AVIAN PROGRAM
2019
WILDLIFE RESEARCH SUMMARIES

JANUARY – DECEMBER 2019

WILDLIFE RESEARCH SUMMARIES

JANUARY – DECEMBER 2019

AVIAN RESEARCH PROGRAM

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

Executive Summary

This Wildlife Research Report contains abstracted summaries of current wildlife research projects conducted by the Avian Research Section of Colorado Parks and Wildlife (CPW) during 2019. 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 research projects addressing management-related information needs for a variety of species of conservation concern and game species and their habitats. These projects are grouped under Gunnison Sage-Grouse Conservation (1 project summary), Greater Sage-Grouse Conservation (7 summaries), Wildlife Habitat Conservation (2 summaries), Spatial Ecology (1 summary), Grassland Bird Conservation (1 summary), Raptor Conservation (1 summary), Quail Conservation (2 summaries), and Wetland Bird Conservation (1 summary).

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 2019. Copies of peer-reviewed research publications can be obtained from the CPW Library. 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, University of Nebraska-Lincoln, University of Wisconsin-Madison, Bureau of Land Management, U.S. Fish and Wildlife Service, U.S. Geological Survey, City of Fort Collins, Species Conservation Trust Fund, GOCO YIP internship program, Colowyo Coal Company L.P., EnCana Corp, ExxonMobil/XTO Energy, Marathon Oil, WPX Energy, Conoco-Phillips, Rocky Mountain Bird Observatory, and the private landowners who have provided access for research projects.

STATE OF COLORADO
Jared Polis, *Governor*

DEPARTMENT OF NATURAL RESOURCES
Dan Gibbs, *Executive Director*

PARKS AND WILDLIFE COMMISSION

DIRECTOR'S LEADERSHIP TEAM

AVIAN RESEARCH STAFF

Colorado Division of Parks and Wildlife
January – December 2019

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

Principal Investigators: Anthony D. Apa tony.apa@state.co.us, James H. Gammonley jim.gammonley@state.co.us, and Jon Runge

Project Collaborators: Daniel Neubaum, Evan Phillips, Nathan Seward, Scott Wait, Brad Weinmeister

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 Information MAY NOT BE PUBLISHED OR QUOTED without permission of the principal invetsigator.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

EXTENDED ABSTRACT

Translocations have been used as a management tool for the federally threatened Gunnison sage-grouse (*Centrocercus minimus*) but have not been rigorously evaluated. We used the nest survival analysis in Program MARK to obtain estimates of daily survival rates (DSR) of 315 translocated Gunnison sage-grouse marked with transmitters, up to one year after release. We considered the following independent categorical factor variables: *population* of release (Crawford, Dove Creek, Piñon Mesa, Poncha Pass, and San Miguel), *sex* (female, male), *age* (juvenile, yearling, adult), and *season* of release (fall, spring), as well a *season***age* interaction. Because movement data suggests a 75 day movement stabilization period post-release (Apa et al. in review), we also examined whether survival differed between the first 75 days and the remainder of the first year following release (*75day*). We estimated annual survival for comparison to other studies. Annual survival estimates were obtained using the formula: annual survival = $DSR^{365.25}$. We used Akaike's Information Criterion adjusted for small sample size (AIC_c) to find the model that best explained the data.

Our top performing survival model included the variables *population* and *75days*. In each release 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. We estimated survival of translocated GUSG during the first year after release 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 Piñon Mesa, and 0.426 (0.261–0.603) in Poncha Pass. Variables *age* and *sex* were included along with *population* and *75days* in models ranking < 2.0 ΔAIC_c from the top model, suggesting these variables may affect survival and more data may be needed to assess their impact and importance. The variable *season* also occurred in a model with $\Delta AIC_c = 1.98$, but this model only differed from the best model by the addition of the variable *season*, indicating that it had little effect on model fit.

High counts of males attending leks were variable in years following translocations. Lek counts declined during 2006-2010 in all satellite populations, including those that received translocated GUSG during this period (Dove Creek, Piñon Mesa, San Miguel).

Survival of translocated GUSG during the first year following release (0.426 – 0.657) was similar to estimates of annual survival reported for resident GUSG and greater sage-grouse. Results of this analysis, along with genetic analyses that indicate translocated GUSG are being incorporated into satellite populations and reproducing with resident individuals (Zimmerman et al. 2019), as well as analysis that indicate translocated GUSG movements are similar to provide support for the use of translocations as a management tool for small populations of GUSG. Given that translocation has been identified as a

primary management action for the recovery of Gunnison sage-grouse, we recommend that a long-term strategy for a translocation program should be developed, and the success of a translocation program should be carefully monitored using demographic metrics.

A manuscript on this study is under-going internal CPW review and will be submitted for publication in early 2020.

LITERATURE CITED

Apa, T. A., M. B. Rice, K. Aagaard, E. Phillips, D. Neubaum, N. Seward, and J. R. Stiver. *In review*. Species distribution models and conservation planning for a threatened species: A case study with Gunnison sage-grouse. Wildlife Research.

Zimmerman, S, J, C. L. Aldridge, A. D. Apa, and S. J. Oyler-McCance. 2019. Evaluation of genetic change from translocation among Gunnison Sage-Grouse (*Centrocercus minimus*) populations. Ornithological Applications 121:1-14.

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Greater sage–grouse response to surface mine mitigation

Period Covered: January 1, 2019 – December 31, 2019

Principal Investigator: Anthony D. Apa tony.apa@state.co.us and A. Kircher

Project Collaborators: Bill deVergie, Area Wildlife Manager; Brad Petch, Senior Terrestrial Biologist; Trevor Balzer, Sagebrush Habitat Coordinator; Kathy Griffin, Grouse Conservation Coordinator; Brian Holmes, Conservation Biologist, Colowyo Coal Company, L.P., Tri-State Energy; R. Scott Lutz, University of Wisconsin-Madison

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 of the aforementioned 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). Therefore, the effectiveness of these costly mitigation efforts is largely unknown. As such industry, and management and regulatory agencies 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 1 active GRSG strutting ground (SG–4) (CPW, unpublished data). Therefore, there is potential for negative consequences to the SG–4 strutting ground even with the implementation of significant avoidance measures. In contrast, it must be noted that the avoidance and minimization measures were based on a different type (e.g. more dispersed fluid minerals) type 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 whether they effectively and successfully conserve the SG–4 strutting ground and breeding and summer habitat. The advanced notice and spatial containment of mining activities provide an opportunity to implement a Before-After-Control-Impact 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. The Axial Basin 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 108 sage-grouse, including 24 adult and 27 yearling males and 23 adult and 24 yearling females. We fit captured females and males with predesignated transmitter sample size allocations. Our 2019 captures supplemented potentially surviving 2018 captures that included 16 adult males (13 VHF; 3 GPS) and 38 adult females. We captured grouse from 25 March – 18 April 2019, and trapped on or near 9 strutting grounds in the Axial Basin and 2 in the Danforth Hills. Adult and yearling male greater sage-grouse mass ($\bar{x}$ ± SE) was 2,923.8 ± 29.8 g (n = 24) and 2,592.8 ± 132.8 g (n = 27), and adult and yearling female mass was 1,569.1 ± 19.4 g (n = 23) and 1,390.0 ± 15.8 g (n = 34), respectively.

We documented 45 nests. One renest was successful. Female nest success was 60.0% (n = 27/45), and lek of capture to nest movements were similar to previous years. We deployed 11 dataloggers on 11 strutting grounds. Datalogger deployment varied by strutting ground, and were deployed from 5 March through 7 June 2019, resulting in 28,824 transmitter detections. We discontinued datalogger use when there were 5 consecutive days with no transmitter detections. We deployed 6 trail cameras in 6 locations and documented the number of vehicles/day in the treatment and control areas.

In 2019, male strutting ground counts continue to decline from historic high numbers documented in 2016, but a high yearling to adult capture ratio for males (1.25:1) and females (1.48:1) is encouraging for future years. We continue to conduct data quality control on the 2018 and 2019 datasets, and on the 2001-2008 dataset that will provide invaluable information on pre-mine and existing mine development.

LITERATURE CITED

Aldridge, C. L. and M. S. Boyce. 2007. Linking occurrence and fitness to persistence: habitat based approach for endangered greater sage-grouse. Ecological Applications 17:508-526.

Buehler, D. A., and K. Percy. 2012. Coal mining and wildlife in the eastern United States: A literature review. University of Tennessee, Knoxville.

Colorado Division of Wildlife (CDOW). 2008. Colorado greater sage-grouse conservation plan. Colorado Division of Wildlife, Denver, USA.

Connelly, J.W., and S. T. Knick (eds). 2011. Greater Sage-Grouse: ecology and conservation of a landscape species and its habitats. Studies in Avian Biology (vol. 38), University of California Press, Berkeley, CA.

Garton, E. O., J. T. Ratti, and J. H. Giudice. 2005. Research and Experimentation Design. Pages 43 – 71 in C. E. Braun, editor. Techniques for wildlife investigations and management. Sixth edition. The Wildlife Society, Bethesda, Maryland, USA.

Green, R. H. 1979. Sampling design and statistical methods for environmental biologists. John Wiley & Sons. New York.

Holloran, M. J. 2005. Greater sage-grouse (*Centrocercus urophasianus*) population response to natural gas field development in western Wyoming. Dissertation, University of Wyoming, Laramie.

Holloran, M. J., B. C. Fedy, and J. Dahlke. 2015. Winter habitat use of greater sage-grouse relative to activity levels at natural gas well pads. Journal of Wildlife Management 79:630-640.
Holloran, M. J., R. C. Kaiser, and W. A. Hubert. 2010. Yearling greater sage-grouse response to energy development. Journal of Wildlife Management 74:65-72.
Lyon, A. G., and S. H. Anderson. 2003. Potential development impacts on sage grouse nest initiation and movement. Wildlife Society Bulletin 486-491.
Manier, D. J., D. J. Wood, Z. H. Bowen, R. M. Donovan, M. J. Holloran, L. M. Juliusson, K. S. Mayne, S. J. Oyler-McCance, F. R. Quamen, D. J. Saher, and A. J. Titolo. 2013. Summary of science, activities, programs, and policies that influence the rangewide conservation of Greater Sage-Grouse (*Centrocercus urophasianus*): U.S. Geological Survey Open-File Report 2013–1098 http://pubs.usgs.gov/of/2013/1098/.
Raphael, M. G., and B. A. Maurer. 1990. Biological considerations for study design. Studies in Avian Biology 13:123-125.
Ratti, J. T., and E. O. Garton. 1994. Research and Experimental Design. Page 1-23 in T. A. Bockhout, editor. Research and management techniques for wildlife and habitats. Fifth edition The Wildlife Society, Bethesda, Maryland, USA.
Schroeder, M. A., C. L. Aldridge, A. D. Apa, J. R. Bohne, C. E. Braun, S. D. Bunnell, J. W. Connelly, P. A. Deibert, S. C. Gardner, M. A. Hilliard, G. D. Kobriger, and C. W. McCarthy. 2004. Distribution of sage-grouse in North America. Condor 106:363–376.
United States Department of the Interior (USDI). 2016. Colowyo Coal Mine Collom Permit Expansion Area Project Federal Mining Plan and Lease Modification final Environmental Assessment. Office of Surface Mining Reclamation and Enforcement and Bureau of Land Management, Program Support Division, Denver CO, and Little Snake Field Office, Craig CO.
Walker, B. L., D. E. Naugle, and K. E. Doherty. 2007. Greater sage-grouse population response to energy development and habitat loss. Journal of Wildlife Management 71:2644-2654.

