WILDLIFE
RESEARCH
REPORT

COLORADO
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WILDLIFE RESEARCH REPORTS

JULY 2014 – JUNE 2015

MAMMALS RESEARCH PROGRAM

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

Executive Summary

This Wildlife Research Report represents summaries (<5 pages each or including short subsections) of wildlife research projects conducted by the Mammals Research Section of Colorado Parks and Wildlife (CPW) from July 2014 through June 2015. 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 mammal 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 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 preliminary results of lynx monitoring in the San Juan Mountain Range of southwest Colorado. The Ungulate Conservation section includes 3 projects addressing mitigation approaches to benefit mule deer exposed to energy development activities, an assessment of potential factors influencing mule deer recruitment the past 40 years, 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 improved understanding and management approaches to address black bear and mountain lion-human interactions, evaluation of sport harvest for mountain lion management, and assessment of non-invasive sampling methods to estimate abundance, diet composition, and age class distribution of carnivore populations. 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 Jeffereson County open space, City of Durango, Big Horn Sheep and Moose Auction/Raffle Grants, Species Conservation Trust Fund, GOCO YIP Internship program, Safari Club International, Boone and Crocket Club, Colorado Mule Deer Association, The Mule Deer 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 2014 – June 2015

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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. The widespread mortality of forested systems in Colorado may have a dramatic, but poorly understood effect on wildlife species that depend on these habitats. The project described here uses occupancy estimation to determine which wildlife species (both species of conservation concern and game species) decrease their use of an area as bark beetles pass through, which increase their use, and which exhibit use similar to levels prior to infestation.

Statewide sampling was conducted during the summers of 2013 and 2014 (Figure 2). We 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 have yet to be 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). For the purposes of this interim document, we report preliminary results for 3 mammalian species of conservation concern: snowshoe hares (*Lepus americanus*) and red squirrels (*Tamiasciurus hudsonicus*), which together comprise nearly 100% of the diet of the federally listed Canada lynx, and American marten (*Martes americana*), which is a USFS Region 2 sensitive 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., linearly, quadratic, spline, change-point, etc.) 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 and/or response to beetles and the severity of the impact (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 to provide a best estimate of response of each species to beetles.

Results indicate that snowshoe hares are more likely to use spruce-fir stands than lodgepole stands (Figure 3). There may be a slight increase in use around the time needles drop, followed by a steady fall back to 'green' forest levels, but in general hare use remained relatively constant for the initial decade after bark beetle infestation. Red squirrel use was similar between the two stand types (Figure 4). However, best fitting models included an interaction between severity of the beetle outbreak and response of red squirrels. In areas of low severity, response was minimal (Figure 4a). However, in areas of high severity, red squirrel use was 25−35% lower (Figure 4b). Use of the two stand types by marten was similar and relatively invariant to beetle impact (Figure 5).

Literature Cited

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

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

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 Supplement:120-138.
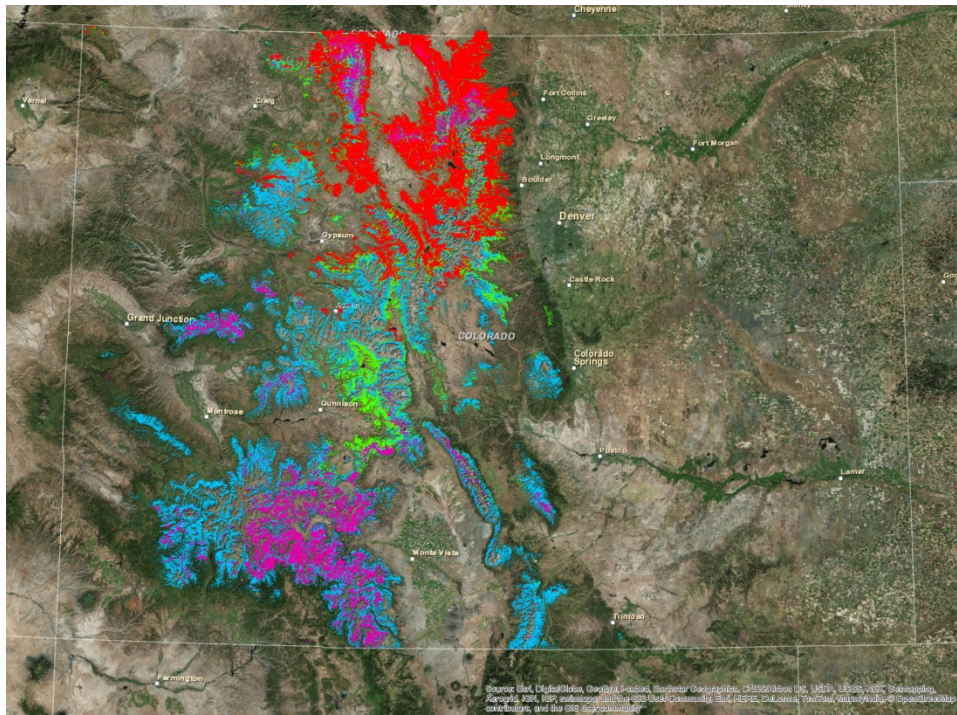
Figure 1. Current (2014) extent of mountain pine beetle (red) and spruce beetle (purple) infestations in spruce/fir (blue-green) and lodgepole pine (bright green) forests in Colorado. Bark beetle data were collected via USFS aerial surveys.
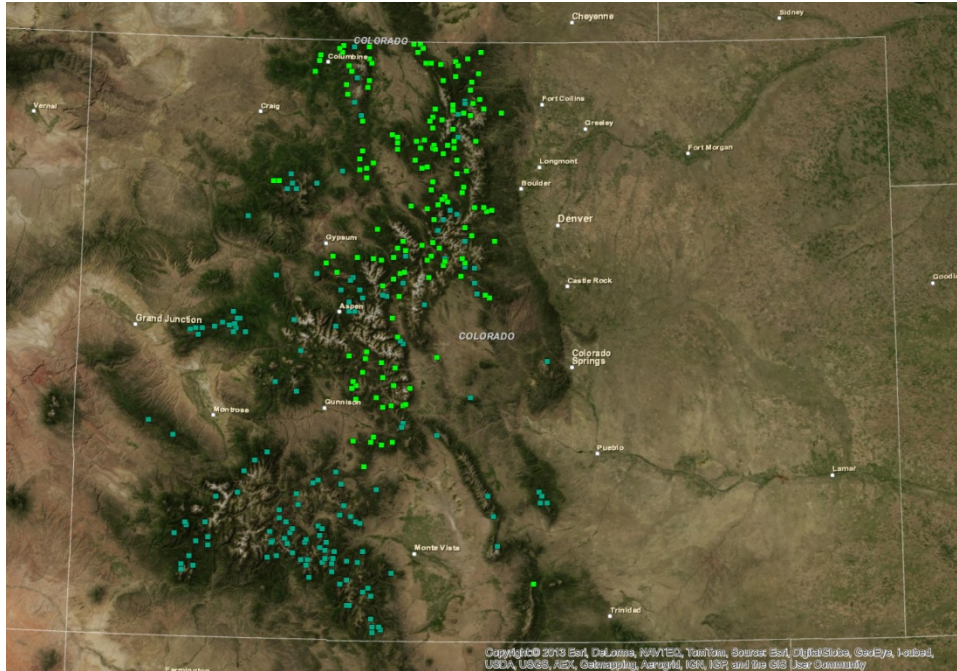
Figure 2. Sites sampled via point counts and remotes cameras to assess impacts of bark beetle infestations on breeding bird and mammal species in spruce/fir (blue-green, N = 150) and lodgepole pine (bright green, N = 150) stands in Colorado, 2013–2014.
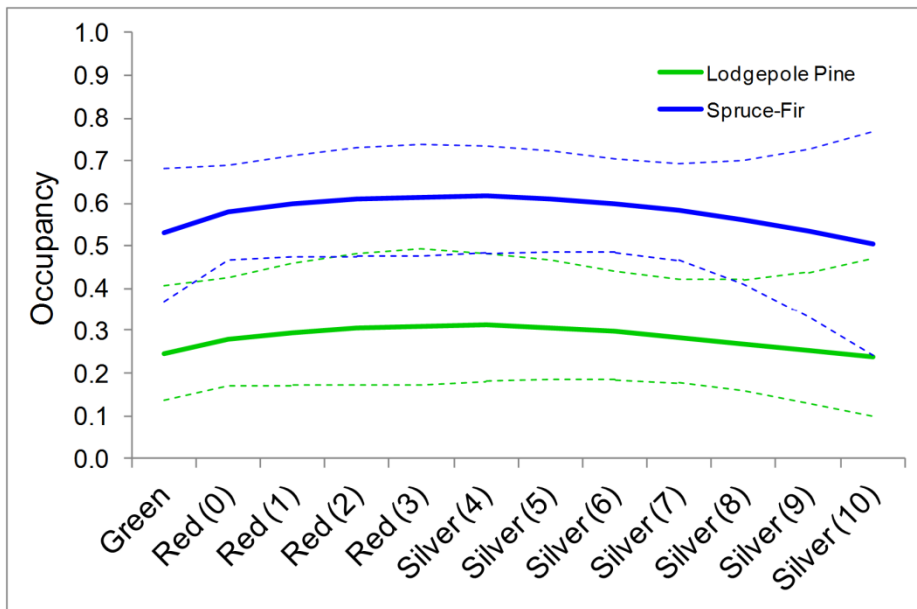
Figure 3. Snowshoe hare occupancy (i.e., use) of stands in relation to stage of infestation by bark beetles. 'Green' forests are those that have not yet been impacted. 'Red' forests are recently impacted; dead needles remain on trees. 'Silver' forests were impacted more distantly in the past and needles have fallen. Numbers in parentheses approximately correspond to the number of years that have passed since trees initially turned red.

a)

