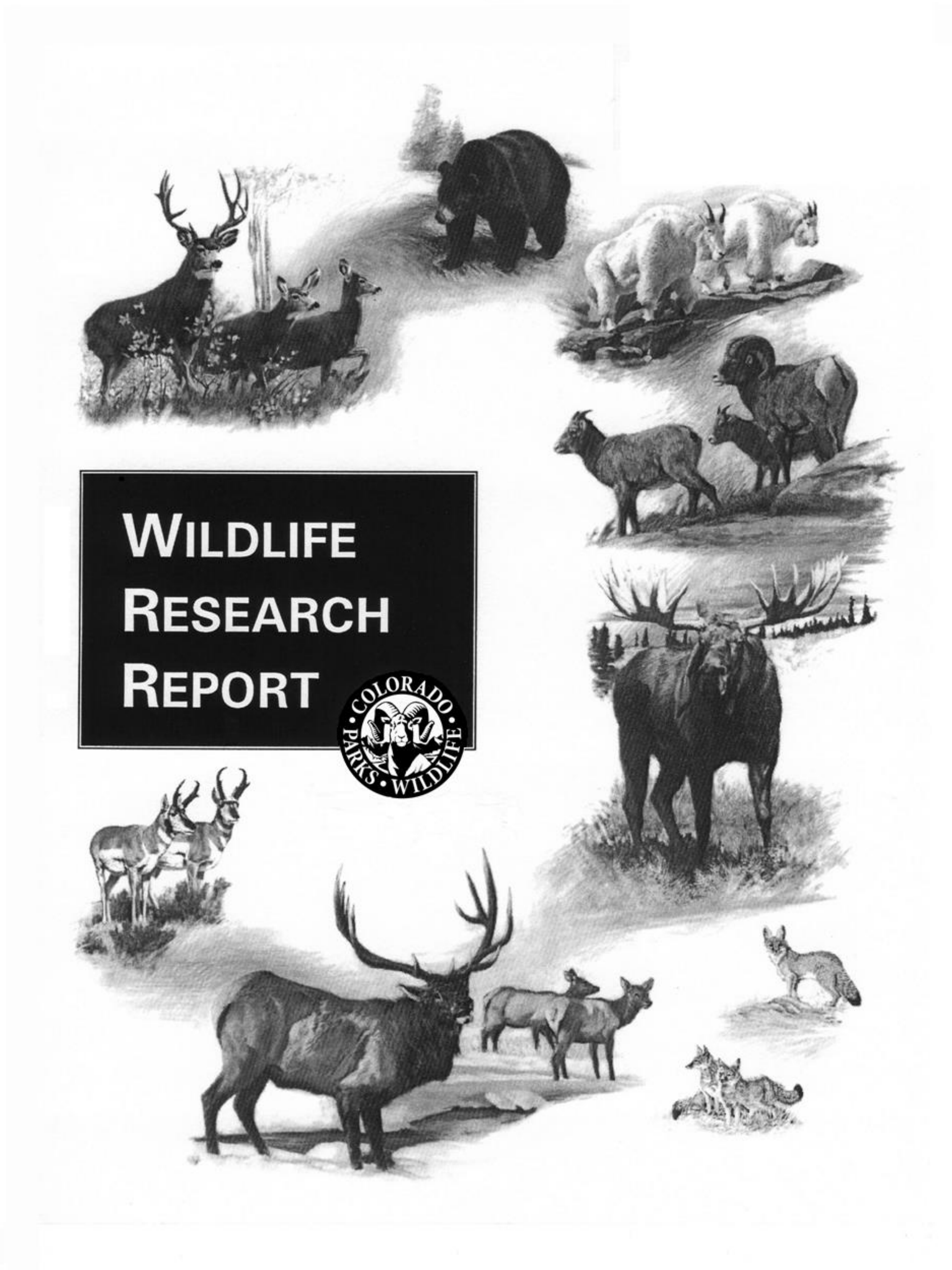
MAMMALS - JULY 2016



WILDLIFE RESEARCH REPORTS

JULY 2015 – JUNE 2016

MAMMALS RESEARCH PROGRAM

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

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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 habitat restoration projects from the CPW Avian Research Section from July 2015 through June 2016. 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 various habitat alterations, human-wildlife interations, and investigating improving approaches to wildlife and habitat management. The Mammal Conservation Section addresses mammal and breeding bird responses to the recent bark beetle outbreak influencing about 3.7 million acres of spruce and pine forests in Colorado and ongoing results of lynx monitoring in the San Juan Mountain Range of southwest Colorado. The Ungulate Conservation section includes 4 projects addressing development planning and mitigation approaches to benefit mule deer exposed to energy development activities, an assessment of mechanical habitat treatment methods to improve mule deer habitat, mitigation techniques to restore native vegetation following energy development disturbances, and an evaluation of moose demographic parameters that will inform future management of this recently established ungulate species in Colorado. The Predatory Mammal Conservation section addresses black bear use of urban environments and approaches for managing black bear-human interactions, evaluation of sport harvest for mountain lion management, and assessment of cougar and black bear demographics and human interactions in Colorado. The Support Services section describes the CPW library services to provide internal access of CPW publications and online support for wildlife and fisheries related publications.

We have benefited from the numerous collaborations that support these projects and the opportunity to work with and train wildlife technicians and gradute students that will enhance 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, the Buerau of Land Management, City of Boulder, Boulder and Jefferson County open space, City of Durango, Big Horn Sheep, Moose and Mule Deer 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 who have provided access for research projects.

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Colorado Division of Parks and Wildlife
July 2015 – June 2016

TABLE OF CONTENTS
MAMMALS WILDLIFE RESEARCH SUMMARIES

MAMMAL CONSERVATION

MAMMAL AND BREEDING BIRD RESPONSE TO BARK BEETLE OUTBREAKS IN COLORADO

CANADA LYNX MONITORING IN COLORADO

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Mammal and breeding bird response to bark beetle outbreaks in Colorado

Period Covered: July 1, 2015 – June 30, 2016

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

Mountain pine beetle (*Dendroctonus ponderosae*) and spruce beetle (*Dendroctonus rufipennis*) infestations have reached epidemic levels in Colorado, impacting approximately 4 million acres since the initial outbreak in 1996 (Figure 1). 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, which in turn may have dramatic, but poorly understood effects on wildlife species that depend on these habitats. This project 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 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 (26 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 fit a base model with parameters for the spruce-fir or lodgepole stratum, percentage of aspen present at the site, canopy cover, shrub cover, amount of down wood, amount of bare ground, and three physiographic variables that collectively account for elevation, 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. Note that because we sampled mobile animals in a continuous landscape, 'occupancy' in this case refers to the probability that a species *uses* the forest stand which the camera was placed.

Mean responses indicate that use of subalpine forest by elk (Figure 2) and mule deer (Figure 3) increased after stands were impacted by bark beetles (either through time or with increasing severity). Use by red squirrels (Figure 4) and coyotes (Figure 5) declined. Use by red fox (Figure 6) and black bears (Figure 7) was mixed as it increased through time after an outbreak, but may have declined with increasing severity. Snowshoe hares (Figure 9), and American martens (Figure 10) were largely unaffected by bark beetles in terms of their use of a stand as a function of beetle outbreaks. Both red squirrels and snowshoe hares used spruce-fir stands more heavily than lodgepole stands. Data from other species was too sparse to support fitting of the suite of models presented here.

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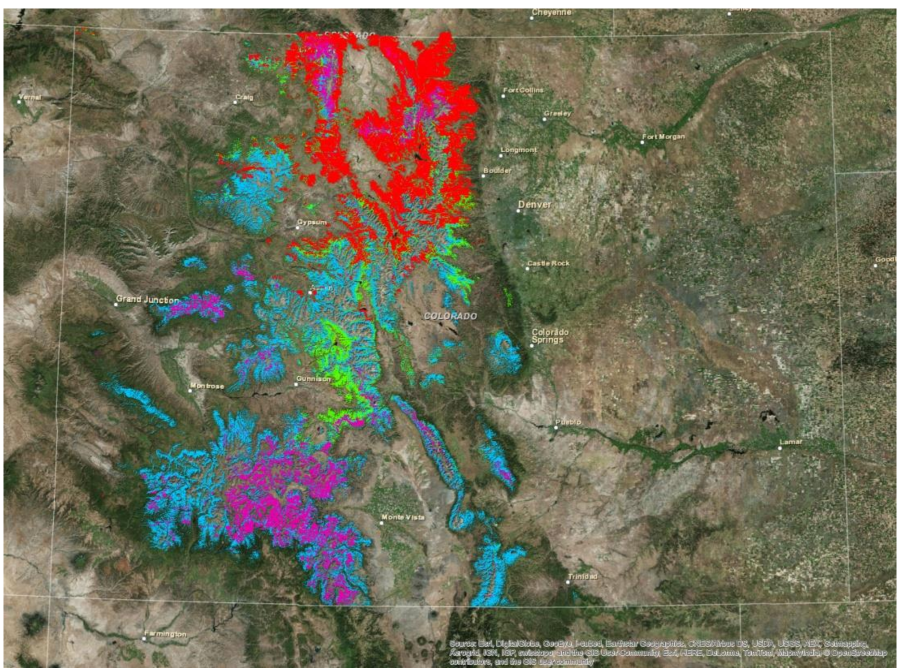

Figure 1. Extent of mountain pine beetle (red) and spruce beetle (purple) infestations in spruce/fir (blue-green) and lodgepole pine (bright green) forests in Colorado, 2014. Data were summarized from USFS Aerial Surveys.

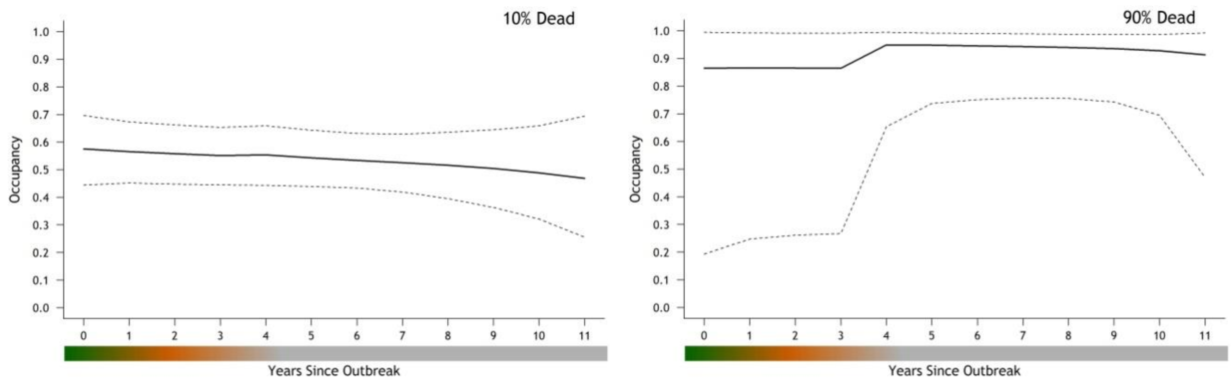

Figure 2. Elk occupancy (use) of subalpine forest stands in relation to the number of years since initial infestation by bark beetles for lightly (left) and severely (right) impacted areas Dotted lines indicate 95% confidence intervals. Color bar indicates approximately when forest canopy changes from green to red (dead needles) to gray (no needles) following a bark beetle outbreak.

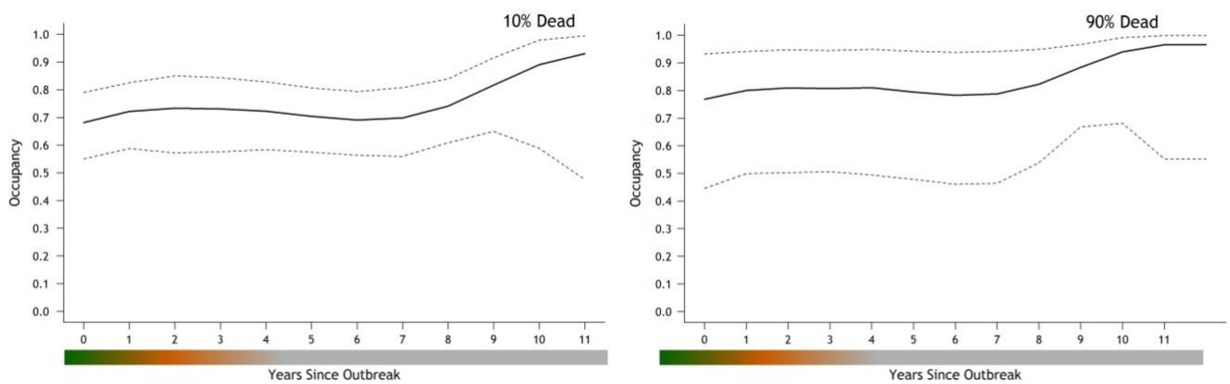

Figure 3. Mule Deer occupancy occupancy (use) of subalpine forest stands in relation to the number of years since initial infestation by bark beetles for lightly (left) and severely (right) impacted areas.

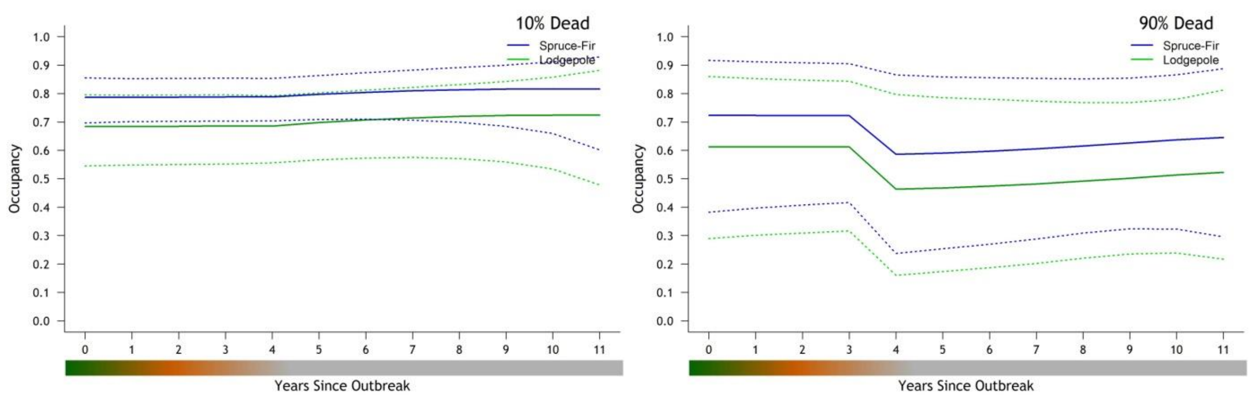

Figure 4. Red squirrel occupancy (use) of subalpine forest stands in relation to the number of years since initial infestation by bark beetles for lightly (left) and severely (right) impacted areas.