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, 2019 – December 31, 2019

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.

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, 2019 – December 31, 2019

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

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

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 Dr. Jessica Shyvers as a collaborator. I now anticipate submitting a publication on GPS male survival, lek attendance, and inter-lek movement in 2020. 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.

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)

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.

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, 2019 – December 31, 2019

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

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

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 to other researchers to exercise caution in using rump-mounted GPS transmitters on females. Nest survival and transmitter GPS transmitter performance analyses will be completed and a manuscript submitted following completion of other, higher priority projects.

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, 2019 – December 31, 2019

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

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

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

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Seasonal habitat mapping in the Parachute-Piceance-Roan region of western Colorado

Period Covered: January 1, 2019 – December 31, 2019

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

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

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 using primarily day-time locations of VHF-marked females (Walker et al. 2016). The second phase of the habitat selection study included examining the effects of energy infrastructure after controlling for topography, other changes to vegetation cover, and non-energy infrastructure. To meet the 2nd objective, we first mapped annual changes in four major components of energy infrastructure (well pads, facilities, pipelines, and roads), non-energy infrastructure (buildings, roads) and other landscape changes (e.g., habitat treatments, fires) from 2005-2015. Because of widespread interest in quantifying and predicting land cover changes associated with energy development from management agencies, I published a manuscript describing that mapping in November 2019. I then incorporated an additional, higher-resolution dataset of seasonal locations collected from GPS-marked males in 2012-2016 to also assess male and night-time seasonal habitat selection in relation to energy infrastructure. The analysis of habitat selection in response to different components of energy and non-energy infrastructure should be completed by early 2020 and submitted for publication shortly thereafter.

Manuscripts (to date):

Walker, B. L., S. R. Goforth, M. A. Neubaum, and M. M. Flenner. 2020. Quantifying habitat loss and modification from recent expansion of energy infrastructure in an isolated, peripheral greater sage-grouse population. Journal of Environmental Management 255:190819.

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.

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Effects of Esplanade herbicide at Bitterbrush State Wildlife Area

Period Covered: January 1, 2019 – December 31, 2019

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

Project Collaborator: Colton Murray (Property Technician, Bitterbrush State Wildlife Area)

EXTENDED ABSTRACT

Annual plant species are known to hinder the establishment of bitterbrush seedlings (Hall et al. 1999). Invasion by annual species, in particular cheatgrass (*Bromus tectorum* L.) also increases fire frequency by increasing fine fuels and fuel continuity (Balch et al. 2013; Davies and Nafus 2013). Since 1976 fire has drastically changed the vegetation quality at Bitterbrush State Wildlife Area (SWA), which serves as important mule deer Winter Range, Severe Winter Range, and Critical Winter Range for the D-7 Data Analysis Unit. Eleven fires have burned a total of 5,468 acres within the property boundary (67% of its area) and 37,089 acres of similar habitat on adjacent property. Recovery of bitterbrush and other shrubs species has been extremely slow. Areas subjected to several burns over multiple years have little to no shrub recruitment occurring, and invasive annual species remain abundant in burned areas.

Recently, the herbicide indaziflam (trade name EsplAnade® 200 SC, Bayer Corp., hereafter Esplanade) has been shown to provide long-term control of annual grasses, and, to a lesser extent, annual forbs (Sebastian et al. 2017; Sebastian et al. 2016). The herbicide is a cellulose biosynthesis inhibitor and provides a different mode of action than other commonly used herbicides for annual grass control. Recent trials near Boulder, Colorado, have resulted in both reduced annual grass cover and increased leader growth on bitterbrush, mountain mahogany (*Cercocarpus montanus*), and fringed sagebrush (*Artemisia frigida, Derek Sebastian, pers. comm.*). However, effects on seedlings may differ from those on mature plants. Esplanade inhibits root elongation, and may have detrimental effects on seedlings. Detrimental effects of the herbicide may be more than offset by reduced annual competition, but the net effect on bitterbrush seedlings is unknown.

We sought to understand how Esplanade effects mature bitterbrush and other desirable shrubs, to quantify its annual grass control performance, and to determine its effect on bitterbrush establishment from seed. We chose three study areas which had burned in the last 35 years, had experienced low to moderate recovery, and had received no prior habitat treatments (aside from seeding). Using prior monitoring data, we identified areas which have potential to show a response in bitterbrush density and/ or leader growth, given a reduction in annual grass competition. We used the following criteria:

- At least trace bitterbrush present, OR seeded with bitterbrush within the last 5 years
- Perennial forb cover is less than 40% [perennial forbs hinder bitterbrush production (Cunningham 1971) and seedling survival (Mummey et al. 2018)]
- Dense bitterbrush stands were present at the site prior to fire

Nine plots approximately 25 m X 75 m and 0.1 ha (0.5 acre) in size were established at each site. We followed the manufacturer's recommendation to combine Esplanade with glyphosate for a spring application (esp + gly), and compared esp + gly plots with glyphosate only (gly) and control plots. Treatments were assigned randomly (n = 3 per site). Colton Murray completed application on 22 April 2019. Esp + gly plots received 73.1 g ai/ha indaziflam (5 oz/ac of Esplanade 200SC which contains 1.7 lbs/gal of active ingredient), 350 g ai/ha glyphosate (8.9 oz/ac of Roundup Power Max which contains 4.5 lb/gal active ingredient), 188 li/ha (20 gal/ac) of water, and 0.125% v/v non-ionic surfactant (Activator 90, Loveland Products). Gly plots received 350 g ai/ha glyphosate, 188 li/ha of water, and 0.125% v/v non-ionic surfactant. Control plots received 188 li/ha of clean water only.

At the time of application, the soils were dry at the surface but wet deeper down. Dry soil at the surface was ideal to prevent downward movement of Esplanade, which could result in injury to desirable species. Cheatgrass was active and at an appropriate developmental stage to be killed by glyphosate. Perennial grasses were just beginning to become active, and slight injury from glyphosate was expected.

One-strand smooth wire solar charged electric fence was installed by Colton Murray on 22 April 2019 around each site. These will be activated for about six weeks in late spring each year to prevent cattle grazing, as Esplanade is not yet approved for grazed lands.

We collected data on percent cover in the second week of June, 2019, using 55m transects centered in the middle of each plot. We took hits to species every 25 cm for a total of 220 hits per plot. Data will be analyzed for a future report. It was obvious, however, that both the esp + gly and the gly only plots achieved some control of cheatgrass. Slight injury to desirable species was also evident in both the esp + gly and the gly only plots (Figure 1).

Figure 1. Plots at the Maybell Sands 1 site on 11 June 2019, two months after herbicide application.

We collected data on shrub density, leader growth, and productivity in all plots the week of August 14. In addition to the important forage species listed in the study plan [whitestem rabbitbrush (*Ericamerian nauseosa* ssp. *hololueca*), big sagebrush (*Artemisia tridentata*), silver sagebrush (*Artemisia cana*), and bitterbrush], we also took data on fringed sage (*Artemisia frigida*). Some species were very sparse, therefore we varied the width of the belt transect from 1m to 21m in order to capture sufficient numbers of each species.

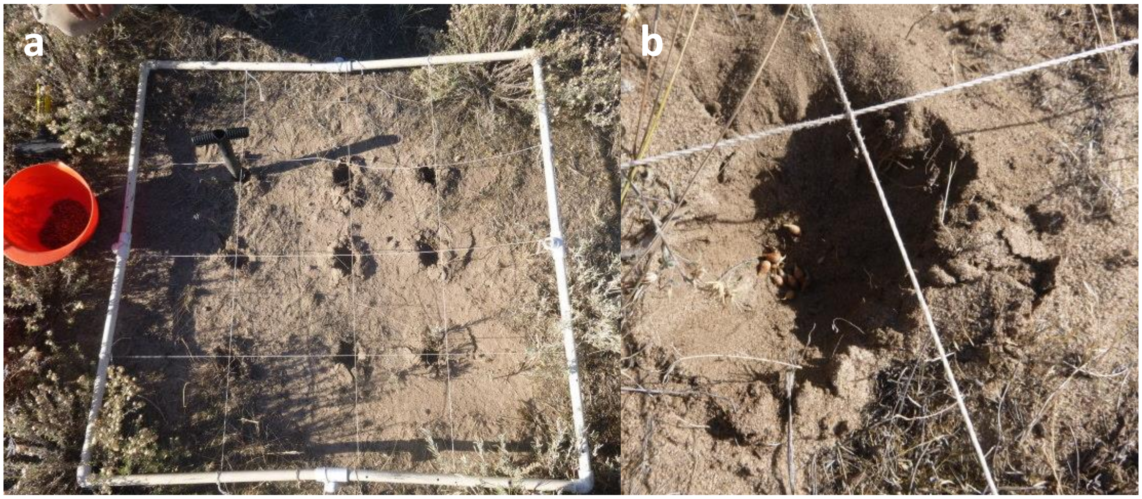

Figure 2. Grid of mimicked rodent caches within a subplot (a) and bitterbrush seed within one cache (b).

To test the impact of herbicides on natural bitterbrush recruitment from seed, we planted bitterbrush seed in mimicked rodent caches, as nearly all bitterbrush seedlings grow from such caches (Vanderwall 1994). We planted the week of 9 October 2019, using seed which had been collected in July 2018 from Bitterbrush SWA. We planted within six 1m X 1m subplots per plot. Subplot locations were chosen by subjectively selecting at least 10 potential $1m^2$ areas which had no perennial vegetation and as little annual vegetation as possible (Hall et al. 1999). We then selected 6 of these which covered the spatial extent of the plot (excluding a 2 m edge buffer), and randomly assigned 3 to receive a grazing cage. For each subplot, we overlaid a grid so that we could create 9 evenly spaced seed caches and planted 10 hard, well-formed seeds 4cm deep at each grid intersection (Figure 2; Hall et al. 1999; Hammon and Noller 2004). We then either marked the corners of the $1m^2$ subplot (for controls) or placed and staked a grazing cage over the subplot (Figure 3). Grazing cages will allow us to determine if large herbivore browsing was a factor in seedling recruitment, as bitterbrush seedlings need about two years of protection from herbivory to become established (Dyer and Noller 2014; Paschke et al. 2003).

Figure 3. Seedling subplot with grazing cage.

In 2020 we plan to monitor the seedling subplots in May, July, and September. We will count the number of seedlings and determine the number of live caches. We will collect percent cover data on each plot in late May or early June, and measure shrub density, leader growth, and production on important forage species in August. Response variables for data analysis will include percent cover of perennial grasses, annual grasses, perennial forbs, and important forage shrubs, leader growth of important forage shrubs, and density of important forage shrubs. We plan to make management recommendations concerning the potential impact of Esplanade herbicide on recovery of bitterbrush and other desirable vegetation.

LITERATURE CITED

Balch, J. K., B. A. Bradley, C. M. D'Antonio, and J. Gomez-Dans. 2013. Introduced annual grass increases regional fire activity across the arid western USA (1980-2009). Global Change Biology 19:173-183.

Cunningham, H. C. 1971. Soil-vegetation relationships of a bitterbrush-sagebrush association in northwestern Colorado. Fort Collins, CO: Colorado State University. 111 p.