b)
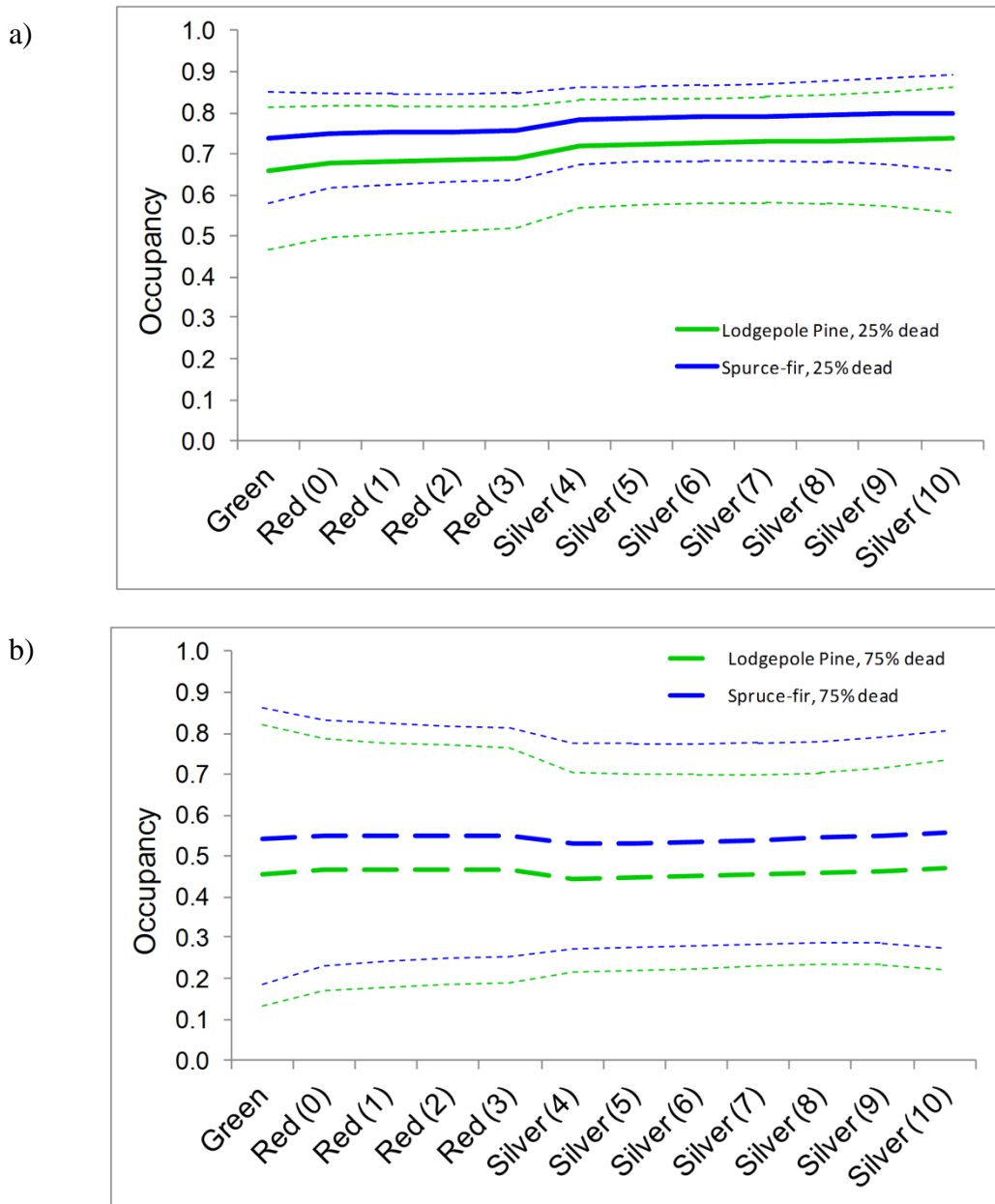
Figure 4. Red squirrel occupancy (i.e., use) of stands in relation to the number of years since initial infestation by bark beetles. Use of spruce-fir and lodgepole stands is generally similar and remains stable for stands that are lightly impacted by beetles (a; 25% dead). However, red squirrel occupancy is reduced by 25-35% in stands that are heavily impacted (b; 75% dead).
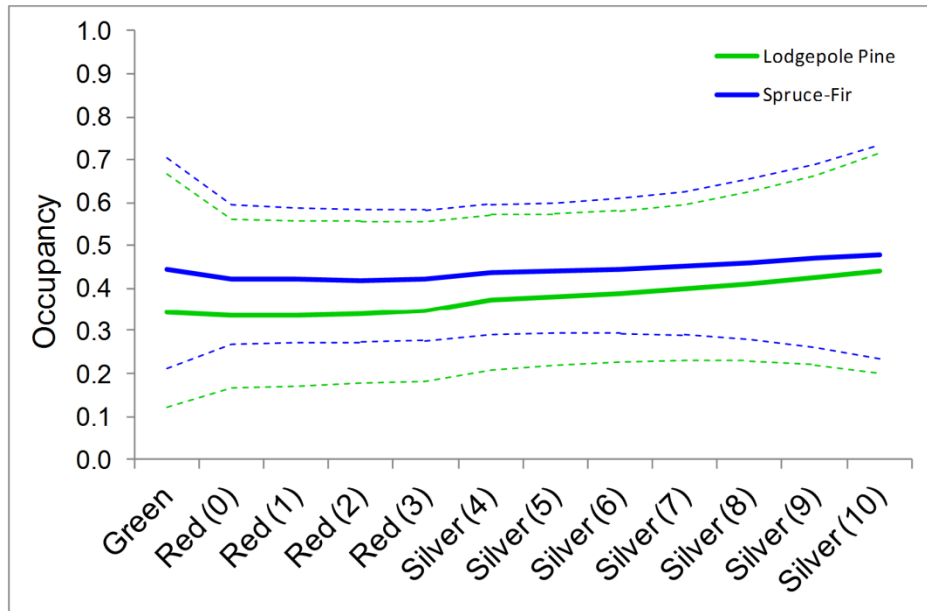
Figure 5. American marten occupancy (i.e., use) of stands in relation to stage of infestation by bark beetles. Use does not vary appreciably by stand type, and remains stable through time as bark beetles pass over an area.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Canada Lynx Monitoring in Colorado

Period Covered: July 1, 2014 − June 30, 2015

Principal Investigators: Jacob S. Ivan, Jake.Ivan@state.co.us; Eric Odell, Eric.Odell@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 we implemented a portion of the statewide monitoring scheme described in
Ivan (2013). Specifically, we sampled 50 75-km^2 units selected at random from a population of 179 units
that collectively encompassed potential lynx habitat in the San Juan Mountain Range of southwest
Colorado (Fig. 1). Of the 50 sample units, 19 were sampled via snow tracking surveys conducted
between January 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. 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
2014. Cameras were baited with visual attractants and scent lure to enhance detection of lynx living in
the area. Cameras were retrieved during summer 2015 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 5
30-day periods from December 1 through April 30 was considered an 'occasion,' and any photo of a lynx
obtained during a 30-day period was considered a detection during that occasion.

Crews covered a total of 884 km during snow tracking surveys − 697 km by snow machine, 140
km by vehicle, and 47 km by snowshoe. Mean distance surveyed per occasion was 20 km. Lynx were
detected at seven snow tracking units (Figure 1). Scat or hair samples were collected from seven of the
12 lynx tracks discovered (tracks were discovered at some units on >1 occasion) and are pending genetic
analysis to confirm that tracks were from lynx. Camera sets yielded 134,695 photos of which 302 were
lynx. Lynx were detected at 27 cameras in seven camera units (Figure 1). Of note, resident lynx were
documented for the first time in the LaGarita Mountains north of Creede. Similarly, resident lynx were
documented about 15 km from the New Mexico border in the South San Juans, an area rarely used by
resident animals in the past. In both cases, lynx were detected at camera sets. Also, adult females with
kittens were detected at cameras in units near Silverton and Platoro Reservoir, thus documenting that at
least some reproduction occurred in the study area.

Using Program MARK (White and Burnham 1999), we 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

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the course of the winter. 'Survey method' was treated as a group so that we could, based on previous work, 1) allow detection probability 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 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 that was burned during Summer 2013, occupancy status of neighboring units, 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 both the pilot study (2010-2011) and first year of implementation (2014-2015) to maximize the information estimates were based on. '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 (occupancy probability), 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 (Table 1). In both cases, the association was positive, indicating that the probability of lynx use increased with more spruce-fir and more hares. Other covariates 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 (Table 1). This phenomenon indicates that these other variables were not as informative. Of these less informative variables, lynx occupancy was negatively associated with bobcat use and proportion of the unit burned but positively associated with the proportion of mapped lynx habitat in the unit; there was no discernible association with any other species and no relationship between lynx occupancy and impact by bark beetles. Detection probability was relatively high for snow tracking surveys ($p = 0.56$, 95% confidence interval: 0.41−0.69), and low for monthly camera surveys ($p = 0.24$, 95% confidence interval: 0.12−0.41) during December−February, although detection increased to 0.41 (95% confidence interval: 0.21−0.65 during breeding season (March and April) as expected. For winter 2014-2015 we estimated that 29% of the sample units in the San Juans were occupied by lynx (95% confidence interval: 0.15 − 0.48). Occupancy estimates from the 2014-2015 monitoring effort were similar to those obtained during pilot research work in 2010-2011 but the sampling frames were different between the 2 years so results are not directly comparable (Figure 2).

Literature Cited

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

Ivan, J. S., M. Rice, P. M. Lukacs, T. M. Shenk, D. M. Theobald, and E. Odell. 2011. Predicted lynx habitat in Colorado. Pages 21-35 *in* Wildlife Research Report - Mammals. Colorado Parks and Wildlife, Fort Collins, CO, USA. http://cpw.state.co.us/learn/Pages/ResearchMammalsPubs.aspx.

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White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 Supplement:120-138.
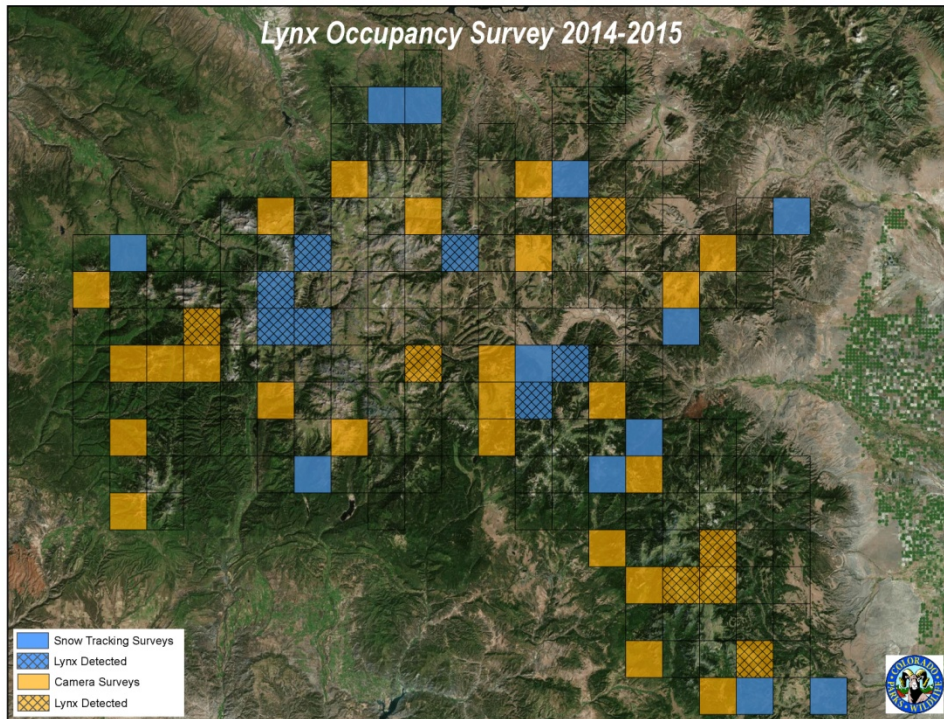
Figure 1. Lynx monitoring results for 2014-2015, San Juan Mountains, southwest Colorado. Colored units (n = 50) indicate those selected at random from the population of units (n = 179) encompassing lynx habitat in the San Juan Mountains. Blue units were surveyed via snow tracking; orange units were surveyed via deployment of four cameras per unit during winter months. Lynx were detected in 14 of the sampled units.
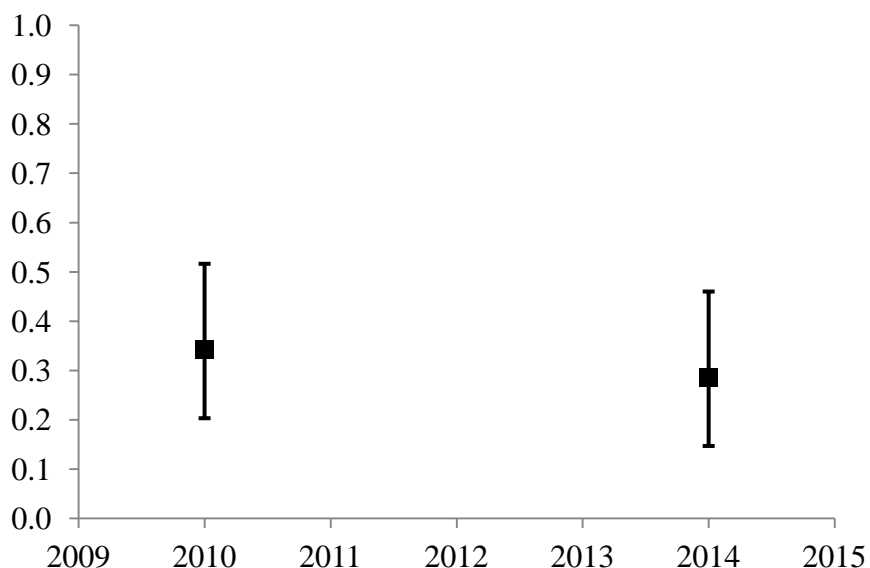
Figure 2. Model-averaged occupancy estimates for lynx in the San Juan Mountains, southwest Colorado. 'Year' indicates when the efforts were initiated (2010-11, 2014-15).

