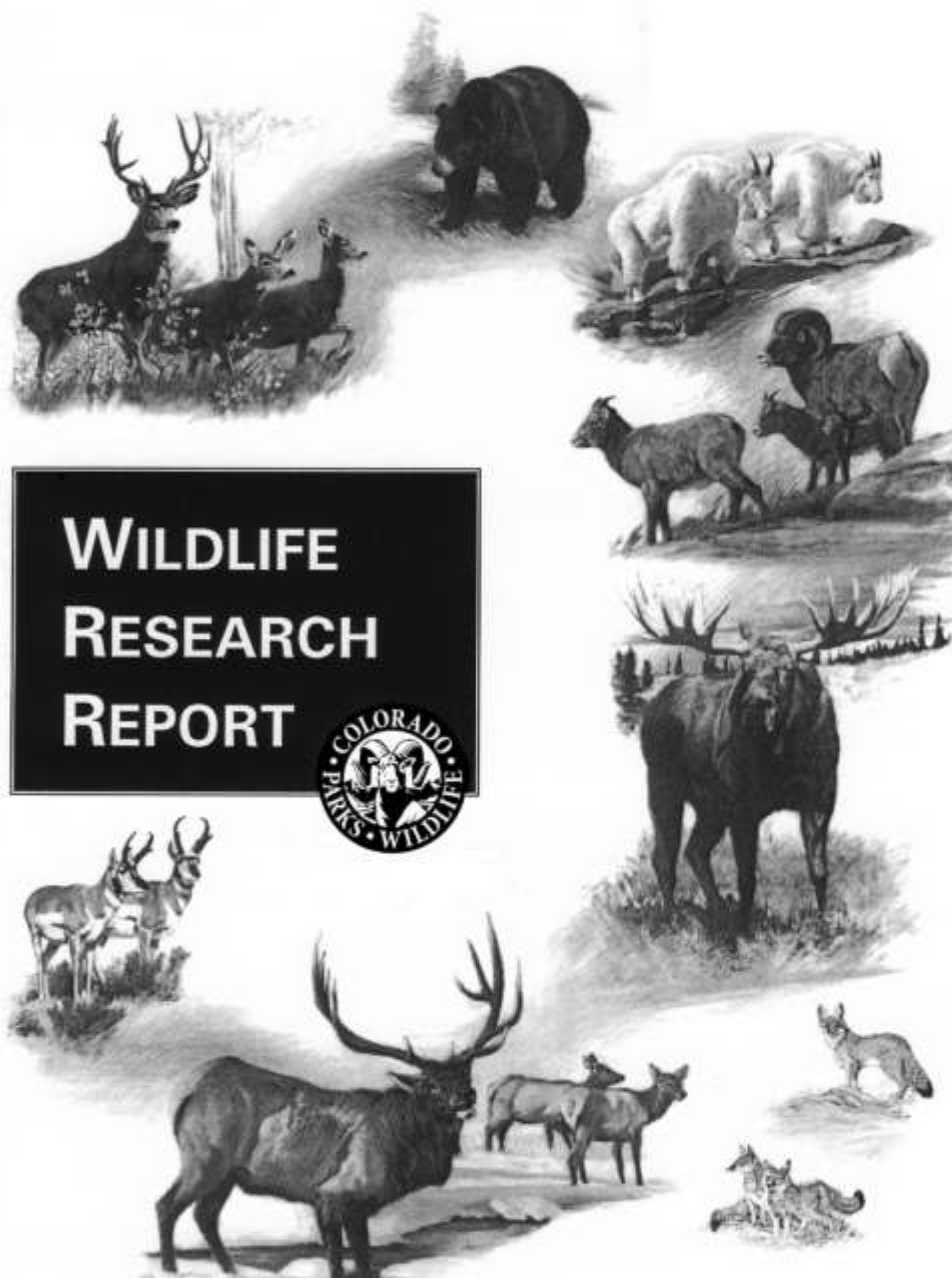
MAMMALS - JULY 2017



WILDLIFE RESEARCH REPORTS

JULY 2016 – JUNE 2017

MAMMALS RESEARCH PROGRAM

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

Executive Summary

This Wildlife Research Report represents summaries (≤5 pages each) of wildlife research projects conducted by the Mammals Research Section of Colorado Parks and Wildlife (CPW) and mechanical habitat treatment method comparisons from the CPW Habitat Reseacher of the Avian Research Section from July 2016 through June 2017. These research efforts represent long term projects (4 – 10 years) in various stages of completion addressing applied questions to benefit the management of various mammal species in Colorado. In addition to the research summaries presented in this document, more technical and detailed versions of most projects (Annual Federal Aid Reports) and related scientific publications that have thus far been completed can be accessed on the CPW website at http://cpw.state.co.us/learn/Pages/ResearchMammalsPubs.aspx or from the project principal investigators listed at the beginning of each summary.

Current research projects address various aspects of wildlife management and ecology to enhance understanding and management of wildlife responses to habitat alterations, human-wildlife interactions, and investigating improved approaches for wildlife and habitat management. The Nongame Mammal Conservation Section addresses preliminary results of mammal responses to the recent spruce beetle outbreak causing large scale changes in subalpine forest habitats in Colorado and lynx population monitoring results from the San Juan Mountain Range in southwest Colorado since 2014. The Ungulate Conservation Section includes 4 projects addressing effectiveness of mechanical treatment methods in restoring mule deer habitats, development planning and mitigation approaches to benefit mule deer exposed to energy development activity, evaluation of moose demographic parameters that will inform future moose management in Colorado, and a pilot study addressing factors influencing elk calf recruitment. The Predatory Mammal Conservation Section addresses black bear use of urban/exurban environments and approaches for managing black bear-human interactions and evaluation of harvest management for mountain lions in western Colorado. The Support Services Section describes the CPW library services to provide internal access of CPW publications and online support for wildlife and fisheries management related publications.

We have benefitted from numerous collaborations that support these projects and the opportunity to work with and train wildlife technicians and graduate students that will enhance understanding of wildlife management and ecology in the future. Research collaborators include the CPW Wildlife Commission, statewide CPW personnel, Federal Aid in Wildlife Restoration, Colorado State University, Idaho State University, University of Wisconsin-Madison, U.S. Bureau of Land Management, U.S. Forest Service, City of Boulder and Jefferson County Open Space, City of Durango, CPW big game auction-raffle grants, Species Conservation Trust Fund, GOCO YIP internship program, CPW Habitat Partnership Program, Safari Club International, Boone and Crocket Club, Colorado Mule Deer Association, The Mule Deer Foundation, Muley Fanatic Foundation, Wildlife Conservation Society, SummerLee Foundation, EnCana Corp., ExxonMobil/XTO Energy, Marathon Oil, Shell Exploration and Production, WPX Energy, and private land owners providing access to support field research projects.

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Colorado Parks and Wildlife
July 2016 – June 2017

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Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Mammal and breeding bird response to bark beetle outbreaks in Colorado

Period Covered: July 1, 2016 – June 30, 2017

Principal Investigators: Jacob S. Ivan, Jake.Ivan@state.co.us; Amy Seglund, Amy.Seglund@state.co.us ;

ABSTRACT: Mountain pine beetle (*Dendroctonus ponderosae*) and spruce beetle (*Dendroctonus rufipennis*) infestations have reached epidemic levels in Colorado, impacting over 4 million acres since the initial outbreak in 1996. Though bark beetles are native to Colorado and periodic infestations are considered a natural ecological process, the geographic scale of their impact and simultaneous infestation within multiple forest systems has never been observed. This historic outbreak is having significant impacts on composition and structure of forest stands that will propagate for decades into the future. Here we used occupancy estimation to determine statewide wildlife response to bark beetle outbreaks, as mediated by changes in forest structure.

Surveys were conducted during the summers of 2013 and 2014. We randomly sampled 150 Engelmann spruce (*Picea engelmanni*)-subalpine fir (*Abies lasiocarpa*) sites and 150 sites consisting mostly of lodgepole pine (*Pinus contorta*) or lodgepole pine mixed with other conifers. For both strata, sampling covered conditions ranging from sites that were not impacted by bark beetles to those that were impacted by beetles more than a decade ago. At each 1-km^2 (0.4 mi^2) site, we sampled the breeding bird community using the Rocky Mountain Bird Observatory's protocol for "Integrated Monitoring in Bird Conservation Regions" (Hanni et al. 2014). We sampled the mammal community by deploying a remote camera near the center of each sample unit. Avian data have not yet been analyzed.

We collected 388,951 photos of 56 species (25 mammalian species). Using Program MARK (White and Burnham 1999), we fit standard occupancy models (MacKenzie et al. 2006) to data for each species in the following manner. First, we identified the best-fitting 'base' model from among all combinations of 0-4 of the following variables: spruce-fir or lodgepole stratum, percentage of aspen present at the site, canopy cover, shrub cover due to deciduous species, shrub cover due to conifer species, shrub height, amount of down wood, amount of bare ground, and four physiographic variables that collectively account for elevation, topographic position (e.g., valley bottom, ridge top), moisture accumulation, and solar radiation at each site. The purpose of this model was to account for basic occupancy patterns of each species in the state irrespective of bark beetles. Next, we fit additional parameters to the base model which allowed occupancy to change in a variety of patterns (e.g., linear, quadratic, 3rd order polynomial, or change points when needles drop following an outbreak) in relation to time elapsed since a stand was initially impacted by beetles. We also explored whether there was any interaction between response to beetles and stratum or the severity of the outbreak (percent of trees that were killed). We used Akaike's Information Criterion (Burnham and Anderson 2002) to assess fit of these various beetle response models, and model-averaged occupancy across the model set (i.e., 'year since beetle outbreak' was treated as a group such that parameters for each group could be averaged across all models in the set) to provide a best estimate of response of each species to beetles.

As per our hypotheses, results suggest that ungulate species are positively associated with bark beetle outbreaks, although the shape and nature of their responses was variable (Fig. 1). Also not

surprisingly, granivore species comprised the majority of species that were negatively associated with bark beetle outbreaks, although again the magnitude and shape of responses was variable (Fig. 2). We did not detect any response to bark beetles by American marten or black bears (Fig. 3). Snowshoe hares did not follow expectation either, as their use did not markedly increase through time with increasing development of a dense understory (Fig. 3). Both red squirrels and snowshoe hares used spruce-fir stands more heavily than lodgepole stands.

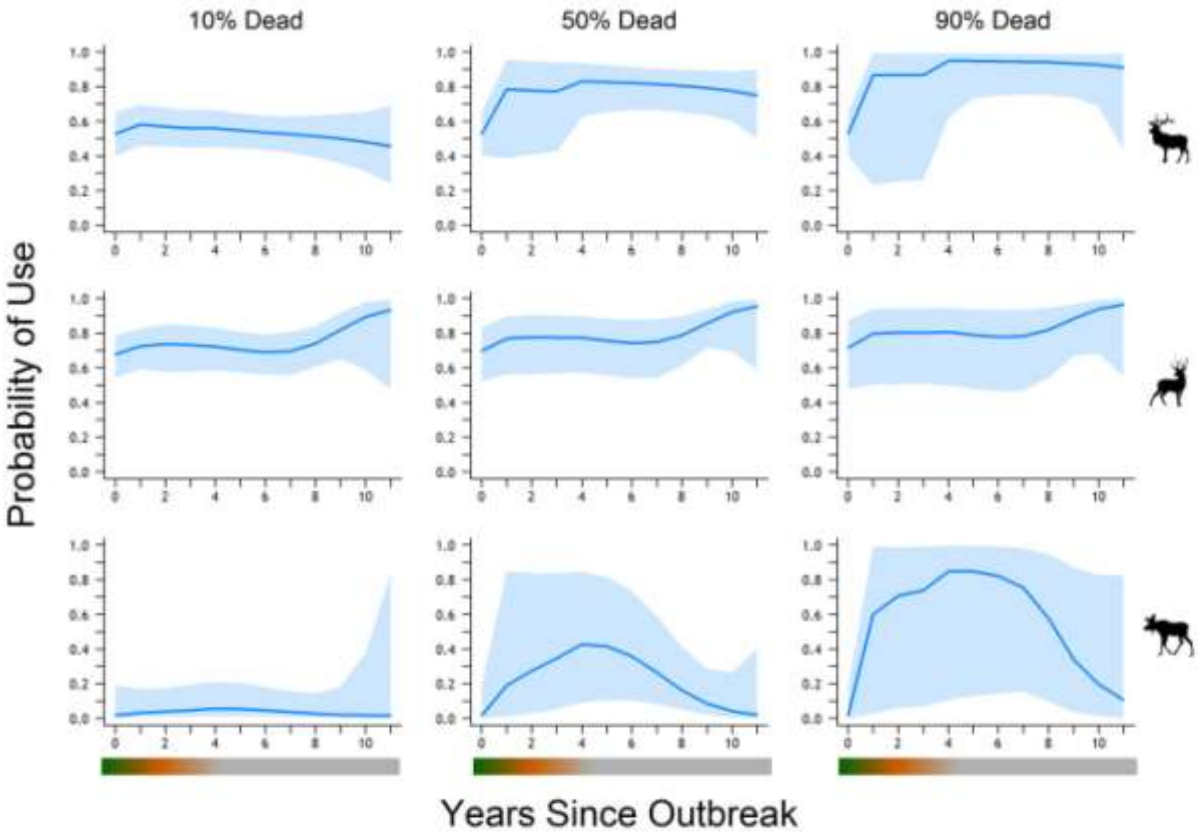


Figure 1. Species that exhibited a positive association between use of forested stands and beetle activity (either years since the outbreak occurred, severity, or both). From left to right, panels indicate predicted model-averaged responses for cases where 10%, 50%, and 90% of the overstory in a stand is killed by beetle activity. From top to bottom, panels show response for elk, mule deer, and moose. Probably of use was estimated to vary little between the spruce-fir and lodgepole pine stands, so responses are pooled among strata for these species. Shaded areas represent model-averaged 95% confidence intervals.