Davies, K. W., and A. M. Nafus. 2013. Exotic annual grass invasion alters fuel amounts, continuity and moisture content. International Journal of Wildland Fire 22:353-358.

Dyer, D. L., and G. L. Noller. 2014. Plant Guide: Antelope bitterbrush. USDA Natural Resources Conservation Service.

Hall, D. B., V. J. Anderson, and S. B. Monsen. 1999. Competitive effects of bluebunch wheatgrass, crested wheatgrass, and cheatgrass on antelope bitterbrush seedling emergence and survival. USDA Forest Service Rocky Mountain Research Station Research Paper Rmrs:1-+.

Hammon, R., and G. Noller. 2004. Fate of fall-sown bitterbrush seed at Maybell, Colorado. 120-124 p.

Mummey, D. L., L. Stoffel, and P. W. Ramsey. 2018. Preestablished plant Influences on antelope bitterbrush (Purshia tridentata Pursh) seedling recruitment and growth: analysis of species and positional effects. Natural Areas Journal 38:44-53.

Paschke, M. W., E. F. Redente, and S. L. Brown. 2003. Biology and establishment of mountain shrubs on mining disturbances in the Rocky Mountains, USA. Land Degradation & Development 14:459-480.

Sebastian, D. J., M. B. Fleming, E. L. Patterson, J. R. Sebastian, and S. J. Nissen. 2017. Indaziflam: a new cellulose-biosynthesis-inhibiting herbicide provides long-term control of invasive winter annual grasses. Pest Management Science 73:2149-2162.

Sebastian, D. J., S. J. Nissen, and J. D. Rodrigues. 2016. Pre-emergence control of six invasive winter annual grasses with imazapic and Indaziflam. Invasive Plant Science and Management 9:308-316.

Vanderwall, S. B. 1994. Seed fate pathways of antelope bitterbrush- dispersal by seed-caching yellow pine chipmunks Ecology 75:1911-1926.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Restoring habitat with super-absorbent polymer

Period Covered: January 1, 2019 – December 31, 2019

Principal Investigators: Magda Garbowski (Graduate Student, Colorado State University), Danielle B. Johnston (CPW), Cynthia S. Brown (Professor, Colorado State University)

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 temperature and precipitation changes make planning for and implementing successful 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 assessed 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 2019, we published the first peer-reviewed paper from the study in *Restoration Ecology* (available at https://onlinelibrary.wiley.com/doi/full/10.1111/rec.13083), and submitted a second paper to *Ecosphere.* Below are the abstracts:

Soil amendment interacts with invasive grass and drought to uniquely influence aboveground vs. belowground biomass in aridland restoration

> Water-holding soil amendments such as super-absorbent polymer (SAP) may improve native species establishment in restoration but may also interact with precipitation or invasive species such as *Bromus tectorum* L. (cheatgrass or downy brome) to influence re-vegetation outcomes. We implemented an experiment at two sites in Colorado, USA in which we investigated the interactions of drought (66% reduction

of ambient rainfall), *B. tectorum* presence (BRTE, 465 seeds m-2) and super-absorbent polymer soil amendment (SAP, 25 g m-2) on initial plant establishment and 3-year aboveground and belowground biomass and allocation. At one site, SAP resulted in higher native seeded species establishment but only with ambient precipitation. However, by the third year, we detected no SAP effects on native seeded species biomass. Treatments interacted to influence aboveground and belowground biomass and allocation differently. At one site, a SAP × precipitation interaction resulted in lower belowground biomass in plots with SAP and drought (61.7 ± 7.3 g m-2) than plots with drought alone (91.6 ± 18.1 g m-2). At the other site, a SAP × BRTE interaction resulted in higher belowground biomass in plots with SAP and BRTE (56.6 ± 11.2 g m-2) than BRTE alone (35.0 ± 3.7 g m-2). These patterns were not reflected in aboveground biomass. SAP should be used with caution in aridland restoration because initial positive effects may not translate to long-term benefits, SAP may uniquely influence aboveground vs. belowground biomass, and SAP can interact with environmental variables to impact developing plant communities in positive and negative ways.

Invasive annual grass interacts with drought to influence plant communities and soil moisture in dryland restoration

Changes in precipitation may facilitate the spread of invasive species, such as the annual grass, *Bromus tectorum* (cheatgrass or downy brome). *B. tectorum* can alter soil moisture availability to hinder recruitment of native species in restoration projects. Understanding the synergistic effects of drought and invasive species on plant community development and soil moisture could provide valuable insight into the mechanisms hindering successful native plant establishment in dryland restoration projects that have success rates as low as 10%. We implemented a re-vegetation experiment at two sites in Colorado, USA (Western Great Plains (WGP), Cold Desert (CD)) to investigate the effects of drought (66% reduction of ambient growing-season rainfall), *B. tectorum* seed addition (BRTE, 465 seeds m^{-2}), and super-absorbent polymer soil amendment (SAP, 25 g m^{-2}) on plant community development and soil volumetric water content (VWC) at 5 cm and 30 cm depth.

Drought resulted in both higher (WGP) and lower (CD) *B. tectorum* cover. The higher cover of *B. tectorum* with drought at WGP is consistent with predictions for the region. At WGP, drought reduced seeded forb cover and interacted with BRTE to reduce seeded grass cover. At CD, drought and BRTE each decreased seeded species cover from approximately 8% to 3%. SAP increased overall seeded grass cover at WGP from 2.2% to 4.9%.

The effects of BRTE and drought on soil VWC varied by site and depth. Notably, at 5 cm depth at CD, BRTE treatment resulted in lower soil VWC than drought. In 2015 at 30 cm depth, BRTE with ambient precipitation resulted in both the highest (WGP) and lowest (CD) soil VWC. Our results demonstrate that *B. tectorum* and drought can uniquely interact at different sites to influence native plant establishment and soil moisture in dryland restoration settings.


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

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Evaluating spatial patterns and processes of avian and mammalian wildlife populations

Period Covered: January 1, 2019 – December 31, 2019

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

Project Collaborators: Jim Gammonley, Reesa Conrey, Tony Apa, Dan Neubaum (CPW); Mindy Rice, Lief Wiechman (USFWS); Julie Heinrichs, Mike O'Donnell, Cameron Aldridge, Sarah Oyler-McCance, Brian Reichert, Kyle Enns, Colin Talbert (USGS); Megan Kocina, Carolyn Gunn

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 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 its target 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 research projects I am associated with, and briefly detail the objectives and current status of each.

- **Raptor Nesting Distribution Model (with R. Y. 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 31,206 recorded nest observations in the database, 1,599 of which are from unique observations of occupied nests in the last 10 years for our focal species.

  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.

We have written the results of these analyses as a manuscript and have submitted it for review at the *Journal of Raptor Research*.

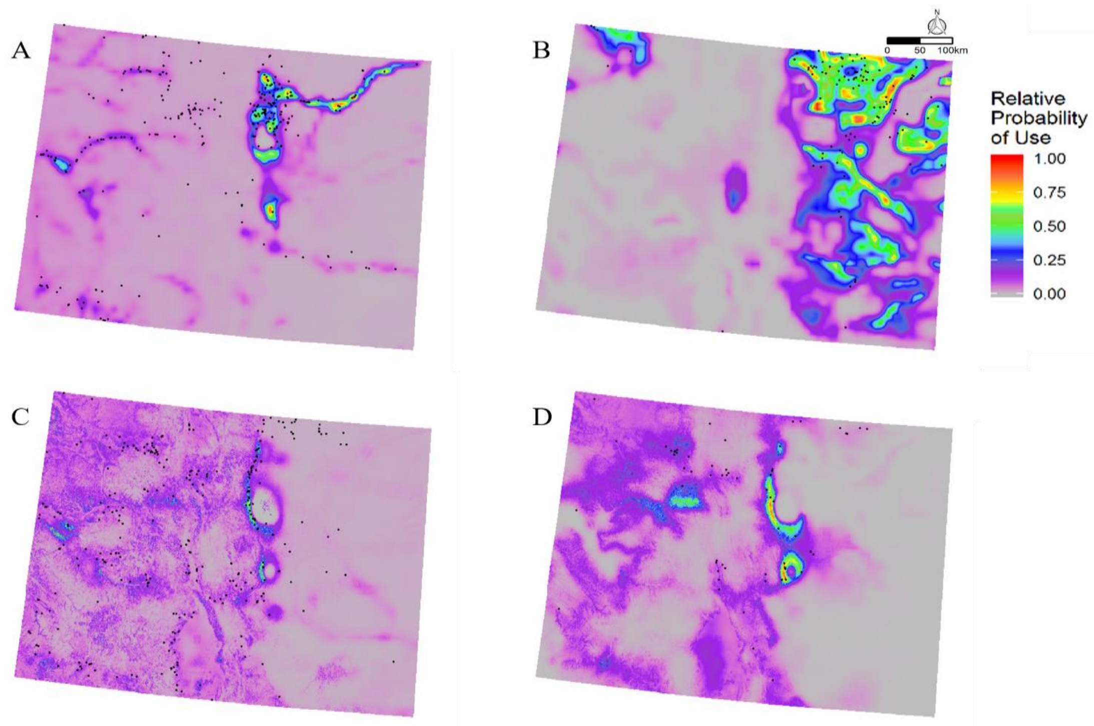

Figure 1. Expected suitable nesting habitat for (A) bald eagle; (B) golden eagle; (C) ferruginous hawk; and (D) prairie falcon in Colorado. White represents likely suitable habitat, black represents unlikely suitable habitat. White points represent observed nest locations.

- **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 (see Figure 1 for example, below). 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. We have completed analyses and submitted the resulting manuscript for peer-review at *Diversity and Distributions*. Future objectives include evaluating likely species movement corridors using landscape movement models.