Table 1. Model selection results for lynx monitoring data collected in the San Juan Mountains, Colorado, 2014-2015. Rankings are based on Akaike's Information Criterion adjusted for small sample size (AIC$_c$). Fourteen variables were considered as covariates to inform estimation of occupancy (ψ). The complete model set (n = 64) 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	AIC$_c$	ΔAIC$_c$	AIC$_c$ Wts	No. Par.
ψ(Year + SpruceFir +Hare)p(Method + Breeding)	281.4	0.0	0.35	7
ψ(Year + SpruceFir)p(Method + Breeding)	283.8	2.4	0.10	6
ψ(Year + SpruceFir + Bobcat)p(Method + Breeding)	284.2	2.8	0.09	7
ψ(Year + SpruceFir + Coyote)p(Method + Breeding)	284.6	3.2	0.07	7
ψ(Year + PropLynxHabitat + Hare)p(Method + Breeding)	285.5	4.1	0.04	7
ψ(Year + SpruceFir + PropBurn)p(Method + Breeding)	285.6	4.2	0.04	7
ψ(Year + SpruceFir + Fox)p(Method + Breeding)	285.6	4.2	0.04	7
ψ(Year + SpruceFir + Cougar)p(Method + Breeding)	285.7	4.3	0.04	7
ψ(Year + SpruceFir + AvgBeetleKill)p(Method + Breeding)	286.0	4.6	0.03	7
ψ(Year + SpruceFir + SDBeetleKill)p(Method + Breeding)	286.1	4.7	0.03	7

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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

QUALIFYING LOSS AND DEGRADATION OF MULE DEER HABITAT
ACROSS WESTERN COLORADO

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, 2014 – June 30, 2015

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., Colorado Mule Deer Found., Colorado State Severance Tax Fund, Boone & Crocket Club, and Safari Club Int.

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.

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 3 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 in March 2015 (all captures = 26-32/study area) 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 3 years to provide sufficient time to measure how vegetation and deer respond to these changes.

Based on data collected during the 5-year pretreatment phase and 3 years post-treatment: (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 related to annual weather conditions; (2) migratory mule deer selected for areas with increased cover and increased their rate of travel through developed areas, and avoided negative influences through behavioral shifts in timing and rate of migration, but did not avoid development structures (Fig. 3); (3) mule deer body condition early and late winter was consistent within areas, with higher variability among study areas early winter, which was likely related to seasonal moisture within areas and relative forage capacity among areas; (4) mule deer exhibited behavioral plasticity in relation to

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energy development, where disturbance distance varied relative to diurnal extent and intensity of development activity (Fig. 4), which may provide for several options in future development planning; (5) mule deer densities appear to be increasing in 3 of 4 areas, with a stable population in North Ridge (Fig. 5); and (6) post treatment vegetation responses have been promising with evidence of improved forage conditions, 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 should be available 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
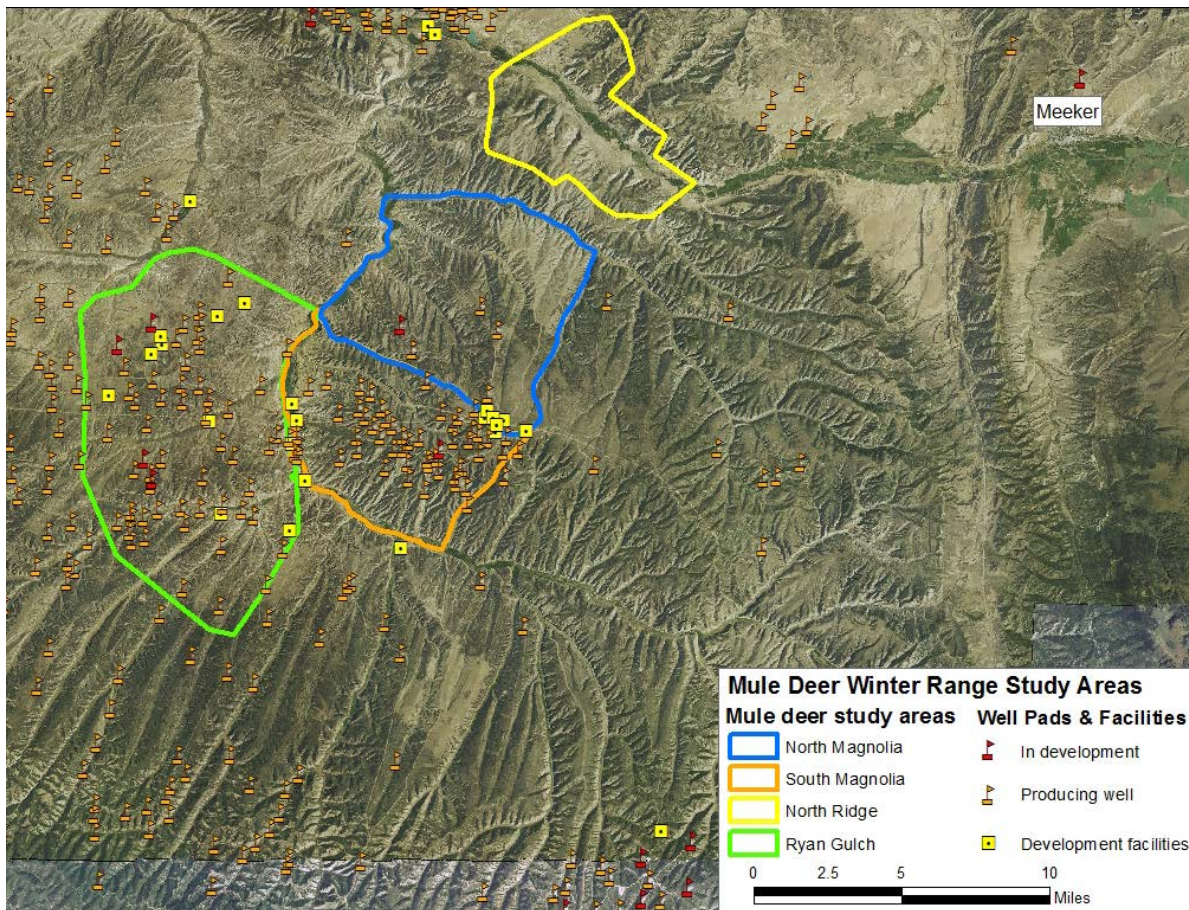
Figure 1. Mule deer winter range study areas relative to active natural gas well pads and energy development facilities in the Piceance Basin of northwest Colorado, winter 2013/14 (Accessed http://cogcc.state.co.us/ Dec. 31, 2013).
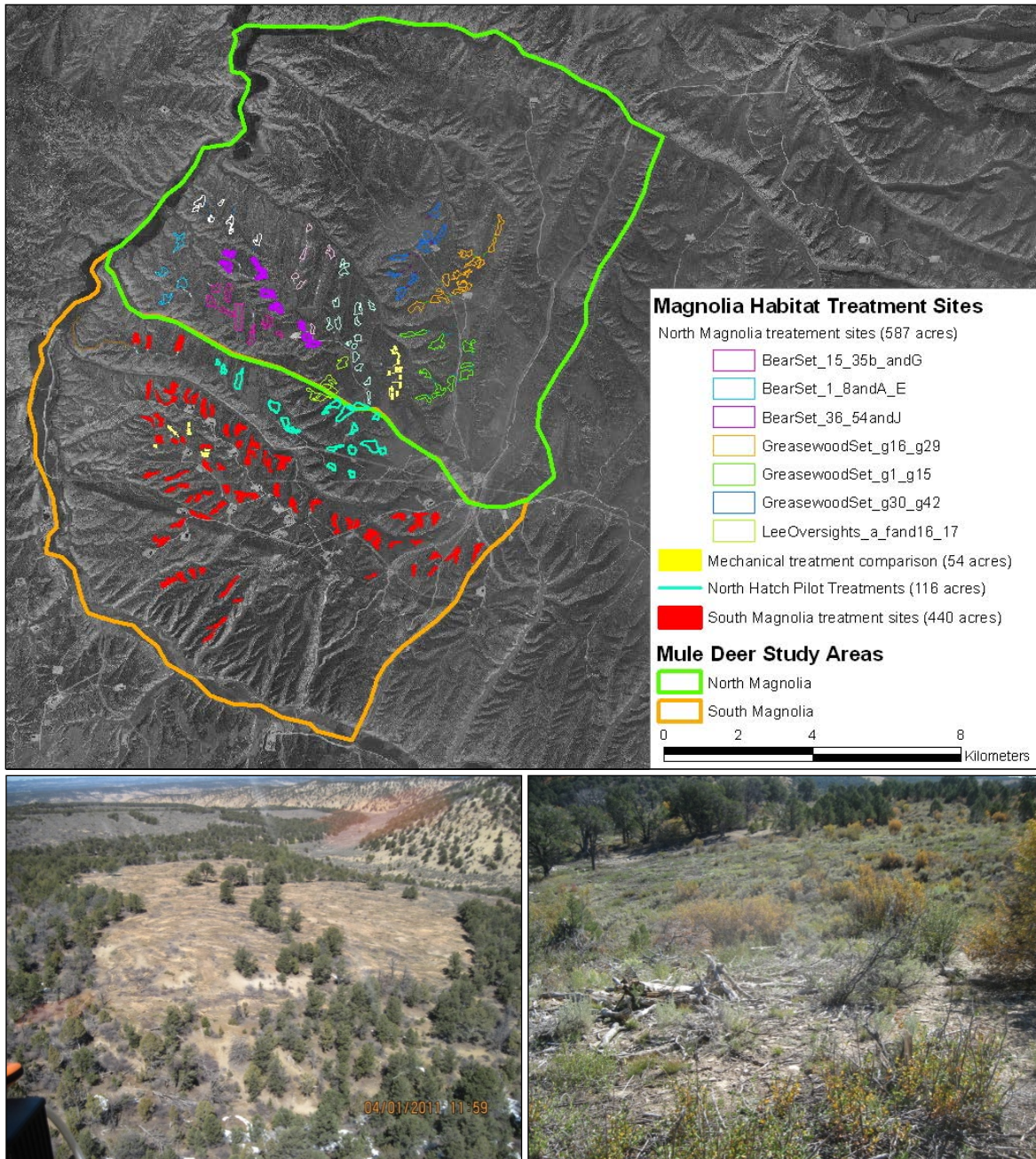
Figure 2. Habitat treatment site delineations in 2 mule deer study areas (604 acres each) of the Piceance Basin, northwest Colorado (Top; cyan polygons completed Jan. 2011 using hydro-axe; yellow polygons completed Jan. 2012 using hydro-axe, roller-chop, and chaining; and remaining polygons completed 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).
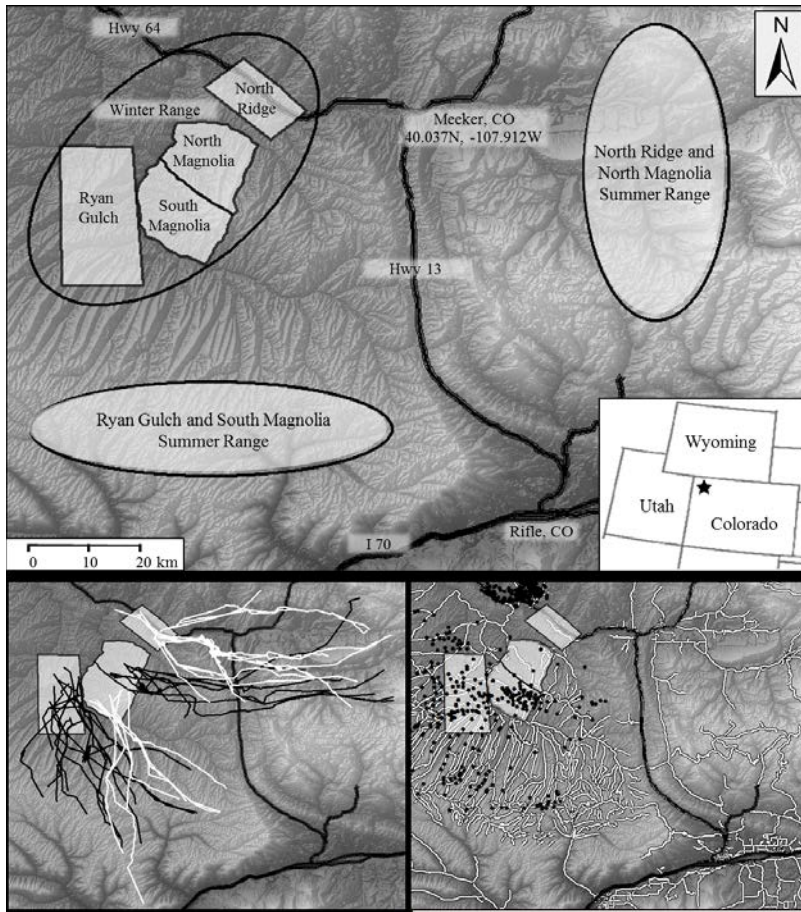
Figure 3. Mule deer study areas in the Piceance Basin of northwestern Colorado, USA (Top), spring 2009 migration routes of adult female mule deer ($n = 52$; Lower left), and active natural-gas well pads (black dots) and roads (state, county, and natural-gas; white lines) from May 2009 (Lower right; from Lendrum et al. 2012; http://dx.doi.org/10.1890/ES12-00165.1).
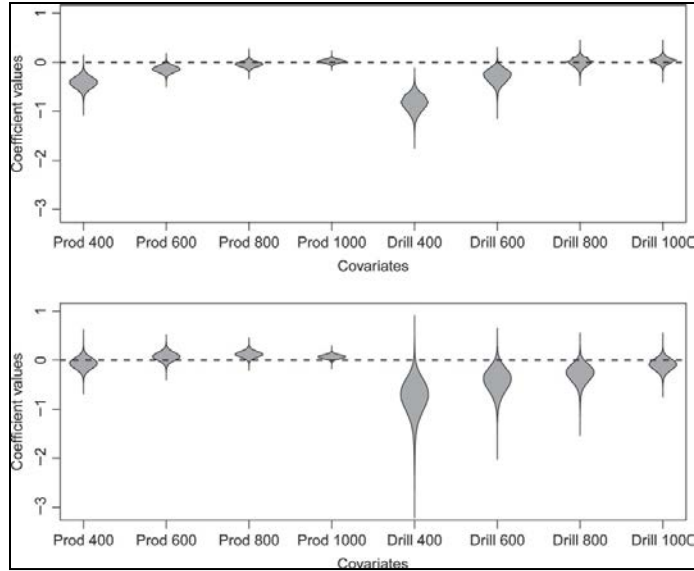
Figure 4. Posterior distributions of population-level coefficients related to natural gas development for RSF models during the day (top) and night (bottom) for 53 adult female mule deer in the Piceance Basin, Northwest Colorado. Dashed line indicates 0 selection or avoidance (below the line) of the 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).
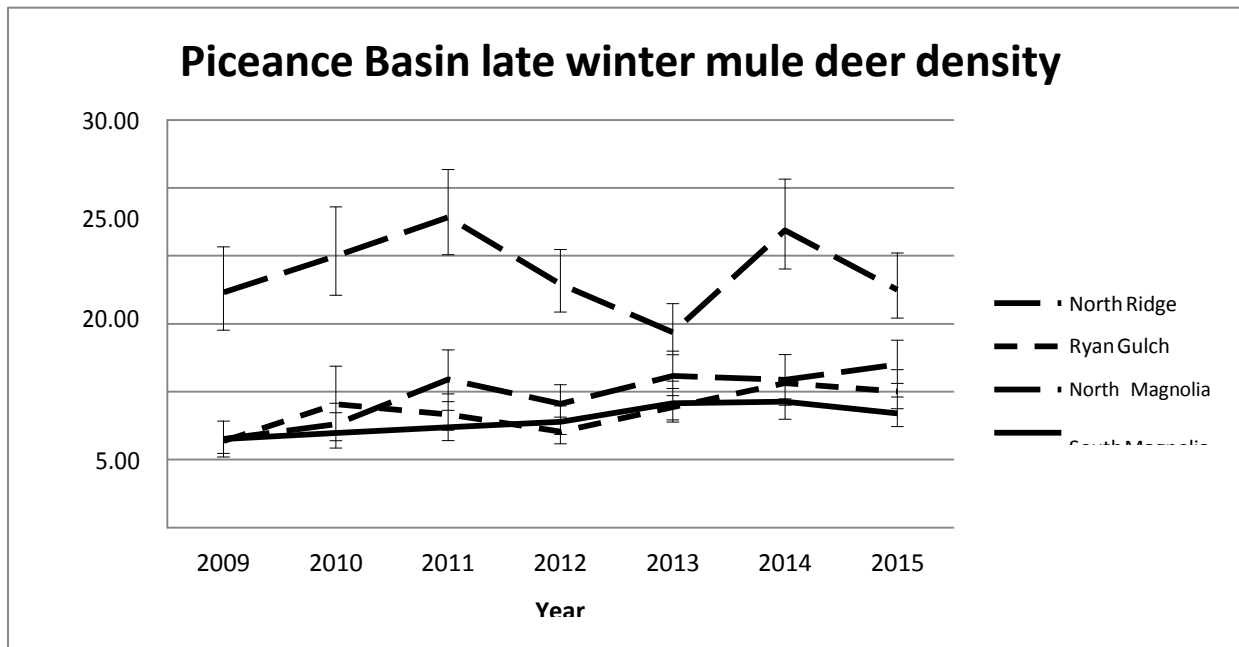
Figure 5. Mule deer density estimates and 95% CI (error bars) from 4 winter range herd segments in the Piceance Basin, northwest Colorado, late winter 2009–2015.