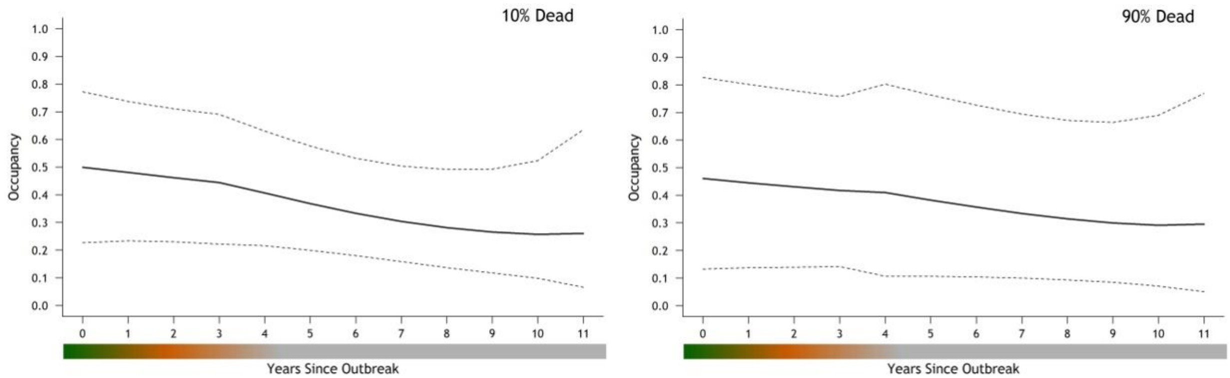

Figure 5. Coyote occupancy (use) of subalpine forest stands in relation to the number of years since initial infestation by bark beetles for lightly (left) and severely (right) impacted areas.

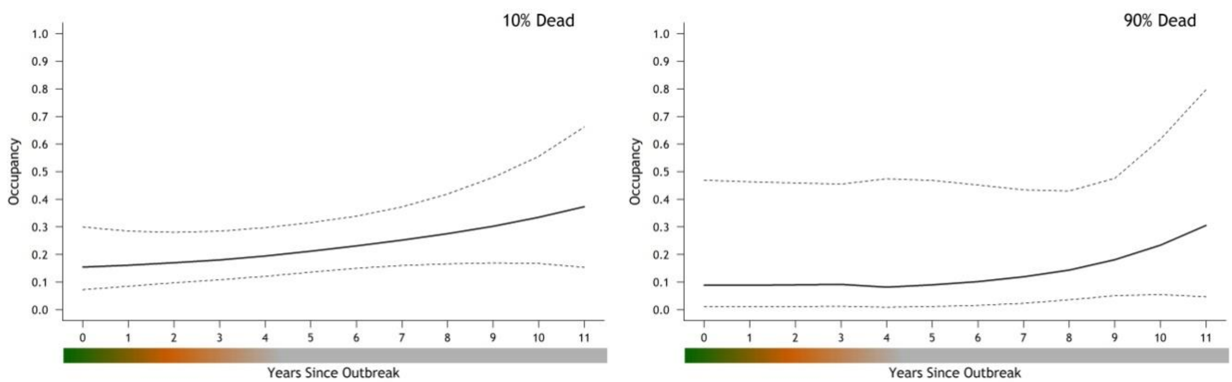

Figure 6. Red Fox occupancy (use) of subalpine forest stands in relation to the number of years since initial infestation by bark beetles for lightly (left) and severely (right) impacted areas.

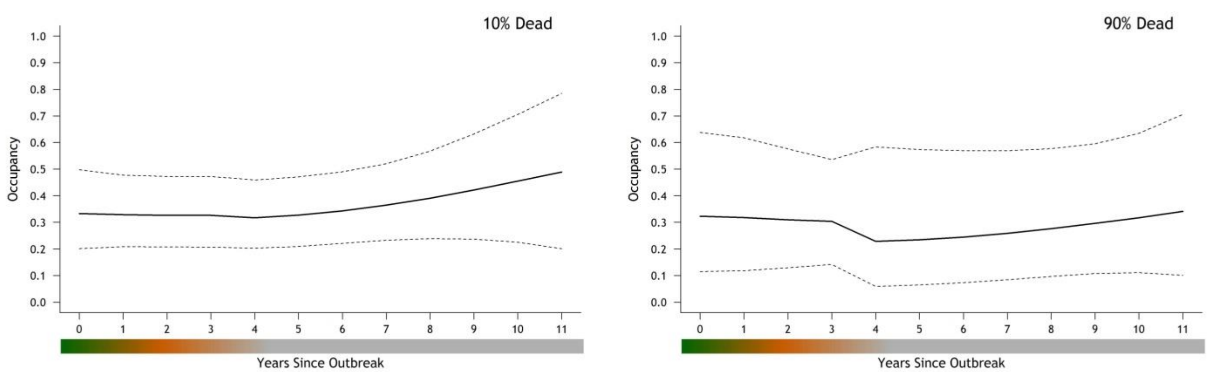

Figure 7. Black bear occupancy (use) of subalpine forest stands in relation to the number of years since initial infestation by bark beetles for lightly (left) and severely (right) impacted areas.

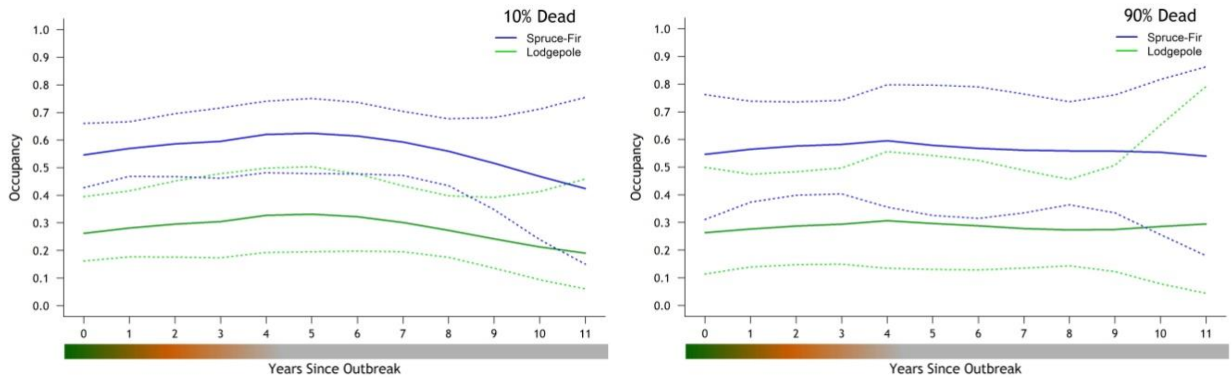

Figure 8. Snowshoe Hare occupancy (use) of subalpine forest stands in relation to the number of years since initial infestation by bark beetles for lightly (left) and severely (right) impacted areas.

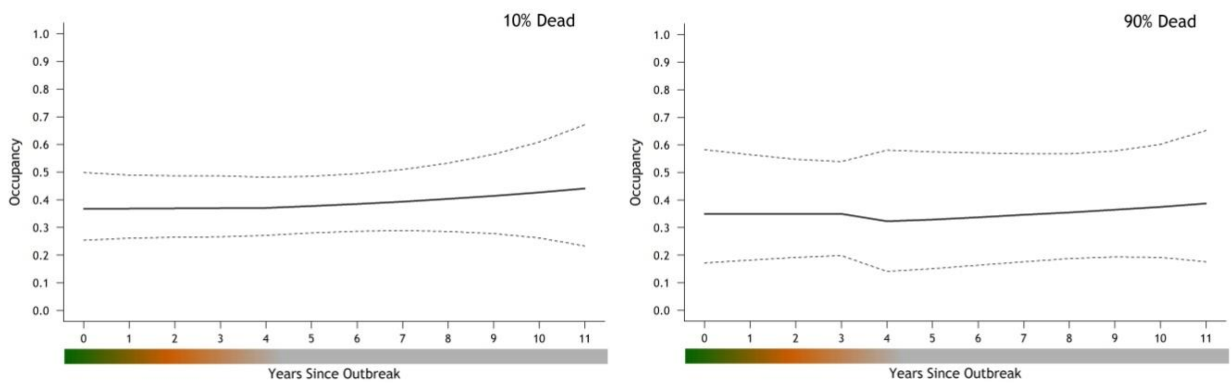

Figure 9. American marten occupancy (use) of subalpine forest stands in relation to the number of years since initial infestation by bark beetles for lightly (left) and severely (right) impacted areas.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Canada Lynx Monitoring in Colorado

Period Covered: July 1, 2015 – June 30, 2016

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 2014−2015 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 2015−2016 personnel from CPW and USFS completed the second year of monitoring work on this same sample of 75-km^2 units (approximate size of female home range). Specifically, 17 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 distributed across at least 2 quadrants of the unit. Two additional units were scheduled for snow track surveys but surveys were not completed due to poor conditions. The remaining 31 units could not be surveyed via snow tracking because they occurred in wilderness or were otherwise inaccessible. Survey crews deployed 4 passive infrared motion cameras in each of these units during fall 2015. Cameras were baited with visual attractants and scent lure to enhance detection of lynx living in the area. Cameras were retrieved during summer 2016 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.

Surveyors covered a total of 898 km during snow tracking surveys and detected lynx at 8 units (Table 1). They also collected 455 photos of lynx from 10 cameras in 7 camera units (Table 2). 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 2 units 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). For the purposes of model-fitting, we included data from the pilot study (2010−2011) and the first (2014−2015) and second (2015−2016) years of implementation 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. We limited our model set by considering only combinations of two of these covariates on ψ, in addition to the two covariates on detection.

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 (Appendix 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 appear in top models with spruce-fir, but addition of these covariates did not improve AIC_c scores beyond the model with spruce-fir only (Appendix 1). This phenomenon indicates that these other variables were not as informative. Of these less informative variables, lynx occupancy was positively associated with the proportion of mapped lynx habitat in the unit, the proportion of the unit that had been impacted by spruce beetles, and the years since beetle impact, although coefficients for each of these effects partially overlapped zero, indicating that the strength of these associations was somewhat weak. 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 = 0.56, 95% confidence interval: 0.44–0.67), and low for monthly camera surveys (p = 0.20, 95% confidence interval: 0.14–0.28) during December–February and April, although detection increased to 0.41 (95% confidence interval: 0.27–0.57) during breeding season (March) as expected. For winter 2015−2016 we estimated that 29% of the sample units in the San Juans were occupied by lynx (95% confidence interval: 0.16–0.46). Occupancy estimates from the 2015−2016 monitoring effort were similar to those obtained during the first year of implementation and to those obtained during pilot research work in 2010−2011, although the sampling frame was different for the pilot work so results are not directly comparable (Figure 2).

Note that during preliminary analyses of these data, we fit 2 new types of occupancy models that incorporate unexplained heterogeneity in detection probability among units, (i.e., mixture models and random effects as per Pledger 2000, McClintock and White 2009, Gimenez and Choquet 2010). That is, they acknowledge that the detection probability in each unit likely varies, and does so in ways that cannot be completely explained by covariates such as effort, conditions, breeding season, etc. According to AIC_c, the fit of these models was a strong improvement over the standard occupancy formulation, however occupancy estimates from these new models were ~0.55 and ~0.85, respectively, and some model parameters could not be estimated. These estimates seem unreasonably high, and the fact that some model parameters could not be estimated is troubling. Thus, we elected to continue reporting results from the standard approach. However, the fit of the new models does suggest unexplained heterogeneity in detection among the units in our survey, and because of this, estimates from the standard approach are likely biased low to some degree.

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Table 1. Summary statistics from snow tracking effort.

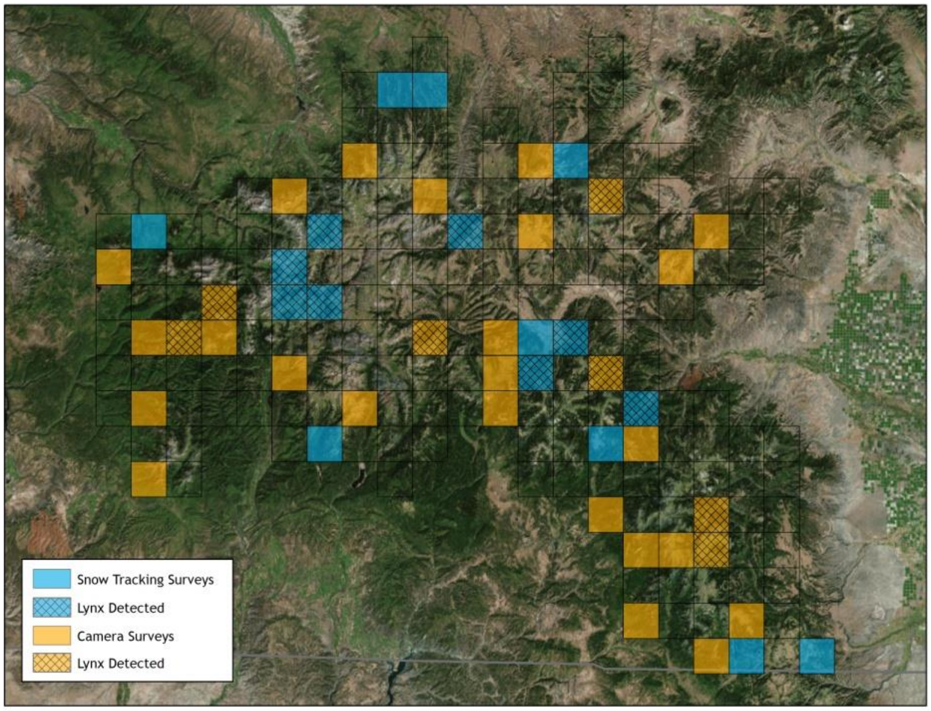
Season	#Units Surveyed	#Units with Lynx	#Lynx Tracks	#Genetic Samples[a]	Km Surveyed (Total)	Mean Km Surveyed per Visit	#CPW Personnel	#USFS Personnel
2014−2015	18	7	12	8[b]	884	20.1	30	13
2015−2016	17	8	14	9[c]	898	21.4	23	6

[a] Number of genetic samples (scat or hair) collected via backtracking putative lynx tracks
[b]DNA analysis confirms that all samples collected from putative lynx tracks were lynx
[c]DNA confirmation pending

Table 2. Summary statistics from camera effort.

