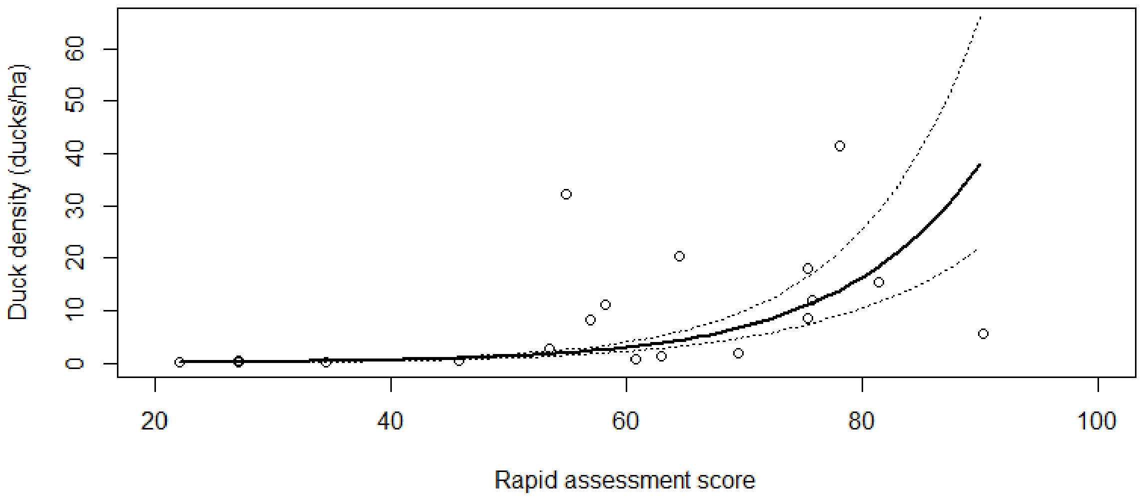


Figure 6. The relationship between rapid assessment score (winter 2016) and mean duck density (ducks/ha) during spring (Mar-Jun 2016). The solid line represents predicted values from a linear model using rapid assessment score to predict mean duck density. Duck density was natural log transformed in 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

Estimates and determinants of duck production in North Park, Colorado: a pilot study

Period Covered: January 1, 2018 – December 31, 2018

Principal Investigators: Adam C. Behney adam.behney@state.co.us, James H. Gammonley jim.gammonley@state.co.us, and Casey M. Setash

Project Personnel: Josh Dilley, Kris Middledorf, Anna O'Malley, Brian Sullivan, Samatha Spaulding, Kara Thompson (CPW); Tara Wertz, Josh Roth (Arapaho National Wildlife Refuge)

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

ABSTRACT

Assessing waterfowl use and productivity throughout the Intermountain West will help managers determine best management practices and quantify the wildlife value of these largely altered, irrigation-driven wetland systems. The North Platte River Basin (hereafter, North Park) in north central Colorado has historically held important breeding and stopover habitat for ducks and is expected to become increasingly important as water demands increase across the state and region. We conducted a pilot season in 2018 to identify logistical constraints and resource needs for a long-term study of duck populations and wetland habitats, and to evaluate field methods to estimating duck breeding populations and production, locate and monitor duck nests, and to initiate a banding program to estimate demographic parameters.

We used independent and dependent double observer methods to estimate numbers of breeding pairs of ducks (as indicated by social behavioral status) on basin wetlands, wet meadows, and riparian wetlands, while accounting for detection probability. Basin wetlands with $\geq$50 individuals could not reliably be surveyed using dependent double observer methodology; in these cases, a single observer recorded the social status of ducks in order to calculate the number of indicated breeding pairs. We conducted a total of 536 surveys of 68 basin wetlands, 6 reservoirs, 10 riparian transects, and 24 wet meadow plots from 10 April until 17 July. We estimated a maximum of 1326 and a mean of 287 duck breeding pairs on the sample of sites we surveyed. Numbers of duck breeding pairs were highest on large, shallow basin wetlands and lowest in flooded hay meadows and riparian corridors. The top model explaining variation in detection probability included observer, site, species, and group size as covariates.