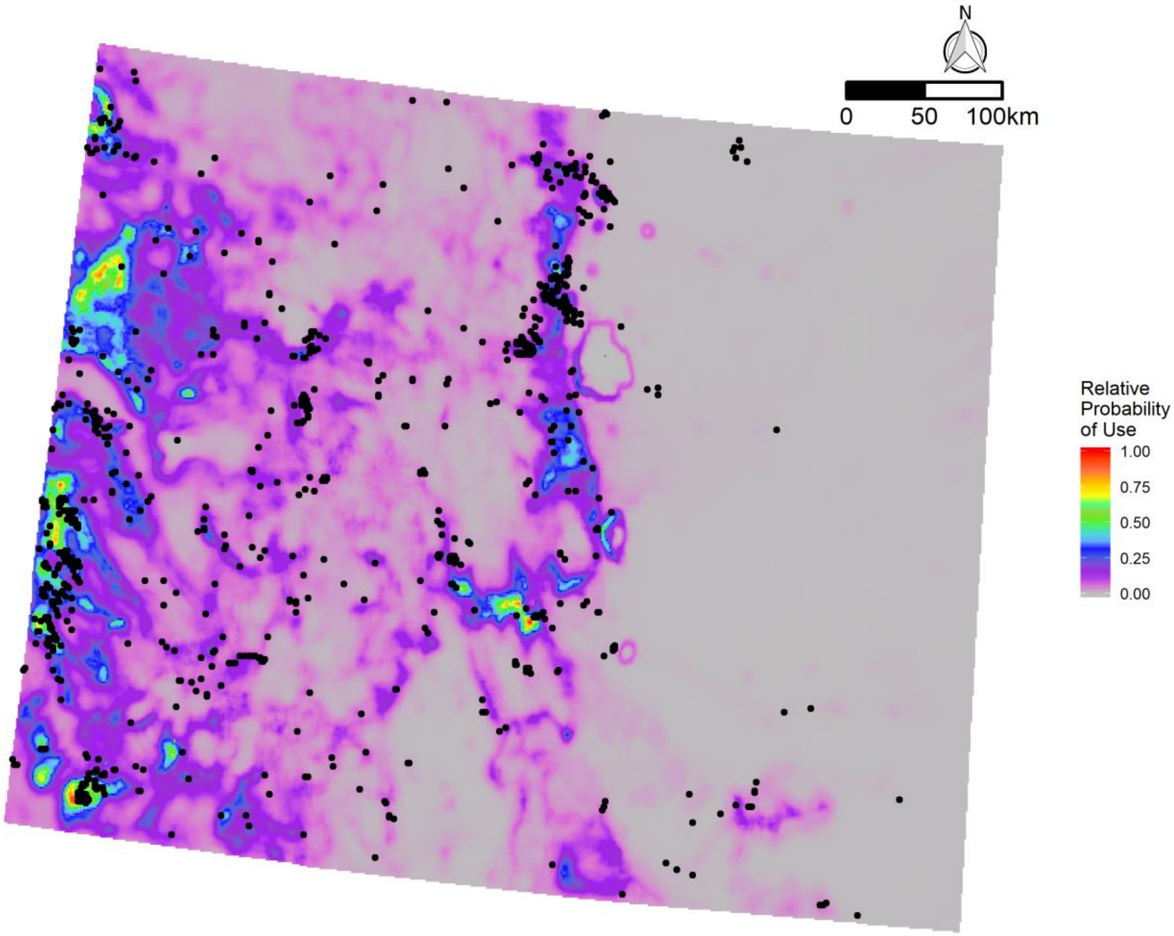

Figure 2. Example bat distribution model for al myotid species across the state. Warm (red) colors represent likely suitable habitat; cool (gray) colors represent likely unsuitable habitat. Black points represent observed locations.

- **Colorado integrated bat distribution modeling effort (with D. Neubaum, B. Reichert [USGS], K. Enns [USGS], C. Talbert [USGS])** — We are beginning collaborations to combine NABat data – collected narrowly using standardized protocols that produce robust presence-absence data – with a CPW dataset assembled from a composite of sources by D. Neubaum, which comprises presence-only data from broadly monitored locations. The goal is to develop a statewide and potentially regional bat distribution model with divergent data sources to leverage the large spatial coverage of the CPW dataset and the NABat dataset. I have obtained a subset of NABat data from the USGS and have integrated that with current CPW bat data and model code.

- **Systematic literature review of select raptor home range size (with M. Kocina)** — We reviewed published literature about home range size (HRS) for Bald Eagles (*Haliaeetus leucocephalus*), Ferruginous Hawks (*Buteo regalis*), Golden Eagles (*Aquila chrysaetos*), and Prairie Falcons (*Falco mexicanus*) in a systematic literature review. We identified 43 articles with quantified HRS estimates and accompanying methodology and demographic information on sampled individuals. Most studies focused on Bald Eagles, followed by Golden Eagles, Prairie Falcons, and Ferruginous Hawks. Prairie Falcon HRS estimates were largest (μ = 5,140 km^2, σ = 6,056 km^2), eagle estimates were similar (1,513 km^2, σ = 2,099 km^2, for Bald Eagles and 1,646 km^2, σ = 1,439 km^2, for Golden Eagles), and Ferruginous Hawk estimates were smallest (29 km^2, σ = 22 km^2). Variation across period (breeding/nonbreeding), sex, life stage, data source, and estimation type was substantial for all species, and points toward the importance of accounting for the context of HRS estimates. The information is useful for the effective conservation and management of these species, and informs other efforts to identify their spatial distribution. The results of this review were written as a manuscript and have been submitted for peer-review at *Western North American Naturalist*.

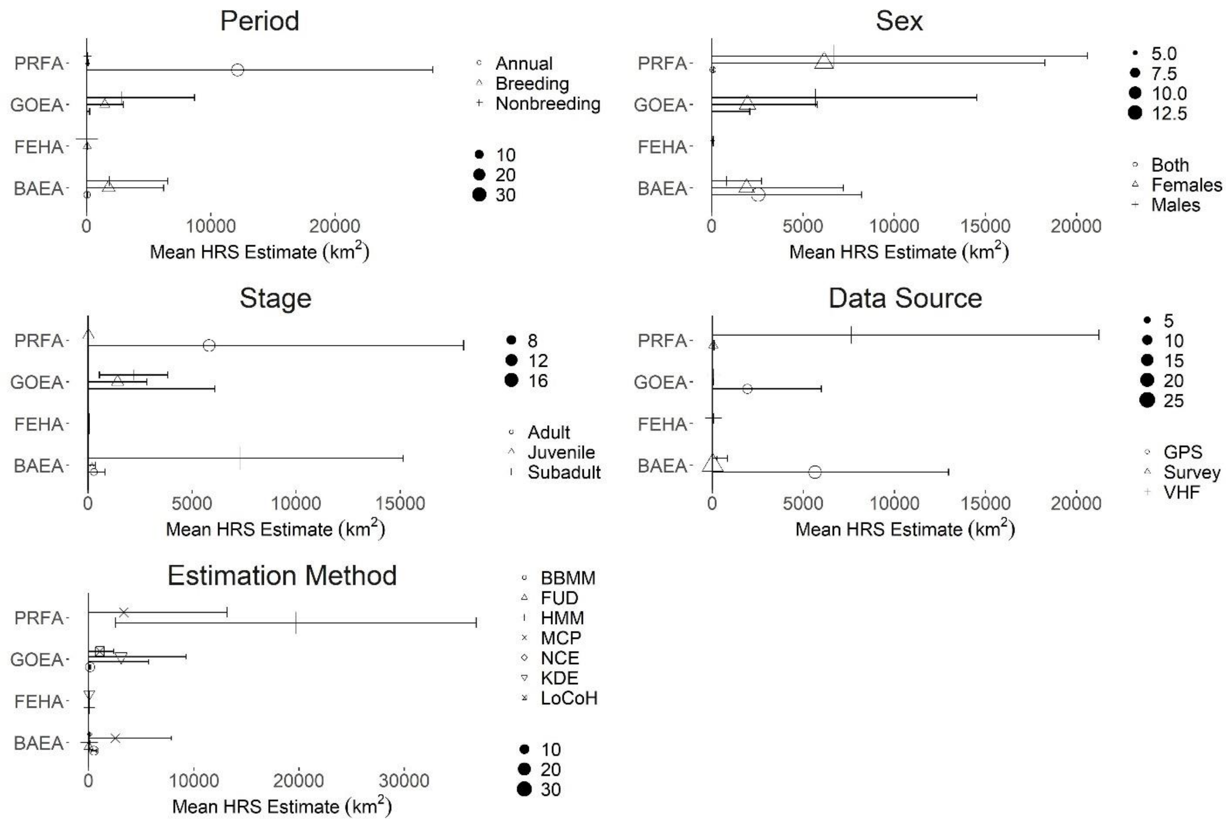

Figure 3. Mean home range size estimates across all studies (shapes) and corresponding standard deviation (error bars) for each domain (species-category-variable combination). Size of shapes indicates the mean number of individuals per study included in the derivation of the mean for that category.

- **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 worked 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 worked with area biologists and wildlife managers to identify which covariates in certain contexts (populations and seasons) are the most useful from a management perspective. The results of this effort have been written in a manuscript and will be submitted for peer-review to *Wildlife Research*.

- **Black swift breeding phenology (with C. Gunn)** — We analyzed over two decades of breeding phenology and nest success data, collected from 1996 through 2017. We documented dates of first arrival, laying, incubation onset, hatching, and fledging, and determined the intervals from arrival to laying and from laying to incubation, and the durations of incubation and nestling period in each year. All breeding events followed each other closely and showed little chronological change throughout the study. The estimate of nest success for all nest attempts was 77.5%. We have written these results in a manuscript which is currently in review at *The Wilson Journal of Ornithology*.

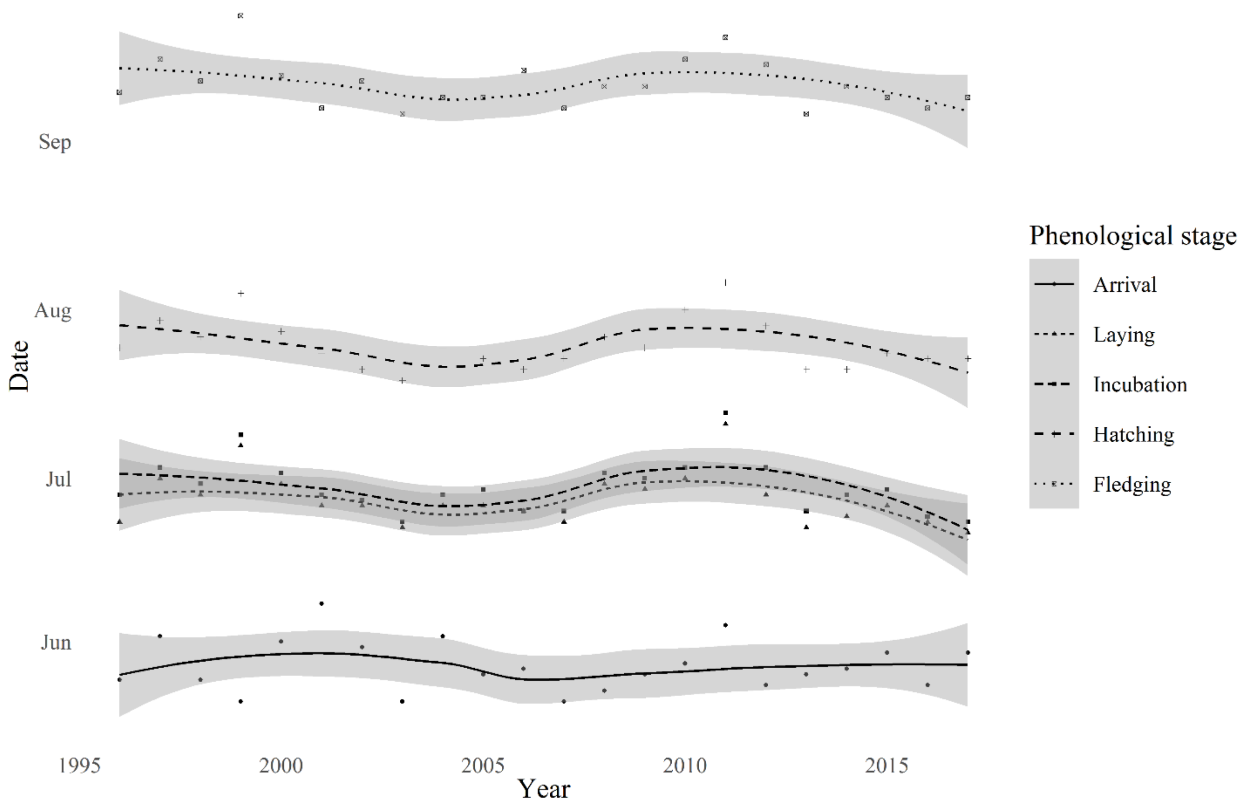

Figure 5. Breeding phenology of Black Swifts at the Box Canyon colony, Ouray, Colorado, 1996-2017. Gray bars indicate the 95% CI.