Season	#Units Surveyed	#Units with Lynx	#Photos (Total)	#Photos (Lynx)	#Cameras with Lynx	#CPW Personnel	#USFS Personnel
2014−2015	32	8	134,694	301	14	46	12
2015−2016	31	7	101,534	455	10	33	9

a)



b)

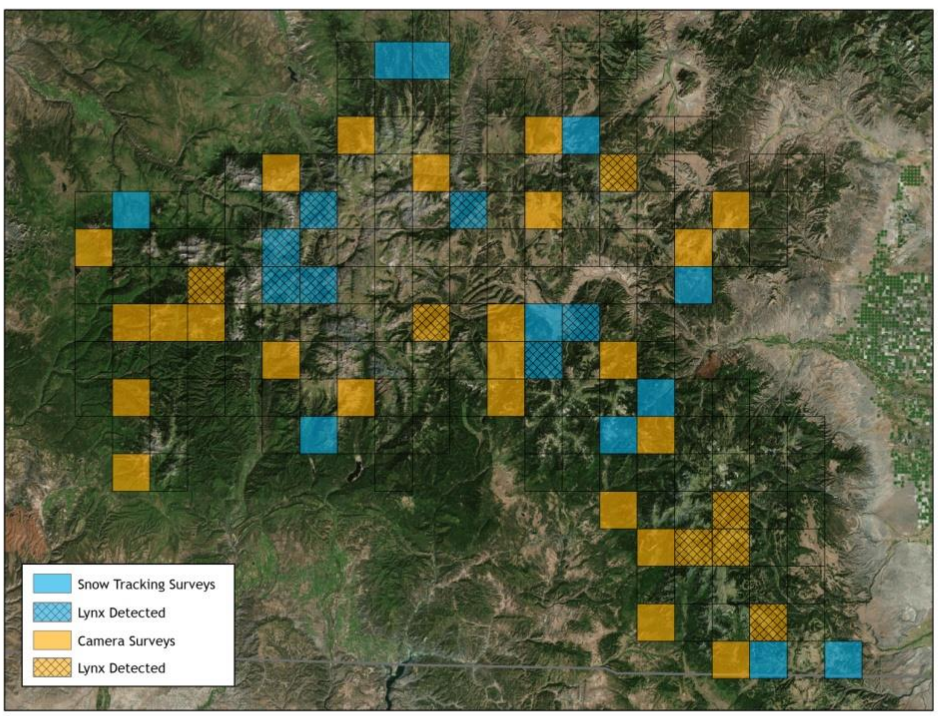


Figure 1. Lynx monitoring results for a) 2015−2016 and b) 2014−2015, San Juan Mountains, southwest Colorado. Colored units (n = 50) indicate those selected at random from the population of units (n = 179) encompassing lynx habitat in the San Juan Mountains. Blue units were surveyed via snow tracking; orange units were surveyed via deployment of four cameras per unit during winter months. Lynx were detected in 14 and 15 of the sampled units in 2014−2015 and 2015−2016, respectively.

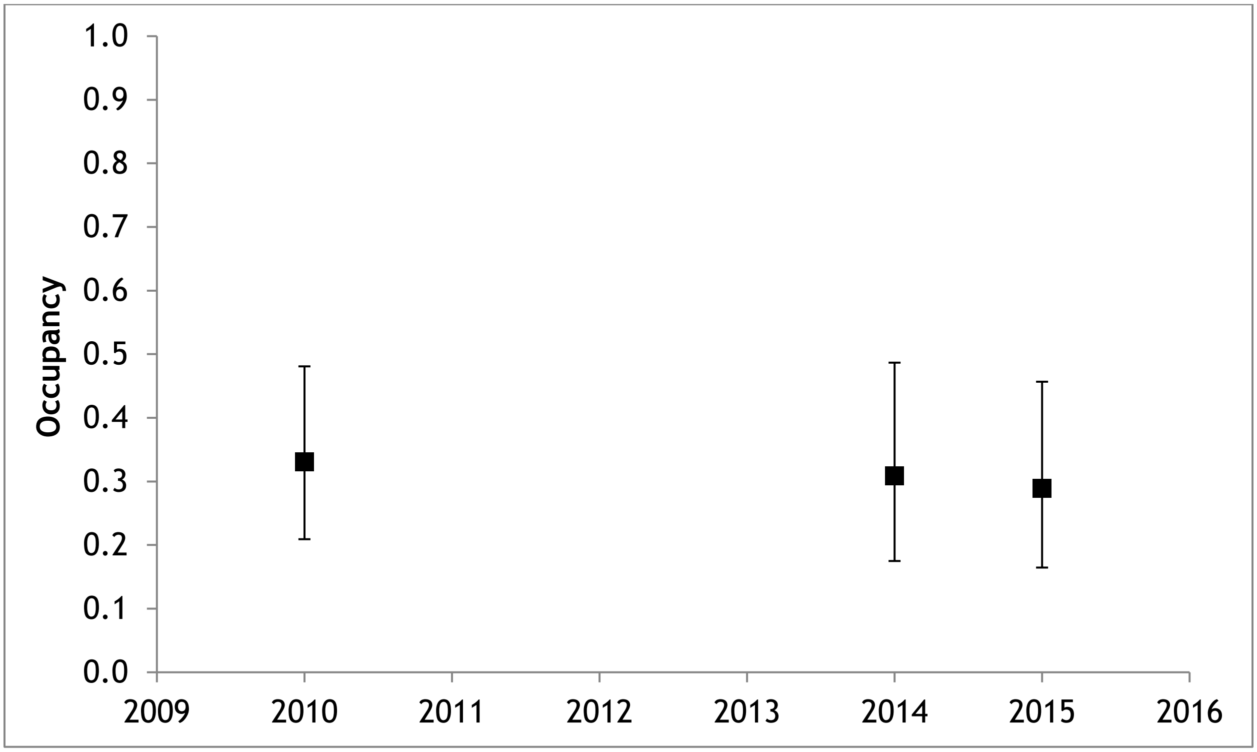


Figure 2. Model-averaged occupancy estimates and 95% Confidence Intervals for Canada lynx in the San Juan Mountains, southwest Colorado. 'Year' indicates when the efforts were initiated (2010−11 [pilot year], 2014−15, 2015−16).

Appendix 1. Model selection results for lynx monitoring data collected in the San Juan Mountains, Colorado, 2015−2016. Rankings are based on Akaike's Information Criterion adjusted for small sample size (AIC_c). Thirteen 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.
ψ (Year + SpruceFir + SnowshoeHare)*p*(Method + Breeding)	527.2	0.0	0.54	8
ψ (Year + SpruceFir)*p*(Method + Breeding)	531.1	3.9	0.08	7
ψ (Year + SpruceFir + Coyote)*p*(Method + Breeding)	532.0	4.7	0.05	8
ψ (Year + SpruceFir + Cougar)*p*(Method + Breeding)	532.6	5.3	0.04	8
ψ (Year + SnowshoeHare + PropBeetleKill)*p*(Method + Breeding)	533.1	5.9	0.03	8
ψ (Year + SpruceFir + Fox)*p*(Method + Breeding)	533.3	6.0	0.03	8
ψ (Year + SpruceFir + Bobcat)*p*(Method + Breeding)	533.3	6.1	0.03	8
ψ (Year + SpruceFir + PropBurn)*p*(Method + Breeding)	533.4	6.1	0.03	8
ψ (Year + SpruceFir + YrSinceBeetle)*p*(Method + Breeding)	533.4	6.1	0.03	8
ψ (Year + SpruceFir + PropBeetleKill)*p*(Method + Breeding)	533.4	6.1	0.03	8

UNGULATE CONSERVATION

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

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

RESTORING ENERGY FIELDS FOR WILDLIFE

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

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, 2015 – June 30, 2016

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 2014 for VHF and GPS radiocollar attachment, respectively, and attempted recapture of 120 does and 40 fawns in March 2015 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 2 years to provide sufficient time to measure how vegetation and mule deer respond to these changes.

Based on data collected prior to habitat improvements (i.e., pretreatment phase): (1) annual adult survival was consistent among areas averaging 79-87% annually, but overwinter fawn survival was variable, ranging from 48% to 95% within study areas, with annual and study area differences primarily due to early winter fawn condition and annual weather conditions; (2) migratory mule deer (Fig. 3) 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; (3) mule deer body condition was generally consistent within areas, with higher variability among study areas early winter, primarily due to December lactation rates, and late winter condition appeared 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 increased in all study areas (Fig. 5), averaging 76% in the low development areas and 80% in the high development areas since 2008; and (6) post treatment vegetation responses have provided evidence of improved forage conditions with improved winter fawn condition, but longer term monitoring will be required to address the full potential of habitat mitigation efforts. We will continue to collect population 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 impacts 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 being peer-reviewed and will be reported in next year's annual report.

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/Documents/Research/Mammals/Publications/AndersonPiceanceDeer_W185-R14_ProgressReport_2014-15.pdf

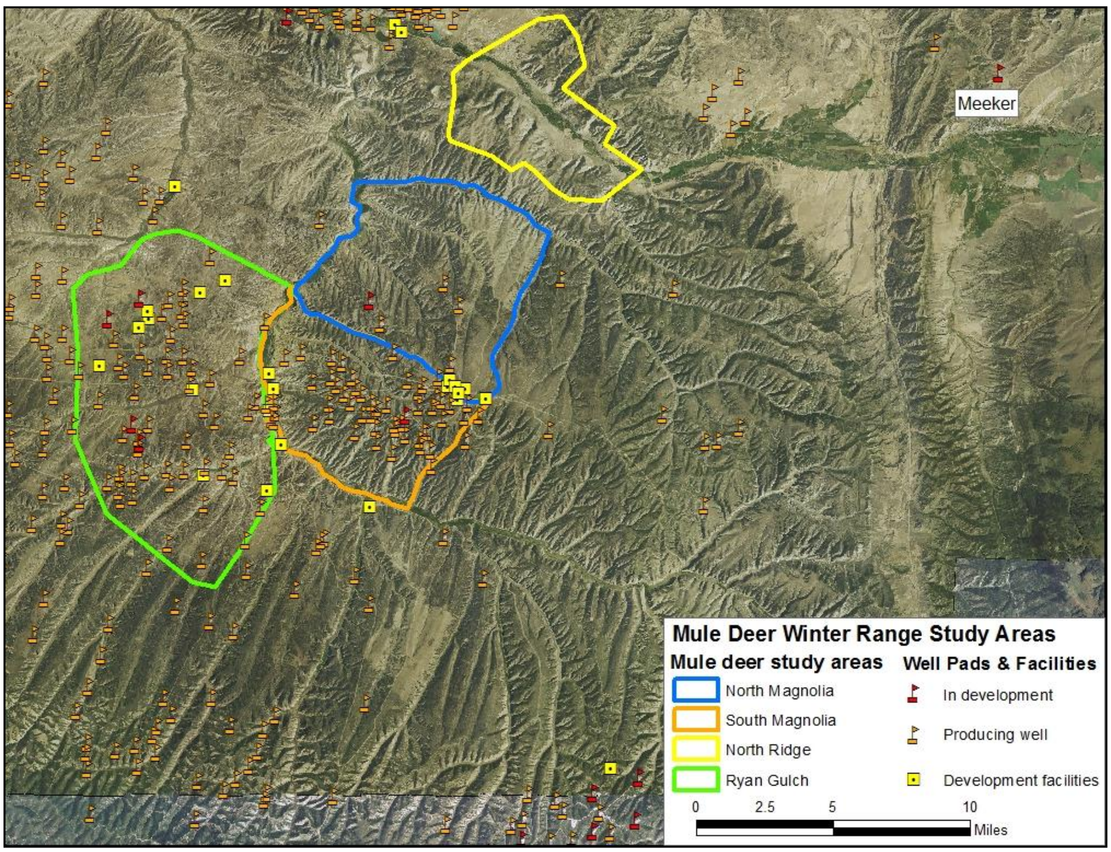


Figure 1. Mule deer winter range study areas relative to active natural gas well pads and energy development facilities in the Piceance Basin of northwest Colorado, winter 2013/14 (Accessed http://cogcc.state.co.us/ Dec. 31, 2013; energy development activity been minor since 2012).

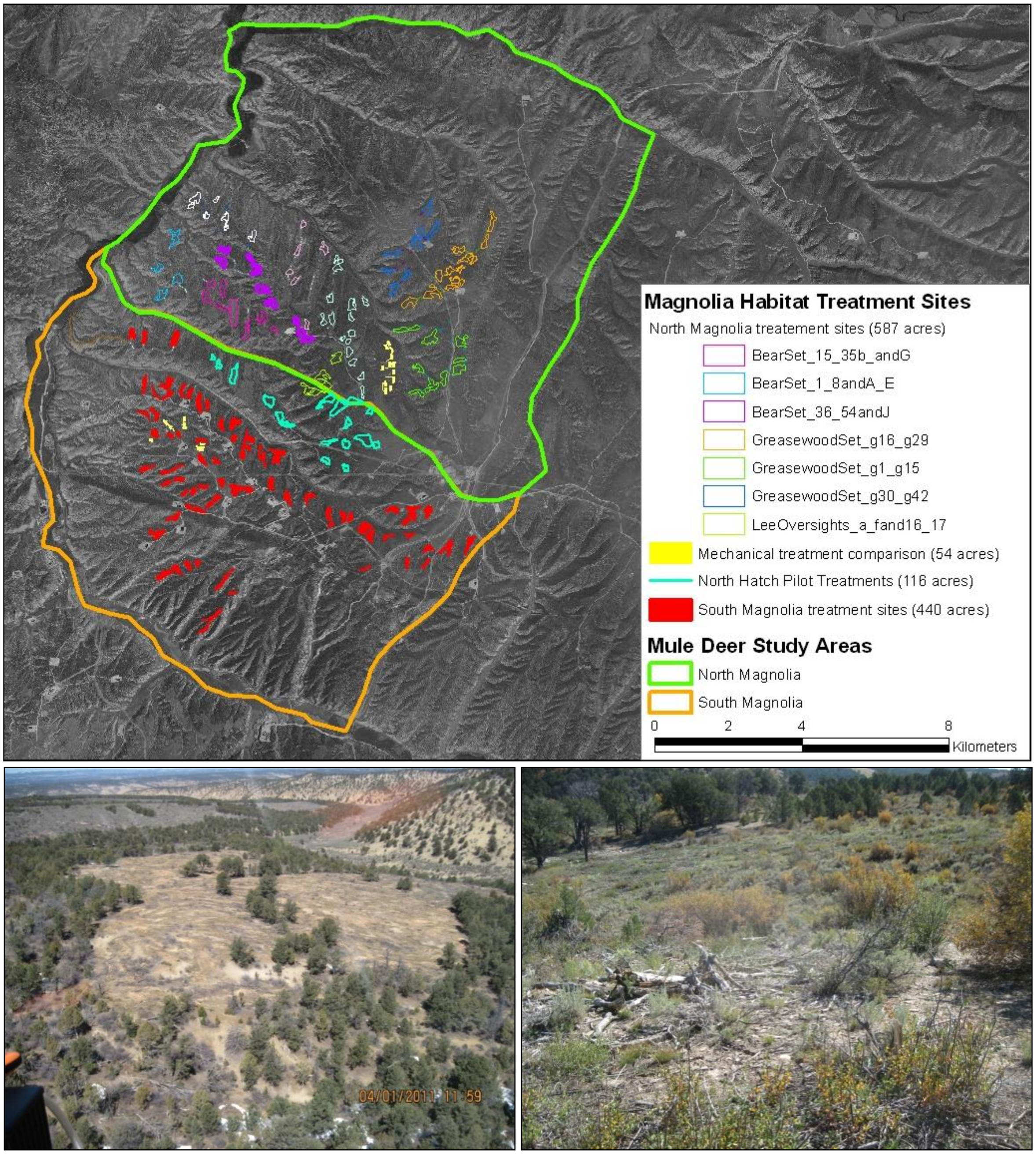


Figure 2. Habitat treatment site delineations in 2 mule deer study areas (604 acres each) of the Piceance Basin, northwest Colorado (Top; cyan polygons completed Jan. 2011 using hydro-axe; yellow polygons completed Jan. 2012 using hydro-axe, roller-chop, and chaining; and remaining polygons completed 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).