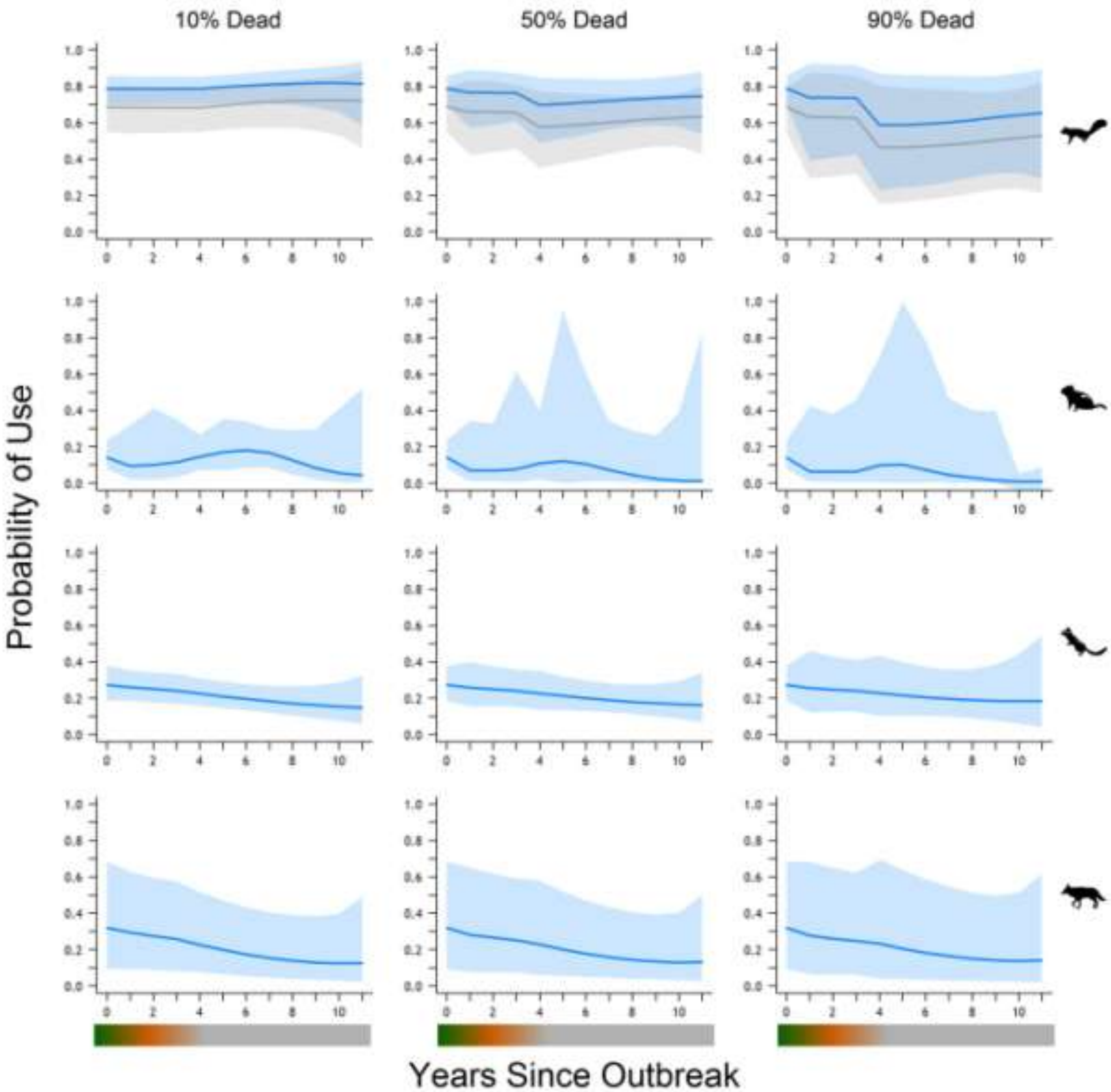


Figure 2. Species that exhibited a negative association between use of forested stands and beetle activity (either years since the outbreak occurred, severity, or both). From left to right, panels indicate predicted model-averaged responses for cases where 10%, 50%, and 90% of the overstory in a stand is killed by beetle activity. From top to bottom, panels show response for red squirrel, golden-mantled ground squirrel, chipmunk spp., and coyote. For red squirrels, use was estimated to vary between the spruce-fir (blue) and lodgepole pine stands (gray); for other species, habitat strata was less important and responses are pooled across habitat types. Shaded areas represent model-averaged 95% confidence intervals.

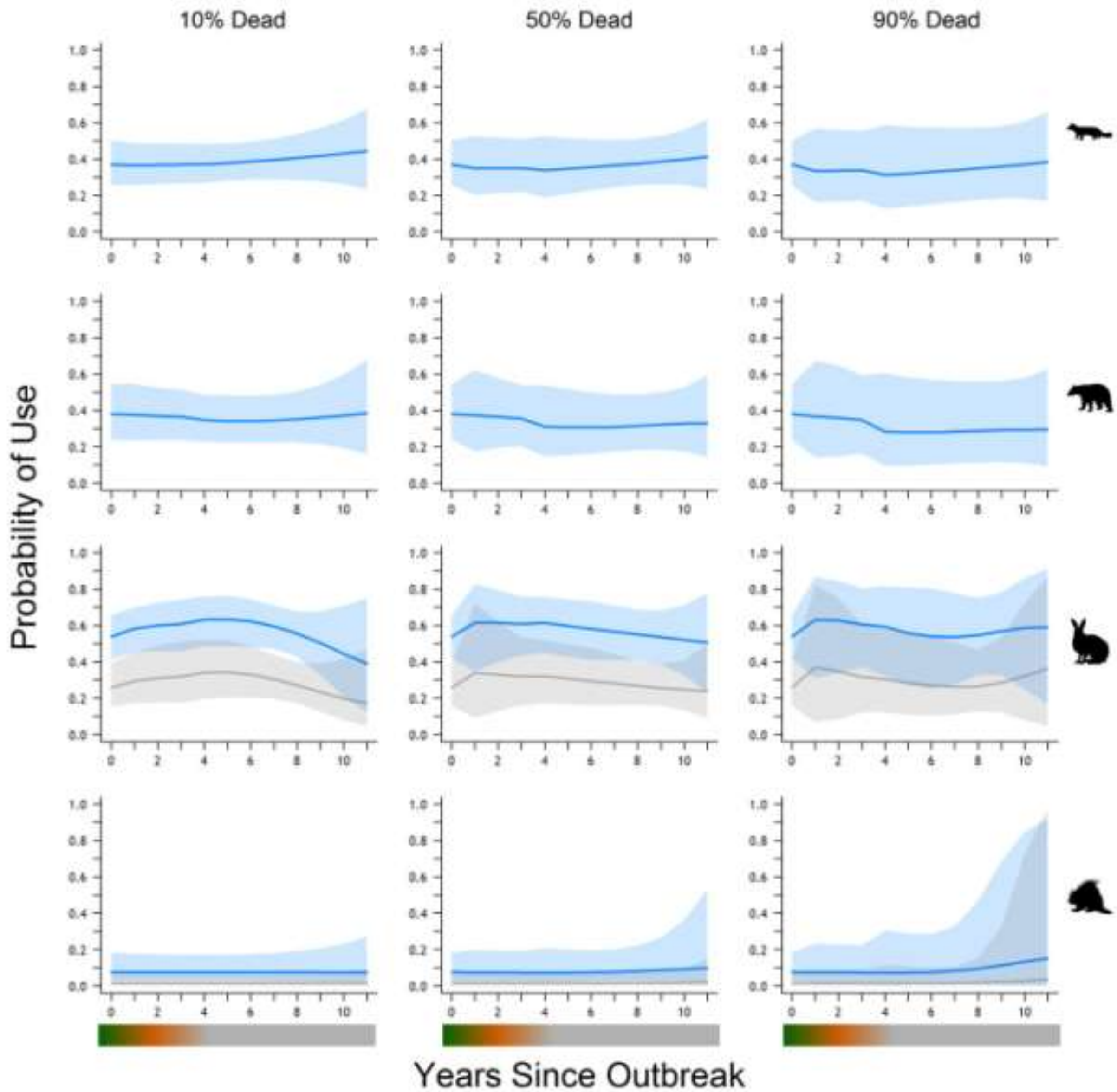


Figure 3. Species that exhibited a little association between use of forested stands and beetle activity (either years since the outbreak occurred, severity, or both). From left to right, panels indicate predicted model-averaged responses for cases where 10%, 50%, and 90% of the overstory in a stand is killed by beetle activity. From top to bottom, panels show response for American marten, black bear, snowshoe hare, and porcupine. For snowshoe hares, and porcupine, use was estimated to vary between the spruce-fir (blue) and lodgepole pine stands (gray); for other species, habitat strata was less important and responses are pooled across habitat types. Shaded areas represent model-averaged 95% confidence intervals.

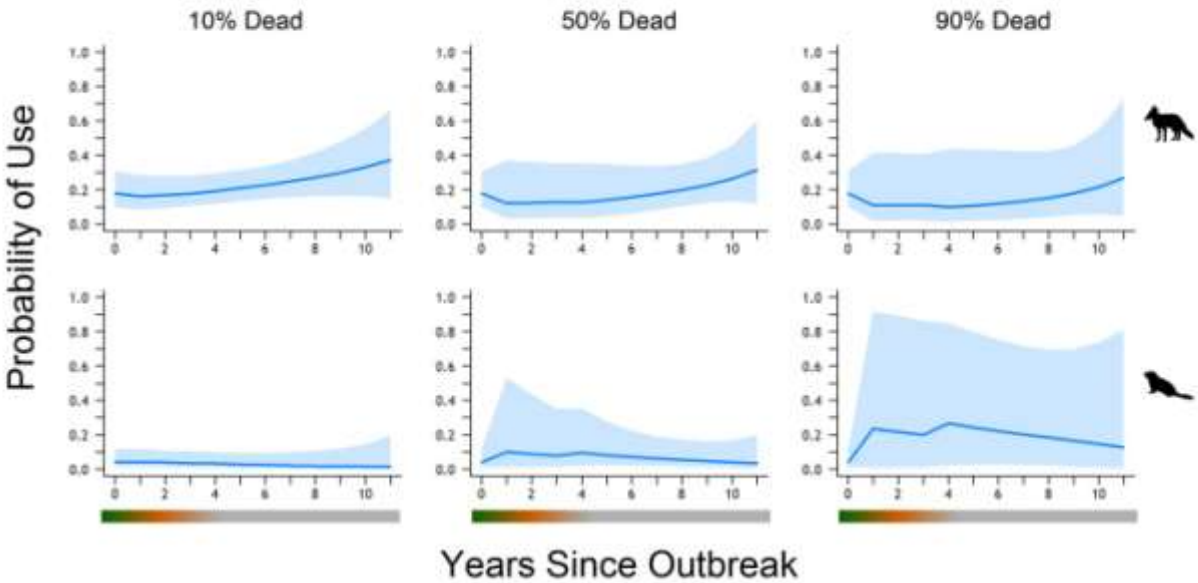


Figure 4. Species that exhibited mixed associations between use of forested stands and beetle activity (positive association with YSO but negative with severity, or vice-versa). From left to right, panels indicate predicted model-averaged responses for cases where 10%, 50%, and 90% of the overstory in a stand is killed by beetle activity. From top to bottom, panels show responses for red fox and yellow-bellied marmot. Use was estimated to vary little between the spruce-fir and lodgepole pine stands, so responses are pooled among strata for these species. Shaded areas represent model-averaged 95% confidence intervals.

LITERATURE CITED

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. 2nd edition. Springer, New York.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Academic Press, Oxford, United Kingdom.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populationsof marked animals. Bird Study 46 Supplement:120-138.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Canada Lynx Monitoring in Colorado

Period Covered: July 1, 2016 – June 30, 2017

Principal Investigators: Eric Odell, Eric.Odell@state.co.us; Jake Ivan, Jake.Ivan@state.co.us; Scott Wait, Scott.Wait@state.co.us

All information in this project summary 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 summary is discouraged.

In an effort to restore a viable population of Canada lynx (*Lynx canadensis*) to the southern portion of their former range, 218 individuals were reintroduced into Colorado from 1999–2006. In 2010, the Colorado Division of Wildlife (now Colorado Parks and Wildlife [CPW]) determined that the reintroduction effort met all benchmarks of success, and that the population of Canada lynx in the state was apparently viable and self-sustaining. In order to track the persistence of this new population and thus determine the long-term success of the reintroduction, a minimally-invasive, statewide monitoring program is required. During 2014−2017 CPW initiated a portion of the statewide monitoring scheme described in Ivan (2013) by completing surveys in a random sample of monitoring units (n = 50) from the San Juan Mountains in southwest Colorado (n = 179 total units; Figure 1).

During 2016−2017 personnel from CPW and USFS completed the third year of monitoring work on this same sample of monitoring units. Specifically, 16 units were sampled via snow tracking surveys conducted between December 1 and March 31. On each of 3 independent occasions, survey crews searched roadways (paved roads and logging roads) and trails for lynx tracks. Crews searched the maximum linear distance of roads possible within each survey unit given safety and logistical constraints. Each survey covered a minimum of 10 linear kilometers (6.2 miles) distributed across at least 2 quadrants of the unit. An additional unit was scheduled for snow track surveys but surveys were not completed. The remaining 33 units could not be surveyed via snow tracking because they occurred in wilderness or were otherwise inaccessible or prone to poor tracking conditions. Survey crews deployed 4 passive infrared motion cameras in each of these units during fall 2016. Cameras were baited with visual attractants and scent lure to enhance detection of lynx living in the area. Cameras were retrieved during summer 2017 and all photos were archived and viewed by at least 2 observers to determine species present in each. Camera data were then binned such that each of 10 15-day periods from December 1 through April 30 was considered an 'occasion,' and any photo of a lynx obtained during a 15-day period was considered a detection during that occasion.

Crews covered a total of 703 km (437 mi) during snow tracking surveys: 511 km (318 mi) by snow machine, 171 km (106 mi) by truck, and 20 km (12 mi) by snowshoe. Mean distance surveyed per occasion was 18 km (11 mi). Lynx were detected at eight snow tracking units (Figure 1). Scat or hair samples were collected from seven of the 13 lynx tracks discovered (tracks were discovered at some units on >1 occasion). Genetic analyses confirmed that 5 of the 7 samples were lynx (one sample was coyote, another was snowshoe hare). Camera sets yielded 168,705 photos of which 251 were lynx. Lynx were detected at 10 cameras in 6 camera units, although detections in 2 units occurred outside of the official survey period (Figure 1).

Resident lynx were documented in the La Garita Mountains north of Creede (Figure 1) for the second consecutive year, which is notable given that resident lynx were never observed in the La Garitas during the reintroduction work. Lynx were again detected in a unit northeast of Wolf Creek Pass, an area that was used during the reintroduction but lacked lynx detections after the West Fork Fire of 2013. Similarly lynx were also detected in a unit southwest of Lizard Head Pass where they occurred during the reintroduction but had not been detected during the monitoring effort. Lynx were not documented near the New Mexico border where they had been detected for the first time during the 2014 effort. Also, an adult female with kittens was detected at cameras in a unit near Platoro Reservoir, thus documenting that at least some reproduction occurred in the study area.