WILDLIFE RESEARCH PROJECT SUMMARY

Quantifying loss and degradation of mule deer habitat across western Colorado

Period Covered: July 1, 2014 – June 30, 2015

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

Project Collaborators: Sarah E. Reed, Jessica R. Sushinsky, Andy Holland, Trevor Balzer, Jim Garner, Eric Bergman

Background

        In recent decades, mule deer populations have declined across the western U.S., causing wildlife management agencies to seek factors limiting deer performance and strategies to increase their population sizes. The trend of declining mule deer populations has been primarily attributed to loss and degradation of deer habitat, through mechanisms such as urban/exurban development, resource extraction, roads and vehicular traffic, and changing patterns in weather and plant productivity. Other factors have also been implicated in contributing to deer declines, such as predation, interspecific competition with elk, and disease, but these factors have not been associated with much empirical support. While wildlife managers are well aware that different habitat factors can negatively affect deer populations, there is no information on their relative or cumulative impacts. In a report to the Colorado state legislature in 2001 titled, "Declining mule deer populations in Colorado: reasons and responses" Gill (2001) concluded that habitat factors had likely taken the greatest toll on deer populations but that there was no information quantifying the extent of habitat loss or deterioration across the state; critical information that is still lacking today.

        To address this issue, we conducted the first spatial and temporal analysis of landscape changes that have occurred to mule deer habitat across western Colorado (west of Interstate 25). Specifically, our objectives were to 1) quantify the annual changes that had occurred across the DAU and within winter and summer ranges relative to residential development, energy development, wildfire, plant productivity and weather conditions, and 2) test for associations between those changes in habitat conditions and deer recruitment. During FY2013-2014 we quantified changes that had occurred within mule deer ranges for each habitat factor (see Johnson et al. 2014), and in FY2014-15 we tested for associations between those factors and patterns in deer recruitment. In this summary we report findings with respect to residential development, energy development and climate conditions using data collected between 1980 and 2010. These habitat factors had consistent data available across this time period, years when major changes in both landscape conditions and deer populations occurred.

Methods

        To quantify changes in residential development, energy development and climate conditions across western Colorado we were limited to coarse data types with high temporal and spatial extents. We tracked changes in residential development using the Spatially Explicit Regional Growth Model dataset (Bierwagen et al. 2010), which estimates changes in areas of rural, exurban, suburban and urban housing units over time (100m resolution). We obtained information on energy development from the Colorado Oil and Gas Conservation Commission, and used the date of first activity to monitor increases in the number of wells over the course of the study. Because the exact impact area for each well was unknown, we calculated areas within deer ranges that were within 2700m of oil and gas wells (100m resolution),

based on Sawyer et al. (2006) that demonstrated mule deer avoidance within that distance. To assess climatic patterns that may influence deer recruitment, we used historic data from the Parameter-elevation Regressions on Independent Slopes Model (www.prism.oregonstate.edu). The model depicts precipitation and temperature on a monthly basis (800m resolution), which we used to calculate several metrics hypothesized to affect recruitment: average June minimum temperature, June precipitation, summer precipitation (May-Sep), average summer maximum temperature (Jun-Aug), winter precipitation (Dec-Mar) and average winter minimum temperature (Dec-Mar). For more detailed information about the data types used in the analysis refer to Sushinsky et al. (2014).

In conducting the analyses, we first estimated changes in habitat conditions across each DAU, winter and summer ranges by fitting linear mixed models with "year" as the explanatory variable and treating DAU as a random intercept to account for repeated measurements over time. We then tested univariate relationships between each habitat variable and recruitment rates (while also testing for lag effects), retaining those variables that had 80% confidence intervals non-overlapping zero. From the remaining variables, we then checked for multicollinearity. If two variables were highly correlated ($r > |0.6|$) we retained the variable with the higher univariate relationship with recruitment rates (based on t-values). Our final variable set included total development across the DAU, exurban development on winter range, energy development on winter range, winter precipitation, June minimum temperature, June precipitation, summer precipitation, the male/female ratio, an interaction between June temperature and precipitation, and an interaction between energy development and precipitation on winter range. We used linear mixed models (DAU was the random intercept) to test all subsets of these habitat variables in predicting fawn recruitment. We used model selection to identify the top models and model averaging to estimate standardized and unstandardized coefficients.