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Avian response to plague management on Colorado prairie dog colonies

Period Covered: January 1 – December 31, 2019

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

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

EXTENDED ABSTRACT

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

Here we briefly summarize research activities from 2013-2019 on both BTPD and GUPD sites and describe plans for long-term monitoring at research sites. Detailed results were provided in previous years' reports and are not replicated here, as final analyses and publications will be prepared over the next several years. 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 seven 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*).

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 in >80% of the BTPD study area. Some colonies, particularly those receiving dust or vaccine, have had increasing prairie dog numbers since initially declining during the peak of the epizootic, while others, especially untreated areas, have continued at severely reduced acreage (Tripp et al. 2017). Precipitation has varied greatly over the course of this study, from slightly dry to very wet, compared to the 30-year average. This plague cycle began during a dry period but peaked during two wet years. In contrast, we observed very little plague activity (two small colonies) at GUPD sites until 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 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, and nest searching at all sites.
- Phase 1.5 (2016) featured the early use of plague vaccine as a management tool for CPW. Plague continued at some BTPD colonies. Because plague research goals could not be pursued 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 then did not happen).
- Phase 2 (2017-2019) featured broader plague management by CPW Terrestrial staff 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, vegetation transects, and camera surveys) of species associated with prairie dogs at sites with varying levels of plague management. This will require close collaboration internally and externally to monitor colony boundaries and changes in prairie dog activity caused by plague.

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. Looking across raptor species, the pattern of higher use of active vs. post-plague colonies was stronger in winter than in summer. Additional analyses of bird data are planned, 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.

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.

We created a time lapse video showcasing diverse wildlife at a prairie dog burrow (posted publicly January 2019):

- https://www.youtube.com/watch?v=CpJYrZ2MMJk
- https://www.facebook.com/104599519602883/posts/2149977435065071/

Progress and completed project components in 2019:

- 2019 was the final year of sampling for this phase of the research project. We completed 7 years of sampling at BTPD sites and 6 years of sampling at most GUPD sites.
- In 2019, we conducted avian point counts, raptor surveys, nest survival monitoring of burrowing owls and other raptors, vegetation transects, and have now collected ~3 million photos from motion-triggered cameras. Data have all been entered and ~75% of photos have been classified.
- We created a time lapse video of a prairie dog burrow in Dec. 2018 that CPW Creative Services edited and posted on CPW's YouTube, Facebook, and Avian Research webpages in Jan. 2019. This video has been shown at various statewide meetings and events, such as a public event at the Fort Collins Museum of Discovery and Black-Footed Ferret recovery team meetings.
- We created a time lapse video at a burrowing owl nest in Dec. 2019 that is currently being edited by CPW Creative Services.
- R. Conrey presented this research at the annual meeting of the American Ornithological Society, Partners in Flight Western Working Group, and City of Fort Collins Soapstone/Meadow Springs Ranch group.
- Co-authored a paper on range expansion of the Baird's sparrow, detected while sampling birds on prairie dog colonies for this project:
    - Youngberg, E. N., A. R. Bankert, A. O. Panjabi, R. Y. Conrey, A. Meyer, and M. D. Correll. 2019. Southward breeding range expansion of the Baird's sparrow. Ecology. https://doi.org/10.1002/ecy.2872

Plans for 2020 and beyond:

- Cooperate with Terrestrial and Wildlife Health staff and external partners to continue monitoring colony boundaries and prairie dog/plague activity at research sites.
- Rotate among BTPD and GUPD sites over future years, conducting point counts, vegetation, and camera surveys every few years.
    - Sampling in 2020 will be minimal unless large changes in activity or colony boundaries are observed, but we will sample at least one site in 2021 (likely Baca NWR).
    - We will continue to collaborate with Bird Conservancy, as they begin a sampling schedule of every 2 – 3 years at BTPD sites.
    - We will track longer-term impacts of different plague management strategies on the community of wildlife associated with prairie dog colonies.
- Data analyses and preparation of manuscripts:
    - Changes in grassland bird densities at BTPD sites over two plague and recovery cycles (14+ years), co-authored with Bird Conservancy of the Rockies.
    - Changes in bird density or occupancy at GUPD sites, with comparisons of active vs. plagued sites and on- vs. off-colony sites.
    - Grassland bird nest survival and relationship to plague, weather, carnivore occupancy, and other factors.
    - Site use/occupancy of mammalian carnivores, with comparisons of active vs. plagued sites.
    - Site use of raptors, with comparisons of active vs. plagued sites.
    - Changes in plant community related to plague, weather, biosolids applications, and other factors.

LITERATURE CITED

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

Butts, K. O. and J. C. Lewis. 1982. The importance of prairie dog colonies to burrowing owls in Oklahoma. Proceedings of the Oklahoma Academy of Sciences 62:46–52.

Conrey, R. Y. 2010. Breeding success, prey use, and mark-resight estimation of burrowing owls nesting on black-tailed prairie dog towns: plague affects a non-susceptible raptor. Ph.D. Dissertation, Colorado State University, Fort Collins, Colorado.

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

Kamler, J. F., Ballard, W. B., Gilliland, R. L., Lemons, P. R., II, and Mote, K. 2003. Impacts of coyotes on swift foxes in northwestern Texas. Journal of Wildlife Management 67:317-323.

Karki, S. M., Gese, E. M., and Klavetter, M. L. 2006. Effects of coyote population reduction on swift fox demographics in southeastern Colorado. Journal of Wildlife Management 71:2707-2718.

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.

.

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, 2019

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

Project Collaborators: Bird Conservancy of the Rockies; U.S. Fish and Wildlife Service; U.S. Forest Service; Bureau of Land Management; National Park Service; Boulder County; other agencies who have submitted nest data; Cornell Lab of Ornithology; CPW Species Conservation Unit, GIS Unit, and Biologists: especially L. Rossi (SCON); J. Thompson (Resource Stewardship); R. Sacco (GIS); A. Estep, M. Sherman, M. Cowardin, L. Carpenter, & Senior Terrestrial Biologists (TERR).

EXTENDED ABSTRACT

Raptor monitoring databases have generated important insights into various aspects of raptor ecology and can provide a sound foundation for management of individual species or within the larger context of managing targeted habitats (Greenwood 2007). CPW has a statewide raptor nest database developed by R. Sacco (GIS Unit), which currently contains records for nearly 10,000 nest locations of 30 species going back to the 1970s. Until recently, the nest database was primarily being used by CPW at a site-specific scale in the oil and gas consultation process (Colorado House Bill 1298) and other local-scale land use input, and this continues to be an important function of raptor data in Colorado. 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, are being assessed during this project.

Research objectives were to 1) Assess and improve the data available in CPW's raptor nest database; 2) Build distribution models for our highest priority raptor species, evaluating the importance of ecological and anthropogenic covariates and identifying priority areas for future surveys; 3) Estimate nest survival for bald eagles, evaluating the importance of ecological and anthropogenic covariates, and offering a comparison of distribution vs. productivity objectives; 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 two objectives have been completed and progress has been made in achieving the last three objectives.

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 but those

records are typically summarized into one end-of-season record before submission to the statewide database.

The CPW raptor nest database contained nest records for 9977 locations of 28 (most recently occupying) raptor species, as of 29 January 2020 (Table 1A). This included 1852 active nests known to be occupied within the past 5 years, which is 375 more active nests than existed at the start of this project. Although the majority of nest locations (6071 nests) have an unknown or undetermined status, this proportion has been reduced from 70% to 61% of the total, due to increased sampling effort, especially at historic nest sites. 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. Due to increased effort, the database has grown from 8696 to 9977 raptor nest locations in 4 years.

Avian Research and Terrestrial staff recently completed a raptor nest monitoring protocol and revised the nest datasheet, which will help to standardize monitoring methods statewide and ensure that relevant data are recorded in fields that can be queried for analysis. This protocol and datasheet have been presented to and vetted by most Terrestrial and some Regional staff. The CPW Raptor Nest Database Nest Monitoring Protocol describes objectives and priorities as well as protocols for field data collection, data entry, and data submission. Stated priorities are nests visits for Golden Eagle, Bald Eagle, Peregrine Falcon, Prairie Falcon, Ferruginous Hawk, and Swainson's Hawk (Northern Goshawk are actively monitored by USFS), especially to nests that were last checked 5 years ago and are losing their "known" 5-year status.

This document will help to standardize protocols that many staff were already using, but it also changes recommendations in several ways. It requests submission of all records, rather than a single annual summary record, including visits to unoccupied alternate nest structures (where birds have built several structures within a territory). It suggests that the best time to make a yearly nest visit is early during incubation but prior to leaf-out, which may obscure views. For nests that will be monitored multiple times within a season, observers should try to determine when incubation is initiated (laying of the first egg) and hatching and fledging occur. The new datasheet provides "unknown" and "not applicable" options in all relevant fields, so there should be no reason for observers to leave fields blank. Unoccupied nest records should continue to list the most recent occupying species (i.e., and unoccupied bald eagle nests continues to list bald eagle as the species, rather than switching to large stick nest). Nest status has been clarified and expanded into three separate fields for bird occupancy, nest structure, and fate of the nesting attempt. Observations of behaviors, nestling age, and potential disturbances that previously could only be described as "Comments" are now quantified in separate fields that can be queried for analysis. We added fields for number of adults, adult behavior, juvenile behavior, juvenile age, and potential disturbances (category, distance from nest, and response of birds). Bird behaviors and responses to disturbance are ranked so that observers can choose the most significant information for those fields (with the opportunity for further description in separate Comment fields). Observers are asked to submit data by December 1 of each year so that they can be uploaded prior to the start of the next breeding season.

We completed distribution models using the existing CPW nest database for four priority species: bald eagle, golden eagle, ferruginous hawk, and prairie falcon (Figure 1). A manuscript (Aagaard et al. *in revision*) was submitted to Condor and will be revised in 2020 for submission to another journal. The goal of distribution modeling was 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. These models are described in Kevin Aagaard's annual research project report.

In 2019, we began a new SCTF-funded raptor project that will continue through 2023 and focuses on Golden Eagles (GOEA) in the SE Region of Colorado; this focus was agreed upon by statewide Regional, Terrestrial, and Research staff during a September 2018 meeting. Objectives are to better describe GOEA population status and analyze the cost:benefit ratio of monitoring methods that incorporate detection probability (therefore allowing estimation of abundance and trend), minimize sampling bias (which will also produce improved distribution models), explore use of citizen science (e.g., eBird) data, and estimate productivity at a subset of nests. An obvious place to start was to revisit historic nest locations, in order to add active nest locations while decreasing the proportion of GOEA nests with unknown status. Area 6 alone had over 900 unknown-status GOEA nests, so we hired temporary employees to survey as many sites as possible. A smaller amount of technician and permanent staff time was also allocated in each of the other regions. We reduced the number of unknown GOEA nests by almost 200 and increased the number of active, inactive, and destroyed structures by 212 (Table 1B). We will continue to visit historic GOEA nest sites in 2020, as well as conducting repeat nest visits to estimate productivity at a subset of nests.