Using Program MARK (White and Burnham 1999), we fit standard occupancy models (MacKenzie *et al.* 2006) to our survey data to estimate the probability of a unit being occupied (or used) by lynx over the course of the winter. 'Survey method' was treated as a group so that we could, based on previous work, 1) allow detection probability (p) to vary by survey method and 2) include a breeding season effect for detection at cameras (lynx tend to move more in late winter when they begin to breed, and thus should encounter cameras more often). We also considered a suite of covariates that could potentially explain variation in occupancy (ψ) including proportion of the unit that was covered by spruce/fir forest, proportion covered by modeled lynx habitat (Ivan *et al.* 2011), average years since bark beetle infestation, variability (standard deviation) in years since bark beetle infestation, proportion of the unit impacted by bark beetles, proportion of the unit that was burned during Summer 2013, and the number of photos of other species that could potentially impact presence of lynx (e.g., snowshoe hares as a food source, coyotes as potential competitors). We limited our model set by considering only combinations of two of these covariates on ψ, in addition to the two covariates on detection. For the purposes of model-fitting, we included data from the pilot study (2010−2011) as well as the first three years of monitoring (2014−2017) to maximize sharing of information across surveys. 'Year' was treated as a group variable in this case to obtain a separate occupancy estimate for each effort. .

The best-fitting model characterized occupancy as a function of 2 covariates: the proportion of the sample unit covered by spruce-fir forest and the number of photos of hares recorded at camera stations (Table 1). In both cases, the association was positive, indicating that the probability of lynx use increased with more spruce-fir and more hares. Other covariates appeared in top models with spruce-fir, but addition of these covariates did not improve AIC_c scores beyond the model with spruce-fir only (Table 1). This phenomenon indicates that these other variables were not as informative. There was no discernible association between lynx occupancy and number of photos of other species outside of hares. Detection probability was relatively high for snow tracking surveys (p = 0.63, 95% confidence interval: 0.52–0.72), and low for monthly camera surveys (p = 0.21, 95% confidence interval: 0.16–0.28) during December–February and April, although detection increased to 0.42 (95% confidence interval: 0.29–0.57) during breeding season (March) as expected. For winter 2016−2017 we estimated that 23% of the sample units in the San Juan's were occupied by lynx (95% confidence interval: 0.13–0.38). Occupancy estimates from the 2016−2017 monitoring effort were slightly smaller to those obtained during the first year of implementation and to those obtained during pilot research work in 2010−2011, although confidence intervals overlapped substantially among years (Figure 2). Note that lynx were detected at the same number of units in 2016−2017 as in previous years, but detections at 2 units occurred outside of the official survey period. Thus, the spatial distribution of lynx in the San Juans is largely unchanged; estimates may have been smaller simply due to when lynx were detected.

LITERATURE CITED

Ivan, J. S. 2013. Statewide Monitoring of Canada lynx in Colorado: Evaluation of Options. Pages 15-27 *in* Wildlife Research Report - Mammals. Colorado Parks and Wildlife., Fort Collins, CO, USA. http://cpw.state.co.us/learn/Pages/ResearchMammalsPubs.aspx

Ivan, J. S., M. Rice, P. M. Lukacs, T. M. Shenk, D. M. Theobald, and E. Odell. 2011. Predicted lynx habitat in Colorado. Pages 21-35 *in* Wildlife Research Report - Mammals. Colorado

Parks and Wildlife, Fort Collins, CO, USA. http://cpw.state.co.us/learn/Pages/ResearchMammalsPubs.aspx.

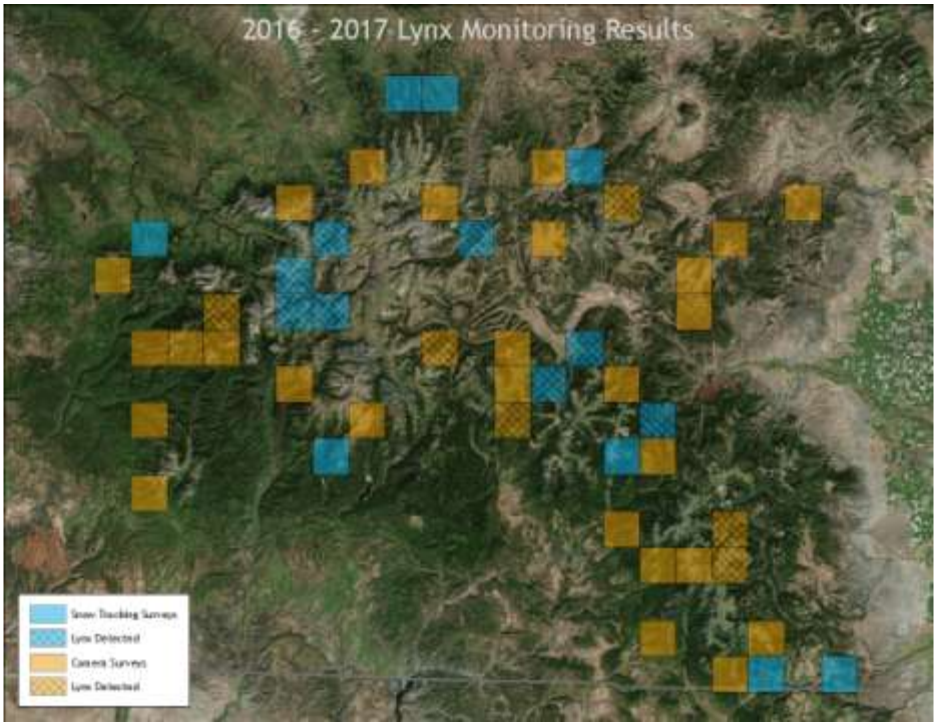
MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Academic Press, Oxford, United Kingdom.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 Supplement:120-138.

Table 1. Model selection results for lynx monitoring data collected in the San Juan Mountains, Colorado, 2010−2017. Rankings are based on Akaike's Information Criterion adjusted for small sample size (AIC_c). Twelve variables were considered as covariates to inform estimation of occupancy (ψ). The complete model set (n = 77) included all combinations of two, in addition to modeling detection (*p*) as a function of survey method and breeding season. Only the best 10 models are shown.

Model	AICc	ΔAIC_c	AIC_cWts	No. Par.
y(Year + SpruceFir + SnowshoeHare)*p*(Method + Breeding)	648.1	0.0	0.54	9
y(Year + SpruceFir)*p*(Method + Breeding)	651.7	3.7	0.09	8
y(Year + SpruceFir + Cougar)*p*(Method + Breeding)	652.3	4.2	0.07	9
y(Year + SpruceFir + Bobcat)*p*(Method + Breeding)	653.4	5.3	0.04	9
y(Year + SpruceFir + Fox)*p*(Method + Breeding)	653.5	5.4	0.04	9
y(Year + SpruceFir + Coyote)*p*(Method + Breeding)	653.5	5.4	0.04	9
y(Year + SpruceFir + PropBeetleKill)*p*(Method + Breeding)	653.6	5.5	0.03	9
y(Year + SpruceFir + SDBeetleKill)*p*(Method + Breeding)	653.7	5.7	0.03	9
y(Year + SpruceFir + PropBurn)*p*(Method + Breeding)	653.9	5.8	0.03	9
y(Year + SpruceFir + YrSinceBeetle)*p*(Method + Breeding)	653.9	5.8	0.03	9

a)



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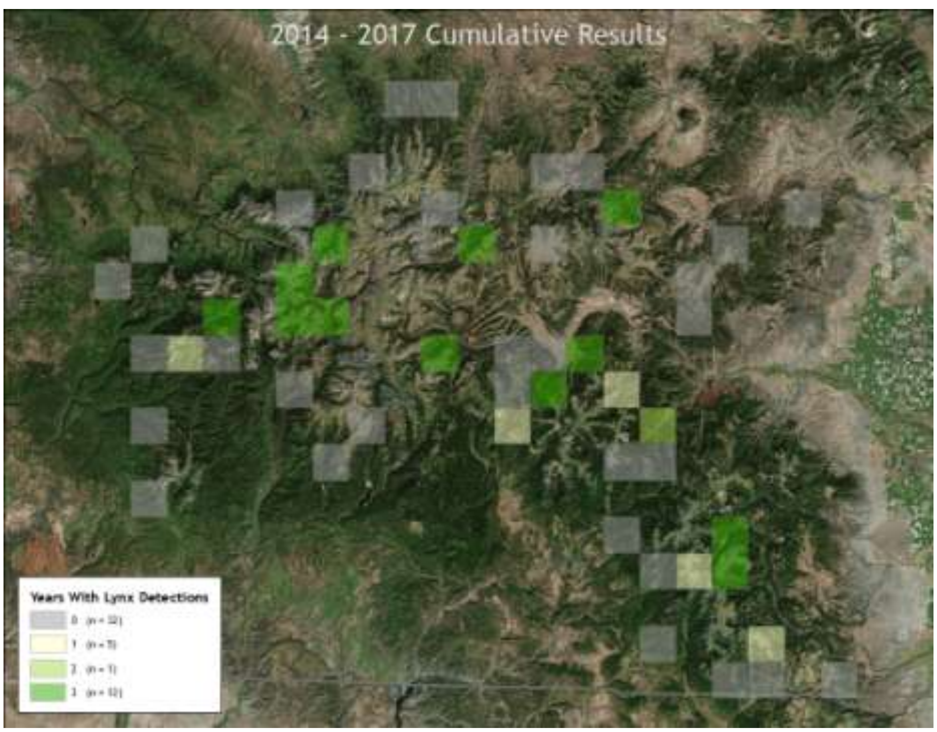

Figure 1. Lynx monitoring results for a) the current sampling season (2016−2017) and b) the cumulative monitoring effort (2014−2017), San Juan Mountains, southwest Colorado. Colored units (n = 50) indicate those selected at random from the population of units (n = 179) encompassing lynx habitat in the San Juan Mountains. Lynx were detected in 14 units in 2016−2017 (but detections at 2 units occurred outside of the official survey period) and 18 units cumulatively since monitoring began in 2014−2015.

UNGULATE AND HABITAT CONSERVATION

EXAMINING THE EFFECTS OF MECHANICAL TREATMENTS AS A RESTORATION TECHNIQUE FOR MULE DEER HABITAT

POPULATION PERFORMANCE OF PICEANCE BASIN MULE DEER IN RESPONSE TO NATURAL GAS RESOURCE EXTRACTION AND MITIGATION EFFORTS TO ADDRESS HUMAN ACRIVITY AND HABITAT DEGRADATION

EVALUATION AND INCORPORATION OF LIGE HISTORY TRAITS, NUTRITIONAL STATUS AND BROWSE CHARACTERISTICS IN SHIRA'S MOOSE MANAGEMENT IN COLORADO

ELK RECRUITMENT AND HABITAT USE IN COLORADO

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Examining the effectiveness of mechanical treatments as a restoration technique for mule deer habitat

Period Covered: July 1, 2016 – September 30, 2017

Principal investigator: Danielle B. Johnston, Danielle.Bilyeu@state.co.us

Collaborators: Colorado Parks and Wildlife, BLM-White River Field Office, Colorado State University, M. Paschke, J. Jonas, ExxonMobil Prod. Co./XTO Energy

The pinyon-juniper (PJ) habitat type has been expanding in the western United States, and understory forage for big game may become reduced in areas where PJ has outcompeted more palatable species. Because prescribed fire is often difficult to implement, managers often rely on mechanical tree removal methods such as ship anchor chaining, roller chopping, and mastication. These methods differ in cost, type of woody debris produced, and soil disturbance (Johnston 2014). We made head-to-head comparisons of understory vegetation changes due to chaining, rollerchopping, and mastication (Figure 1), and also examined how each treatment impacted the success of seeding desirable understory forage species. Each plot was divided into 2 subplots, one of which was seeded with a shrub-heavy seed mix including big sagebrush (*Artemisia tridentata*), chokecherry (*Prunus virginiana*), Saskatoon serviceberry (*Amelanchier alnifolia*), Utah serviceberry (*Amelanchier utahensis*), mountain mahogany (*Cercocarpus montanus*), bitterbrush (*Purshia tridentata*), and winterfat (*Kraschenninnikovia lanata*). The study was conducted at two sites in the Magnolia region of the Piceance Basin, Rio Blanco County, Colorado. The North Magnolia site (n = 4) had higher control plot tree density, lower tree basal area, and higher shrub cover than the South Magnolia site (n = 3).

Treatments were implemented in fall 2011, and understory vegetation data (cover, biomass, and shrub density) was collected in 2012 and 2013 through collaboration with Colorado State University. Site visits in 2014 and 2015 indicated significant changes from this initial assessment period, particularly in the cover of cheatgrass (*Bromus tectorum*), an invasive annual grass that reduces wildlife habitat quality. In addition, the earlier study did not assess palatable shrub biomass, a key response for big game in this winter range area. In 2016 and 2017, we assessed understory vegetation cover in July using about 300 point-intercept hits arrayed over 13 transects in each subplot. In September 2017, we assessed density, summer utilization, and winter-available forage (hereafter winter forage) for the most prevalent palatable shrubs: big sagebrush, serviceberry (both species lumped), bitterbrush, and mountain mahogany. This report summarizes the 2017 shrub density, utilization and winter forage data; 2017 cover data is still being processed.

We measured shrubs within 4 belt transects totaling ~ 240 m^2 (0.6 acres) per subplot. Summer utilization was assessed by trained ocular estimation of average twig length removal per shrub. We estimated winter forage by canopy measurements of shrubs. For serviceberry, bitterbrush, and mountain mahogany, regressions predicting winter forage from canopy measurements had been developed 2013-2016 within the study area (average R^2 = 0.73). A regression for big sagebrush was available in the literature (Cleary et al. 2008). We considered winter forage to be current-year shoots without leaves, excluding portions removed by summer browsing. We included non-ephemeral leaves for big sagebrush.

We conducted separate analyses to test for effects of mechanical treatment vs. seeding (Stephens et al. 2016).

We saw no significant effects of mechanical treatment on total shrub density. Summer utilization differed by mechanical treatment, with masticated plots having greater utilization than chained or roller chopped plots, which were in turn greater than control plots (Fig. 2). There was a trend for lower total winter forage in masticated plots than in chained or control plots ($p = 0.07$; Figure 3). Mountain mahogany winter forage followed the same pattern ($p = 0.05$). Other species had no significant effects for winter forage.