Results

Increases in residential housing were significant for all development classes (rural, exurban, suburban and urban), particularly on mule deer winter ranges (Fig. 1). Between 1980 and 2010, across all DAUs, the proportion of winter range that was associated with residential development (all types) increased by an average 0.25%/year (SE=0.01, range = 0 – 0.85%/year), while on summer range it increased by an average of 0.18% (SE=0.01, range = 0.02 – 0.65%/year). Both winter and summer ranges experienced major increases in rural development, and winter ranges also experienced major increases in exurban development. On average, 23.8% of deer winter ranges overlapped with some form of residential development in 1980 and 31.2% overlapped with development in 2010; on average, 14.0% of deer summer ranges overlapped with development in 1980 and 19.5% in 2010. Changes in development were greatest in the Southwest and Southeast regions, driven by increases in the number of rural housing units. By 2010 between 0.7% (DAU 1) and 66.0% (DAU 29) of DAU winter ranges overlapped with residential development, while between 0.8% (DAU 41) and 46.0% (DAU 34) of summer ranges overlapped with development.

On both winter and summer ranges, energy development significantly increased over time, although winter ranges experienced the greatest increase. Between 1980 and 2010, on average, the

proportion of winter range associated with a well within 2700 m increased by an average of 0.24%/year (SE=0.01; range = 0.0 – 1.4%/year), while on summer range it increased by 0.18%/year (SE=0.01, range = 0.0 – 1.9%/year). Across all DAUs the average proportion of winter range within 2700 m of a well was 16.7% in 1980 and 23.8% in 2010. The average proportion of summer range within 2700 m of a well was 9.6% in 1980 and 15.6% in 2010. Rates of energy development differed among regions with the Northwest and Southeast experiencing the highest rates of increase. By 2010, the proportion of deer winter ranges within 2700 m of a well varied among DAUs between 0% (DAUs 14, 18, 25, and 53) and 79% (DAUs 11 and 12), while summer range varied between 0% (DAUs 18 and 25) and 68% (DAU 11).

Seasonal temperature metrics significantly increased over time, while seasonal precipitation metrics significantly decreased, with the exception of winter precipitation which displayed no temporal trend. Between 1980 and 2010, models estimated that on average, June mean minimum temperatures increased from 3.91°C to 5.23°C, summer mean maximum temperatures increased from 21.98°C to 22.58°C, winter mean minimum temperatures increased from -10.72°C to -9.84°C, June precipitation decreased from 3.42 cm to 3.00 cm, and summer precipitation decreased from 26.29 cm to 21.42 cm. The only metric that showed a significant difference by region was the change in minimum temperatures in June, which were much higher in Southwest Colorado than any other region of the state (Table 1).

The mean fawn ratio across all DAUs over the course of the study was 56.0 fawns/100 adult females (SE=13.6), with mean ratios in different DAUs ranging between 42.9 (SE=7.6; DAU 23) and 76.6 (SE=12.7, DAU 27). Across years, the mean ratio in the Southwest was 50.2 (SE=11.3), in the Southeast was 58.5 (SE=16.9), in the Northwest was 60.3 (SE=12.4) and in the Northeast was 64.6 (SE=14.6; Fig. 2A). Across all DAUs, in 1980 the modeled mean ratio was 65.4 (SE = 1.4) and in 2010 it was 50.4 (SE = 1.3). Over the course of the study, recruitment decreased by an average of 0.5 fawns/100 adult females/year, with the greatest rates of decline in Southwest (-0.66) and Northwest (-0.46) Colorado. Rates of change were highly variable among DAUs. Forty DAUs exhibited declining trends over time while 4 DAUs exhibited slightly increasing trends, with the rates of change varying between -8.50 to 0.15 fawns/100 adult females/year (Fig. 2B). In contrast to fawn ratios, the ratio of adult male/adult female mule deer significantly increased over the course of the study. In 1980 the mean was 13.5 adult males/100 adult females (SE = 1.1) and by 2010 the mean was 34.0 adult males/100 adult females (SE = 1.0). This increase was influenced by conservative buck harvest strategies implemented during the late 1990s. On average the number of adult males/100 adult females increased by 0.68 males/100 adult females/year (SE=0.03). There was no significant difference in the rate of change in male ratios among regions.

Fawn ratios generally decreased in association with increasing residential development, energy development, June temperatures, winter precipitation, and male ratios. Fawn ratios increased in association with higher June precipitation, summer precipitation and winter precipitation in the previous year (lag effect). The interaction of June temperature and precipitation indicated that cold, dry weather had the greatest positive correlation with fawn recruitment, while warm, dry weather had the greatest negative correlation with recruitment. The interaction of energy development and precipitation on winter range suggested that winter severity had the strongest association with fawn recruitment when development was minimal. When a greater proportion of the winter range was impacted by energy development, the negative association with winter precipitation dampened. Fawn recruitment was predicted to be highest when both winter precipitation and energy development were low. Standardized coefficients of the main effects suggested that residential development had the strongest association with fawn recruitment (>2 times the magnitude of any other main effect), and fawn ratios were predicted to vary by 16 fawns/100 adult females across the observed range of development values. Energy development had the second strongest association with recruitment, followed closely by the climate variables.

Conclusions

Our results indicate that declining trends in mule deer recruitment are correlated with increasing residential and energy development on deer ranges, particularly within winter ranges. Recruitment is the

primary demographic parameter responsible for ungulate population growth, and thus, factors that reduce deer productivity have long-term consequences for overall population performance. Comparing the relative magnitude of correlations of human development factors with climate factors, which are well-known to be important drivers of juvenile survival, we found that residential housing had >2 times the magnitude of association of any other factor, and that the association with energy development was similar to key climate variables.

We detected significant relationships between deer recruitment and habitat conditions, but it is important to acknowledge drawbacks of our analysis that limit our inference. For example, the correlations we detected between recruitment and habitat conditions do not demonstrate causation, as we could not experimentally manipulate levels of human development or climate metrics. Additionally, the data sources used in this analysis were coarse, limited to those that were available over extensive spatial and temporal scales. While development factors were associated with declining recruitment, the specific mechanisms responsible for these correlations are largely unknown and will require additional investigation. Finally, it is important to remember that this analysis only examined a few factors affecting deer habitat, but numerous factors have been associated with demographic trends in deer (i.e., predation, disease, competition with native and domestic ungulates, etc).

Our findings have key implications for the conservation of mule deer across Colorado. Adequate, high quality winter range has been speculated to be the primary factor limiting mule deer in the state, and our findings generally corroborate this hypothesis. Indeed, development impacts on winter ranges were more strongly correlated with declining recruitment than impacts on summer ranges, and increases in both development types were greater on winter ranges. Our results suggest that expanding residential and energy development on mule deer ranges may not be compatible with the goal of maintaining highly productive deer populations, and that additional development may further reduce recruitment rates, and potentially, population sizes. Additionally, historic mule deer population objectives may be unrealistic given the increased development activity associated with declining fawn recruitment. While additional research is needed on the mechanisms driving the correlation between anthropogenic developments and declining deer recruitment, wildlife professionals should carefully consider changes to the human footprint when specifying long-term population objectives. If healthy mule deer populations are going to be maintained across the state, conservation practitioners, policy-makers, and land-use planners will need to collectively work to ensure that seasonal habitats, particularly winter ranges, are well preserved.

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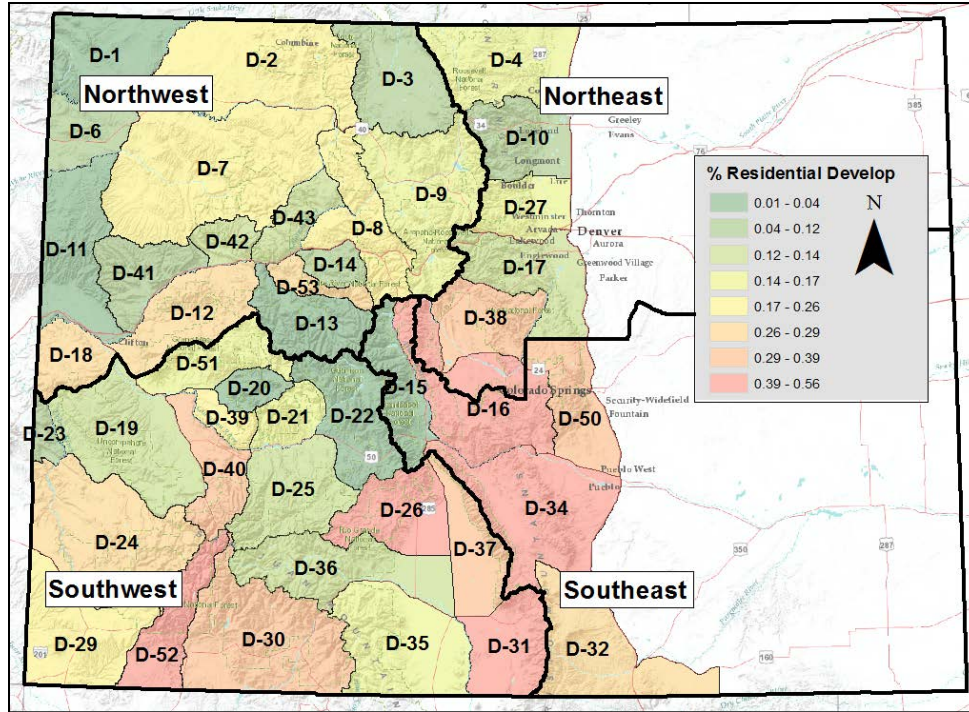
Figure 1. Map of Colorado deer data analysis units (DAUs) and regions (heavy black lines) designated by Colorado Parks and Wildlife. DAU colors represent the average annual rate of increase in residential development between 1980 and 2010.
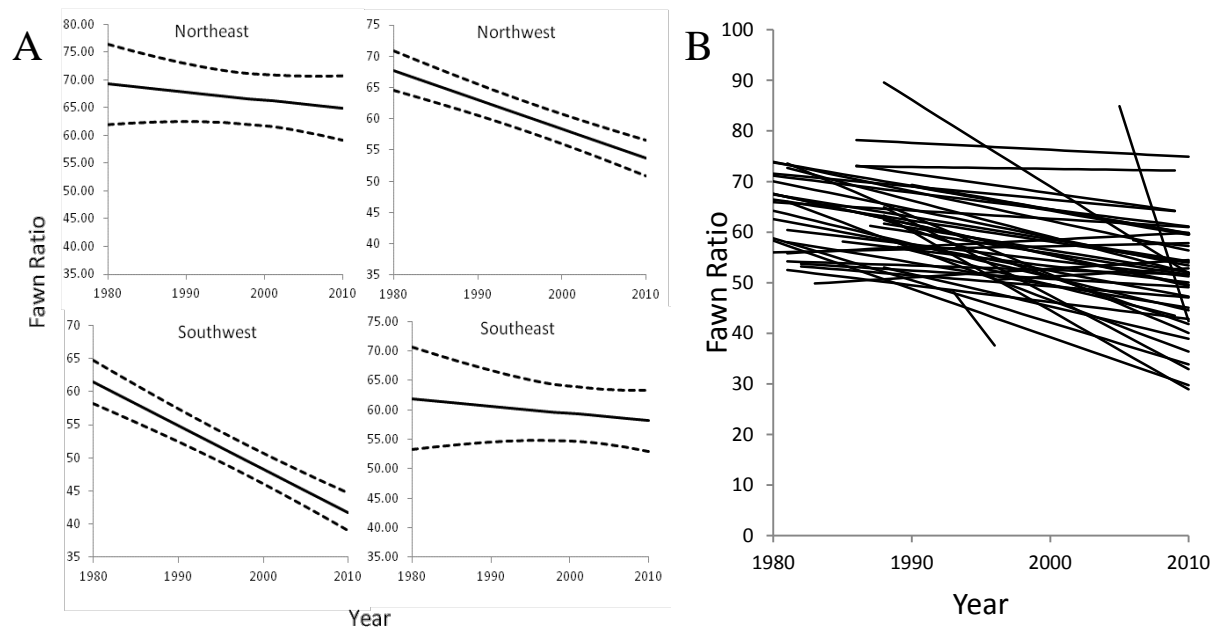

Figure 2. Mean temporal trends between 1980 and 2010 in mule deer recruitment in Colorado by a) region and b) deer data analysis unit.