In April 2019, we piloted a method for aerial raptor nest surveys that allows estimation of detection probabilities, documents non-detections (rather than presence-only), and minimizes road bias. This will ensure a more representative sample and could eventually produce estimates of abundance, density, and trend. We flew north-south transects as well as one tributary and one canyon route that covered most of Crowley and ~half of Otero County in Area 12 (Figure 2). We selected this area because it was expected to be a good area for testing methodology and have a high impact on the database, as only three bald eagle nests were being actively monitored there. During each flight, two observers on the right side of the plane independently recorded nest locations using double-observer methods and distance sampling. For two days, a third observer was added to the left side behind the pilot so that both sides of the plane could be surveyed simultaneously and the transect width doubled. Nests were categorized into one of three strata (plains, canyon/bluff, or associated with water) and placed into ¼ mile distance bins. We attempted to record UTMs when the plane drew even with the nest. We also recorded bird species and structural characteristics (e.g., intact/dilapidated and tree species) whenever possible, plus time, weather, and altitude.

As a result of these flights, we detected ~80 raptor nest structures in an area where only three bald eagle nests were being actively monitored (with ~10 additional structures last observed by USFS partners in 2009). We also recorded six black-billed magpie nests and two additional false positives. Not all locations could be accessed for follow-up ground-truthing, and SE Terrestrial staff are currently preparing data for submission to the statewide database (including use of digital maps for comparison to UTMs marked from the transects). Therefore, analyses of detection probability and comparison of efficacy of distance sampling versus double-observer methods is ongoing. Plans for 2020 to fly a new portion of Area 12 will be based on results of these analyses, but several lessons were learned. We will incorporate a training flight for observers, a follow-up flight over structures detected during the survey, and optimize flights over canyons and tributaries (where detection was difficult due to topography and aircraft speed). We may also experiment with helicopters or drones in future, as these aircraft can fly more slowly and potentially get more direct line-of-sight.

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. Preliminary results suggest daily nest survival is best modeled by nest stage, maximum temperature in June, and time in season. Thus far, this effort has produced dates for bald eagle nest phenology that were incorporated by CPW staff into recommendations for new High Priority Habitat seasonal restrictions.

Results for BAEA will be finalized and nest success estimates available after we complete revisions on the input data file. Extra effort is required in the field and in follow-up data management to get information that will produce productivity estimates versus distribution estimates. Edits to the statewide raptor nest protocol and datasheet for 2020 (described above) should make it possible to much more efficiently estimate nest survival and productivity without the need to access external data (i.e., the original data entry from State Parks, Bird Conservancy and others) or extensively reformat data from Comment fields.

The traditional nest survival model (as implemented in Program MARK) does not incorporate uncertainty in nest initiation or completion dates or nest stage (incubation of eggs vs. chick-rearing). Therefore, Bill Kendall, our collaborator at USGS Colorado Cooperative Fish and Wildlife Research Unit, has begun development of a multi-event nest survival model that explicitly incorporates at least some types of uncertainty (age of the nest when first monitored and date when the nest transitions from egg to nestling stage). Thus far, he has simulated 50 bald eagle nests with 2 – 3 visits each, calculating only two survival parameters (one for each stage). The model seems to produce unbiased estimates and reasonable precision, with higher precision for the nestling stage (which lasts longer) than the incubation stage and when nests are visited more frequently.

Other data sources have potential to contribute to our understanding of Colorado raptors, including eBird, Breeding Bird Survey, and Colorado Breeding Bird Atlas. In 2020, we hope to further evaluate eBird as a source of data for distribution or occupancy modeling. We will also incorporate ground surveys of raptor nest locations identified by Colorado Breeding Bird Atlas II (COBBAII) observers. However, their data collection protocols did not include recording UTMs of confirmed or suspected nest structures (some observers may have done this while others just included nesting comments for that block), so we are still working out the details of these surveys. It is important to evaluate citizen science data not associated with CPW data collection such as eBird, while also recognizing the importance of data collected by volunteers associated with CPW and partners such as Bird Conservancy of the Rockies Bald Eagle Watch.

We hope to continue progress on statewide assessments of raptors in Colorado during 2020 by providing improved data collection and modeling. However, meeting these goals will also require continued articulation of CPW objectives for raptor monitoring and priorities for raptor conservation and management.

Progress and project components completed during 2019:

- Original SCTF project on the CPW raptor nest database was completed.
- Co-authored a raptor monitoring protocol and revised the nest datasheet (along with other Research and Terrestrial staff) to standardize monitoring methods statewide and ensure that relevant data are reported in fields that can be queried for analysis. This was begun in 2019 and finalized in early 2020.
- Submitted manuscript (Aagaard et al.) on distribution models based on the CPW raptor nest database (will be revised and resubmitted in 2020).
- Conducted 1 week of aerial surveys in Area 12, testing distance sampling and double-observer methods. Located ~80 nests, where previously only three bald eagle nests were actively monitored.
- Began revisions of input files for bald eagle nest survival models and collaboration with B. Kendall on an alternate multi-state model.
- Produced dates for bald eagle nest phenology that were incorporated by CPW staff into recommendations for new High Priority Habitat seasonal restrictions.
- R. Conrey and K. Aagaard presented at the annual meeting of the Raptor Research Foundation.

Plans for 2020:

- Revise and re-submit Aagaard et al. manuscript on raptor distribution models.
- Conduct additional aerial surveys in the SE Region to locate previously unreported raptor nests while testing methods that account for detection probability.
- Investigate subset of raptor nest locations identified in COBBAII blocks (exact coordinates unavailable).
- Continue to work on air- and ground-based raptor nest surveys that will allow estimation of detection probabilities, document non-detections (rather than presence-only), and minimize road bias. This will ensure a more representative sample and could produce estimates of abundance, density, and trend.

- Use monitoring methods at a subset of golden eagle nests that can produce productivity estimates.
- Continue revisions and testing of alternate models of bald eagle nest survival.

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, 2019 – December 31, 2019

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

Project Collaborators: 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, one of which was grazed each year over a three year period and one 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 some 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 2019, we were able to graze seven plots in late winter/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 87 VHF radio transmitters on northern bobwhites and collected 4,053 locations. Overall adult survival from April through September was 0.34 ± 0.06. Estimated nest survival was 0.43. 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). Five nests were in plots grazed in 2018, 2 in plots grazed in 2017, 1 in a plot grazed in 2019, 4 in control plots, and 9 were not in plots. We monitored 10 broods and survival to 30 days post-hatch was 0.41. Broods selected sites with less bare ground than associated random points. Ten brood sites were in plots grazed in 2018, 5 were in control plots, 2 were in plots grazed in 2019, 1 was in a plot grazed in 2017, and the rest were not in plots. Overall, all our demographic data seem to be consistent with published values from elsewhere.

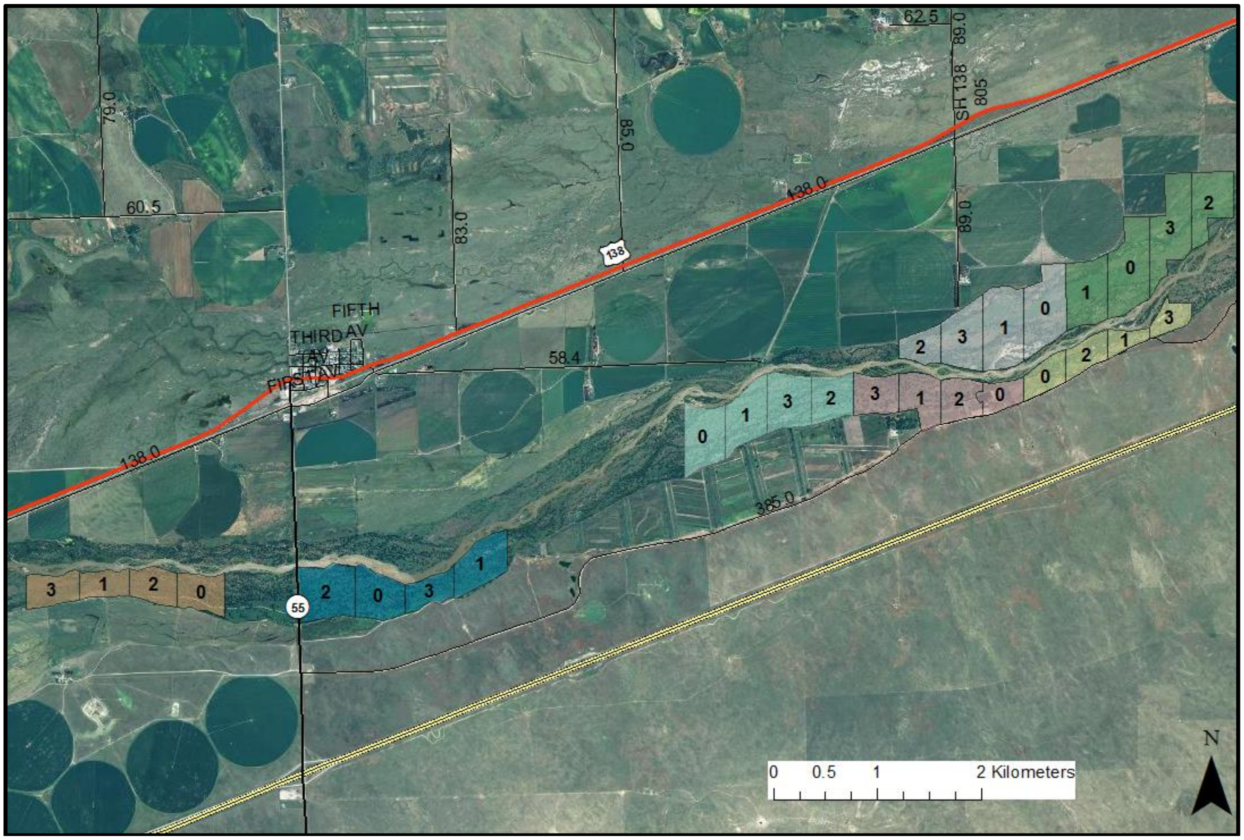

Figure 1. Grazing treatment plot layout for Tamarack State Wildlife Area. Numbers represent the year of treatment, zeros indicate control plots.