To assess duck nest density, success, and site selection, we used hand-held rope drags to locate nests in 21 8-ha nest-searching plots in wet meadows, and also systematically searched areas around selected basin wetlands. We monitored 42 duck nests and estimated a 35-day nest survival rate of 0.432 (SE=0.112) across duck species. Covariates associated with nest site selection included percent litter surrounding the nest site ($\hat{\beta}$=-1.21, $\widehat{SE}$=0.285) and visual obstruction rating ($\hat{\beta}$=1.10, $\widehat{SE}$=0.259).

We conducted three sets of independent double observer surveys of duck broods on basin wetlands, reservoirs, and riparian areas during July and August, to estimate numbers of duck broods and ducklings per brood. We conducted brood surveys on 65 wetlands and observed broods of 12 duck species. Brood:pair ratios ranged from 0.099-3.52 and averaged 1.46 (SD=0.947). Duckling:pair ratios ranged

from 0.97-6.31 and averaged 1.35 (SD=1.13). Brood abundance, averaged across age classes, was positively associated with higher percentages of herbaceous emergent vegetation ($\hat{\beta}$=1.09, SE=0.392).

We used 11 baited swim-in traps to capture and band ducks. We banded 791 ducks during 242 total trap-days in 2018. We also recorded 738 recaptures of ducks that we had previously banded. The majority (78%) of our captures were mallards. As of December 31, 2018, 32 mallards and 1 green-winged teal we banded in 2018 had been harvested by hunters and reported to the Bird Banding Laboratory.

We will use results from the pilot study to design a longer-term research project. In 2019, we will select a representative sample of basin wetlands, wet meadows, and riparian sections across North Park for monitoring. We will monitor hydrology and vegetation on each selected wetland. We will use methods developed in 2018 to estimate duck breeding pairs and broods on the samples wetlands. We will expand duck banding efforts, particularly the use of methods effective in capturing gadwall. We will collaborate with a graduate student project at Colorado State University that will mark ducks with transmitters and track their movements and breeding activity in North Park.

Publications, presentations, workshops and committee involvement by Avian Research staff
January – December 2018

PUBLICATIONS

Aagaard, K., J. Eash, W. Ford, P. J. Heglund, M. McDowell, and W. E. Thogmartin. 2018. Modeling the relationship between water level, wild rice abundance, and waterfowl abundance at a central North American wetland. Wetlands. DOI: 10.1007/s13157-018-1025-6

Aagaard, K, S. K. Jacobi, E. V. Lonsdorf, M. T. Jones, V. Hunt, and W. E. Thogmartin. *In review*. A continental generalizable avian movement and energetics model. Ecological Applications.

Aagaard, K, J. E. Lyons, and W. E. Thogmartin. 2018. Comparing effort adjustments in a large-scale monitoring program. Journal of Fish and Wildlife Management. 9, e1944-687x. DOI: 10.3996/022018-JFWM-012

Aagaard, K., W. E. Thogmartin, and E. V. Lonsdorf. 2018. Temperature-energy relations in migratory waterfowl. Ecological Modelling. 348, 46-58. DOI: 10.1016/j.ecolmodel.2018.04.001

Behney, A. C., R. O'Shaughnessy, M. W. Eichholz, and J. D. Stafford. 2018. Indirect risk effects reduce feeding efficiency of ducks during spring. Ecology and Evolution 8:961-972.

Behney, A. C., R. O'Shaughnessy, M. W. Eichholz, and J. D. Stafford. *In review.* Worth the reward? An experimental assessment of risk-taking behavior along a life history gradient. Journal of Avian Biology.

Brown, J.A., J.L. Lockwood, J.D. Avery, J.C. Burkhalter, **K. Aagaard**, and K.H. Fenn. *Accepted*. Evaluating the long-term effectiveness of terrestrial protected areas: a 40-year look at forest bird diversity. Biological Conservation.

Conrey, R. Y., D. W. Tripp, E. N. Youngberg, and A. O. Panjabi. 2018. Bird and mammalian carnivore response to plague in prairie dog colonies. Pages 48-50 *in* Knuffman, L., editor. America's Grasslands Conference: United for Conservation. Proceedings of the 4th Biennial Conference on the Conservation of America's Grasslands. National Wildlife Federation.