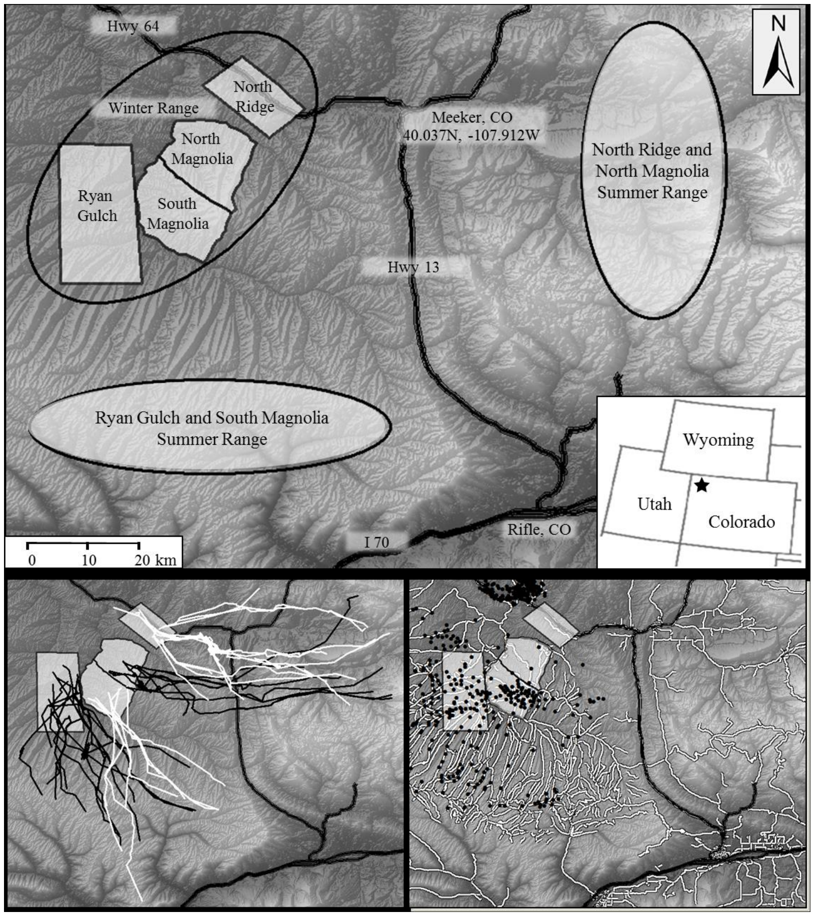


Figure 3. Mule deer study areas in the Piceance Basin of northwestern Colorado, USA (Top), spring 2009 migration routes of adult female mule deer (n = 52; Lower left), and active natural-gas well pads (black dots) and roads (state, county, and natural-gas; white lines) from May 2009 (Lower right; from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

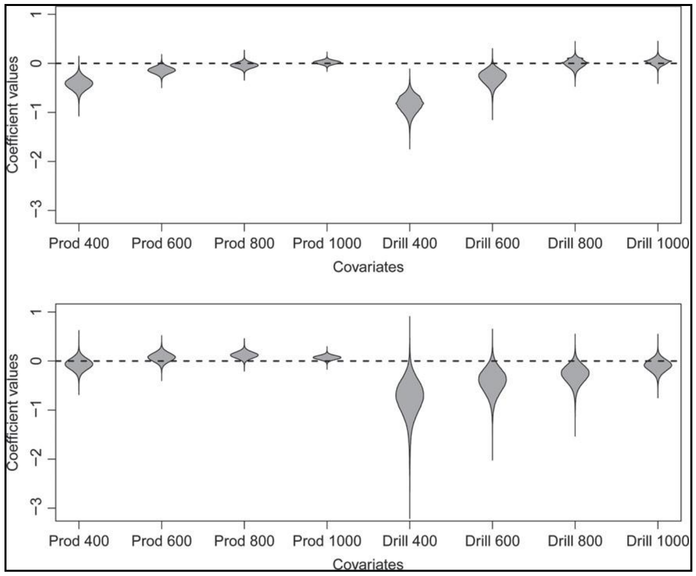


Figure 4. Posterior distributions of population-level coefficients related to natural gas development for RSF models during the day (top) and night (bottom) for 53 adult female mule deer in the Piceance Basin, Northwest Colorado. Dashed line indicates 0 selection or avoidance (below the line) of the 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).

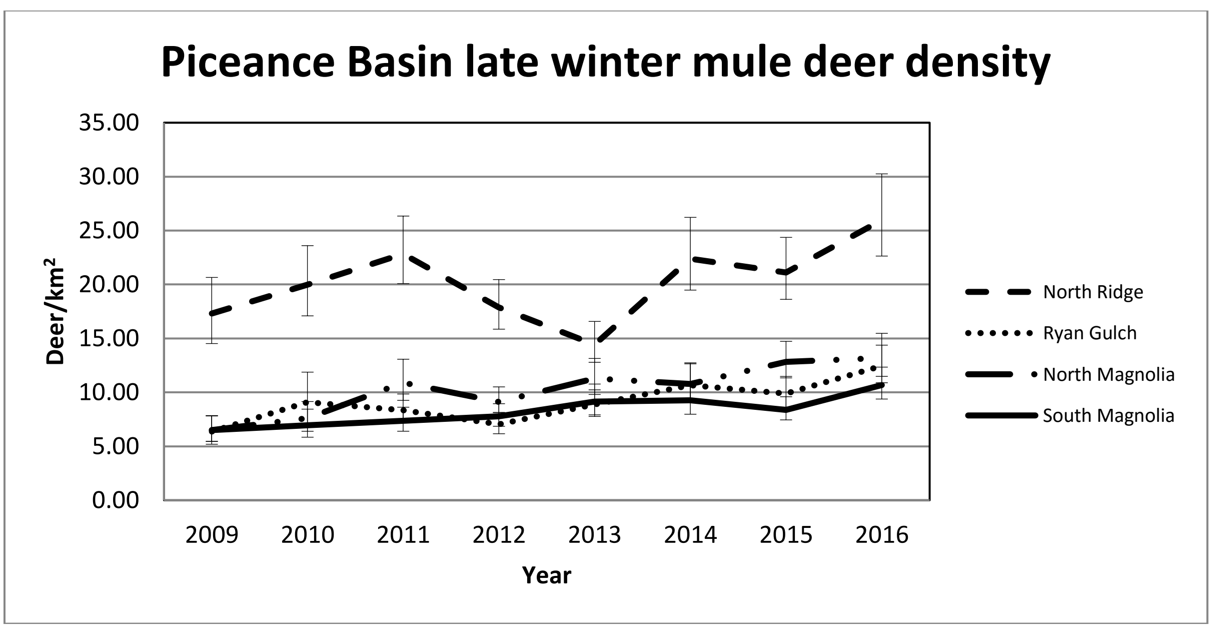


Figure 5. Mule deer density estimates and 95% CI (error bars) from 4 winter range herd segments in the Piceance Basin, northwest Colorado, late winter 2009–2016.

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, 2015 – July 30, 2016

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, 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. Half of each treated plot was seeded with a shrub-heavy seed mix including 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. Understory vegetation cover was assessed in July 2016 using about 300 point-intercept hits (arrayed over 13 transects) in each plot.

Five years post-treatment, differences in understory vegetation due to type of mechanical treatment were minimal, but all treated plots differed greatly from controls. Treated plots had 3-5 times higher perennial grass cover than control plots, with bottlebrush squirreltail (*Elymus elymoides*), Indian ricegrass (*Achnatherum hymenoides*), and western wheatgrass (*Pascopyrum smithii*) dominating (Figure 2). In addition, treatment plots had about 10 times higher cheatgrass cover than control plots (Figure 3). Cheatgrass had been present at only 1-3% cover in the 2013 data (Stephens et al. 2016), and was practically undetectable at the South Magnolia site. By 2016, cheatgrass cover in treated plots was about 27% at North Magnolia and about 7% at South Magnolia.

Differences in shrub cover were apparent at North Magnolia only (Figure 4), with chaining and mastication producing higher shrub cover than the control. Much of this increase was due to snowberry (*Symphoricarpos rotundifolius*; Figure 4), which is not a preferred forage species in the study area. A companion study in nearby locations quantified both cover and forage biomass in response to mastication for preferred species including serviceberry, bitterbrush, and mountain mahogany. Although cover 2-

years post-treatment did not differ, forage biomass increased nearly 2-fold in masticated plots. It is reasonable to conclude that forage biomass of preferred species was also higher in treated versus control plots in this study. Even so, a shift in dominance towards snowberry with mechanical treatment is a possible negative consequence which should be noted.

Seeding had effects only on forb cover and cheatgrass cover five years post-treatment. In the absence of seeding, forb cover was similar between treated and control plots, but within treated plots, seeding increased forb cover from 2.4% to 5.4% at South Magnolia and from 3.5% to 7.9% at North Magnolia ($p < 0.006$). Utah sweetvetch (*Hedysarum boreale*) accounted for most of the difference, followed by Lewis flax (*Linum lewisii*). Again, results were similar among each of the three mechanical treatment types. Seeding had no effect on cheatgrass at North Magnolia, but at South Magnolia, cheatgrass cover was 2-3 times higher in seeded subplots within chained ($p < 0.01$) and rollerchopped ($p < 0.008$) plots. We suspect cheatgrass contamination in the seed that was used. This was not apparent in our earlier analysis. Apparently, seed contamination may cause problems which take several years to manifest. We urge practitioners to be cautious when applying seed, especially in areas previously free of cheatgrass.

Seeding did not affect grass or total shrub cover 5 years post-treatment. In the earlier analysis, we found an effect of seeding on density of seeded shrubs at South Magnolia, due largely to bitterbrush. In the 2016 data, we looked at bitterbrush cover specifically, and found that seeding had an effect across sites, increasing it from 2.9% to 3.8% ($p = 0.04$). Again, there was no difference among mechanical treatment types. The seed mix used was very expensive, about $714/ac. If we had seeded only the species which actually responded (bitterbrush, Utah sweetvetch, and Lewis flax), the price would have been $173/ac. Obviously, it is important to choose species judiciously and to limit seeding only to those sites lacking in a desirable plant type. Utah sweetvetch is a species which has performed well at many research sites in northwest Colorado (Johnston 2016).

In the treatments which used bulldozers, chaining and rollerchopping, we planted large-seeded species with a Hansen dribbler (Johnston 2014). This tool dribbles the seed onto the track and facilitates deep planting. Bitterbrush and Utah sweetvetch were both planted this way, and it is interesting to note that bitterbrush established as well in the rollerchop and chaining treatments as it did in the mastication treatment. In the mastication treatment, all species were broadcast-seeding prior to treatment, which required more effort. The dribbler seems to be a useful tool to plant large-seeded species efficiently.

We found little difference in understory cover in 2016 with mechanical treatment type in our study area. This differed somewhat from analysis of 2012-2013 data, which found that undesirable non-natives were somewhat worse with rollerchopping, and native annuals established best with mastication (Stephens et al. 2016). While more years of sampling would be desirable, it seems that the differences in vegetation response are sufficiently small that the choice of mechanical treatment type should be dictated by other factors in this study area.

Among these factors are per-acre cost, mobilization cost, and the ability to create the desired spatial arrangement of treatment patches. More detailed mosaics are possible with mastication than with rollerchopping, and chaining is the least flexible. We used a shorter-than-typical 50-foot smooth chain in our study, which could be a viable and cost-effective option for creating small treatment patches. However, it is not possible to leave isolated trees with chaining. Chaining costs are one-third to one-sixth that of mastication, with rollerchopping having intermediate costs. More detailed cost information is available in a prior report (Johnston 2014).

The increase in cheatgrass with all three treatment types, at both study sites, is somewhat alarming. Recent research has shown that cheatgrass is adapting to higher elevation sites (Merrill et al. 2012), therefore problems with cheatgrass can be expected to worsen. Nevertheless, the substantial amount of perennial grass cover at these sites should prevent cheatgrass from dominating. Wildlife benefits are still possible with PJ removal if enough understory vegetation is present to respond (Miller et al. 2005), but practitioners should consider potential risks as well as benefits when selecting projects (Figure 5).

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.