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, 2014 – June 30, 2015

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 2014–2015 fiscal year. During the first year of this project, field efforts were primarily focused on the capture and collaring of moose. These capture efforts were continued into the 2nd year of the study. Field efforts were also expanded to include estimation of parturition rates. During the second year of the study, all captures occurred during late December (2014). During both years, capture efforts were focused in 3 study areas in Colorado — the Laramie River and Red Feather Lakes areas (NE Colorado), the Rabbit Ears range that separates North Park from Middle Park (NW Colorado), and along the Upper Lake Fork, Rio Grande Reservoir, and near Slumgullion Pass (SW Colorado; Fig. 1).

Fifty-eight and 50 cow moose were captured and radio-collared during the first and second years of the study, respectively. Of the 50 cows that were captured during December 2014, 11 were recaptures of animals that were first caught during the 2013–2014 field season. Twenty moose were captured in the NW study area (including 3 recaptures of cows originally captured during the 2013–2014 field season), 14 moose were captured in the NE study area (0 recaptures), and 16 were captured in the SW study area (including 8 recaptures of cows originally captured during the 2013–2014 field season). Body condition and pregnancy status was determined for each animal at the time of capture. Annual survival rates for each study area were calculated for the 12-month period ending in mid-May. During May and June of 2015 parturition and twinning rates were estimated for the northeast and northwest study area.

Mean measured rump fat during December 2014 ranged between 6.21–7.25 mm among study areas. Mean measured loin depth at the time of capture ranged between 41.7–43.3 mm among study areas. When data from 2013–2014 and 2014–2015 were pooled, pregnancy status was best predicted by maximum rump fat (Fig. 3). As was the case during the first year of the study, survival of radio collared animals was high in all study areas. Survival rates ranged between 85%–94% during 2013–2014 and from 88%–96% during 2014–2015. Pregnancy rates during 2013–2014 ranged between 68%–95%, and increased slightly during 2014–2015, ranging between 78%–95% (Fig. 2). Parturition rates were consistent between the northeast and northwest study areas (80%). Twinning rates at the time of capture ranged between 5.3%–12.5%.

Thus far, data collected during this project have met expectations. In particular, survival rates have been consistently high in all study areas. Lower productivity was consistently observed in the northeast herd during both years. 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.
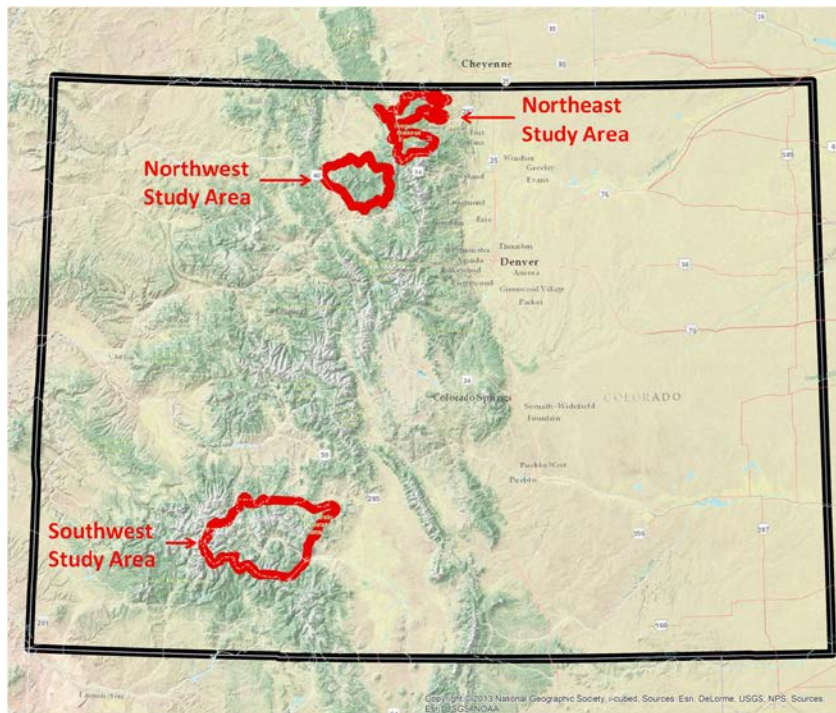
Figure 1. Moose research study areas, located in 3 regions in Colorado. A total of 58 moose were captured during the winter of 2013–2014 and 50 moose were captured during the winter of 2014–2015. Survival of moose was high in all study areas and during both years.
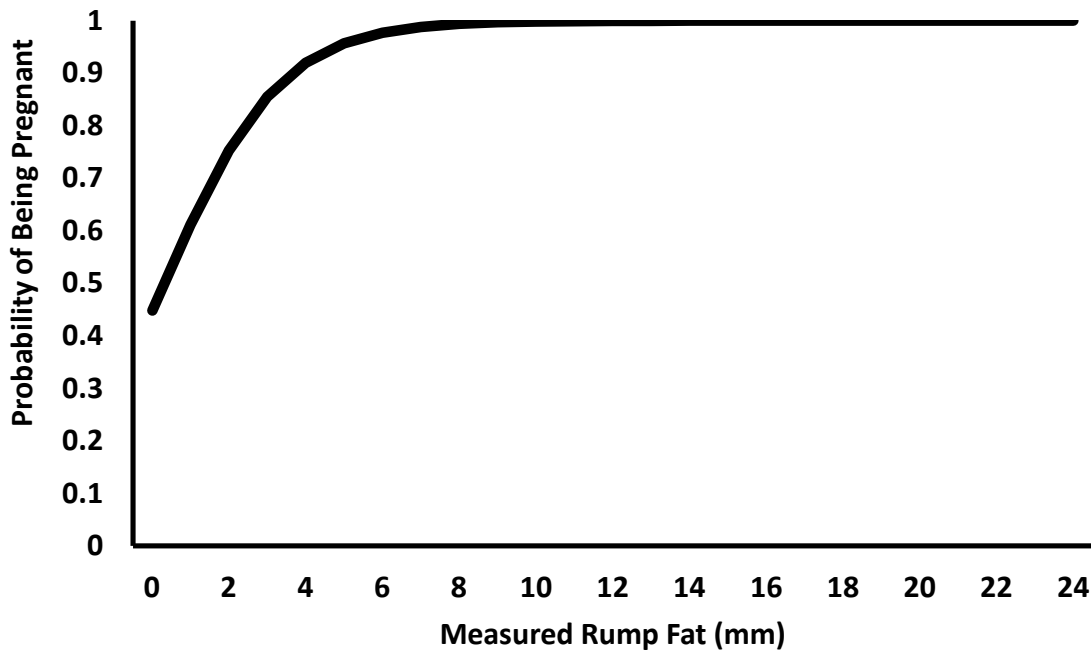
Figure 2. Probability of moose pregnancy was best predicted by maximum measured rump fat. This strong relationship between body condition and pregnancy status reflects how nutritional condition can influence pregnancy, with animals in the poorest condition having lower probabilities of breeding.
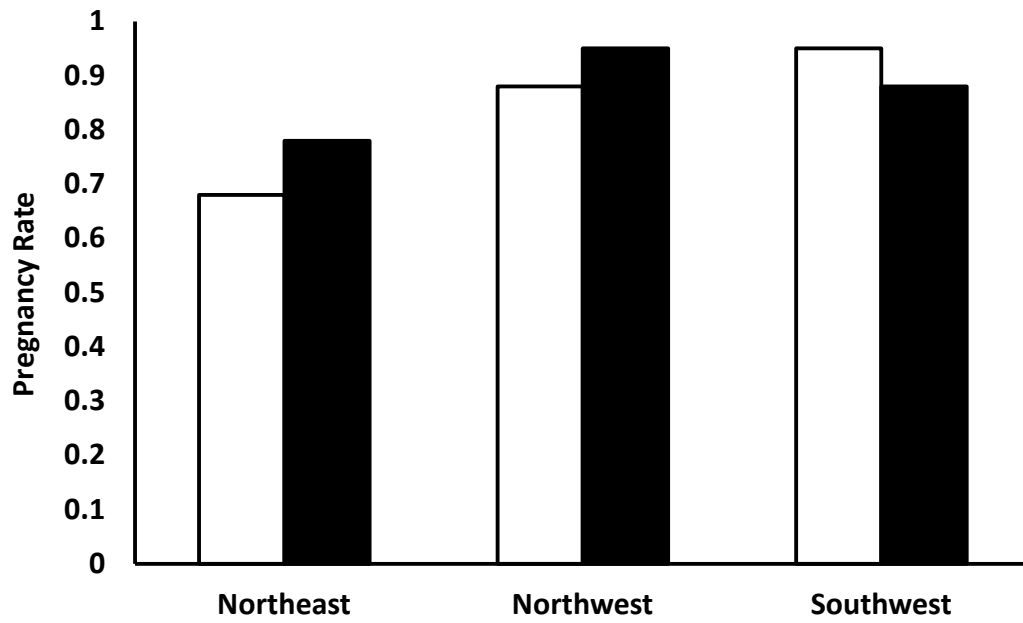
Figure 3. Pregnancy rates for all moose at the time of capture from 2013–2014 (white bars) and 2014–2015 (black bars). Lower pregnancy rates were observed in the northeast study area during both years.

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 BLACK BEAR DEMOGRAPHICS AND COUGAR-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, 2014 – June 30, 2015

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

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

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

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

This project was initiated in FY2010-11; during this past fiscal year we have primarily focused on collecting field data in the vicinity of Durango, Colorado. Our efforts focused largely on field data needed to meet research objectives 1-3, information which will eventually be used to address objective 4. Specifically, we worked with collaborators and stakeholders on research logistics, trapped and marked black bears, monitored bear demographic rates (adult female survival, adult female fecundity and cub survival) through telemetry and winter den visits, tracked human-related bear mortalities and removals from the study area, performed non-invasive genetic mark-recapture surveys to estimate bear density, collected GPS collar location data on bears along the urban-wildland interface, monitored the availability of late summer/fall mast, obtained data on garbage-related bear-human conflicts, and assessed resident use of project-supplied bear-resistant garbage containers.

Major research accomplishments from fiscal year 2014-15:

- Between July 2014 and March 2015 (the 2014-2015 capture year), an additional 63 unique bears were marked during 147 bear captures. To date on the project there have been 327 different individuals marked during 717 captures. Five new adult females were collared during summer 2014 to collect demographic and habitat-use data (70 adult females have been collared to date). Bear capture and marking efforts are allowing us to track bear population parameters and habitat-use patterns along the urban-wildland interface.

- During January - March 2015, we visited the winter dens of 37 collared females (Photo 1). Of those females, 11 did not have any cubs or yearlings, 8 had yearlings (12 total yearlings in total), and 19 had newborn cubs (41 cubs). We found that reproductive success, measured as the number of cubs/adult female, was 1.15 (SE = 0.20). This was the highest observed fecundity rate to date, as previous rates ranged between 0.52 (SE=0.16) and 0.95 (SE=0.24). Cub survival for 2015 (survival from newborn to 1 year) was 58% (based on 24 cubs), compared to 50% in 2014 and 40% in 2013.

Photo 1. Cubs at a black bear den. Fecundity rates in 2015 were the highest that have been observed during the study (Photo Credit: Bill Masure).