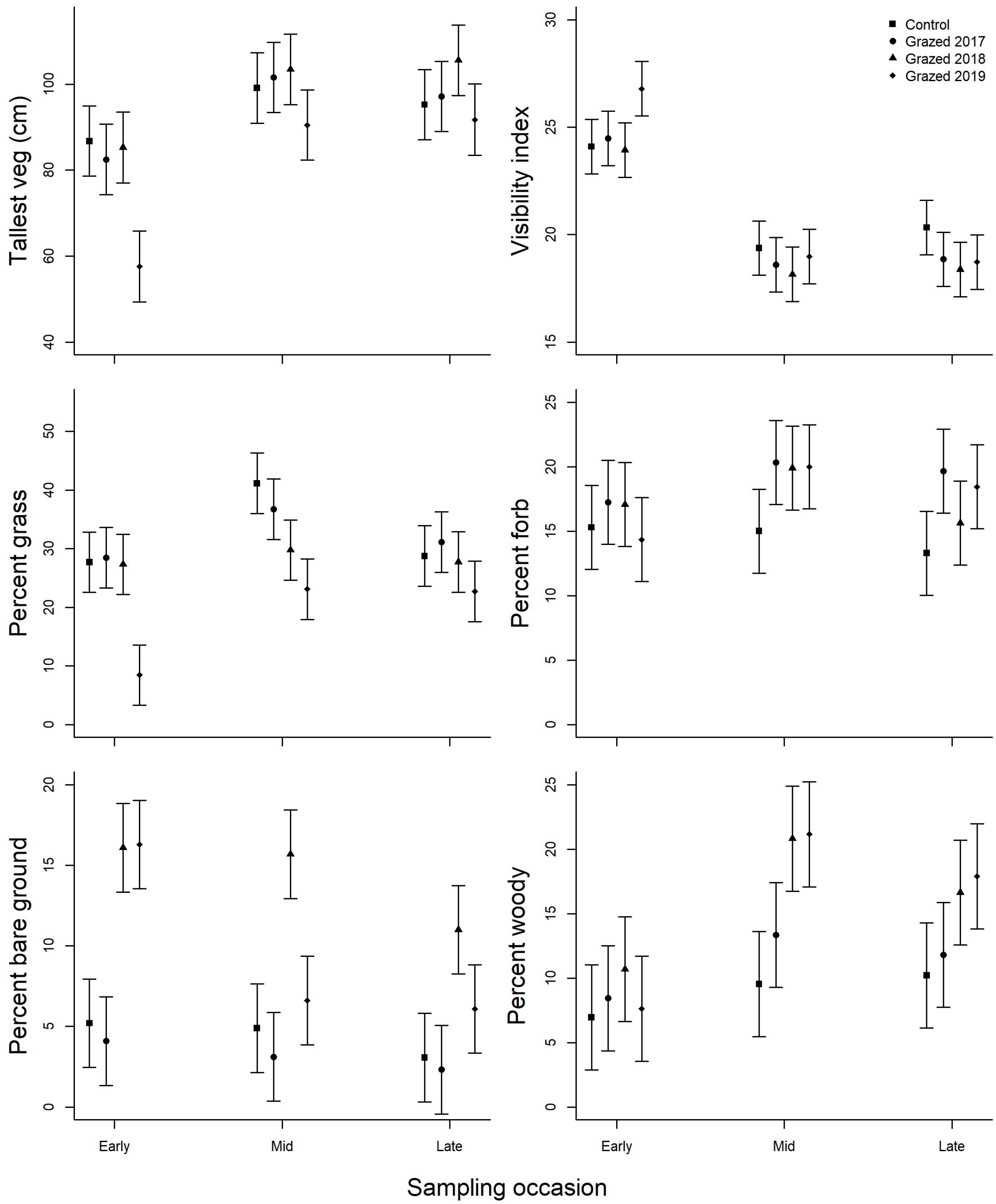

Figure 2. Vegetation characteristics at random points in grazed and control plots during three sampling occasions at Tamarack State Wildlife Area. Error bars represent one standard error.

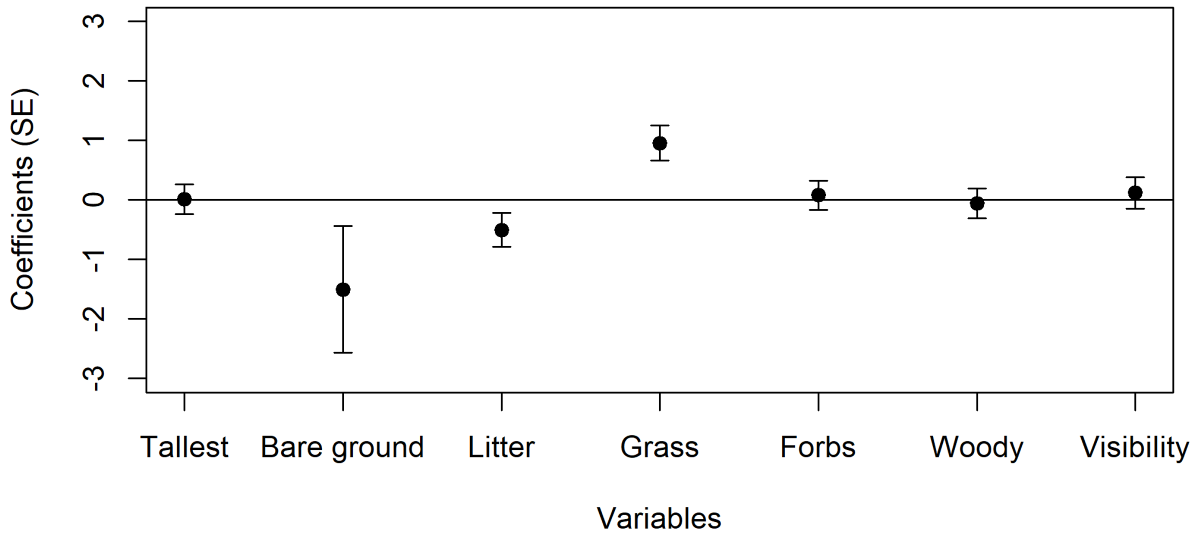

Figure 3. Standardized coefficients ± SE from discrete choice models predicting nest site selection of northern bobwhites at Tamarack State Wildlife Area in 2019. Positive values indicate selection for a variable and negative values indicate selection against a variable. All coefficients are taken from single variable models.

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Nonbreeding season survival and habitat use of northern bobwhite

Period Covered: January 1, 2019 – December 31, 2019

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

Project Collaborators: Larkin Powell, Joseph Wolske, University of Nebraska-Lincoln

ABSTRACT

Identifying the vital rates to which population growth rate is limited by, or sensitive to, can help guide management actions aimed to affect population size. For bobwhites, some studies have suggested that some populations can be sensitive to adult nonbreeding season survival, especially in northern parts of their range. We have recently completed a research project looking at bobwhite demography during the breeding season but we do not have any information on population characteristics during the nonbreeding season. Therefore, our goals with this project were to estimate survival and assess habitat selection of northern bobwhites during the nonbreeding season. We also assessed whether bobwhites would use artificial structures in areas that seem suitable except for a lack of cover. If we observed bobwhites using artificial structures, it would confirm our suspicion that woody cover limits bobwhite occupancy in those areas. The first field season began in September 2019 and will go through March 2020. We deployed 98 transmitters on bobwhites in September-October 2019 across two state wildlife areas. We created five individual artificial quail structures in October 2019. We are currently tracking bobwhites to monitor survival and habitat selection.

Colorado Parks and Wildlife

WILIDLIFE RESEARCH PROJECT SUMMARY

Estimates and determinants of duck production in North Park, Colorado

Period Covered: January 1, 2019 – December 31, 2019

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

Project Collaborators: Ella Engelhard, Makenna Fair, Emma Ferdig, Melissa Marshall, Kris Middledorf, Brian Sullivan (CPW); Casey M. Setash and David Koons (Colorado State University); Tara Wertz (Arapaho National Wildlife Refuge); Matt Reddy (Ducks Unlimited Inc.)

EXTENDED ABSTRACT

Assessing waterfowl use and productivity throughout the Intermountain West can inform habitat management practices across various land use regimes. The North Platte River Basin (hereafter, North Park) in north central Colorado has historically held important breeding and stopover habitat for ducks and is expected to become increasingly important as water demands increase across the state. In 2018, we began a study to examine duck breeding populations and production in North Park, in relation to wetland habitat conditions. During the 2019 field season, our first objective was to estimate the breeding population of ducks and evaluate the variation in abundance across wetlands. We used dependent or independent double observer methods and surveyed 86 individual wetlands for waterfowl (Fig. 1). Indicated breeding pairs were highest on wetlands with more open water and robust emergent vegetation. Summed across all sites, we observed 259 mallard, 610 gadwall, 219 cinnamon teal, and 170 green-winged teal indicated breeding pairs.

Our second objective was to assess nesting characteristics of waterfowl throughout the park. We searched nest plots in flood-irrigated hay meadows on private and public land throughout the breeding season.We monitored 26 duck nests and seven successfully hatched at least one egg. We used an unmanned aerial vehicle (hereafter, drone) affixed with a thermal camera to search for duck nests on 7 occasions between 28-Jun and 23-Jul. Each flight lasted approximately 2 hours. We flew on private land over irrigated grass fields and riparian areas during early morning (started 30 min prior to sunrise). We flew over one known nest and we were able to detect the incubating hen. We did not find any additional nests using the drone. The grass fields we flew over were not very dense so it is likely that no ducks were nesting there. The riparian areas had heavy willow cover which would make detecting nesting ducks difficult. In the future, we plan to fly over denser grass that has a greater chance of harboring nesting ducks.

A third objective was to estimate duck production using brood surveys across the park (Fig. 2). We used independent double observer surveys to account for detectability and conducted brood surveys on 67 wetlands and observed broods of 11 duck species. Duckling:pair ratio ranged from 0.00-4.35 and averaged 0.71 (SE=0.10). Brood:pair ratio ranged from 0.00-1.63 and averaged 0.15 (SE=0.03). Summed across sites we observed 14 mallard, 82 gadwall, and 8 cinnamon teal broods.

Another study objective is to use banding data to obtain demographic estimates and the contribution of North Park ducks to hunting opportunity. In 2019 we banded 812 ducks (Table 1). At the

time of this report, 84 ducks we banded in 2018 and 50 ducks we banded in 2019 (total = 134) had been harvested by hunters and reported to the USGS Bird Banding Laboratory. We plan to continue annual data collection on this study through 2023.

Table 1. Numbers of ducks banded in North Park in 2018. LM = local male, LF = local female, HYM = hatch year male, HYF = hatch year female, AHYM = after hatch year male, and AHYF = after hatch year female.

Species	LM	LF	HYM	HYF	AHYM	AHYF	Total
Mallard	7	11	109	73	234	104	538
Cinnamon teal	0	0	28	0	19	0	47
Unidentified teal[a]	0	11	0	54	0	32	97
Blue-winged teal	0	0	1	0	0	0	1
Gadwall	7	11	8	10	2	19	57
Green-winged teal	4	8	16	19	0	11	58
American wigeon	0	0	4	0	1	1	6
Northern shoveler	0	0	0	1	0	0	1
Lesser scaup	0	0	0	0	0	1	1
Redhead	0	1	0	0	0	1	2
Ring-necked duck	0	0	0	0	0	4	4
Total	18	42	166	157	256	173	812

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

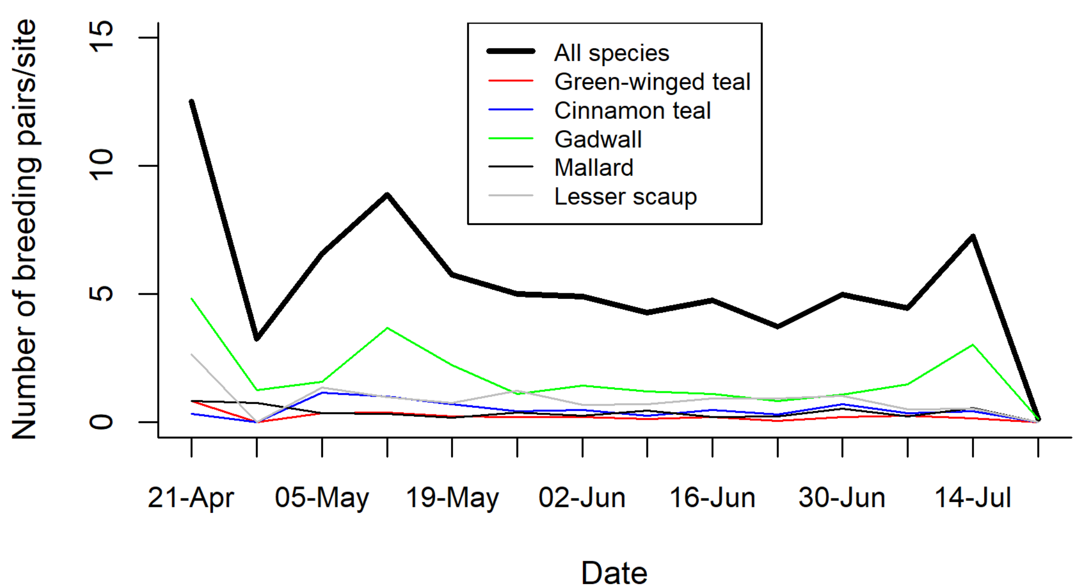

Figure 1. Number of indicated breeding pairs per site per visit throughout the breeding season.