Seeding increased total shrub density only within roller chopped plots (treatment*seeding interaction $p = 0.01$), where shrub density increased from 0.23 ± 0.05 plants/m^2 to 0.46 ± 0.10 plants/m^2 (1 m^2 = 10.8 ft^2). Bitterbrush and mountain mahogany density followed the same pattern, with effects of seeding evident within roller chopped plots only. There was no effect of seeding on serviceberry or sagebrush density. Summer utilization was higher in seeded plots at North Magnolia only ($p = 0.04$), where it increased from 12.0 ± 1.4% to 14.5 ± 1.4%.

Seeding effects on winter forage differed by site (site*treatment*seeding interaction, $p = 0.01$). At North Magnolia, there were no significant effects, although there was a trend for lower winter forage with seeding in chained plots ($p = 0.08$). At South Magnolia, there was lower winter forage with seeding in chained plots ($p = 0.01$), and trends for higher winter forage with seeding in masticated and roller chopped plots ($p < 0.07$).

The most obvious explanation for lower winter forage in masticated plots is the greater summer utilization in those plots. Unlike in chained and roller chopped plots, shrubs within masticated plots were specifically targeted for biomass removal. The increased utilization of these plants is probably because of this rejuvenation, which increased palatability. The trend for lessened winter forage with mastication differs from a 2014 analysis of nearby mastication treatments which were a part of a more extensive study on mitigation treatments for mule deer impacted by oil and gas development. In that study, masticated plots had about double the winter forage of control areas. The discrepancy between these studies may be due to the age of the treatments; in this study shrub productivity has likely already peaked.

In a 10-year study of effects of biomass removal on productivity of mountain mahogany, serviceberry, and bitterbrush, Shepard (1971) found that heavy clipping causes these species to have an initial spike in productivity. However, continued heavy removal in subsequent years causes drought sensitivity and lower productivity (Shepard 1971). The masticated shrubs in this study experienced initial heavy biomass removal followed by increased utilization, conditions somewhat similar to the plants in Shepard's study. Although the level of removal does not appear to be enough to jeopardize plant survival, it looks likely that it is impacting productivity. Repeated rejuvenation of these shrubs is not advised.

Seeding of shrubs was successful only in roller chopped plots. Roller chopping produced the largest amount of bare ground out of the 3 treatments tested, and also produced more undesirable non-natives in the early years of this study (Stephens et al. 2016). The disturbance induced by roller chopping apparently has benefits as well as drawbacks.

Lessened winter forage with seeding in chained plots is a perplexing result. In 2016, greater cheatgrass (*Bromus tectorum* L.) cover was evident in seeded subplots at South Magnolia, possibly the result of seed contamination. Forb cover, particularly Utah sweetvetch (*Hedysarum boreale*), was also higher in seeded subplots. There may be competitive dynamics in chained plots which differ from those in other treatments. An explanation may be more apparent once the 2017 cover data is analyzed.

The second phase of monitoring of this study is now complete. Data from 2016 and 2017 will be synthesized for a final report and publication.

Figure 1. Looking west from Rio Blanco CR 76 to treatment plots in North Magnolia in fall of 2012. The three rectangular patches in the left, along with a control plot, comprise one of 4 experimental blocks at this site. Each treatment plot received either chaining, mastication, or rollerchopping, and half of each treated plot was seeded with a shrub-heavy seed mix. Plot size is about 2 acres.

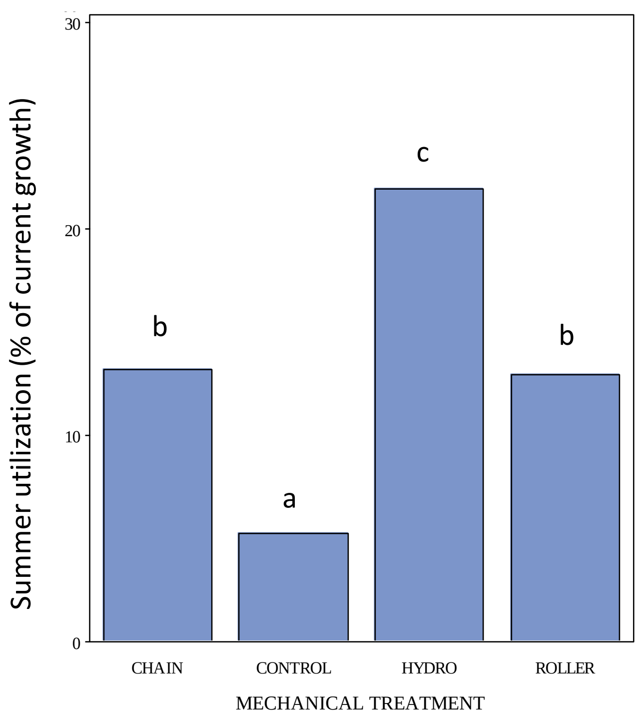

Figure 2. Average 2017 summer utilization of serviceberry, bitterbrush, mountain mahogany, and sagebrush plants within mechanical pinyon/juniper removal treatments of different types (Chain = trees removed by ship anchor chaining, Hydro = trees removed by mastication with mastication of shrubs as well, Roller = trees removed by a heavy rotating drum). Letters indicate significantly different means at $\alpha = 0.05$.

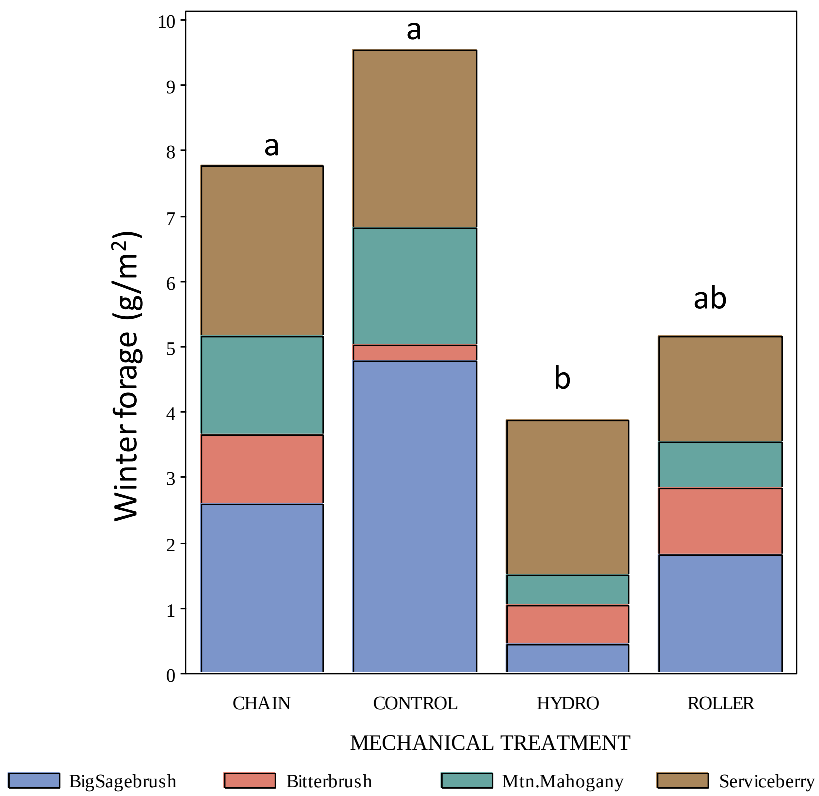

Figure 3. 2017 winter-available forage of serviceberry, bitterbrush, mountain mahogany, and sagebrush plants within mechanical pinyon/juniper removal treatments of different types (Chain = trees removed by ship anchor chaining, Hydro = trees removed by mastication with mastication of shrubs as well, Roller = trees removed by a heavy rotating drum). Letters indicate significantly different means at $\alpha = 0.05$.

Literature Cited

Cleary, M. B., E. Pendall, and B. E. Ewers. 2008. Testing sagebrush allometric relationships across three fire chronosequences in Wyoming, USA. Journal of Arid Environments **72**:285-301.

Johnston, D. B. 2014. Examining the effectiveness of mechanical treatments as a restoration technique for mule deer habitat: Colorado Division of Parks and Wildlife Avian Research Program annual progress report, Colorado Parks and Wildlife, Fort Collins, CO.

Shepard, H. 1971. Effects of clipping on key browse species in Southwestern Colorado, Technical Publication Number 28. Colorado Division of Game, Fish, and Parks, Denver, Co.

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

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Population performance of Piceance Basin mule deer in response to natural gas resource extraction and mitigation efforts to address human activity and habitat degradation

Period Covered: July 1, 2016 – June 30, 2017

Principal Investigator: Charles R. Anderson, Jr., Chuck.Anderson@state.co.us

Collaborators: Colorado Parks and Wildlife, BLM-White River Field Office, Idaho State University, Colorado State University, Federal Aid in Wildlife Restoration, EnCana Corp., ExxonMobil Prod. Co./XTO Energy, Marathon Oil Corp., Shell Petroleum, WPX Energy, Colorado Mule Deer Assn., Muley Fanatic Found., Colorado Mule Deer Found., Colorado State Severance Tax Fund, Boone & Crocket Club, and Safari Club Int.

We propose to experimentally evaluate winter range habitat treatments and human-activity management alternatives intended to enhance mule deer (*Odocoileus hemionus*) populations exposed to energy-development activities. The Piceance Basin of northwestern Colorado was selected as the project area due to ongoing natural gas development in one of the most extensive and important mule deer winter and transition range areas in Colorado. The data presented here represent the first 5 pretreatment years and 4 years post treatment of a long-term study addressing habitat improvements and evaluation of energy development practices intended to improve mule deer fitness in areas exposed to extensive energy development.

We monitored 4 winter range study areas representing varying levels of development to serve as treatment (North Magnolia, South Magnolia) and control (North Ridge, Ryan Gulch) sites (Fig. 1) and recorded habitat use and movement patterns using GPS collars (≥5 location attempts/day), estimated neonatal and overwinter fawn and annual adult female survival, estimated early and late winter body condition of adult females using ultrasonography, and estimated abundance using helicopter mark-resight surveys. During this research segment, we targeted 240 fawns (60/study area) and 120 does (30/study area) in early December 2016 for VHF and GPS radiocollar attachment, respectively, and attempted recapture of 120 does and 40 fawns in March 2017 for late winter body condition assessment. Winter range habitat improvements completed spring 2013 resulted in 604 acres of mechanically treated pinion-juniper/mountain shrub habitats in each of the 2 treatment areas (Fig. 2) with minor and extensive energy development, respectively. Post-treatment monitoring will continue for another year to provide sufficient time to measure how vegetation and mule deer respond to these changes.

Based on data collected through year 9 of this 10-year project: (1) annual adult female survival was consistent among areas averaging 79-87% annually, but overwinter fawn survival was variable, ranging from 31% to 95% within study areas, with annual and study area differences primarily due to early winter fawn condition, annual weather conditions, and winter conditions potentially enhancing predation success; (2) migratory mule deer selected for areas with increased cover and increased their rate of travel through developed areas, and avoided negative influences through behavioral shifts in timing and rate of migration, but did not avoid development structures (Fig. 3); (3) mule deer body condition early and late winter was generally consistent within areas, with higher variability among study areas early winter, primarily due to December lactation rates, and late winter condition related to seasonal moisture and winter severity; (4) mule deer exhibited behavioral plasticity in relation to energy development, where disturbance distance varied relative to diurnal extent and magnitude of development activity (Fig. 4), which may provide for several options in future development planning; (5) late winter mule deer densities have consistently increased in 3 of 4 study areas, averaging about +6% annually, with the North Ridge study area exhibiting erratic population changes that may be an artifact of periodic migration behavior prior to survey timing (Fig. 5); and (6) post treatment vegetation responses have provided evidence of improved forage conditions, but longer term monitoring will be required to address the full potential of habitat mitigation efforts. Detailed habitat use analyses in relation to habitat treatments are still pending for the pre and post-treatment periods. We will continue to collect demographic and habitat use data across all study sites to evaluate the effectiveness of habitat improvements on winter range. This approach will allow us to determine whether it is possible to effectively mitigate development disturbances in highly developed areas, or whether it is better to allocate mitigation efforts toward less or non-impacted areas.

In collaboration with Colorado State University, we are also monitoring neonate survival in relation to energy development from all study areas. This will allow us to include neonatal data to other demographic parameters for improved evaluation of mule deer/energy development interactions. Results from the neonate survival component of the project are currently in peer-review and should be published by the next reporting period.

The study is slated to run through 2018 to allow sufficient time for measuring mule deer population responses to landscape level manipulations. A more detailed version of this project summary and information about recent publications from this effort can be accessed at: http://cpw.state.co.us/learn/Pages/ResearchMammalsPubs.aspx

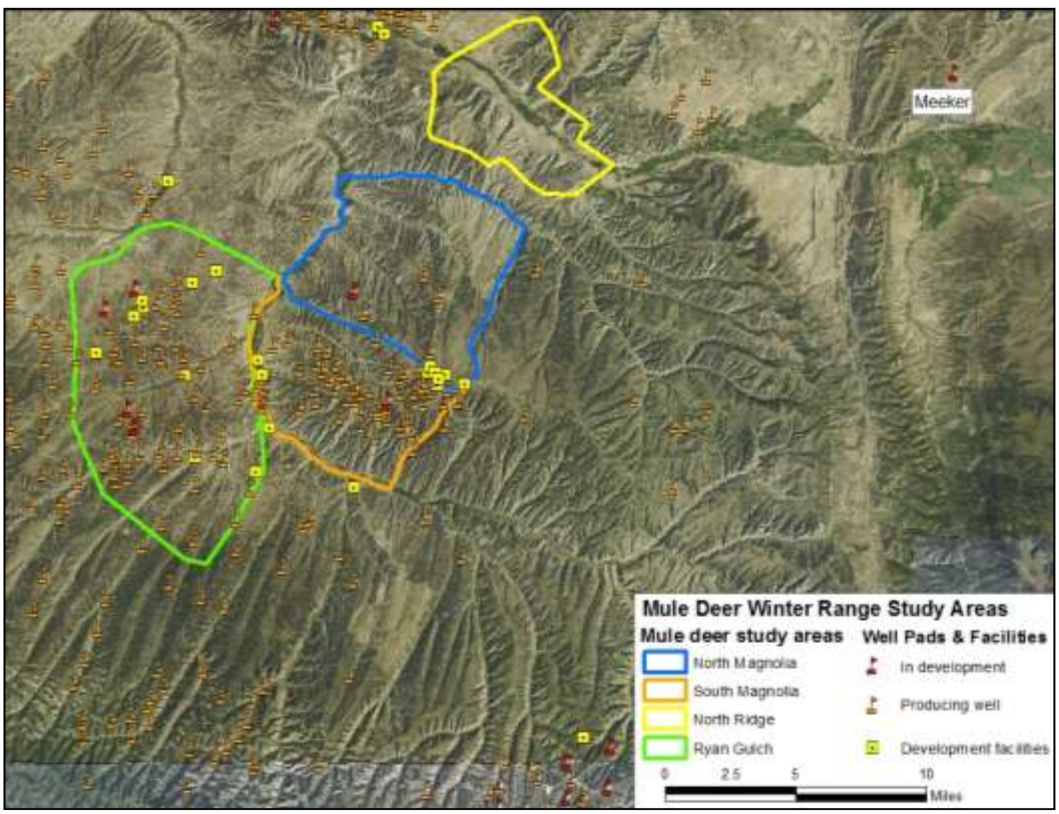

Figure 1. Mule deer winter range study areas relative to active natural gas well pads and energy development facilities in the Piceance Basin of northwest Colorado, winter 2013/14 (Accessed http://cogcc.state.co.us/ Dec. 31, 2013; energy development activity been minor since 2012).