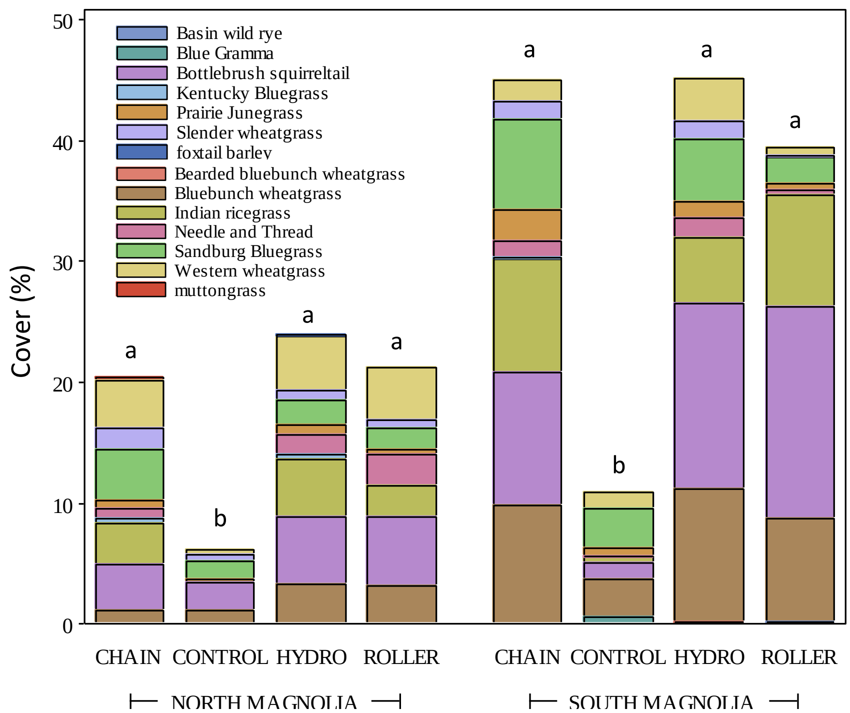


Figure 2. Cover of perennial grasses in response to chaining (CHAIN), mastication (HYDRO), and rollerchopping (ROLLER) at two sites, North Magnolia and South Magnolia. Letters indicate significantly different means among treatments at α = 0.05 (Sites considered separately). Seeding had no effect on perennial grasses.

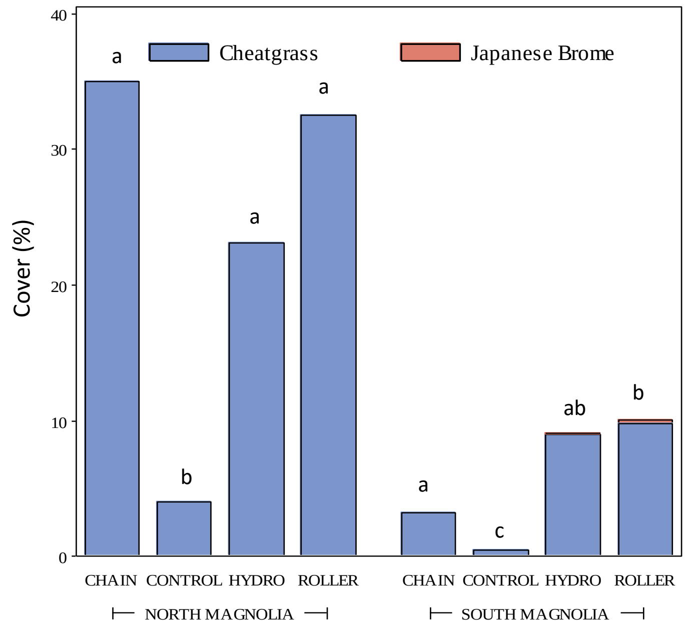


Figure 3. Cover of annual grasses in response to chaining (CHAIN), mastication (HYDRO), and rollerchopping (ROLLER) at two sites, North Magnolia and South Magnolia. Letters indicate significantly different means among treatments at α = 0.05 (Sites considered separately).

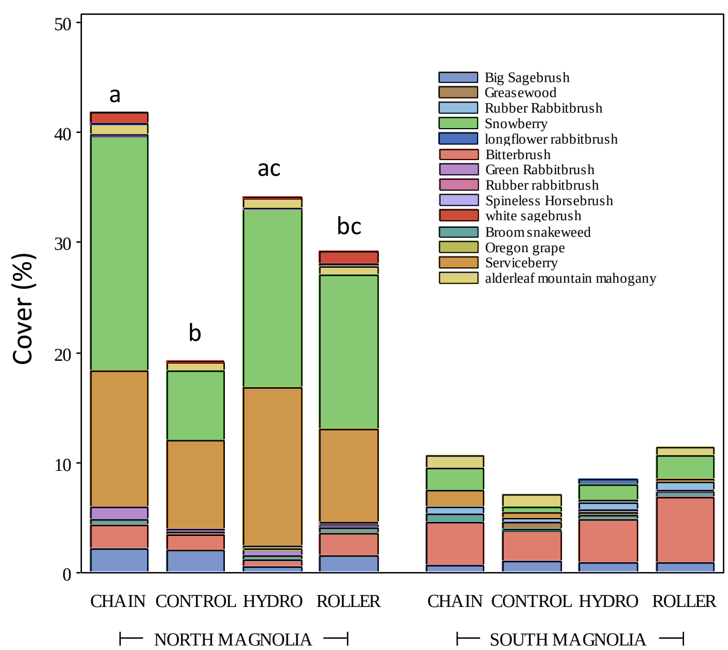


Figure 4. Cover of shrubs in response to chaining (CHAIN), mastication (HYDRO), and rollerchopping (ROLLER) at two sites, North Magnolia and South Magnolia. Letters indicate significantly different means among treatments at α = 0.05 (Sites considered separately). Seeding had no effect on total shrub cover.

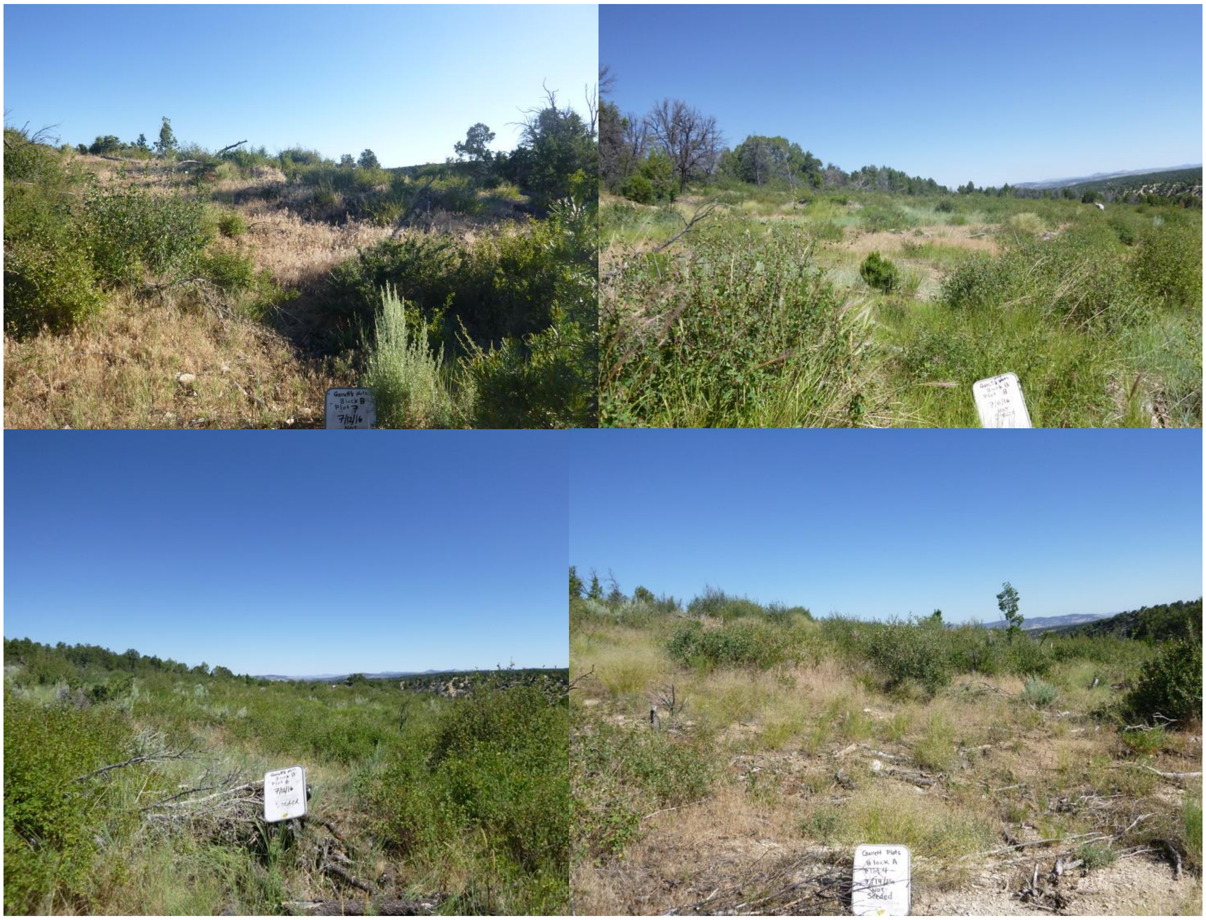


Figure 5. A photo collage of sites where PJ was removed at the North Magnolia site shows good perennial grass and shrub cover, but also reveals some undesirable cheatgrass patches.

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Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Restoring energy fields for wildlife

Period Covered: January 16, 2013 – June 30, 2016

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

Collaborators: Colorado Parks and Wildlife, BLM-White River Field Office, BLM- Colorado River Valley Field Office, Colorado State University, Phillip L. Chapman, EnCana Corp., ExxonMobil Prod. Co./XTO Energy, Marathon Oil Corp., Shell Petroleum, WPX Energy

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

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

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

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

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

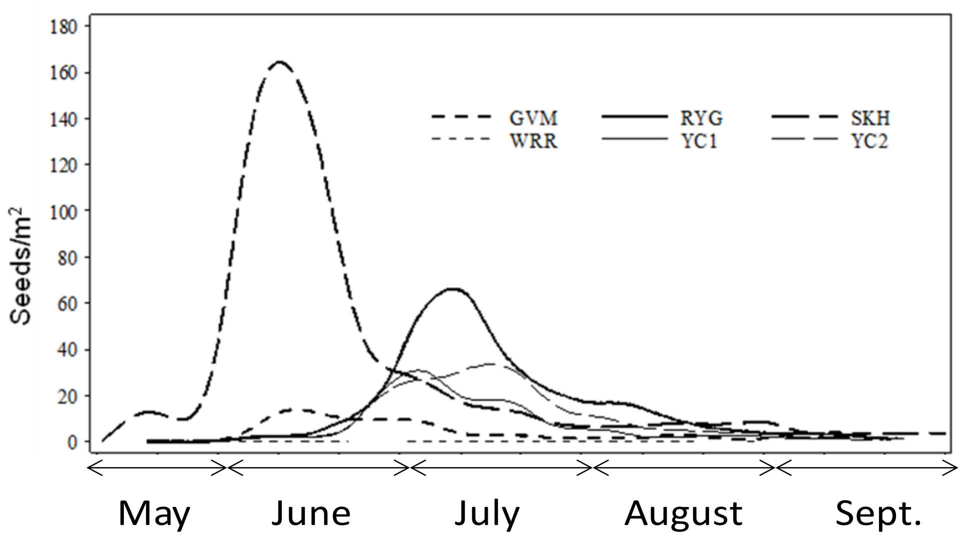

Figure 1. Propagule pressure of cheatgrass seeds between May and September in undisturbed locations near 6 sites: GVM, RYG, SKH, WRR, YC1, and YC2, which varied in elevation from 1561- 2216 m (5120-7268 ft.) and cheatgrass cover from 0% to 70%. Data are averages over 3 years, 2009-11

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

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

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

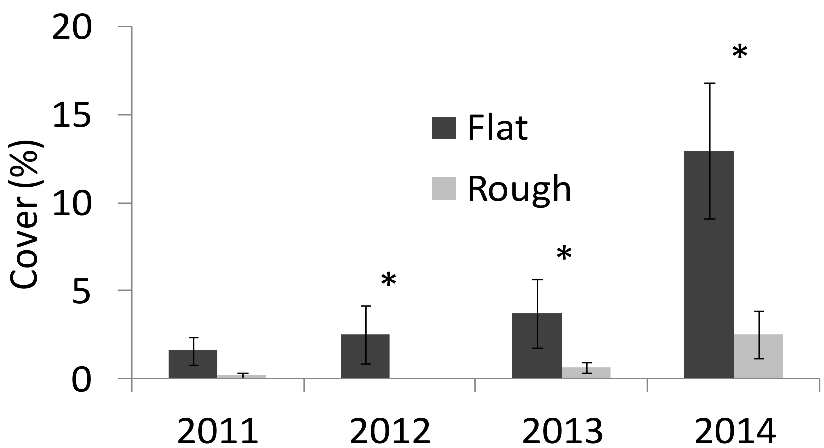

Figure 2. Percent cover of annual grass (*Bromus tectorum*) in response to a rough versus flat soil surface in unseeded plots at Scandard Ridge 2-5 years post-disturbance. Error bars are SE. Stars denote significant differences at α = 0.05.

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

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

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

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

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

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

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Colorado Parks and Wildlife

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, 2015 – June 30, 2016

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 2015–2016 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 the FY 2014-2015 and FY 2015-2016, field efforts were expanded to include estimation of parturition rates. During the third year of the study, all captures occurred during late December (2015) and were focused in 3 study areas in—along the Laramie River (NE Colorado), southern North Park and the Williams Fork drainage (NW Colorado), and near the community of Creede and near the Rio Grande Reservoir (SW Colorado).

During the third year of the study 42 cow moose were captured and collared. Of these 42 animals, 25 were recaptures of animals that had been captured during previous winters of the study. Eleven of these recaptures occurred along the Laramie River (NE Colorado), and 14 recaptures occurred in North Park and along the Williams Fork River (NW Colorado). No recaptures occurred in southwest Colorado during FY 2015-2016, although capture efforts in this region were concentrated in areas where no collars had previously been deployed. 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 2016, parturition and twinning rates were also estimated for all 3 study areas.

Measured rump fat at the time of capture (December 2015) ranged between 0–31 mm among study areas. Measured loin depth at the time of capture ranged between 29–58 mm among study areas. Measured loin fat, at the time of capture, ranged between 0–36mm. When data from 2013–2016 were pooled, pregnancy status was best predicted by the additive model of maximum rump fat plus the number of calves-at-heel. However, no regional or annual effects in pregnancy rates were detected. 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%. In comparison to previous years, lower pregnancy rates were observed during 2015–2016 in southwest Colorado, although these lower rates are believed to be associated with a younger age class of animals being captured (multiple yearling females in sample). Compared to previous winters, higher pregnancy rates were observed in northeast

Colorado during 2015–2016. During 2015–2016, observed twinning rates at the time of parturition were low in northeast and northwest Colorado (0%), but high in southwest Colorado (33%).

Thus far, data collected during this project have met expectations. In particular, survival rates have been consistently high in all study areas. Lower reproductive rates previously observed in the northeast herd were more similar to other herds during 2015–2016. During future years, we will investigate opportunities to evaluate moose browse selection behavior. Likewise, we will begin investigations for determining herd level pregnancy status in cost effective ways.