Custer, T. W., C. M. Custer, P. M. Dummer, C. W. Matson, E. Bigorgne, E. Oziolor, N. Karouna-Renier, S. Schultz, R. A. Erickson, and **K. Aagaard**. 2017. EROD activity, chromosomal damage, and oxidative stress in response to contaminant exposure to tree swallows (*Tachycineta bicolor*) nesting in the Great Lake Areas of Concern. Environmental Toxicology and Chemistry. 26, 1392-1407. DOI: 10.1007/s10646-017-1863-7

Gerber, B. D., M. B. Hooten, C. P. Peck, M. B. Rice, **J. H. Gammonely, A. D. Apa**, and A. J. Davis. 2018. Accounting for location uncertainty in azimuthal telemetry data improves ecological inference. Movement Ecology 6:14 https://doi.org/10.1186/s40462-018-0129-1

Gerber, B. D., M. B. Hooten, C. P. Peck, M. B. Rice, **J. H. Gammonely**, **A. D. Apa**, and A. J. Davis. *In review.* No reason to leave: extreme site fidelity of a lekking species in a homogeneous and unpredictable environment. Functional Ecology.

Gunn, C, K. M. Potter, J. P. Beason, and **K. Aagaard**. 2018. Sexually dimorphic plumage characteristics in the Northern Black Swift. Western Birds. 49, 214-225. DOI: 10.21199/WB49.3.4.

Johnston, D. B. 2018. Rough soil surface lessens annual grass invasion in disturbed rangeland. Rangeland Ecology & Management, https://doi.org/10.1016/j.rama.2018.10.010

Seglund, A., P. A. Street, **K. Aagaard**, J. Runge, and M. Flenner. 2018. Southern white-tailed ptarmigan (*Lagopus leucura altipetens*) population assessment and conservation considerations in Colorado. Final Report, 2018. Colorado Parks and Wildlife.

Shyvers, J. E., **B. L. Walker**, and B. R. Noon. 2018. Dual-frame lek surveys for estimating sage-grouse populations. Journal of Wildlife Management. DOI: 10.1002/jwmg.2154.

Shyvers, J. E., **B. L. Walker**, and B. R. Noon. *In revision.* Noninvasive genetic mark-recapture analysis to estimate pre-breeding population size of greater sage-grouse (*Centrocercus urophasianus*). Ibis.

Shyvers, J. E., **B. L. Walker**, and B. R. Noon. *In review.* Estimating winter sex ratio and flock composition of greater sage-grouse (*Centrocercus urophasianus*) from non-invasive genetic mark-recapture analysis of fecal pellets in western Colorado. Condor: Ornithological Applications.

Youngberg, E. N., A. R. Bankert, A. O. Panjabi, T. Luke George, **R. Y. Conrey**, A. Meyer, and M. D. Correll. *In revision.* Southward breeding range expansion of the Baird's Sparrow. Ecology: the Scientific Naturalist.

Zimmerman, S., Aldridge, C., **A. Apa**, and S. Oyler-McCance. 2019. Evaluation of genetic change from translocation among Gunnison sage-grouse (*Centrocercus minimus*) populations. Condor 121:1-14.

PRESENTATIONS, WORKSHOPS, AND COMMITTEES

Aagaard, K. Spatial distribution of Colorado raptor nests. Colorado Parks and Wildlife Raptor Meeting. Summit County Library North Branch, Silverthorne, CO, 13-14 September 2018.

Aagaard, K. Spatial distribution of the southern white-tailed ptarmigan. Southern white-tailed ptarmigan Species Status Assessment workshop. USGS Fort Collins Science Center, Fort Collins, CO, 5-6 June, 2018.

Apa, A. D. CPW Science support presentation. Species Distribution Mapping. Presented to the United States Fish and Wildlife Service Grand Junction Field Office Staff.

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

Apa, A. D., and **B. L. Walker.** Technical support, CPW Northwest region ruffed grouse translocation project.

Apa, A.D. CPW science support, United States Fish and Wildlife Service Species Status Assessment Science GUSG Expert Team for Gunnison sage-grouse.

Apa, A. D. Faculty Committee member for M.S. degree candidate Rachel Barker (Harris), University of Wisconsin-Madison.

Apa, A. D. Faculty Committee member for M.S. degree candidate Alyssa Kircher, University of Wisconsin-Madison.

Apa, A. D., and **B. L. Walker.** CPW science support, CPW Terrestrial greater sage-grouse transplant project.

Apa, A.D. Science support, Collaborative Action Plan for Gunnison sage-grouse.

Apa, A.D. Science support, BLM Habitat Assessment Framework, Colorado habitat guidelines.