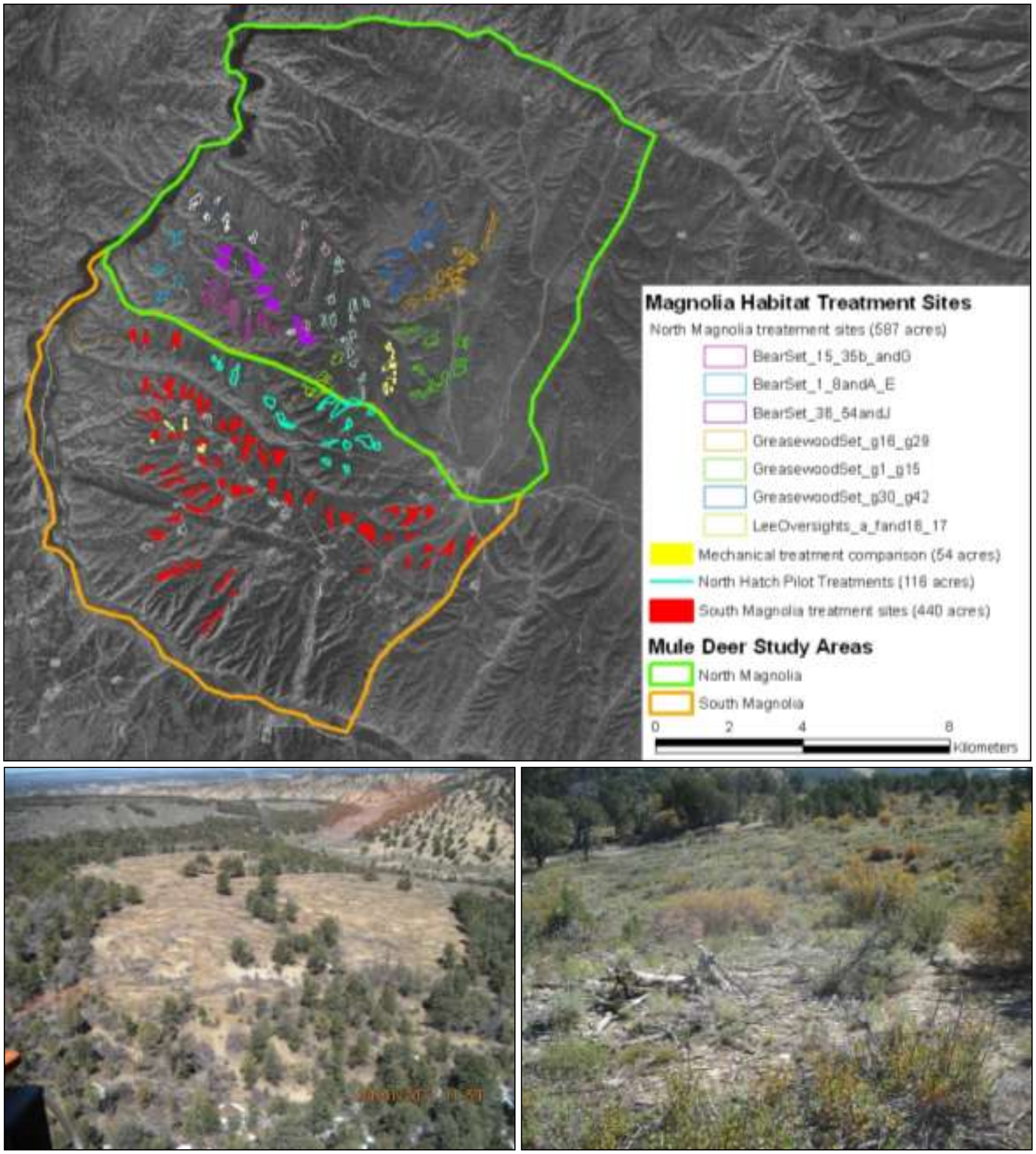

Figure 2. Habitat treatment site delineations in 2 mule deer study areas (604 acres each) of the Piceance Basin, northwest Colorado (Top; cyan polygons completed Jan. 2011 using hydro-axe; yellow polygons completed Jan. 2012 using hydro-axe, roller-chop, and chaining; and remaining polygons completed April 2013 using hydro-axe). January 2011 hydro-axe treatment-site photos from North Hatch Gulch during April (Lower left, aerial view) and October, 2011 (Lower right, ground view).

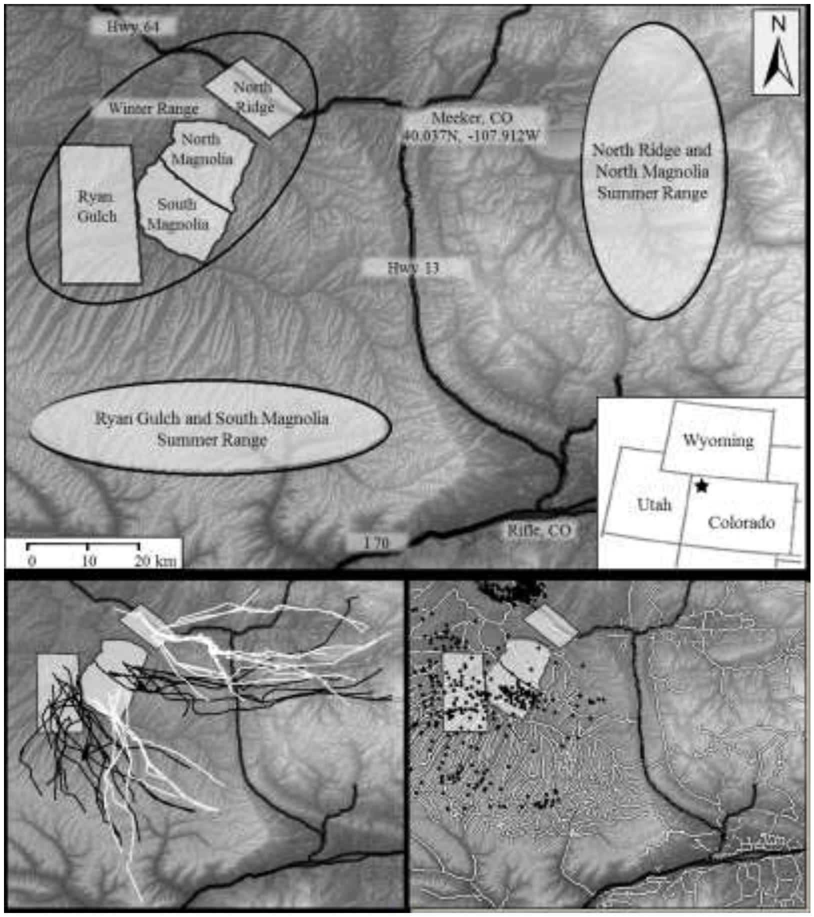

Figure 3. Mule deer study areas in the Piceance Basin of northwestern Colorado, USA (Top), spring 2009 migration routes of adult female mule deer (n = 52; Lower left), and active natural-gas well pads (black dots) and roads (state, county, and natural-gas; white lines) from May 2009 (Lower right; from Lendrum et al. 2012; http://dx.doi.org/10.1890/ES12-00165.1).

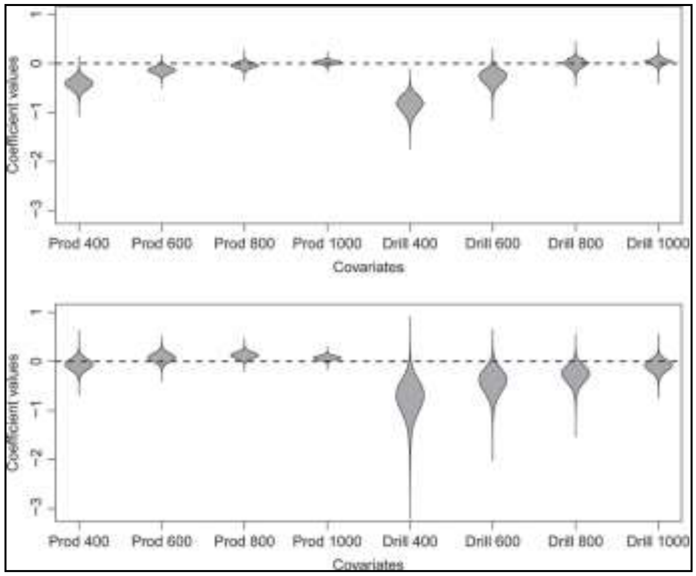

Figure 4. Posterior distributions of population-level coefficients related to natural gas development for RSF models during the day (top) and night (bottom) for 53 adult female mule deer in the Piceance Basin, northwest Colorado. Dashed line indicates 0 selection or avoidance (below the line) of the habitat features. 'Drill' and 'Prod' represent drilling and producing well pads, respectively. The numbers following 'Drill' or 'Prod' represent the distance from respective well pads evaluated (e.g., 'Drill 600' is the number of well pads with active drilling between 400–600 m from the deer location; from Northrup et al. 2015; http://onlinelibrary.wiley.com/doi/10.1111/gcb.13037/abstract). Road disturbance was relatively minor (~60–120 m, not illustrated above).

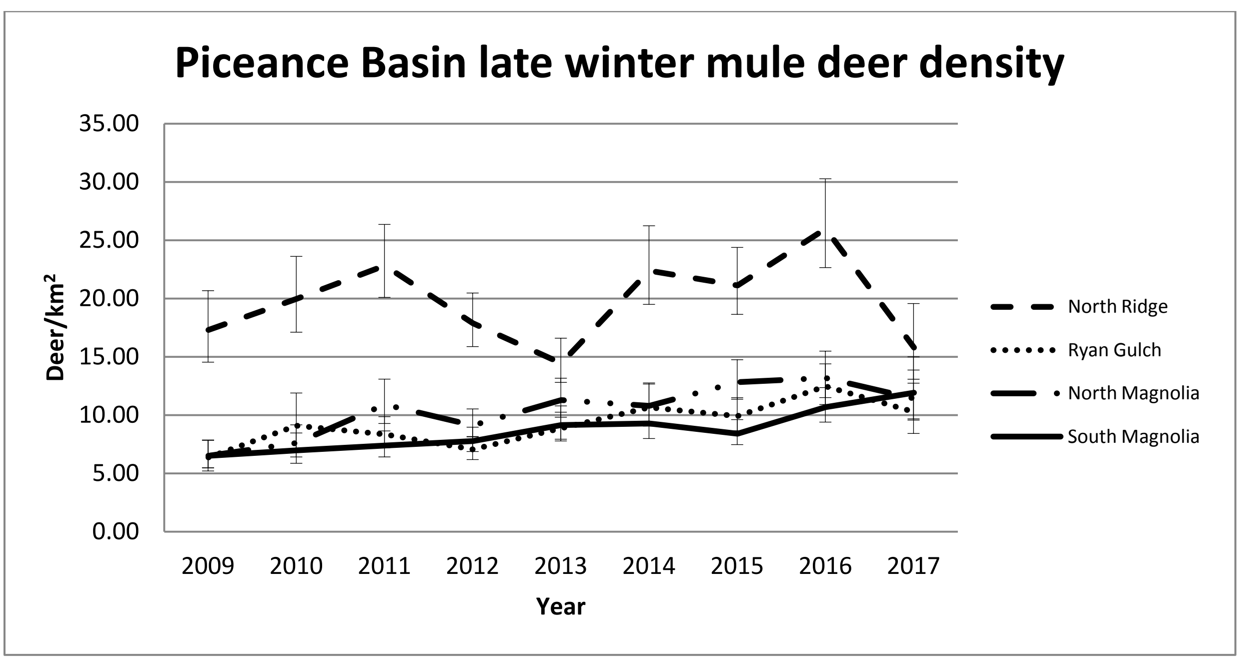

Figure 5. Mule deer density estimates and 95% CI (error bars) from 4 winter range herd segments in the Piceance Basin, northwest Colorado, late winter 2009–2017.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Evaluation and incorporation of life history traits, nutritional status, and browse characteristics in Shira's moose management in Colorado

Period Covered: July 1, 2016 – June 30, 2017

Principal Investigator: Eric J. Bergman, eric.bergman@state.co.us

All information in this project summary 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 summary is discouraged.

During November of 2013 we initiated a large scale moose research project in 3 of Colorado Parks and Wildlife's 4 geographical regions. This project was continued into the 2016–2017 fiscal year. A primary objective during all years of this project has been the capture of adult female moose for the purposes of deploying VHF and GPS collars, collecting pregnancy data via blood serum, evaluating body condition via ultrasonography, evaluating body condition via blood thyroid hormone concentrations, and collecting early winter calf-at-heel ratios. During fiscal years 2014–2015, 2015–2016, and 2016–2017 field efforts included estimation of parturition rates. During the fourth year of the study, all captures occurred during late December (2016) and early January (2017). Captures during the 2016–2017 winter were concentrated in 2 study areas: the Laramie River (NE Colorado), and southern North Park (NW Colorado).

During the fourth year of the study 30 cow moose were captured and radio-collared. Of these 30 animals, 11 were recaptures of animals that had been captured during previous winters of the study. Five of these recaptures occurred along the Laramie River (NE Colorado), and 6 recaptures occurred in North Park (NW Colorado). Individual animals were recaptured to meet 2 objectives. First, many animals wore GPS collars that stored location data within the collar. Those data could not be retrieved without retrieving the collar. These animals were subsequently re-collared with satellite collars that are now capable of transmitting location data. The second objective was to establish a longitudinal data set that will allow us to determine long-term productivity of individual animals. In particular, repeated measurements of individuals will allow us to evaluate if different reproductive strategies occur within moose, and if those strategies can be linked to annual variation within individual condition. Annual adult female moose survival rates for each study area were calculated for the 12-month period ending in mid-May. During May, June, and July of 2017, parturition and twinning rates were also estimated for all 3 study areas.