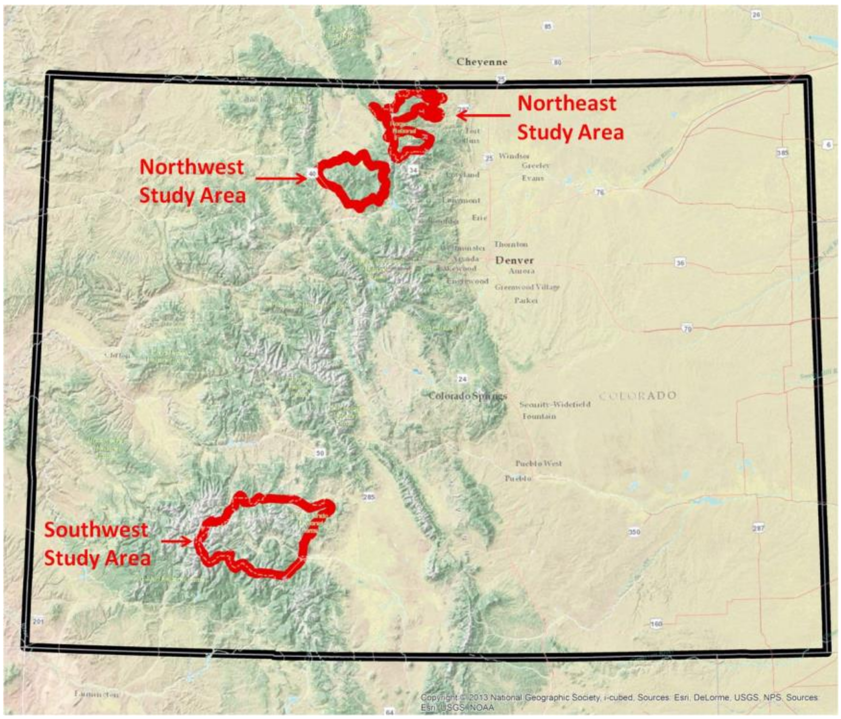


Figure 1. Moose research study areas, located in 3 regions in Colorado. A total of 43 moose were captured during the winter of 2015–2016. Survival of moose was high in all study areas and during both years.

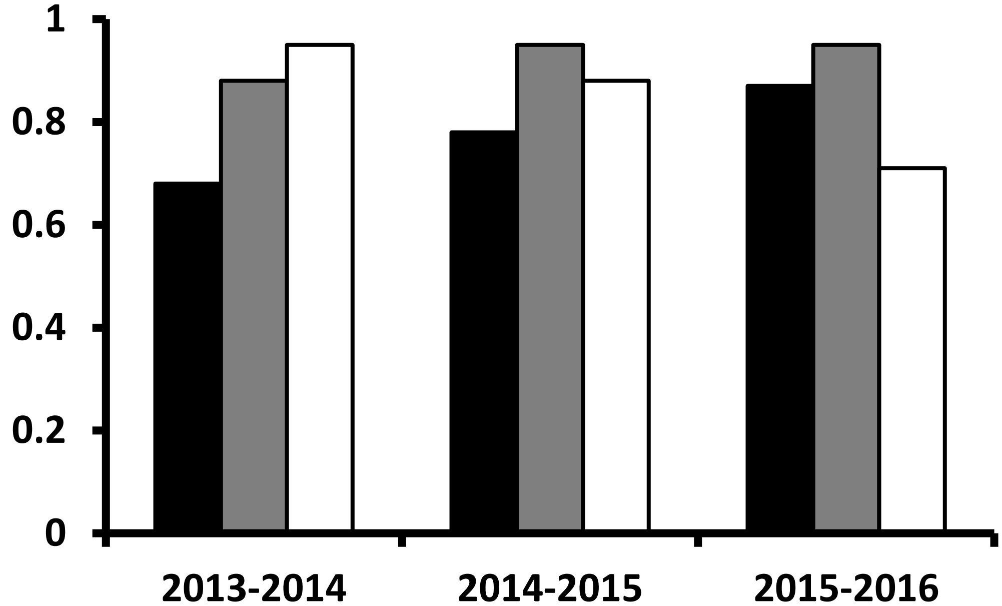


Figure 2. Pregnancy data were collected for all moose at the time of capture. Data from northeast Colorado are depicted by black bars, data from northwest Colorado are depicted by gray bars, and data from southwest Colorado are depicted by white bars.

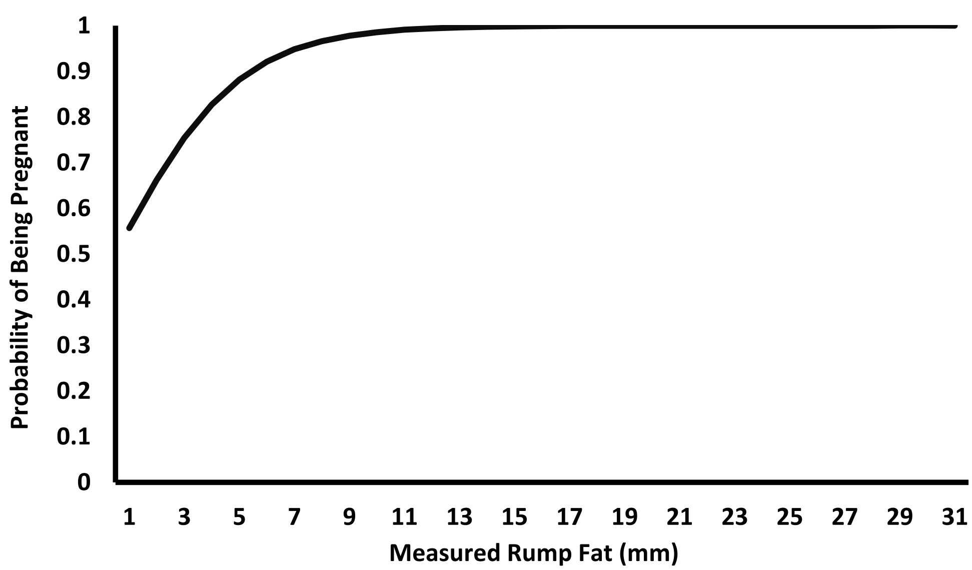


Figure 3. Probability of moose pregnancy was best predicted by maximum measured rump fat. This strong relationship between body condition and pregnancy status reflects how nutritional condition can influence pregnancy, with animals in the poorest condition having lower probabilities of breeding.

PREDATORY MAMMAL CONSERVATION

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

MOUNTAIN LION POPULATION RESPONSES TO SPORT-HUNTING ON THE UNCOMPAHGRE PLATEAU, COLORADO

COUGAR AND BEAR DEMOGRAPHICS AND HUMAN INTERACTIONS IN 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, 2015 – June 30, 2016

Principal Investigator: Heather E. Johnson, Heather.Johnson@state.co.us

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

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.

This project was initiated in FY2010-11; during this past fiscal year we focused on collecting field data in the vicinity of Durango and modeling demographic parameters from known-fate and mark-recapture data. With respect to data collection, we worked with collaborators and stakeholders on research logistics, trapped and marked black bears, monitored bear demographic rates through telemetry and winter den visits, tracked human-related bear mortalities and removals from the study area, collected GPS collar location data from bears along the urban-wildland interface, monitored the availability of summer/fall mast, obtained data on garbage-related bear-human conflicts, assessed resident use of project-supplied bear-resistant containers, and surveyed residents about their attitudes and behaviors with respect to bears. Information from this study will provide solutions for sustainably managing black bears *outside* urban environments, while reducing bear-human conflicts *within* urban environments; knowledge that is critical for wildlife managers in Colorado and across the country.

Major research accomplishments from fiscal year 2015-16:

- Between 5 July 2015 and 23 March 2016 (the 2015-2016 capture year), an additional 54 unique bears were marked during 136 bear captures. To date on the project there have been 380 different individuals marked during 891 captures. Five new adult females were collared during summer 2015 (83 adult females have been collared to date). Annual survival of all collared bears during the year (1 April – 30 March) was 0.88 (SE = 0.05), which was close to the 5 year study average (range: 0.82 – 0.94). Bear capture and marking efforts are allowing us to track bear population parameters and habitat-use patterns along the urban-wildland interface.
- Between January and March 2016, we visited the winter dens of 34 collared female bears. Of those females, 7 did not have any cubs or yearlings, 15 had yearlings (24 total yearlings in total), and 12

had newborn cubs (25 cubs). We found that reproductive success, measured as the number of cubs/adult female, was 0.74 (SE = 0.15); previous rates have ranged between 0.58 and 1.28. Annual cub survival (survival from newborn to 1 year) was 66% (based on 33 cubs), which was the highest rate observed during the study (range: 0.42 – 0.54; Photo 1).

- To date, we have obtained >705,000 locations from GPS collars on 83 different adult female bears along the urban-wildland interface; 46 different bears provided location data during the active bear year of 2015 (May – October; Fig. 1). There were no extraordinary movements recorded this past year, as collared bears generally stayed within the vicinity of Durango. The furthest a bear traveled to the north was up Hermosa Creek, to the east was Vallecito Reservoir, to the south was the Colorado-New Mexico border, and to the west was the La Plata River.
- Based on 15 1-km transects in the study area, the availability of natural mast foods was generally moderate in late summer and fall of 2015. Surveys demonstrated that the peak time for mast maturation of native crabapple was early August, serviceberry was between mid-August and mid-September, chokecherry was early September, gambel oak was mid-September, and pinyon pines was in mid- to late-September. Generally, the maturation of soft and hard mast occurred later in 2015 than in previous years. On transects that had key mast species, mast was present on about 25% of chokecherry, 15% of native crabapple, and 10% of oak and serviceberry shrubs, while approximately 30% of pinyon pines produced moderate to abundant cones. While mast from important species like oak and chokecherry were relatively low in 2015, mast from native crabapple and pinyon pines were quite high; pinyon pines had >3 times the mast that had been observed during any previous year of the study.
- This past year we used genotype data to estimate female bear abundance and density around Durango. We used an integrated modeling approach that simultaneously combined spatially-explicit capture-mark-recapture data from non-invasive hair snags and location data from GPS-collared females. Based on a study area size of 840 km^2, integrated spatially-explicit capture-mark-recapture models estimated that female bear abundance in the vicinity of Durango was 156.6 (SE = 22.2) in 2011, 182.7 (SE = 35.7) in 2012, 83.7 (SE = 9.8) in 2013, and 76.2 (SE = 11) in 2014. Density estimates ranged from 0.09 (SE = 0.01) to 0.22 (SE = 0.04; Fig. 2). Abundance and density estimates were dramatically lower in 2013 and 2014, which followed a severe natural food failure in late summer/fall of 2012.
- During summer 2015 (July through September) we collected our third year of post-treatment data on an experiment designed to assess the effectiveness of wide-scale urban bear-proofing for reducing bear-human conflicts (pre-treatment data were collected 2011 - 2012, post-treatment data were collected 2013 – 2015). Within treatment and control areas we observed 473 instances of bears accessing residential garbage during morning patrols; observations generally peaked in late-August. Of those garbage containers accessed by bears, 76% were regular and 24% were bear-resistant; 115 garbage conflicts were observed in treatment areas (across ~1230 total residences) and 358 occurred in control areas (across ~1260 total residences). We used kernel density functions to spatially estimate the probability of trash-related bear conflicts before and after the distribution of bear resistant containers. We found that since the implementation of the bear-proofing experiment in 2013, trash conflicts have been significantly reduced in the northern experimental unit, and have shifted to the control area in the south experimental unit (Fig. 3).
- During summer 2015 we found that the average compliance of residents to wildlife ordinances was 59% in the north treatment area and 35% in the south treatment area. “Compliance” was defined as having a container that was properly locked (both latches clipped) or secured in a garage or shed before 6:00 am. In the northern area, compliance increased from 45% in 2013 to 52% in 2014, to 59% in 2015. In the southern area compliance increased from 29% in 2013, to 34% in 2014, to 35% in 2015.
- A journal article was published this past year from the study, evaluating a new immobilization drug combination for black bears: Wolfe, L.L., H.E. Johnson, M.C. Fisher, W.R. Lance, D.K. Smith, and

M.W. Miller. Chemical immobilization in American black bears using a combination of nalbuphine, medetomindine, and azaperone. Ursus 27:1-4.

Data collection for this project will persist through winter 2017, and we will continue to analyze data and prepare research publications. In the coming year, we will be finalizing demographic estimates from the non-invasive genetic mark-recapture data, and developing integrated population models which can be used to better track trends in bear population dynamics. In addition, we will be identifying factors affecting driving tolerance for black bears, compliance behaviors related to bear-proofing, and the effects of bear-proofing efforts on risk of conflict with bears. Once data collection is complete, we will then be able to conduct the remainder of the analyses needed to meet project goals. By addressing our research objectives we hope to better understand the influence of urban environments on bear populations, elucidate the relationship between human-bear conflicts and bear behavior and demography, understand the effect of human-bear interactions on human attitudes and actions, develop tools to promote the sustainable management of bears in Colorado, and ultimately, identify solutions for reducing bear-human conflicts in urban environments. See Johnson et al. (2016, Federal Aid Report W-204-R1) for a more detailed version of this project summary.

Photo 1. Two immobilized yearling black bears laying on top of their mother while completing data collection at a winter den in 2016.

Figure 1. GPS collar locations from 46 adult female black bears collected during 1 January – 31 December 2015 in the vicinity of Durango, Colorado (different colors represent different bears).