- To date, we have obtained >500,000 locations from GPS collars on 70 different adult female bears along the urban-wildland interface; 42 different bears provided location data during the active bear year of 2014 (May – October; Fig. 1). While most locations were in close proximity to Durango, a couple of bears were found outside the primary study area (Fig. 1). For example, B67 had moved to New Mexico in 2013, but moved back to Durango in fall of 2014 (with 2 cubs in tow). Another sow, B57, left her home range in lower Junction Creek (just north of Durango) to travel north to Hamilton Mesa (just south of Norwood), before returning to her original range.

- In summer 2014, we collected 1,209 hair samples for a non-invasive genetic mark-recapture study designed to estimate bear densities and population sizes around the vicinity of Durango and an adjacent "wildland" site. Over a 6 week sampling period, a total of 551 hair samples were collected from the Durango grid and 658 samples from the wildland grid. The number of samples/snare ranged from 0 to 66 in the Durango grid and from 2 to 50 in the wildland grid. Genotype results should be returned from Wildlife Genetics International during fall 2015. Detailed mark-recapture analyses of these data to estimate density and abundance will be conducted in FY15-16.

- Based on 15 1-km transects in the study area, the availability of natural mast foods was generally very good in late summer and fall 2014. Mast surveys demonstrated that the peak time for maturation of wild crabapple was late July, serviceberry was the first half of August, chokecherry was mid-August, hawthorne was late August, gambel oak was early September, and pinyon pines had cones developing in mid-September. On transects that had those species, mast was present on approximately 40% of wild crabapple shrubs, 70% of hawthorne shrubs and trees, and 50% of chokecherry, serviceberry oak and pinyon pine shrubs and trees.

- During summer 2014 (July through September) we collected our second 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 during 2011 and 2012, post-treatment data were collected in 2013 and 2014). Within treatment and control areas we observed 202 instances of bears accessing residential garbage during morning patrols; observations generally peaked in mid-August. Of those garbage containers accessed by bears, 79% were regular and 21% were bear-resistant; 40 garbage conflicts were observed in treatment areas (across ~1230 total residences) and 162 occurred in control areas (across ~1260 total residences; Fig. 2). We will continue to collect post-treatment data through 2015.

- During summer 2014 we found that the average compliance of residents to wildlife ordinances was 55% in the north treatment area and 45% 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. Across all sampling periods, compliance was generally higher in the northern experimental area than in the southern area. In the northern area, compliance increased from ~45% in 2013 to ~55% in 2014. In the southern area compliance remained ~45% in both years.

- Two journal articles were published this past year that used data from the study. In one article, black bear GPS collar locations were used to examine bear selection for human development (Johnson et al. 2015) and the other article evaluated a new immobilization drug combination for bears (Wolfe et al. 2014).

In addressing our research objectives we hope to better understand the influence of human development on bear populations, elucidate the relationship between bear-human conflicts and bear behavior and demography, understand the effect of bear-human 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. For a more detailed version of this project summary see Johnson et al. (2015, Federal Aid Report W-204-R1): http://cpw.state.co.us/Documents/Research/Mammals/Publications/AlldredgeFrontRangeCougar_W204-R4_ProgressReport_2014-15.pdf

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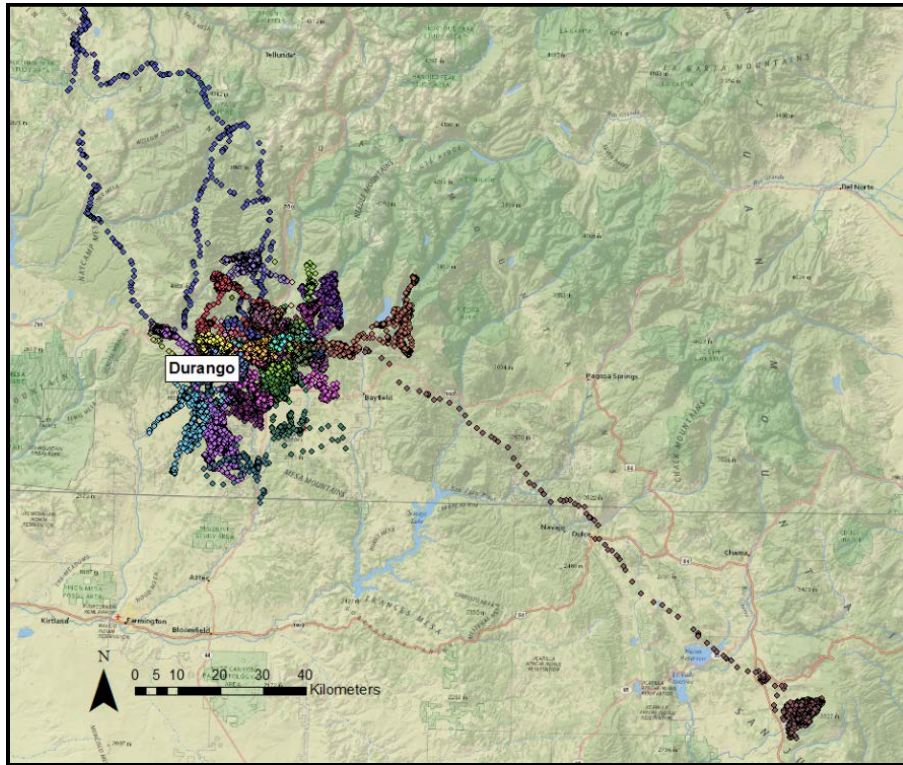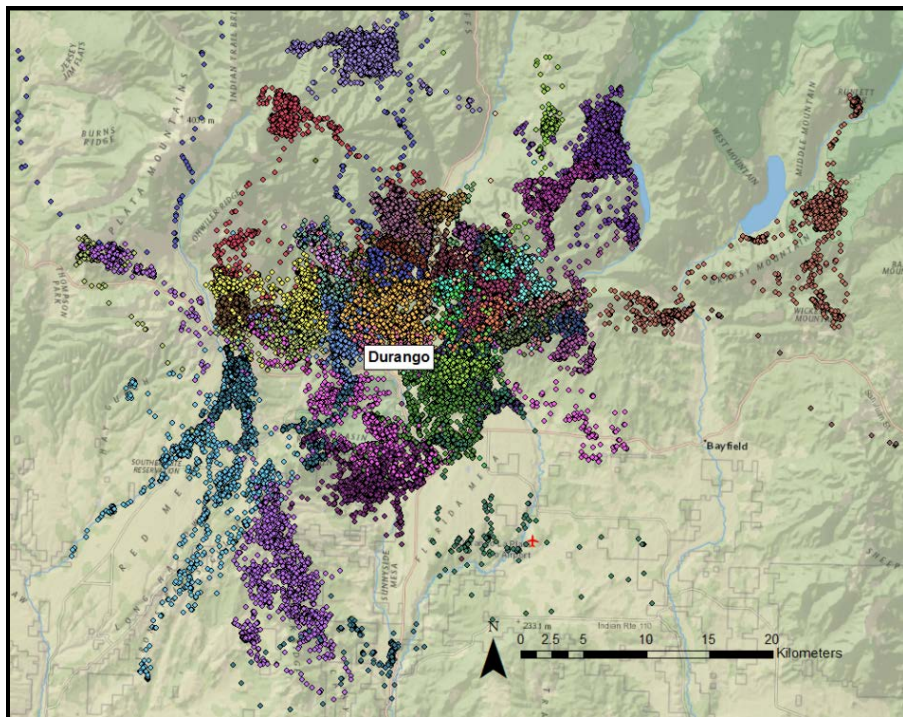
Figure 1. GPS collar locations from 42 adult female black bears collected during 1 January – 31 December 2014 in the vicinity of Durango, Colorado (different colored clusters of points represent different individual bears): A) an overview of all locations and B) locations around the town of Durango.
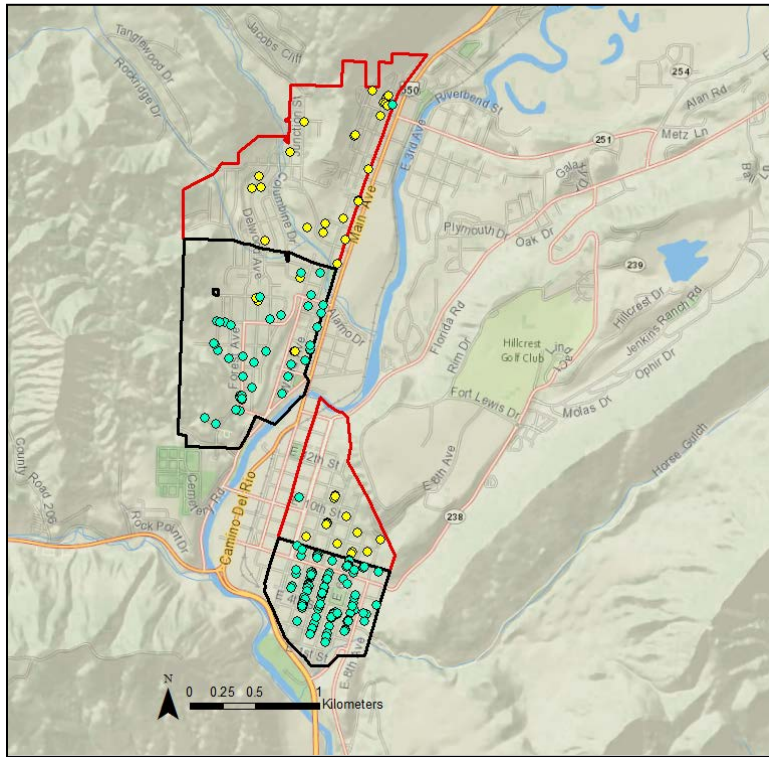
Figure 2. Garbage-related black bear-human conflicts observed during July through September 2014. Red lines indicate treatment areas and black lines indicate control areas. Green circles represent conflicts with regular residential garbage containers and yellow circles represent conflicts with wildlife-resistant containers.

The Colorado Parks and Wildlife (CPW) initiated a 10-year study in 2004 on the effects of sport-hunting on a mountain lion population on the Uncompahgre Plateau. This study was designed to provide information that can be applied to future lion management. The study quantifies lion population characteristics in the absence of hunting (termed the *reference* period, years 1-5) and the application of hunting (termed the *treatment* period, years 6-10). The purpose of the study is to evaluate the current biological assumptions used by CPW to manage lions with hunting and to learn how lion hunter behavior may influence harvest. Testing the management assumptions is important, because managers normally have no information on lion abundance, population sex and age structure, or effects of hunting on lions for any region of Colorado; therefore, unreliable assumptions might lead to management errors that could affect regional lion populations. Lion hunter behavior is important to understand because it may influence the sex and age structure of lions killed by hunters, and those harvest data are used by CPW managers in an effort to make biological judgments about lion populations and effects of hunting.

Field operations for this study were completed in December 2014. Starting January 2015 the principal investigator along with collaborators began a formal phase of data analysis, partially included in this report. Analyses are ongoing and are expected to provide reliable information for application in lion management in Colorado.

The *reference* period began December 2004 and ended October 2009, during which we captured, sampled, and marked 109 individual lions for research purposes. During this 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 *reference* year 4 to a high of 56 lions counted in the *treatment* year 1 (Fig. 1). This was an indication that lion management on the Uncompahgre Plateau previous to this study likely 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; expected characteristics of an increasing population. The main cause of death in adults was aggression by other lions (57%, $n = 4$). Two deaths of radio-collared adult lions were due to human causes; 1 adult female killed for depredation control and 1 adult female killed by vehicle strike. Only 1 subadult lion died of human causes; 1 female killed by vehicle strike. Infanticide by male lions was the main cause of death for cubs (81%, $n = 13$).