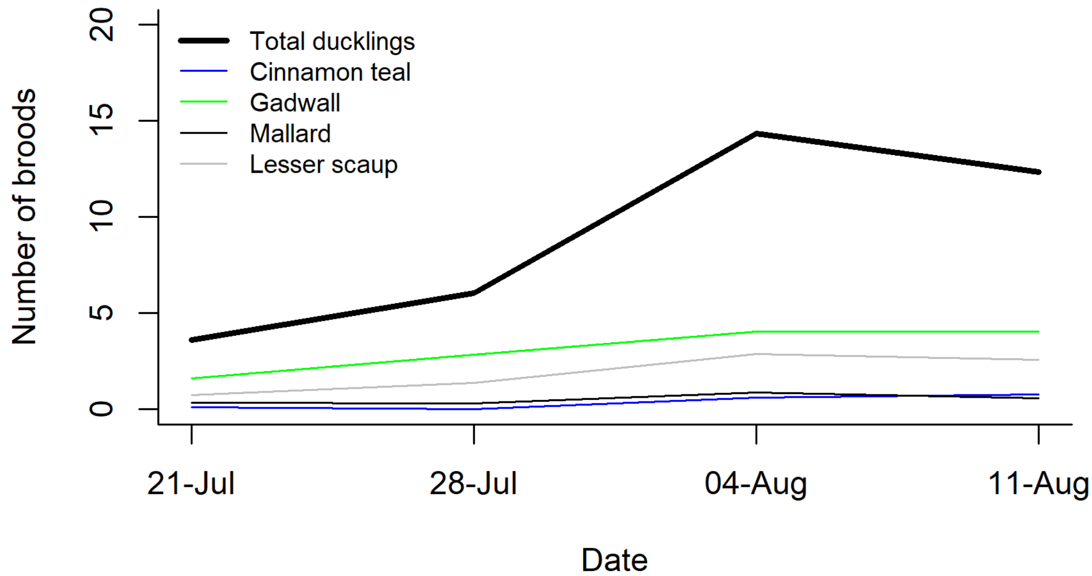

Figure 2. Number of ducklings per site per visit throughout the breeding season.

Publications, presentations, workshops and committee involvement by Avian Research staff
January – December 2019

PUBLICATIONS

Aagaard, K., **R. Y. Conrey**, and **J. H. Gammonley**. *In Review*. Spatial analysis of raptor nesting distribution: An evaluation of four priority species in Colorado using presence-only data. Journal of Raptor Research.

Apa, T. A., M. B. Rice, **K. Aagaard**, E. Phillips, D. Neubaum, N. Seward, and J. R. Stiver. *In review*. Species distribution models and conservation planning for a threatened species: A case study with Gunnison sage-grouse. Wildlife Research.

Barker, R. E., **A.D. Apa**, and R. Scott Lutz. *In Review*. Comparison of marking techniques for Columbian sharp-tailed grouse chicks. Wildlife Society Bulletin.

Behney, A. C. 2020. The influence of water depth on energy availability for ducks. Journal of Wildlife Management.

Behney, A. C. *In Review*. Ignoring uncertainty in predictor variables leads to false confidence in results: a case study of duck habitat use. Ecology.

Behney, A. C., R. O'Shaughnessy, M. W. Eichholz, and J. D. Stafford. 2019. Worth the reward? An experimental assessment of risk-taking behavior along a life history gradient. Journal of Avian Biology 50:e02068.

Behney, A. C., J. M. Wolske, T. M. Cucinotta, and C. Tappe. *In Press*. Factors influencing trapping success of northern bobwhites. Wildlife Society Bulletin.

Brown, J. A., J. L. Lockwood, J. D. Avery, J. C. Burkhalter, **K. Aagaard**, and K. H. Fenn. 2019. Evaluating the long-term effectiveness of terrestrial protected areas: a 40-year look at forest bird diversity. Biodiversity and Conservation 28:811-826.

Gerber, B., M. Hooten, C. Peck, M. Rice, **J. Gammonley**, **A. D. Apa**, and A. Davis. 2019. Extreme site fidelity as an optimal strategy in an unpredictable and homogeneous environment. Functional Ecology 33:1695-1707.

Gunn, C., S.E. Hirshman, and **K. Aagaard**. *In review*. Trends in black swift (*Cypseloides niger*) breeding phenology and success in southwest Colorado, 1996 – 2017. The Wilson Journal of Ornithology.

Johnston, D. B., and M. Garbowski. 2019. Responses of native plants and downy brome to a water conserving soil amendment. Rangeland Ecology & Management, https://doi.org/10.1016/j.rama.2019.10.001

Kircher, A. A., **A. D. Apa**, **B. L. Walker**, and R. Scott Lutz. *Accepted*. A rump-mount harness design improvement for Greater Sage-grouse with protocols for harness construction and attachment. Wildlife Society Bulletin.

Kocina, M., and **K. Aagaard**. *In review*. A review of home range sizes of four raptor species of regional conservation concern. Western North American Naturalist.

Lindstrom, J. M., M. W. Eichholz, and **A. C. Behney**. 2020. Effect of habitat management on duck behavior and distribution during spring migration in Indiana. Journal of Fish and Wildlife Management.

Youngberg, E. N., A. R. Bankert, A. O. Panjabi, **R. Y. Conrey**, A. Meyer, and M. D. Correll. 2019. Southward breeding range expansion of the Baird's Sparrow. Ecology. https://doi.org/10.1002/ecy.2872

Zimmerman, S, J, C. L. Aldridge, **A. D. Apa**, and S. J. Oyler-McCance. 2019. Evaluation of genetic change from translocation among Gunnison Sage-Grouse (*Centrocercus minimus*) populations. Ornithological Applications 121:1-14.

PRESENTATIONS, WORKSHOPS, AND COMMITTEES

Aagaard, K., **R. Y. Conrey** (presenter), and **J. H. Gammonley**. Modeling Raptor Nesting Distributions in Colorado. Raptor Research Foundation Conference. 05 November – 09 November, 2019 – Fort Collins, CO.

Alward, R. (presenter), A. Langton, **D. B. Johnston**, T. Minnick, and G. Koenemann. Tree canopy removal relases shurb understory in mule deer habitat: Monitoring restoration success using drones in western Colorado, USA. Eighth World Conference on Ecological Restoration. Cape Town, South Africa. September 24-28, 2019.

Apa, A. D. 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 Expert Team for Gunnison sage-grouse.

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

Apa, A. D. Faculty Committee member for M.S. degree candidate Rachel Barker (Harris), University of Wisconsin-Madison. Successfully defended her thesis in May 2019: Barker, R. E. 2019. Columbian sharp-tailed grouse reproductive ecology and chick survival in restored grasslands in northwest Colorado. M.S. Thesis. University of Wisconsin-Madison**.**

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

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

Apa, A. D, Science support. Provide updates and advice on Gunnison sage-grouse captive-rearing to Dr. María Suárez Álvarez program coordinator for Capercaillie recovery in Spain

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

Behney, A. C. 2019. Accounting for the effects of water depth on energy availability estimates for ducks in northeastern Colorado. North American Duck Symposium, Winnipeg, Canada. Oral Presentation.

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

Behney, A. C. Federal Aviation Administration Remote Pilot License. May, 2019.

Conrey, R. Y. (presenter), D. W. Tripp, E. N. Youngberg, and A. O. Panjabi. Plague management on prairie dog colonies maintains habitat for birds. Presented at Partners in Flight Western Working Group Meeting, Fort Collins, CO, 17 April 2019.

Conrey, R. Y. Black-footed ferrets and our prairie wildlife. Presented for 1st grade class at Rice Elementary School's wildlife weeks, Wellington, CO, 23 April 2019.

Conrey, R. Y., D. W. Tripp, E. N. Youngberg, and A. O. Panjabi. Plague management on prairie dog colonies maintains habitat for birds. Presented at City of Fort Collins Meadow Springs Ranch and Soapstone Prairie Natural Area meeting, Fort Collins, CO, 29 April 2019.

Conrey, R. Y. (presenter), D. W. Tripp, E. N. Youngberg, and A. O. Panjabi. Plague management on prairie dog colonies maintains habitat for grassland passerines and raptors. Presented at 137th Annual Meeting of American Ornithological Society, Anchorage, AK, 26 June 2019.

Conrey, R. Y. Owls of Colorado: featuring the Burrowing Owl. Poster and activity table at HOOTenanny Owl and Music Festival, Audubon Society of Greater Denver, Littleton, CO, 21 September 2019.

Conrey, R. Y. (presenter), J. DeCoste, W. L. Kendall, and **J. H. Gammonley**. Developing models for nesting success of bald eagles in Colorado. Presented at Raptor Research Foundation Annual Conference, Fort Collins, CO, 8 November 2019.

Gammonley, J. H. Central Flyway Waterfowl, Webless Migratory Game Bird, and Central Management Unit Dove Technical Committee meetings, Port Aransas, TX, January 29 – February 2, 2019.

Gammonley, J. H. Central Flyway wing bee, Hartford, KS, February 17-22, 2019.

Gammonley, J. H. Central Flyway Council meeting, Denver, CO, March 5, 2019.

Gammonley, J. H. U.S. Fish and Wildlife Service Regulations Committee meeting, Denver, CO, April 23, 2019.

Gammonley, J. H. Central Flyway Waterfowl Technical Committee and Council meetings, Alta, WY, August 25-30, 2019.

Garbowski, M. G. (presenter), C. S. Brown, and **D. B. Johnston.** Intraspecific trait variation of restoration grass seedlings at early developmental stages. High Altitude Revegetation/ Society for Ecological Restoration Joint Conference. Fort Collins, CO. March 14, 2019.

Garbowski, M. (presenter), C. S. Brown, and **D. B. Johnston**. Intra-specific trait variation of seedlings of restoration species commonly used in United States arid land restoration. Eighth World Conference on Ecological Restoration. Cape Town, South Africa. September 24-28, 2019.

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

Johnston, D. B. (presenter)**,** I. Archer, D. Lovoi, and J. Garner. Pothole seeding for cheatgrass control in early restoration. High Altitude Revegetation/ Society for Ecological Restoration Joint Conference. Fort Collins, CO. March 14, 2019.

Setash, C. M. (presenter), D. N. Koons, **J. H. Gammonley**, **A. C. Behney**, and M. Reddy. 2019. Breeding waterfowl productivity in a flood-irrigated agricultural system. North American Duck Symposium, Winnipeg, Canada. Poster Presentation.

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.