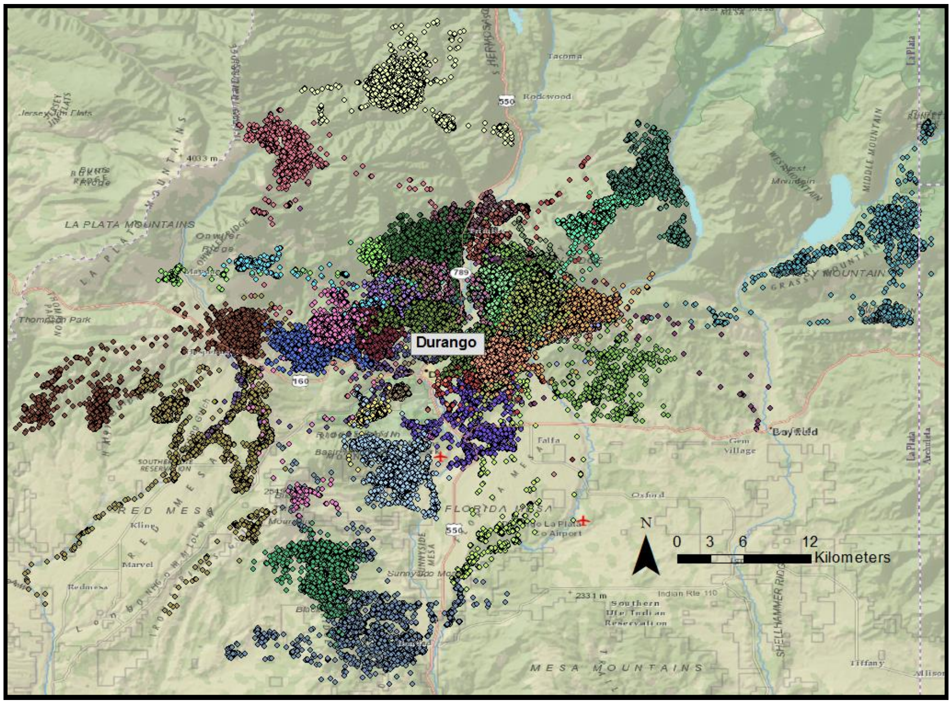


Figure 2. Model averaged density estimates based on integrated spatially-explicit capture-mark-recapture models (solid lines; using both hair-snare and GPS collar data) and standard spatially-explicit capture-mark-recapture models (dashed lines; using hair-snare data only) for female black bears near Durango, Colorado, USA from 2011 to 2014.

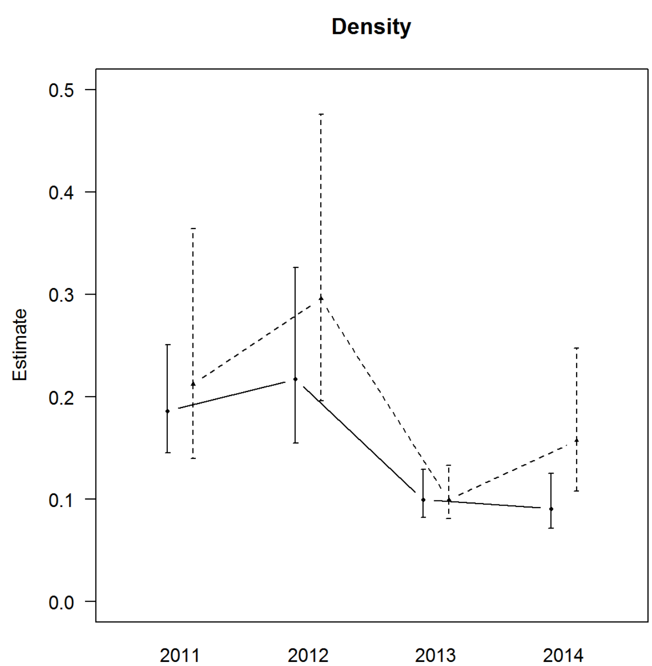
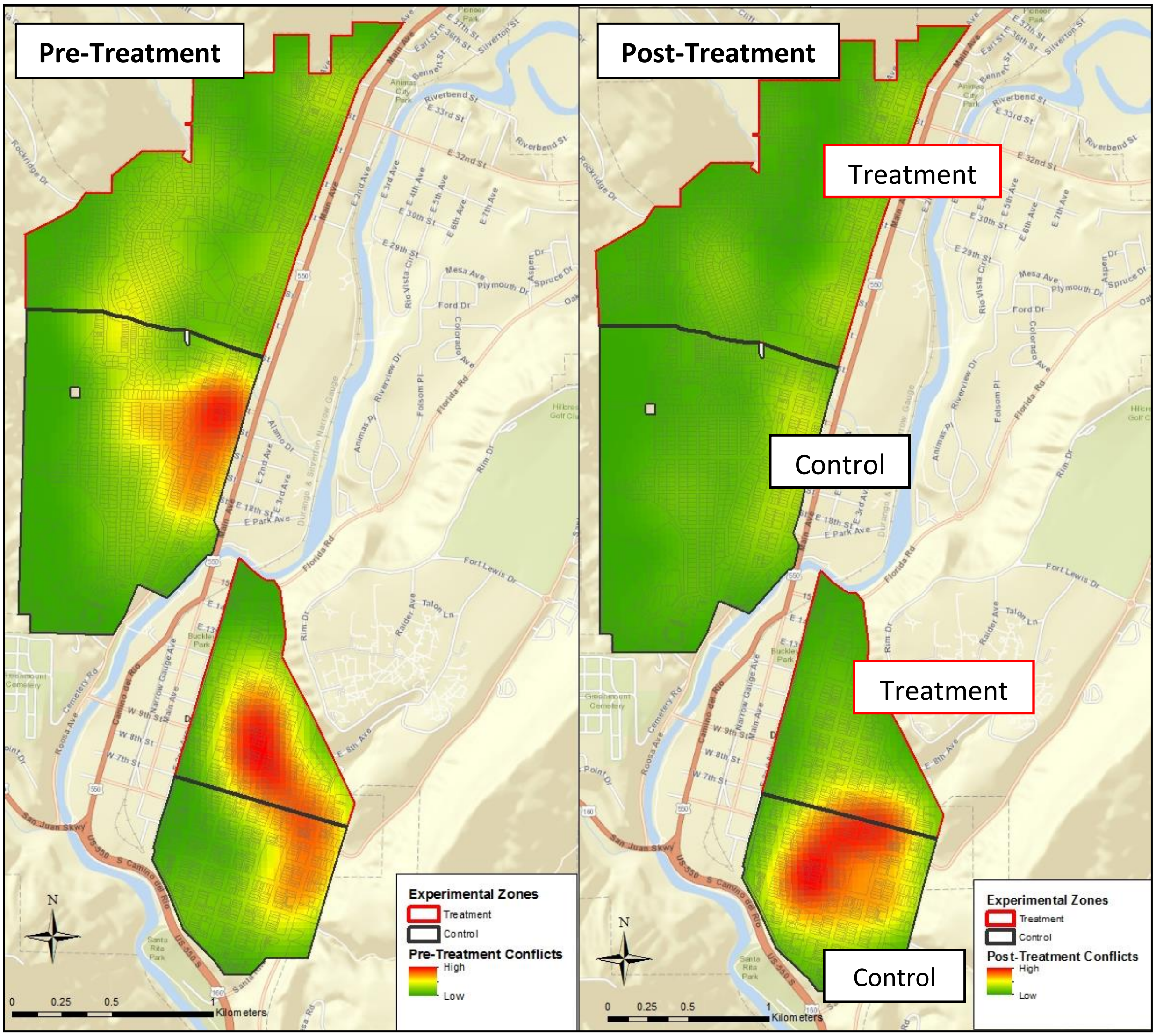


Figure 3. ‘Hot spots’ of black-bear human trash conflicts pre- and post-distribution of bear-resistant trash containers in Durango, Colorado. All residents in treatment areas (outlined in red) were given bear-resistant trash containers in 2013; residents in the control areas (outlined in black) did not receive bear-resistant containers. Pre-treatment data were collected 2011-2012, and post-treatment data were collected 2013-2015. Hot spots were identified as those areas with the highest probabilites of conflict from kernal density functions of all observed trash conflicts.



Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Mountain lion population responses to sport-hunting on the Uncompahgre Plateau, Colorado

Period Covered: July 31, 2015−June 30, 2016

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. Manipulation of these data beyond that contained in this report is discouraged.

Colorado Parks and Wildlife (CPW) conducted a 10-year (2004−2014) study on effects of sport-hunting on a mountain lion population on the Uncompahgre Plateau. The purpose was to examine effects of hunting on a lion population, to evaluate assumptions used by CPW in lion management, and learn how lion hunter behavior may influence harvest. This report summarizes the latest analysis of the effects of hunting and other causes of mortality on a lion population. Analyses are ongoing and are expected to provide reliable information for application in lion management in Colorado.

The study was designed with a *reference* period (years 1−5, RY1−RY5) without mountain lion hunting, and a *treatment* period (years 6−10, TY1−TY5) with lion hunting. The *reference* period began December 2004 and ended October 2009. The *treatment* period began November 2009 and all data collection ended in December 2014.

The study area was on the Uncompahgre Plateau in Mesa, Montrose, Ouray, and San Miguel Counties. The 2,996 km^2 (1,157 mi.^{2}) 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 from here on) was in the largest 8% of the 185 GMUs used to manage lions in Colorado (average = 1,457 km^2, range = 71−4,460 km^2). Because this study was designed to represent a lion population segment on a Colorado GMU scale, the study area was managed as its own GMU so that inferences from the study could be interpreted at the GMU scale.

From December 2, 2004 to October 30, 2014 we captured about 256 individual lions a total of 440 times on the UPSA. 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, 75 subadults, 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 having captured and released 30 independent lions, with their reported gender identification of 19 females and 11 males.

During the *reference* period without sport-hunting as a mortality factor the population of independent lions comprised of adults and subadults increased from a low of 33 lions counted in RY4 to a high of 56 lions counted in TY1 (Fig. 1). This indicated that lion management on the study area before this study probably suppressed the lion population. Along with the population increase during the *reference* period, adult lion survival was high and the age structure of independent lions increased.

In the *reference* period, of the 32 (21 females, 11 males) adult radio-collared lions we monitored 7 adult lions died but none from hunting. Causes of death were attributed to: 5 natural causes (4 intra-specific strife, 1 unknown), 1 vehicle strike, and 1 depredation control. Of the 22 subadults (8 females, 14 males) providing known-fate data, 3 died. One male that had dispersed from the study area was killed by a hunter that did not see the tags (tagged lions that ranged north of the study area were protected from hunting during the *reference* period). Other causes of death in subadults were 1 natural cause (trampled by elk) and 1 vehicle strike. Of 55 radio-collared cubs (28 females, 27 males) monitored in the *reference* period, 16 died. Causes included: 13 infanticide, 1 predation, 1 unknown natural, and 1 vehicle strike. In the *reference* period natural causes dominated deaths of adults and cubs (71.3% and 93.8%, respectively), but 2 of 3 subadult deaths were from human causes.

The *treatment* period was managed with mountain lion sport-hunting. TY1 was the first year that hunting influenced the lion population after 5 years of no hunting, and it was marked with the highest count of independent lions (56) on the study area. TY1−TY3, the lion harvest rate was set with a design quota of 8 lions to test if a 15% harvest of independent lions with 35−45% independent females in the harvest would result in a stable-to-increasing population. However, the expectation that a 15% harvest results in a stable-to-increasing population was not supported as the population of independent lions declined steadily from 56 in TY1 to 42 by TY4 (Fig. 1). Results from TY1−TY4 indicated that reducing a lion population with hunting is achievable at a 15% harvest rate with other human-caused and natural mortality operating on the population.

The lion population in the *treatment* period was expected to continue to decline if the quota remained at 8 lions. Therefore, in an effort to find a harvest rate useful to managers that might result in a stable-to-increasing population for the remainder of the study, the quota was reduced to 5 lions. This quota represented about 11−12% harvest rate of independent lions for TY4 and TY5.

Sport-hunting was the most important cause of death for independent lions during the *treatment* period. Of the 61 adults (39 females, 22 males) we radio-monitored during the period, 37 died. Hunting caused 56.8% of adult deaths (*n* = 21: 14 males, 7 females), followed by natural causes (27%; *n* = 10: 7 unknown with 6 probably disease-related and 1 due to starvation with senescence, 3 intra-specific strife), and other human causes (16.2%; *n* = 6: 3 vehicle strike, 2 depredation control, and 1 illegal kill). Of the 53 subadults (19 females, 34 males) providing known-fate data, 20 died. Hunting caused 55% of the subadult deaths (*n* = 11: 9 males, 2 females). Natural mortality followed in importance with 25% (*n* = 5: 3 intra-specific strife, 2 other natural), then closely by 20% other human causes of death (*n* = 4: 3 depredation control, 1 vehicle strike). Combining adult and subadult lion deaths in the *treatment* period, human causes were 73.7 % (i.e., 42/57*100), of which hunting caused 76.2% (i.e., 32/42*100) and other human causes comprised 23.8% (10/42*100). Of the 63 radio-collared cubs (27 females, 36 males) monitored, 27 died. Mortality causes in the cubs included: 9 infanticide, 4 other natural, 2 vehicle strike, 3 depredation control, and 9 starvation. The 9 cubs starved after the deaths of 5 mothers due to: hunting (2 mothers involving 3 cubs), depredation control (1 mother with 3 cubs), and natural causes (2 mothers involving 3 cubs). Natural mortality comprised the majority of cubs' deaths (15/27*100 = 55.6%). But, human-caused cub deaths in the *treatment* period increased to 44.4% (12/27*100 = 44.4%) from 6.2% in the *reference* period.

In the *treatment* period, the population of independent lions declined from a total count of 56 in TY1 to a low of 42 in TY4, a 25% decline after three hunting seasons (Fig. 1). The abundance of adult females declined 23.3% by TY5. Adult males declined 55% by TY3 and TY4, and 50% by TY5. The percentage of females in the harvest TY1−TY5 was 31.6%; comprised of 23% adult females and 8.6% subadult females. The remainder of the harvest was comprised of adult males (45.7%) and subadult males (22.9%). After we reduced the quota to 5 for TY4 and TY5, the abundance of independent pumas seemed to stay in a low phase and may have slightly increased (Fig. 1).

Hunting in surrounding GMUs also contributed to the decline in the abundance of independent lions on UPSA. Ten radio-collared independent lions (2 adult females, 7 adult males, 1 subadult female) included in *treatment* year winter counts were killed by hunters in adjoining GMUs 61 North, 62 North, 65, and 70 because those lions had home ranges that extended beyond the boundaries of UPSA. Those lions were counted in the hunting quota in the adjoining GMUs, not UPSA. Including these deaths off the study area, the percent of hunting kill from TY1−TY5 ranged from 11.4%−25% (average = 18.2%) of independent lions in winter counts on the UPSA. The actual hunter-kill of the number of independent lions during TY1−TY3 ranged from 17.3−25% (average = 21.8%), and was associated with the population decline phase. During TY4−TY5 the actual hunter-kill was 11.4−19.0% (average = 15.2%), and was associated with the low population phase.

We used an information-theoretic approach and Akaike's Information Criterion to rank survival models with and without the treatment effect for adults, subadults, and cubs. The hunting treatment was indicated as an important factor explaining variation in adult and subadult male lion survival rates. Average annual survival rates of adult male lions declined significantly from 0.96 in the *reference* period to 0.40 in the *treatment* period. Likewise, subadult male lion survival rates declined significantly from 0.92 in the *reference* period to 0.43 in the *treatment* period. Although average annual adult female lion survival in the *reference* period, 0.86, was not statistically different than in the *treatment* period, 0.74, the decline in the abundance of adult females by 23.3% from TY1−TY5 suggested that the lower survival rate during the *treatment* period was biologically significant. Subadult female survival in the *reference* period, 0.63, was not statistically different from survival in the *treatment* period, 0.70. For cubs, models indicated that whether the dam lived or died was the single most important factor affecting cub survival. For the entire study period, the rate of cub survival to the subadult stage was 0.45. Female cub survival, 0.42, was not statistically different than male cub survival, 0.48.