During the 2016–2017 winter, measured rump fat at the time of capture ranged between 0–17 mm among study areas. Measured loin depth at the time of capture ranged between 32–55 mm among study areas. Measured loin fat, at the time of capture, ranged between 0–5 mm. When data from 2013–2017 were pooled, pregnancy probability was best predicted by the additive model of maximum rump fat plus a subjective Body Condition Score (BCS) as well as the number of calves-at-heel. Due to the unbalanced sampling design, regional and annual effects in pregnancy rates were not evaluated. As has been the case during all years of the study, survival of radio collared animals was high in all study areas (85%–96%). During 2015–2016 pregnancy rates ranged between 70%–95%, but during 2017 low pregnancy rates in NW Colorado were detected (47%). No clear cause of this anomaly was observed. During the 4 winters of data collection, an upward trend in pregnancy rates has been observed in northeast Colorado. During 2016–2017, observed twinning rates at the time of parturition were low (9%), which is consistent with past years of data collection (observed range has been 5%–12%).

During the summer of 2017 an initial round of vegetation sampling occurred in NW and NE Colorado. These efforts are directed at: 1) identifying willow community diversity at known moose locations, 2) determining if moose demonstrate preference among willow species while browsing, and 3) to determine the nutritional quality of willows throughout the summer period. Ultimately, these data will be used to develop a linkage between moose body condition, moose pregnancy, and moose habitat conditions.

Thus far, data collected during this project have met expectations. In particular, survival rates have been consistently high in all study areas. However, the singularly low pregnancy rate observed in NW Colorado during 2016–2017 is noteworthy. Future sampling efforts will demonstrate if this data point was a single stochastic event or indicative of a pattern. During future years, we will develop methodology for determining herd level pregnancy status in cost effective ways.

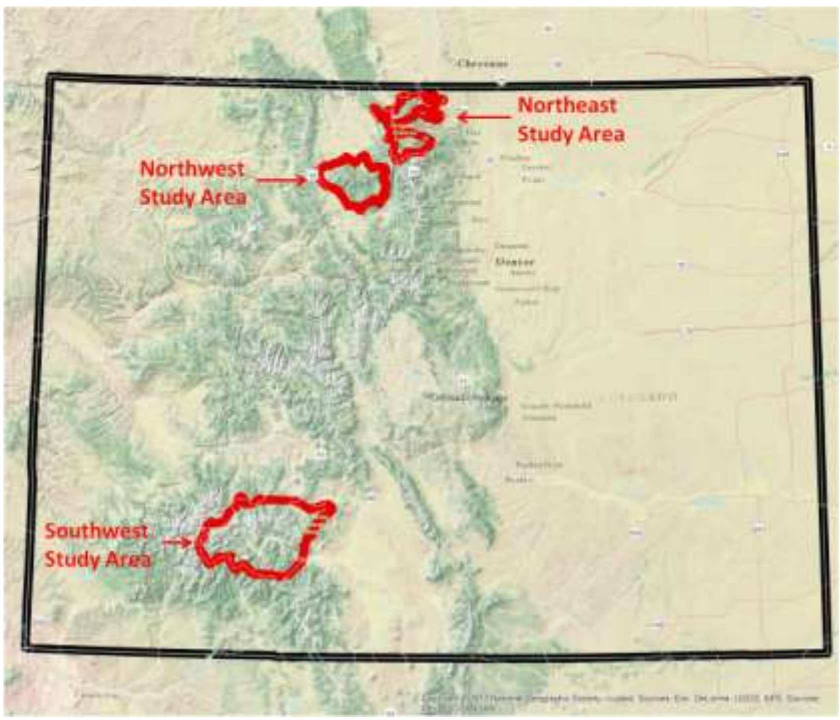

Figure 1. Moose research study areas, located in 3 regions in Colorado. A total of 181 moose were captured during winters between 2013–2014 and 2016–2017. During the winter of 2016–2017, a total of 30 moose were captured in the Northeast and Northwest study areas. Survival of moose was high in all study areas and during all years of the study.

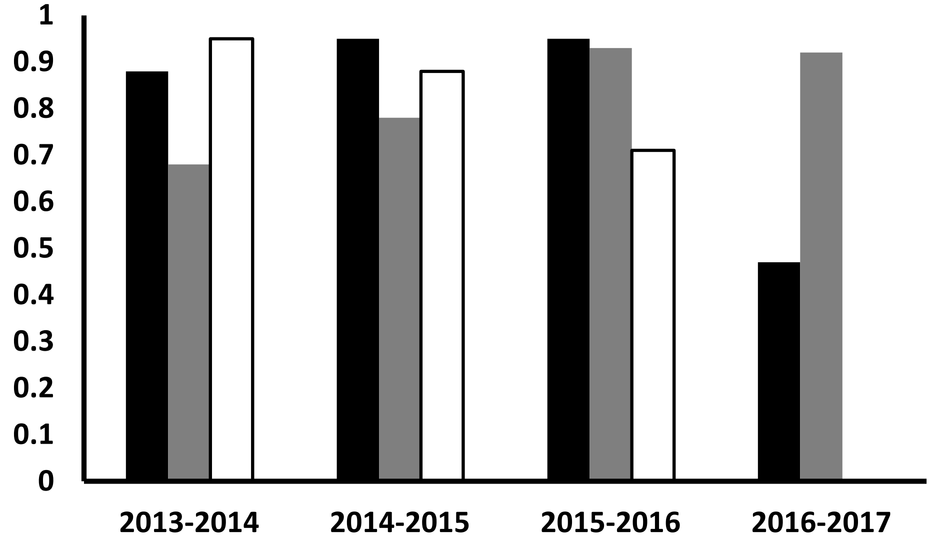

Figure 2. Pregnancy data were collected for all moose at the time of capture. Data from northwest Colorado are depicted by black bars, data from northeast Colorado are depicted by gray bars, and data from southwest Colorado are depicted by white bars. Data from southwest were sparse during 2015–2016 (n = 7 animals) and not collected during 2016–2017. The cause and consequences of the low pregnancy rate observed in northwest Colorado during 2016–2017 are yet to be determined.

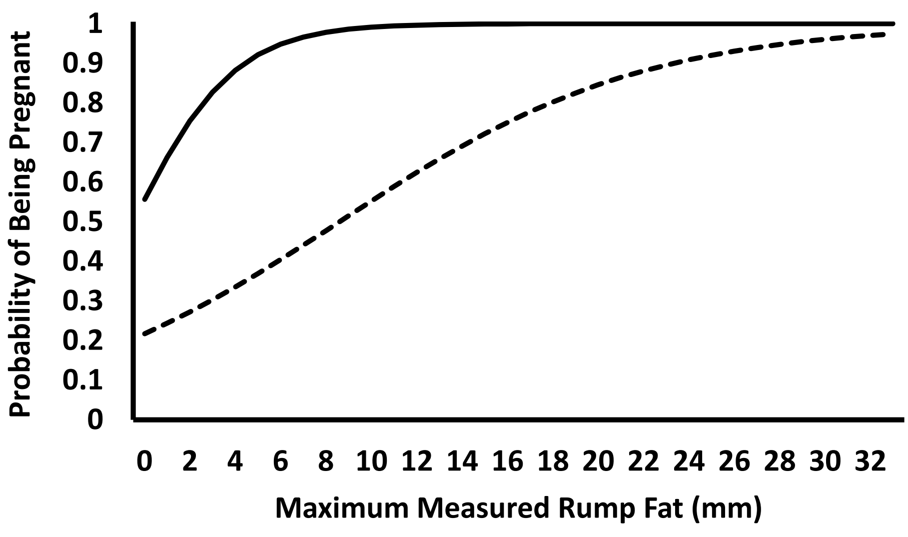

Figure 3. Probability of moose pregnancy was best predicted by maximum measured rump fat, body condition score, and the number-of-calves as heel. The strong relationship between body condition and pregnancy status, reflected by the solid black line and data collected during the first 3 years of the study, was diminished by the low pregnancy rate observed in northwest Colorado during 2016–2017 (dashed black line). Data collected during 2017–2018 will help inform if the 2016–2017 data were a singular stochastic event or indicative of an emerging pattern or trend of concern.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

PILOT STUDY—Elk recruitment and habitat use in Colorado

Period Covered: July 1, 2016 – June 30, 2017

Principal Investigators: Mathew W. Alldredge, mat.alldredge@state.co.us; Brad Banulis, brad.banulis@state.co.us; Allen Vitt, allen.vitt@state.co.us

All information in this project summary 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 summary is discouraged.

ABSTRACT

Our principal research objective is to address elk (*Cervus canadensis*) recruitment across southern Colorado in response to declining December calf:cow ratios. These ratios have been declining for more than a decade in the majority of the data analysis units (DAUs) across the southern half of Colorado. We have specifically focused on Data Analysis Units E-20 and E-33 as these two analysis units have some of the lowest reported ratios in the state, nearing 20 calves per 100 cows in December. To address this we have initiated a pilot study to examine potential drivers of low recruitment. This includes examining body condition and pregnancy rates of cow elk and cause specific mortality of calves. Body condition and pregnancy rates of cows did not indicate that low recruitment was being driven by these factors. Preliminary results suggest that mortality of calves in E-33 is a contributing factor to low recruitment rates but retention of calf collars in both areas has limited our assessment of calf mortality. Collar failure issues evident this past year will be addressed during the next field season.

PROJECT NARRITIVE OBJECTIVE

1. To assess adult cow elk body condition and pregnancy rates in two different elk populations, DAUs E-20 and E-33, in southern Colorado.
2. Assess cause specific calf mortality and recruitment into the yearling age class for two different elk populations, E-20 and E-33, in southern Colorado.
3. Assess cow and calf habitat use in relation to body condition and survival.

SEGMENT OBJECTIVES

Elk Recruitment

1. Measure body condition, pregnancy and fetal rates for cow elk within each study area.
2. Measure calf elk weight at parturition and relate this to the dam's body condition and whether she had a calf the previous year.
3. Determine cause specific mortality for elk calves from birth to age one.
4. Examine cow elk habitat use, including use of habitat treatments in the study area.

2016-2017 Project Overview

Rocky Mountain Elk is an iconic species throughout western North America and especially in Colorado, with a high recreational value to hunters, photographers, artists and wildlife enthusiasts in general. Elk populations are known to fluctuate greatly following habitat alteration, especially following historic wildfires. Human exploitation, habitat loss, predation and disease are all factors that can lead to population declines. In order to maintain healthy populations, managers must understand these factors and use their best knowledge to set herd objectives, harvest strategies and monitoring programs.

Concerns about elk calf ratios have been expressed for about a decade, but factors influencing local populations remain largely unknown. During the 1990's and early 2000's, elk herds were above objective and efforts were made to reduce elk populations. Calf ratios started declining in the early 2000's while herds were generally still above objective. Many studies have been conducted to investigate environmental influences on elk, many of which center around juvenile recruitment (Alldredge and Phillips 2000, White et al. 2010, Sargeant et al. 2011, Cook et al. 2013, Proffitt et al. 2014). Colorado is no exception, in many parts of the state recruitment rates are low and declining, which will have long term ramifications on elk populations across the state.

Low recruitment rates for elk across the state and potential long term population level ramifications are of great concern to CPW wildlife managers and biologists. If the trend of low recruitment rates continues, resulting declining elk populations will significantly impact both recreational opportunity and economics in Colorado and for CPW. Furthermore, CPW has a statutory responsibility to manage elk. However, very little is known as to the factors driving declining recruitment rates. Research on this topic is vital. A recent study on mule deer (*Odocoileus hemionus*) has demonstrated a paradigm shift in causes of low recruitment for this species from the historical research demonstrating low over-winter survival (Bartmann et al. 1992) to recent developments suggesting low neonatal survival (Anderson 2015). It is imperative that CPW conduct similar investigations on elk to gain information on factors affecting low recruitment across the state and develop management strategies to mitigate these factors.

Because little is known about the factors affecting elk recruitment in the state, we proposed a pilot study designed to identify primary factors. Given that this low recruitment is occurring across a broad spatial scale we also proposed that this work be conducted in multiple study areas exhibiting low recruitment and one study area with higher recruitment as a reference area. The intent of this 2 year pilot study is to determine pregnancy rates, fetal counts, and cause specific mortality of calf elk from birth to age 1. Additional data on cow body condition, birth weights and consecutive year reproduction will allow determination of potential causes of low elk recruitment. Measuring individual body condition of cow elk in the study and then ascertaining the fate of each cow's calf will provide valuable insights regarding nutritional influences on both calf survival and future pregnancy rates. Examinations of cow elk habitat use will also be conducted, including use of habitat treatments that exist on the landscape, to determine differences in habitat use and the impact that has on pregnancy rates and calf survival.

Cow elk capture was initiated in late February, 2017 in E-20 and E-33. Weather was hot and dry so baiting elk had limited success as natural forage was starting to develop. A total of 8 elk were caught in E-20 and 5 in E-33 using clover traps. The remaining elk were caught in early March using helicopter net gunning. Body condition was estimated for 32 and 29 elk in E-20 and E-33 respectively and 23 were GPS collared in each area. Body condition of elk, based on loin thickness, rump fat and a body condition score was reasonably good in both study areas (Table 1). Vaginal implant transmitters (VITs) were placed in pregnant elk. Pregnancy rates were 78.1% and 90.0% in E-20 and E-33 respectively (Table 1).

Calf capture began in the middle of May. Only 2 of 40 VITs functioned properly so capture was primarily opportunistic. A total of 40 and 57 calves were caught in E-20 and E-33, respectively (Table 2). Average age at capture was estimated at just over 2 days old, although some older calves were caught at a week old. Average capture weight was 17.3 kg for both areas. In E-33, initial calf mortality was significant (19 total mortalities). However, collar retention has been an issue in both areas as numerous collars have dropped off as the belting is not holding up as expected, so it will be difficult to address cause specific mortality of calves in E-33 and early collar drops prohibited mortality assessment in E-20.

As this is the first year of the study and data is just starting to be collected, no factors have been identified as potentially contributing to low recruitment rates for these elk herds. In the southwest corner of E-20, pregnancy rates were very low. Of the 8 cows captured there, only 4 were pregnant. However, pregnancy rates in the rest of this unit were high. This may be of interest for further investigation to determine if there are localized low pregnancy rates in this area. Beyond this, the project is on schedule and proceeding as planned.