Barker, R.E., R.S. Lutz, and **A.D. Apa**. 2018. Technical Presentation. Survival of Columbian sharp-tailed grouse females in restored grassland habitat in northwestern Colorado. Presented at the WAFWA Biennial Meeting of the Sage and Columbian sharp-tailed grouse Technical Meeting, Billings, MT, 19-21 June 2018.

Kircher, A., **A.D. Apa**, and R.S. Lutz. Poster Presentation. Beneficial rump-mount harness alterations. Presented at the WAFWA Biennial Meeting of the Sage and Columbian sharp-tailed grouse Technical Meeting, Billings, MT, 19-21 June 2018.

Apa, A. D., A. C. Behney, and **R. Y. Conrey.** CPW Animal Care and Use Committee.

Behney, A. C. 2018. Rapid assessment of wetland management for forage production, avian use, and cultural ecosystem services. Invited presentation, Society of Wetland Scientists Annual Meeting, Denver CO, May 30, 2018.

Behney, A. C. Executive board member, Central Mountains and Plains Section of The Wildlife Society.

Conrey, R. Y., **K. Aagaard**, J. DeCoste, L. Rossi, W. Kendall, and **J. H. Gammonley**. Modeling raptor distribution and creating consistent statewide survey protocols. Presented at IGNITE Session, Colorado Chapter of the Wildlife Society 2018 Annual Meeting, Grand Junction, CO, February 8, 2018.

Conrey, R. Y., **K. Aagaard,** and **J. H. Gammonley**. Modeling raptor distribution and creating consistent statewide survey protocols. Colorado Parks and Wildlife Raptor Meeting. Summit County Library North Branch, Silverthorne, CO, 13-14 September 2018.

Conrey, R. Y. Burrowing Owl and the shortgrass community. Poster and activity table at HOOTenanny Owl and Music Festival, Audubon Society of Greater Denver, Littleton, CO, September 15, 2018.

Conrey, R. Y. Faculty Committee member for M.S. degree candidate Tyler Michels, University of Colorado-Boulder.

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

Gammonley, J. H. Central Flyway wing bee, Hartford, KS, February 19-23, 2018.

Gammonley, J. H. Central Flyway Waterfowl, Webless Migratory Game Bird, and Central Management Unit Dove Technical Committee meetings, Wichita, KS, February 23-26, 2018.

Gammonley, J. H. CPW Avian Research update. Intermountain West Joint Venture State Conservation Partners meeting, Salida, CO, March 26-27, 2018.

Gammonley, J. H., M. G. Anderson, R. G. Clark, and D. D. Humburg. Invited Presentation. Integrating science, practice, and policy in the North American Waterfowl Management Plan. Society of Wetland Scientists Conference, Denver, CO, 30 May, 2018.

Aloia, C., **J. H. Gammonley**, J. Nehring, and K. A. Voss. Poster Presentation. Using long-term monitoring to guide spring wetland management for migrating ducks in the San Luis Valley, Colorado. Society of Wetland Scientists Conference, Denver, CO, 31 May, 2018.

Gammonley, J. H. Mid-Continent Mallard Adaptive Harvest Management Committee workshop, Kansas City, MO, June 11-13, 2018.

Gammonley, J. H. Central Flyway Waterfowl Technical Committee and Council meetings, Waskesiu Lake, Saskatchewan, Canada, August 26-31, 2018.

Gammonley, J. H. North American Waterfowl Management Plan Update Steering Committee.

Johnston, D. B. Co-advisor for Ph.D. Candidate Magda Garbowski, Colorado State University, Fort Collins.

Johnston, D. B. Field lecture and tour: Rangeland restoration with pothole seeding at Horsethief State Wildlife Area. Colorado Plateau Native Plant Program Annual Meeting. Grand Junction, CO. February 6, 2018.

Garbowski, M. G., C. S. Brown, and **D. B. Johnston.** Cheatgrass and drought interact to influence soil moisture and vegetation responses in restored plant communities. Joint meeting of the Society of Wetland Scientists and the Pacific Norhwest Regional Chapter of the Society for Ecological Restoration. Spokane, WA. October 15, 2018.

Walker, B. L. Faculty Committee member for Ph.D. candidate Jessica Shyvers, Colorado State University.

Walker, B. L. The Wildlife Society Rusch scholarship committee member, reviewed and commented on scholarship applications; Cesar Kleberg Award committee member, reviewed and commented on TWS member lifetime achievement nominations.