Age structure of independent lions declined from TY1−TY5. After 5 years of no hunting, the younger and up to middle aged (i.e., 1−5 years old) lions comprised the majority of the population and with both adult females and males being represented up to the oldest ages (i.e., >5−10+ years old). After 5 years of hunting, adult males >5 years old were eliminated from the age structure.

Average litter size in the *reference* period, 2.76, was not statistically different from the *treatment* period, 2.38. Likewise, parturition rate for adult females in the *reference* period, 0.63, was not statistically different from the *treatment* period, 0.48. Sex ratio of cubs born in the *reference* or *treatment* periods, and in the study overall was not statistically different from parity.

Management Implications

1) In the GMU-based mountain lion management structure in Colorado, a design harvest of ≥15% of independent lions with an average of ≥20% adult (i.e., 2+ years old) females in the harvest, and with other human and natural causes of mortality operating on a relatively high density lion population, can cause population decline in as few as 3 years. Managers should consider accounting for all detectable (i.e., recorded) human-caused mortality in quotas when setting removal rates in respect to lion population management objectives. Other human causes of death comprised about 24% of the total human-caused mortality with the remaining 76% of deaths due to hunting in the *treatment* period on the UPSA GMU when the lion population declined and reached a low phase.
2) It can take up to 5 years for a lion population previously reduced to a low density to recover to a relatively high density after hunting has been eliminated.
3) Design harvests of up to 11−12% of independent lions with an average of <20% adult females in the harvest is expected to result in a stable, possibly increasing population, considering that other human- and natural-causes of mortality operate on the population.
4) Lion population segment management objectives and attendant harvest rates can affect lion abundance in the particular GMUs of interest and adjacent GMUs where lions have home ranges overlapping GMU boundaries because GMUs in connected lion habitat are not closed lion populations.
5) Lion harvest management structure which includes provisions for reducing lion population segments to achieve specified management objectives (e.g., reduce predation on livestock or mule deer populations) should also provide for lion population segments managed with conservative harvest rates to allow for stable or increasing lion population segments (i.e., source-sink management) to ensure overall lion population resiliency because of all the unknowns and uncertainties associated with lion population management, including lion abundance and effects of harvest and other human and natural causes of lion mortality in GMUs.
6) Management experiments and research involving lion population segments should consider potential effects of historical lion hunting on and around the study areas. When experimental designs require reference conditions, human-caused mortality to lions should be limited or eliminated if possible.

Final publications from this work are in preparation and will be submitted to the USFWS Wildlife & Sport Fish Restoration Program upon completion.

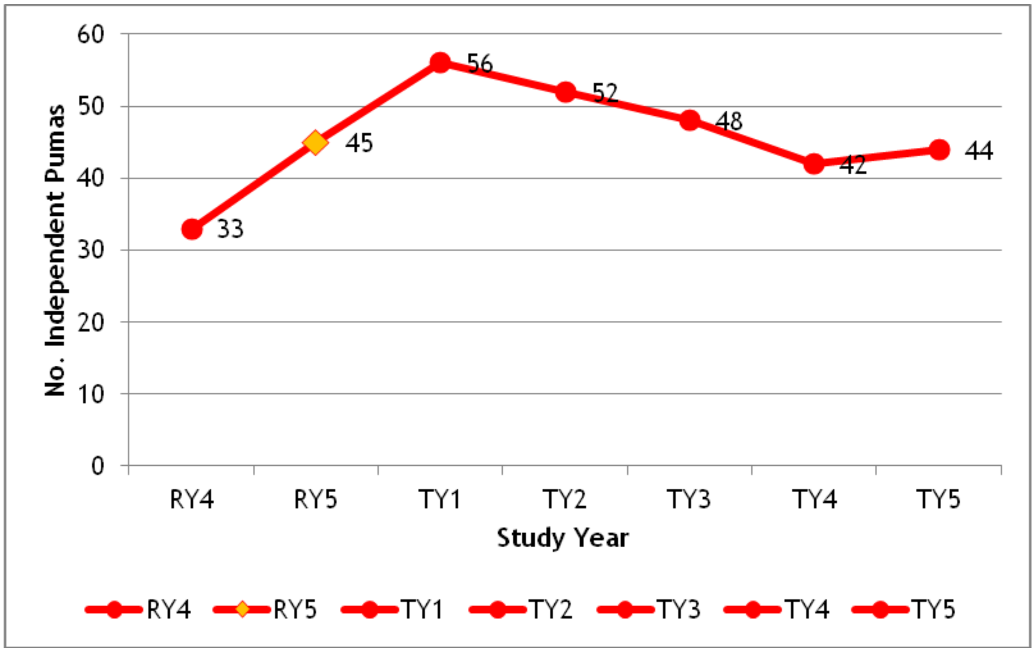


Figure 1. Trends in the population of independent mountain lions associated with no sport-hunting in the *reference period* years 4 and 5 (RY4, RY5) and with sport-hunting in the *treatment period* years 1 through 5 (TY1−TY5), Uncompahgre Plateau, Colorado. The count data were gathered from November through April each winter in efforts to canvass the study area thoroughly to count the number of independent lions in addition to the lion harvest. These data represent the number of independent lions expected to have been at risk to hunting during the Colorado lion hunting season November through March each year.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Cougar and bear demographics and human interactions in Colorado

Period Covered: July 1, 2015 – June 30, 2016

Principal Investigator: Mathew W. Alldredge, mat.alldredge@state.co.us

Collaborators: Jefferson County Open Space, Boulder County Open Space, Boulder Open Space and Mountain Parks, U.S. Forest Service, USGS Fort Collins Science Center

ABSTRACT

Our principal research objective was to assess cougar population ecology, prey use, movements, and interactions with humans along the urban-exurban Front Range of Colorado. This year capture efforts focused on removing collars from previously collared cougars. Only 4 cougars remain with collars as batteries died before they could be captured and collars removed. Only one mortality was documented this year, an adult male injured while preying on an elk. Home-range patterns remained consistent to previous years. Mule deer are the predominant prey in cougar diets, although cougars will also utilize elk regularly. The focus of this year's efforts was on further development of noninvasive sampling of cougars and bobcats. This project has been completed with the exception of final publications.

Project Narrative Objectives

1. To assess cougar (*Puma concolor*) population demographic rates, movements, habitat use, prey selectivity and human interactions along the urban-exurban Front Range of Colorado.
2. Develop methods for delineating population structure of cougars and black bears (*Ursus americanus*), assessing diet composition and estimating population densities of cougars for the state of Colorado.

Segment Objectives

Front Range cougars

1. Capture and mark independent age cougars and cubs to collect data to examine demographic rates for the urban cougar population. Remove collars in final year (Completed).
2. Continued assessment of aversive conditioning techniques on cougars within urban/exurban areas, including use of hounds and shotgun-fired bean bags or rubber bullets (Completed).
3. Continue to assess relocation of cougars as a practical management tool (Completed).
4. Assess cougar predation rates and diet composition based on GPS cluster data (Completed).
5. Model movement data of cougars to understand how cougars are responding to environmental variables (Field work completed, publication pending).
6. Develop non-invasive mark-recapture techniques to estimate cougar population size (Field work completed, publication pending).

2015-2016 Project Overview

Field efforts during the 2015-2016 year were primarily focused on the development of noninvasive population estimation techniques for cougars and bobcats (see summary for Noninvasive genetic sampling to estimate cougar and bobcat abundance, age structure, and diet composition). The field efforts for the remaining segment objectives listed above have been completed and are in various stages of data analysis and publication. Capture efforts focused on catching and removing collars from all previously collared cougars. We are continuing to collaborate with CSU to examine cougar movement models to better understand how cougars are responding to their environment.

1. Model movement data of cougars to understand how cougars are responding to environmental variables.
   Field work completed - (see abstract Mountain Lion Movement Dynamics in the Wildland-Urban Interface)
2. Develop non-invasive mark-recapture techniques to estimate cougar population size.
   Field work completed - data analysis and publication in progress

Mountain Lion Movement Dynamics in the Wildland-Urban Interface

Assessing preferential use of the landscape is important for managing wildlife and can be particularly useful in transitional habitats, such as at the wildland-urban interface. We characterized preferential habitat selection by a population of mountain lions (*Puma concolor*) inhabiting the Front Range of Colorado, an area exhibiting rapid population growth. Preferential use is often evaluated using resource selection functions (RSFs), but they do not account for the habitat available to an individual at a given time and may mask conflict or avoidance behavior. Contemporary approaches to account for availability based on movement include spatio-temporal point process models, step-selection functions, and continuous-time discrete-space (CTDS) models. We used a continuous-time discrete-space (CTDS) framework to model transition rates among grid-cells as a function of landscape covariates. The CTDS framework is based on an underlying movement model and allows for inference on the same spatial scale as the covariates. We exploited the flexibility of the CTDS framework to accommodate location- and gradient-based drivers of movement, individual variation, and time-varying responses to variables such as prey availability, development, topography, and canopy cover. We failed to detect a significant population-level response to any of the covariates except for distance to kill site, which had a positive effect on both transition rates (as individuals were further from a kill site, they were more likely to transition out of a grid cell) and directionality (individuals were more likely to transition towards a kill site).

Noninvasive genetic sampling to estimate cougar and bobcat abundance, age structure, and diet composition

Cougar and bobcat populations are actively hunted throughout the state of Colorado and management is applied using the best available information. Unfortunately, reliable information on cougar and bobcat populations is nascent. The best information available comes from long-term studies on relatively small populations where animals have been repeatedly captured. However, to better manage these populations, broad-scale information for these species is necessary.

We have continued developing noninvasive genetic sampling (NGS) techniques to provide better, less expensive data for cougars and bobcats that can be implemented at broad geographic scales with state-wide application. The methods being developed should provide information on population size, sex structure, age structure, and diet composition. This information is valuable to the future management of these species and for the justification of harvest levels imposed on them.

Over the last few years we have further refine these NGS techniques for cougars and bobcats so that they could be reliably implemented to inform management decisions. We have also performed a full survey over multiple years to assess the reliability and repeatability of this approach. Following these efforts we hoped to have a fully developed NGS approach for cougars and bobcats that could be implemented at a state-wide level for future monitoring of these species.

Objectives

1. Continue to evaluate the use of auditory calls for NGS sampling of cougars.
2. Implement a NGS survey for cougars over multiple years to evaluate the consistency of the approach.
3. Use collared cougars to evaluate trap response of cougars and assess potential biases in the NGS approach.
4. Evaluate the potential to sample bobcats using the same NGS approach.
5. Test alternative hair snaring devices for felids.
6. Assess a simultaneous sampling approach for bobcats and cougars relative to differences in home-range size.
7. Implement an NGS survey over multiple years for bobcats and cougars to determine the logistics, cost and feasibility of sampling to obtain estimates of density, sex structure, age structure and diet composition.

Following on the success of the development of noninvasive techniques for sampling cougars, we initiated a three-year study to continue to develop noninvasive methods for sampling cougars and bobcats. Sites were built in November and December, 2013, and were monitored for 12 weeks during January – April, 2014. In 2014/15 and 2015/16 sites were built during November and monitored for three months starting the 1st of December and continuing through the first week of March.

Sites were modified in 2014/15 to use vertical hair snags instead of horizontal snags in an attempt to get more animals to enter the cubbies and to create a snag that could obtain samples from both bobcats and cougars. The number of unique observations of cougars increased this year compared to the previous and was comparable to the first year (Table 3). Hair samples from cougars increased accordingly and was comparable to the first year of the study. Hair samples from bobcats increased from 5 the first year to 12 the second year and 31 this year. This is likely a result of narrowing the spacing between the barbed wire to approximately 6 inches. Genotypes from bobcat hair has had limited success but is more successful for cougars. Field efforts for this portion of the study have concluded.

Table 3: Noninvasive hair snag capture results for bobcats and cougars. Number of animals seen, number of hair samples collected and number of successful genotypes.

Species	Year	Pictures	Hair Samples	Genotypes
Bobcat	2014	31	5	0
Bobcat	2015	68	12	1
Bobcat	2016		31	4
Cougar	2014	86	55	20
Cougar	2015	42	32	11
Cougar	2016		51	15

SUPPORT SERVICES

RESEARCH LIBRARY ANNUAL REPORT

Colorado Parks and Wildlife

WILDLIFE RESEARCH REPORT SUMMARY

Research library, annual report

Period Covered: July 1, 2015 – June 30, 2016

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

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.

The Colorado Parks and Wildlife Research Center Library has existed for several decades in the Ft. Collins office. Early librarians can be credited with the physical organization of the Library including Federal Aid reports, Wildlife Commission reports and a unique book and journal collection. The goal of the Library is to provide an effective program of library services for Colorado Parks and Wildlife employees, cooperators and wildlife educators. The Library also serves as an archive for CPW publications. The mission of outreach and support is fulfilled using technology to provide a library website with the online catalog, wildlife databases and digitized documents available to CPW staff statewide.

As of June 30, 2016, the Research Library held 19,714 titles and 29,175 items (these are the multiple copies of a title) and had 177 registered patrons (CPW staff). As part of the project to digitize CPW documents, the equivalent of 8GB 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. Print subscriptions to the major wildlife journals were cancelled several years ago however online access to the journals was retained and continues as a primary usage point for staff. CPW staff statewide are authenticated through CPWNet (intranet) eliminating the need for individual usernames and passwords.

Major special projects this year focused on maintenance of the physical Library collection. When the Library catalog was automated in 1994, the records for some books were not converted from the old card catalog to the online version. These books were inaccessible online but were taking up shelf space desperately needed for new material. As the collection was inventoried, retention decisions were made with the help of Research managers and staff. All theses and dissertations were retained and cataloged if necessary. In addition, there was a huge backlog of items that had never been cataloged. The Collection Development Policy states that the Library is to be an archive for CDOW/CPW material. Therefore, the priority was to catalog and retain reports authored by Division of Wildlife or CPW staff or those reports with a strong Colorado connection. The non-Colorado material was sent to a Library-material recycler. 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 the Rio Grande turkey, the Georgetown bighorn sheep herd, Cyprinid fish larvae (written by staff at CSU's Larval Fish Lab) 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 8 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 March 2016*.

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