<u>Table 1:</u> Cow capture statistics for E-20 and E-33. Loin thickness (mm), rump fat thickness (mm), body condition score (BCS) and percent pregnant by year and location.

	Year	n	Loin	Rump	BCS	% Pregnant
E-20						
	2017	32	48.7	7.1	3.4	78.1
E-33						
	2017	29	52.0	5.7	3.4	90.0

<u>Table 2:</u> Calf capture summary for E-20 and E-33. Sex ratio (female:male), estimated capture age (days) and capture weight (kg).

	Year	n	F:M	Age	Weight
E-20					
	2017	40	20:20	2.3	17.3
E-33					
	2017	57	29:26	2.6	17.3

PREDATORY MAMMAL CONSERVATION

BLACK BEAR EXPLOITATION OF URBAN ENVIRONMENTS: FINDING MANAGEMENT SOLUTIONS AND ASSESSING REGIONAL POPULATION EFFECTS

EFFECTS OF HUNTING ON A MOUNTAIN LION POPULATION ON THE UNCOMPAHGRE PLATEAU, COLORADO

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Black bear exploitation of urban environments: finding management solutions and assessing regional population effects

Period Covered: July 1, 2016 – June 30, 2017

Principal Investigator: Heather E. Johnson, heatherjohnson@usgs.gov

Project Collaborators: S.A. Lischka, S. Breck, J. Beckmann, J. Apker, K. Wilson, and P. Dorsey

All information in this project summary 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 summary is discouraged.

Across the country conflicts among people and black bears are increasing in frequency and severity, and have become a high priority wildlife management issue. Whether increases in conflicts reflect recent changes in bear population trends or bear behavioral shifts to anthropogenic food resources, is largely unknown, with key implications for bear management. This issue has generated a pressing need for bear research in Colorado and has resulted in a collaborative study involving Colorado Parks and Wildlife (CPW; lead agency), the USDA National Wildlife Research Center, Wildlife Conservation Society and Colorado State University. Collectively, we have designed and implemented a study on black bears that 1) determines the influence of urban environments on bear behavior and demography, 2) tests a management strategy for reducing bear-human conflicts, 3) examines public attitudes and behaviors related to bear-human interactions, and 4) develops population and habitat models to support the sustainable monitoring and management of bears in Colorado.

Field data collection for this project was initiated spring 2011 and completed spring 2016. Several publications from this work are in various stages of analyses, peer-review and publication. Publications in progress and published abstracts are listed below:

Publications in Progress:

Laufenberg, J., H.E. Johnson, S. Breck, and P. Doherty. Using integrated population models to understand spatio-temporal dynamics in Colorado black bear populations. *In Preparation* for *Ecological Applications.*

Kirby, R., H.E. Johnson, M.W. Alldredge, and J.N. Pauli. The tension between foraging and hibernation shapes biological aging in bears. *In Preparation* for *Journal of Animal Ecology.*

Lischka, S., T. Teel, H. E. Johnson, S. Breck, and K. Crooks. Factors associated with public compliance of wildlife ordinances. *In Preparation* for *Journal of Wildlife Management.*

Johnson, H.E., S.W. Breck, and D.L. Lewis. The effects of human development on black bear survival and fecundity. *In Preparation* for *Journal of Animal Ecology.*

Lischka, S. T. Teel, H.E. Johnson, S. Breck, and K. Crooks. What drives real and perceived risk of human-wildlife conflict? *In Preparation* for *Human Dimensions of Wildlife.*

Johnson, H.E., D.L. Lewis, S. Lischka, and S.W. Breck. Bear-resistant containers reduce human-black bear conflicts and improve public perceptions. *Journal of Wildlife Management*, *In Press*.

Wibur, R.C., S.A. Lischka, J.R. Young and H.E. Johnson. 2017. Experience, attitudes and demographic factors influence the probability of reporting human–black bear interactions. *Wildlife Society Bulletin*, *In Press*.

Published Abstracts:

Shifting perceptions of risk and reward: Dynamic selection for human development by black bears in the western United States

H.E. Johnson[1], S.W. Breck[2], S. Baruch-Mordo[3], D.L. Lewis[4], C.W. Lackey[5], K.R. Wilson[4], J. Broderick[6], J.S. Mao[7], J.P. Beckmann[8]

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[3]The Nature Conservancy, 117 E Mountain Ave, Suite 201, Fort Collins, CO 80524, USA
[4]Colorado State University, 1474 Campus Delivery, Fort Collins, CO 80523, USA
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[7]Colorado Parks and Wildlife, 0088 Wildlife Way, Glenwood Springs, CO 81601, USA
[8]Wildlife Conservation Society, 301 North Willson Ave, Bozeman, MT 59715, USA

Citation: Johnson, H. E., Breck, S. W., Baruch-Mordo, S., Lewis, D. L., Lackey, C. W., Wilson, K. R., Broderick, J., Mao, J. S., & Beckmann, J. P. 2015. Shifting perceptions of risk and reward: Dynamic selection for human development by black bears in the western United States. Biological Conservation 178:164–172.

Abstract

As landscapes across the globe experience increasing human development, it is critical to identify the behavioral responses of wildlife to this change given associated shifts in resource availability and risk from human activity. This is particularly important for large carnivores as their interactions with people are often a source of conflict, which can impede conservation efforts and require extensive management. To examine the adaptations of a large carnivore to benefits and risks associated with human development we investigated black bear behavior in three systems in the western United States. Our objectives were to (1) identify temporal patterns of selection for development within a year and across years based on natural food conditions, (2) compare spatial patterns of selection for development across systems, and (3) examine individual characteristics associated with increased selection for development. Using mixed effects resource selection models we found that bear selection for development was highly dynamic, varying as a function of changing environmental and physiological conditions. Bears increased their use of development in years when natural foods were scarce, throughout the summer-fall, as they aged, and as a function of gender, with males exhibiting greater use of development. While patterns were similar across systems, bears at sites with poorer quality habitat selected development more consistently than bears at sites with higher quality habitat. Black bears appear to use development largely for food subsidy, suggesting that conflicts with bears, and potentially other large carnivores, will increase when the physiological demand for resources outweighs risks associated with human activity.

Human development and climate affect hibernation in a large carnivore with implications for human–carnivore conflicts

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Abstract
1. Expanding human development and climate change are dramatically altering habitat conditions for wildlife. While the initial response of wildlife to changing environmental conditions is typically a shift in behaviour, little is known about the effects of these stressors on hibernation behaviour, an important life-history trait that can subsequently affect animal physiology, demography, interspecific interactions and human-wildlife interactions. Given future trajectories of land use and climate change, it is important that wildlife professionals understand how animals that hibernate are adapting to altered landscape conditions so that management activities can be appropriately tailored.
2. We investigated the influence of human development and weather on hibernation in black bears (*Ursus americanus*), a species of high management concern, whose behaviour is strongly tied to natural food availability, anthropogenic foods around development and variation in annual weather conditions. Using GPS collar data from 131 den events of adult female bears (n = 51), we employed fine-scale, animal-specific habitat information to evaluate the relative and cumulative influence of natural food availability, anthropogenic food and weather on the start, duration and end of hibernation.
3. We found that weather and food availability (both natural and human) additively shaped black bear hibernation behaviour. Of the habitat variables we examined, warmer temperatures were most strongly associated with denning chronology, reducing the duration of hibernation and expediting emergence in the spring. Bears appeared to respond to natural and anthropogenic foods similarly, as more natural foods, and greater use of human foods around development, both postponed hibernation in the fall and decreased its duration.
4. *Synthesis and applications*. Warmer temperatures and use of anthropogenic food subsides additively reduced black bear hibernation, suggesting that future changes in climate and land use may further alter bear behaviour and increase the length of their active season. We speculate that longer active periods for bears will result in subsequent increases in human–bear conflicts and human-caused bear mortalities. These metrics are commonly used by wildlife agencies to index trends in bear populations, but have the potential to be misleading when bear behaviour dynamically adapts to changing environmental conditions, and should be substituted with reliable demographic methods.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Effects of hunting on a mountain lion population on the Uncompahgre Plateau, Colorado

Period Covered: July 31, 2016−June 30, 2017

Principal Investigator: Kenneth A. Logan, Ken.Logan@state.co.us

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

We conducted a 10-year (2004−2014) study on effects of hunting on a mountain lion population on the Uncompahgre Plateau. The purpose was to examine lion demographics without and with hunting, and learn how lion hunter behavior may influence harvest and the lion population. This report summarizes the latest analysis of the effects of hunting and other causes of mortality on a lion population in preparation of this information for publication. Final analyses and writing are in final stages and are expected to provide reliable information for application of lion management in Colorado.

The study was designed with a five-year *reference* period (years RY1−RY5) when mountain lion hunting was prohibited and a five-year *treatment* period (years TY1−TY5) with regulated hunting of lions. The *reference* period began December 2004 and ended October 2009. The *treatment* period began November 2009 and ended in December 2014. During the *treatment* period we surveyed lion hunters to learn about their participation in the hunting treatment and hunting preferences.

The study area was on the Uncompahgre Plateau in Mesa, Montrose, Ouray, and San Miguel Counties. The 1,157 square mile study area included the southern halves of Game Management Units (GMUs) 61 and 62, and the northern edge of GMU 70. The Uncompahgre Plateau Study Area GMU (UPSA for short) was the 8th largest lion GMU in Colorado. The UPSA contained about 657 square miles of big game winter range where we focused our efforts to study lion demographics.

We examined effects of hunting on mountain lions starting at the GMU scale because GMUs were used in Colorado to spatially distribute and regulate lion harvest to achieve specified population objectives at the much larger Data Analysis Unit (DAU) scale. Each GMU was assigned a lion hunting quota (i.e., harvest limit) as a portion of a target DAU lion harvest. Hunting in the GMU was closed when the lion quota was reached or the end of the hunting season, whichever came first. Prior to this research there was no information in Colorado indicating how lion harvest at the GMU scale related to lion management objectives at the larger DAU scale.

From December 2, 2004 to October 30, 2014 we captured 256 individual mountain lions a total of 440 times. We individually marked 226 lions: 109 in the *reference* period and 115 in the *treatment* period. Marked lions provided known-fate data on 75 adults (2+ yr. old), 75 subadults (1−2 yr. old), and 118 cubs. In addition to the lions captured by our research team during the *treatment* period, lion hunters captured and killed a total of 35 lions, including 8 adult females, 16 adult males, 3 subadult females, and 8 subadult males. Lion hunters also reported capturing and releasing 30 lions, including 19 females and 11 males.

We assessed effects of hunting on mountain lions based on changes in four variables: 1) abundance of independent lions (i.e., adults and subadults; legal game in Colorado), 2) survival of adult, subadult, and cub lions, 3) reproduction, including litter sizes, birth intervals, and birth rates, and 4) gender and age structure of the independent (>1 year old) lions. We estimated abundance of independent lions by using the ratio of marked lions in the population each winter that were re-detected in the population and applied that to the total number of lions caught each winter. The estimates included lions that were not observed, but expected to be present. We estimated survival for the marked samples of adults, subadults, and cubs and identified factors that best explained animal survival. We estimated reproduction rates by intensively monitoring adult females the year-round. We compared the gender and age structure of the lion population after five years of no hunting (start of TY1) and after four years of hunting (start of TY5).

Mountain lion mortality and hunting

In the *reference* period, mortality from natural causes, vehicle strikes and depredation control affected individual lions. However, the totality of the mortality did not inhibit population increase.

The hunting treatment was intended to remove a 15% target harvest of independent lions on the UPSA during TY1−TY3 and 11−12% target harvest during TY4− TY5. These percentages were based on modeled lion abundance projections for TY1 and TY4. The observed (actual) harvest rates of independent lions on the UPSA based on the abundance estimates for TY1 and TY2 and associated with the decline in abundance of independent lions by TY3 ranged from 0.14−0.16. During TY3−TY5 the observed harvest rate on the UPSA ranged from 0.12−0.18. However, hunters killed 11 additional radio-collared independent lions (2 adult females, 8 adult males, 1 subadult female) in adjacent GMUs because those lions had home ranges beyond the UPSA boundaries. The number of marked lions killed by hunters outside of UPSA ranged from 0 to 5 and averaged 2 each year from TY1−TY5. These additional hunting deaths contributed to the demographic response of lions on the UPSA.

Other causes of mortality, including natural causes, vehicle strikes and depredation control also affected independent lions in the *treatment* period. Considering all known deaths (i.e., from hunting, other human and natural causes) to independent lions in the *treatment* period hunting seasons on UPSA, total observed mortality during TY1−TY2 ranged from 0.16−0.18, and 0.14−0.23 during TY3−TY5. However, four adult females that died of natural causes on the UPSA were not detected by wildlife officials, but by our radiotelemetry monitoring. Just counting the deaths on UPSA that would have been detected by wildlife officials (i.e., harvest, depredation control) the total observed mortality during TY1−TY2 ranged from 0.16−0.18. Likewise, during TY3−TY5 the total observed mortality rates were 0.12−0.18.

Mountain lion hunters overwhelmingly indicated they were selective hunters. They exhibited selectivity directly by harvesting mostly adult male lions and capturing and releasing mostly female lions. Furthermore, they exhibited selection even though they encountered fresh female tracks more frequently than male tracks.

Mountain lion abundance

Abundance of independent lions increased in the *reference* period (without hunting) from 33 in RY4 to 57 in TY1 at annual rates of 24% and 39% between RY4−RY5 and RY5−TY1, respectively (Fig. 1). In the *treatment* period (with hunting) estimates of independent lions were 57 and 56 in TY1 and TY2, respectively, and declined to a low of 37 by TY5. There was no apparent decline in abundance of independent lions until after TY2. Abundance declined by 21% between TY2 and TY3, and thereafter remained in a low phase to TY5.

Survival of mountain lions

Gender and period (i.e., *reference* and *treatment*) were important factors explaining adult and subadult male lion survival. Adult male survival was 0.96 (95% CI = 0.75−0.99) in the *reference* period and 0.40 (95% CI = 0.22−0.57) in the *treatment* period. Adult female survival was 0.86 (95% CI = 0.72−0.94) in the *reference* period and 0.74 (95% CI = 0.63−0.82) the *treatment* period. Subadult male survival was 0.92 (95% CI = 0.57−0.99) in the *reference* period and 0.43 (95% CI = 0.25−0.60) in the *treatment* period. However, subadult female survival was similar in the *reference* (0.63, 95% CI = 0.17−0.89) and *treatment* periods (0.70, 95% CI = 0.39−0.88).

The most important factor explaining cub survival was survival of the dam during the time the cubs were dependent on her. The cub survival rate was 0.45 (95% CI = 0.303−0.587) for the *reference* and *treatment* periods combined.

Mountain lion reproduction

Reproduction rates, including litter sizes, birth intervals, and birth rates were not statistically different in the *reference* and *treatment* periods. Average litter size was 2.8 (95% CI = 2.4−3.1) for the *reference* period and 2.4 (95% CI = 2.0−2.8) for the *treatment* period. Average birth interval length in the *reference* period was 18.3 months (95% CI = 15.5−21.1), and for the *treatment* period was 19.4 months (95% CI = 16.2−22.6). Average birth rate (proportion of adult females giving birth each year) was 0.63 (95% CI = 0.49−0.75) for the *reference* period and 0.48 (95% CI 0.37−0.59) for the *treatment* period.

Mountain lion gender and age structure

After 5 years of no hunting, lions 1−5 years old comprised 66% of the independent lions; the other 34% were adult females and males 6−10+ years old. Adult males declined 62% between TY1 and TY5. In TY1 adult males over 5 years old comprised 43% of the adult males; but after 4 years of hunting 13% were over 5 years old (Fig. 2). Adult female abundance fluctuated from TY1−TY5 but with a declining trend. At the beginning of TY1 independent males averaged 4.2 years old (95% CI = 3.1−5.2), similar to the average of 4.4 years for adult females (95% CI = 3.4−5.3). By the start of TY5 the average age of independent males had declined to 2.9 years old (95% CI = 2.1−3.7); independent females averaged 4.5 years old (95% CI = 3.3−5.7), similar to TY1.

Other important mountain lion demographics

We estimated a minimum frequency of emigration of offspring (i.e., animals leaving the UPSA) by using the known fate data on the radio-collared cubs we used in the survival analysis. Of 37 cubs surviving to the subadult stage in the reference period at least 10 (9 males, 1 female) or 27% were known to have emigrated from the UPSA. Similarly, of 36 cubs surviving to subadult stage in the treatment period at least 9 (8 males, 1 female) or 25% were known to have emigrated from the UPSA. Most emigrating lions moved into other parts of western Colorado and eastern Utah, but extreme dispersals of lions were to southern Wyoming and northern New Mexico.

Management Implications

1) Regulated hunting can affect mountain lion abundance. Harvest rates of 0.14−0.16 and observed human-caused mortality rates of 0.16−0.18 in two hunting seasons on the UPSA was associated with a decline in abundance of independent lions.
2) Additional hunting mortality of independent lions from the UPSA that ranged onto adjacent GMUs contributed to the decline of lions on the UPSA. Therefore, the expected hunting mortality rate from a harvest limit set at the GMU may be biased low.
3) Considering that the harvest of lions inside and outside the UPSA boundaries and emigration and apparent immigration all affected lion population response, lion management is better considered at scales larger than GMUs, such as DAUs or larger regions. Although GMUs could be used to address local lion management concerns, such as predation on wild ungulates or livestock, or to limit adult female lion harvest.
4) Dam survival was important to cub survival, supporting current regulation in Colorado protecting dams that are detected by hunters. In addition, regulations that limit adult female harvest could be used in areas with management objectives for lion conservation and hunting opportunity.
5) Lion hunters using dogs to catch lions can practice selection, affect the harvest and the lion population, and facilitate lion population management.

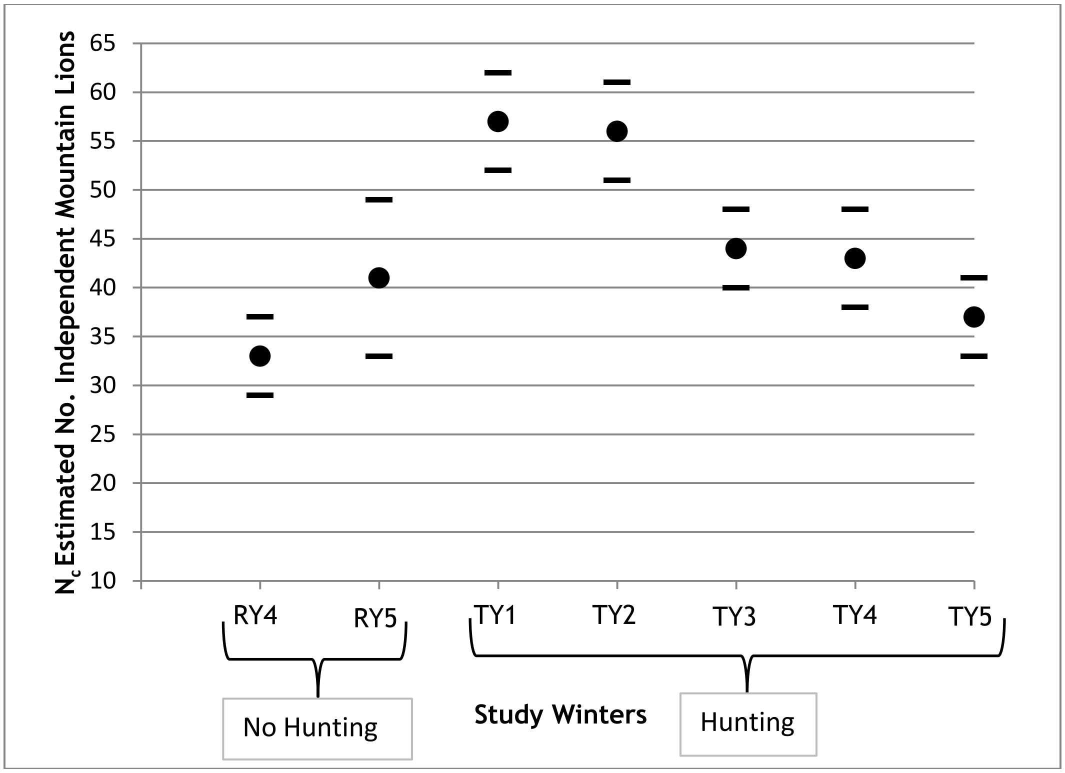
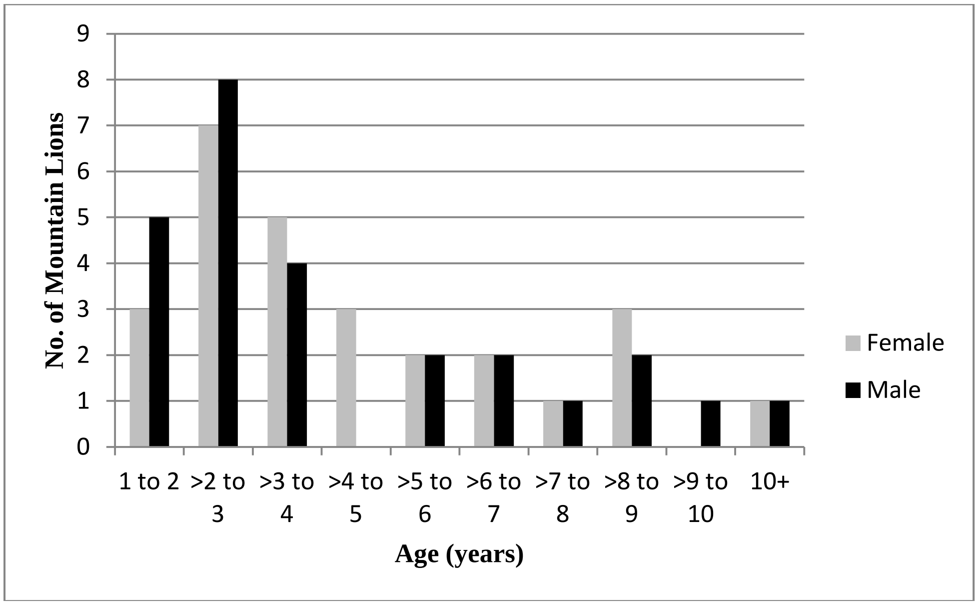


Figure 1. Change in abundance (black dots) of independent mountain lions (i.e., adults and subadults) during reference year 4 (RY4) through treatment year 5 (TY5), Uncompahgre Plateau, Colorado. Bars represent 95% confidence intervals. We were sufficiently familiar with the study area to thoroughly search it for lion estimates by RY4; so lion abundance estimates span from RY4 to TY5.

A



B

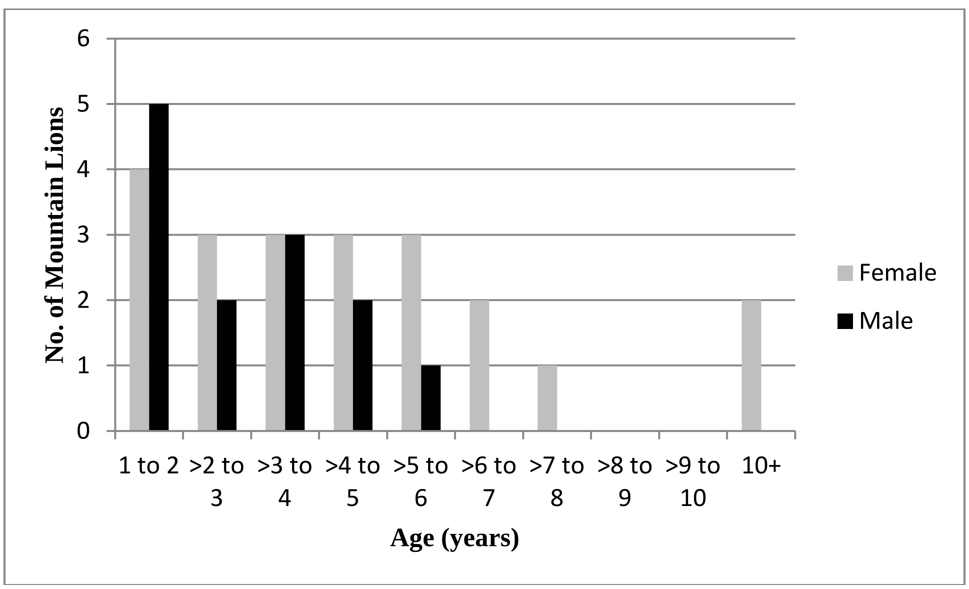


Figure 3. Age structures of independent mountain lions in November, Uncompahgre Plateau, Colorado. Graph A shows the age structure after 5 years of no hunting and just before the first treatment hunting season (TY1). Graph B shows the change in age structure at the start of TY5 after 4 years of hunting lions (TY1–TY4).

SUPPORT SERVICES

RESEARCH LIBRARY ANNUAL REPORT

Colorado Parks and Wildlife

WILDLIFE RESEARCH REPORT SUMMARY

Research library, annual report

Period Covered: July 1, 2016– June 30, 2017

Author: Kay Horton Knudsen, kay.knudsen@state.co.us

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The Colorado Parks and Wildlife Research Center Library has existed for several decades in the Ft. Collins office. However, the mission of the Library has expanded in recent years to serve all CPW staff regardless of location. The Library is now vital to the science-driven wildlife management work of the agency. The Librarian has become a valued partner in assisting with research and supplying full-text reference resources for the work done by biologists, researchers and wildlife managers across the state.

Early librarians can be credited with the physical organization of the Library which continues to serve as the center for effective research services for employees, cooperators and wildlife educators. The goal of outreach and support is today fulfilled using technology to provide a Library website with the online catalog, wildlife databases and digitized documents. The website, available on CPWNet, is a 24/7 resource with 70 years of Colorado Federal Aid reports, online access to numerous wildlife journals and databases, as well as an index to the unique book collection. The Federal Aid reports are required by the Pittman-Robertson (Terrestrial) and Dingell-Johnson (Aquatic) Acts; federal funding awarded to the State of Colorado for wildlife and sport fish restoration. CPW may be the only wildlife agency to have digital access in the form of full-text, word-searchable PDFs, for this important collection. The Library is also an archive for historic CPW publications including 80 years of Wildlife Commission minutes and Director's reports beginning in 1877. The special collection of original Colorado hunting and fishing brochures, some digitized, serve as a history of our rules and regulations and are often accessed by staff.

As of October 2017, the Research Library held 19,966 cataloged titles and 29,395 items (these are the multiple copies of a title) and had 183 registered patrons (CPW staff). As part of the project to digitize CPW documents, the equivalent of 9GB of data has been scanned and uploaded to the catalog vendor.

Current wildlife databases include BioOne, four of EBSCO's specialty databases (Environment Complete, Fish and Fisheries Worldwide, Wildlife and Ecology Studies Worldwide and CAB Abstracts), Birds of North America, ProQuest Dissertations and Theses and the JSTOR Life Sciences collection. Online subscriptions to the major wildlife journals continue to be a primary usage entry point. CPW staff statewide are authenticated through CPWNet (intranet) eliminating the need for individual usernames and passwords.

As a form of outreach to staff and stakeholders, the Research branch has made an effort to restart the Technical Publication series. The Librarian was involved in editing and proofreading as well as coordinating publications on Cyprinid fish larvae (written by staff at CSU's Larval Fish Lab), Field investigations of mortality in mule deer, the Upper Arkansas River habitat restoration project and others currently in process.

The Library website provides more full-text resources than ever before, however there are also more abstract-only indexes. A major role of the Librarian is to assist CPW staff with document delivery and research assistance. The Library is not open on a walk-in basis to the general public but the Librarian does assist the Denver Help Desk and area staff with questions they receive from citizens. The Librarian has Affiliate Faculty status with the Colorado State University Library which provides access to the large natural resources and science collection at that facility. The chart below shows the number of reference questions and document requests handled by the Librarian each month during the past 9 years. Please note that one request from a CPW staff member may be for multiple journal or book titles. A new record for the most requests in a month was set in January 2017*.

Table 1. Monthly CPW Research Library reference requests August 2008–June 2017.

	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
July		20	45	28	37	60	44	64	49
Aug	15	25	34	52	44	45	25	39	40
Sept	21	30	37	53	48	46	42	59	48
Oct	33	38	41	42	39	74	37	46	57
Nov	14	28	46	52	51	48	47	48	59
Dec	28	32	34	52	49	46	35	56	69
Jan	33	62	48	64	46	53	75	56	**90***
Feb	30	43	43	43	54	62	77	67	68
Mar	35	36	46	36	53	48	70	79	82
Apr	24	23	30	42	70	57	58	45	49
May	13	17	51	53	65	39	58	54	68
June	20	26	27	36	35	34	34	37	55
TOTAL	266	380	482	553	591	612	602	650	734