The *treatment* period, in which managed sport-hunting of lions resumed on the study area, began in November 2009 and ended December 2014. An additional 115 lions were captured and marked in the *treatment* period. As indicated previously, *treatment* year 1 was the first year that hunting influenced the lion population after 5 years of no hunting, and it was marked with the highest estimate of independent lions (56) on the study area. During *treatment* years 1 through 3, the lion harvest rate was set with a design quota of 8 lions to test a prediction that a 15% harvest of independent lions would result in a stable-to-increasing population. This is an important management assumption to test, because it represented a maximum mortality rate on independent lions that was assumed to achieve a stable-to-increasing population trend, one of two CPW lion population management objectives that are applied to certain regions (Data Analysis Units, DAUs, each comprised of multiple Game Management Units,

GMUs). However, the expectation that a 15% harvest results in a stable-to-increasing population was not supported as the population of independent lions declined from 56 in *treatment* year 1 to 42 by *treatment* year 4 (Fig. 1). The other CPW lion management objective was to manage certain regions to substantially reduce or suppress lion abundance with hunting. Results from *treatment* years 1 through 4 indicated that reducing a lion population with hunting is achievable at a 15% harvest rate. Hunting-caused mortality was the single most important cause of mortality in adult and subadult lions, comprising 57% ($n = 21$) and 55% ($n = 11$) respectively. Starvation and infanticide by male lions were the main causes of death for cubs, 33% ($n = 9$) and 30% ($n = 8$) respectively.

The lion population was expected to continue to decline if the quota remained at 8 lions, because 8 lions represented a 19% harvest by *treatment* year 4, a larger percentage than the 15% harvest that had already contributed to population decline. Therefore, in an effort to find a harvest rate useful to managers that would 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 treatment years 4 and 5. The count of independent lions in treatment years 4 and 5 were 42 and 44 lions, respectively, suggesting that the lower harvest rate of 11-12% resulted in a cessation of the decline in the number of independent lions. The minimum of 42 independent lions counted in treatment year 4, represented a 25% decline since treatment year 1.

We used an information-theoretic approach and Akaike's Information Criterion to rank survival models with and without the treatment effect. The hunting treatment was indicated as an important factor explaining variation in lion survival rates. Survival rates of adult male lions declined from 0.96 in the *reference* period to 0.40 in the *treatment* period, and adult female survival declined from 0.86 to 0.74 in those respective periods. Subadult survival rates declined from 0.84 in the *reference* period to 0.52 in the *treatment* period. Cub survival rates declined from 0.50 in the *reference* period to 0.34 in the *treatment* period. The age structure of independent lions also declined in the *treatment* period. Moreover, there was a substantial biological effect in the fecundity rate, which declined from 0.63 in the *reference* period to 0.48 in the *treatment* period.

During the *treatment* period, additional independent radio-collared lions were killed by hunters outside of the study area during the Colorado lion hunting season spanning November through March each winter. Those lions were counted as part of the harvest quota in other GMUs. This occurred even though the study area was one of the largest GMUs in Colorado. Home ranges of most lions, particularly of males, were large enough to span at least two GMUs so lion movements put some individuals at risk of hunting mortality even after the study area quota was filled. Therefore, hunting-caused mortality affected the study lion population over a larger area and for a longer period of time than was expected under the current lion management structure. The total hunting mortality plus other human causes of mortality, such as road kill and depredation control, and natural mortality contributed to the lion population decline and low phase. This indicated a need for managers to consider how all mortality might impact a lion population, as well as, modifications to the current management structure.

Besides the study on effects of sport-hunting on lions, other projects associated with lion biology were developed in collaboration with colleagues in CPW, Colorado State University, Colorado Cooperative Fish and Wildlife Research Unit, Oklahoma State University, University of Wisconsin, and Arizona State University. From August to December 2009 we collaborated with Ph.D. student Jesse Lewis and Dr. Kevin Crooks (C.S.U., Dep. of Fish, Wildlife, and Conservation Biology) in a study of relationships of bobcats to mountain lions and considerations in using a camera grid with marked lions to estimate lion detection, abundance, and density. Jesse completed his Ph.D. dissertation and manuscripts submitted to journals by December 2014. From December 2012 to March 2013 we collaborated with Master's student Kirstie Yeager (Colorado Cooperative Fish and Wildlife Research Unit) and Dr. Mat Alldredge (Mammals Researcher, CPW) to test non-invasive methods for detecting lions for efforts to estimate abundance. Her work also allowed us to assess the proportion of lions marked in the population on the Uncompahgre Plateau study. Kirstie defended her thesis in May 2015, is making final edits to her thesis, and is in the process of submitting papers for publication in journals. We are also involved in an ongoing study of diseases in mountain lions and bobcats with Dr. Sue VandeWoude (C.S.U., Dep. Of

Microbiology, Immunology, and Pathology), Dr. Kevin Crooks and their colleagues and graduate students. Diseases and pathogens to which lions and bobcats sampled from the Uncomphagre Plateau study area were exposed, included: plague (caused by the bacteria *Yersinia pestis*), Feline immunodeficiency virus, *Bartonnela* sp., and *Toxoplasma gondii*. Several manuscripts have been published on those efforts. In addition, Dr. Mason Reichard (Dep. of Veterinary Pathology, Oklahoma State University) found that up to 45% of independent lions sampled may be infected with 3 species of *Trichinella* sp. A manuscript on that work is in review for journal publication. We collaborated with Master's student Wynne Moss (Dep. of Forestry and Wildlife Ecology, Univ. of Wisconsin) to conduct isotopic analysis of lion diet in wildland and developed habitats to examine shifts in lion diet and niche breadth. A manuscript by Wynne is *in press*. Finally, we are collaborating with Dr. Melody Roelke (Arizona Cooperative Fish and Wildlife Research Unit, Univ. of Arizona) and Ph.D. student Alex Erwin to examine lion genetic relatedness, reproductive success, and population structure. The projected time for completion for that work is spring 2017.
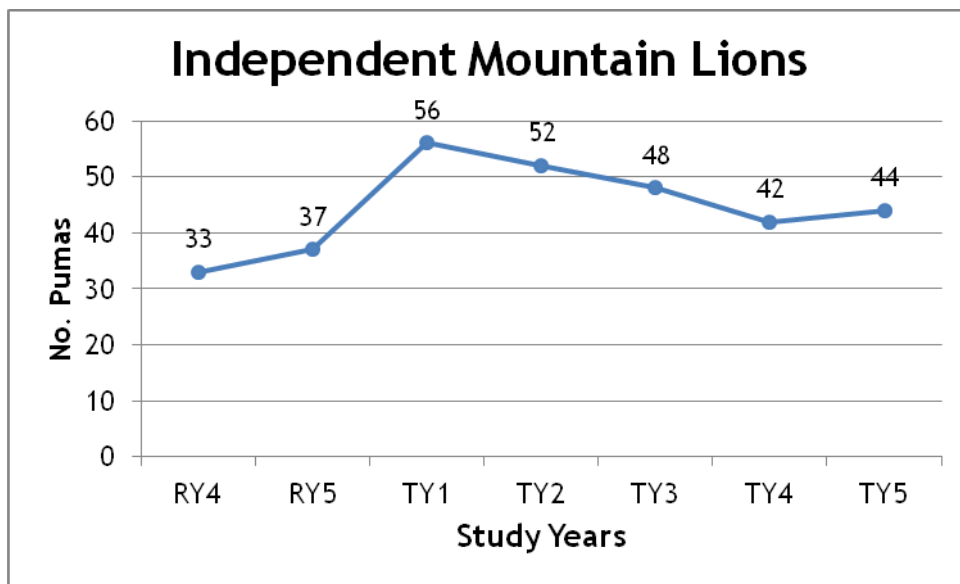
Figure 1. Trends in the population of independent mountain lions associated with no sport-hunting in the *reference period* years 4 and 5 (RY4, RY5) and with sport-hunting in the *treatment period* years 1 through 5 (TY1 to TY5), Uncompahgre Plateau, Colorado. The count data were gathered from November 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, 2014 – June 30, 2015

Principal Investigator: Mathew W. Alldredge, mat.alldredge@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.

PROJECT NARRITIVE 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

Section A: Telomeres and Stable Isotopes
1. Evaluate the potential to develop a model for estimating age of bears and cougars based on telomere length.
2. Determine diet composition of bears and cougars using stable isotopes.

Section B: Front Range cougars
3. Capture and mark independent age cougars and cubs to collect data to examine demographic rates for the urban cougar population.
4. 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).
5. Continue to assess relocation of cougars as a practical management tool.
6a. Assess cougar predation rates and diet composition based on GPS cluster data (Completed).
6b. Assess kill site dynamics and prey selection of cougar kills.
7. Model movement data of cougars to understand how cougars are responding to environmental variables.
8. Develop non-invasive mark-recapture techniques to estimate cougar population size.

2014-2015 Project Overview
Field efforts during the 2014-2015 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.

Section A: Telomeres and Stable Isotopes
1. Evaluate the potential to develop a model for estimating age of bears and cougars based on telomere length.
   Field work completed—data analysis and publication (see summary **Spatio-temporal patterns of diet and telomere length in Colorado black bears**)
2. Determine diet composition of bears and cougars using stable isotopes.
   Field work completed—data analysis and publication (see summaries **Spatio-temporal patterns of diet and telomere length in Colorado black bears** and thesis abstracts **Novel habitats present novel challenges for an apex carnivore (*Puma concolor*) and Niche sprawl in an opportunistic apex predator (*Puma concolor*)**)

Section B: Front Range cougars
3. Capture and mark independent age cougars and cubs to collect data to examine demographic rates for the urban cougar population.
   Field work completed—see Federal Aid Report for preliminary summaries
4. Continued assessment of aversive conditioning techniques on cougars within urban/exurban areas, including use of hounds and shotgun-fired bean bags or rubber bullets.
   Field work completed—see Federal Aid Report for preliminary results and summaries
5. Continue to assess relocation of cougars as a practical management tool.
   In progress—see Federal Aid Report for preliminary data
6a. Assess cougar predation rates and diet composition based on GPS cluster data.
   Field work completed—data analysis and publication (see thesis abstract **Risk-reward tradeoffs in the foraging strategy of cougar (*Puma* concolor): Prey distribution, anthropogenic development, and patch-selection**)
6b. Assess kill site dynamics and prey selection of cougar kills.
   Field work completed—data analysis and publication in progress
7. Model movement data of cougars to understand how cougars are responding to environmental variables.
   Field work completed—contact Mat Alldredge for current publications.
8. Develop non-invasive mark-recapture techniques to estimate cougar population size.
   Field work completed—data analysis and publication (see thesis abstracts **The Use of Lures, Hair Snares, and Snow Tracking as Non-Invasive Sampling Techniques to Detect and Identify Cougars**)

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 begun 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 next few years we intend to further refine these NGS techniques for cougars and bobcats so that they can be reliably implemented to inform management decisions. We also intend to perform at least one full survey over multiple years so that we can assess the reliability and repeatability of this approach. Following these efforts our hope is that we will have a fully developed NGS approach for cougars and bobcats that can 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 (see study plan for details, Appendix VI). This year sites (Figure 1) 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 this year 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 decreased from 86 in 2014 to 42 in 2015, while observations of bobcats increased from 31 to 68 across years (Table 1). Hair samples for cougars decreased accordingly from 55 in 2014 to 32 the following year. Hair samples from bobcats increased from 5 the first year to 12 the second year. Genotypes from bobcat hair have not been successful, but is somewhat successful for cougars.

Table 1: Noninvasive hair snag capture results for bobcats and cougars. Number of animals seen, number of hair samples collected and number of successful genotypes.

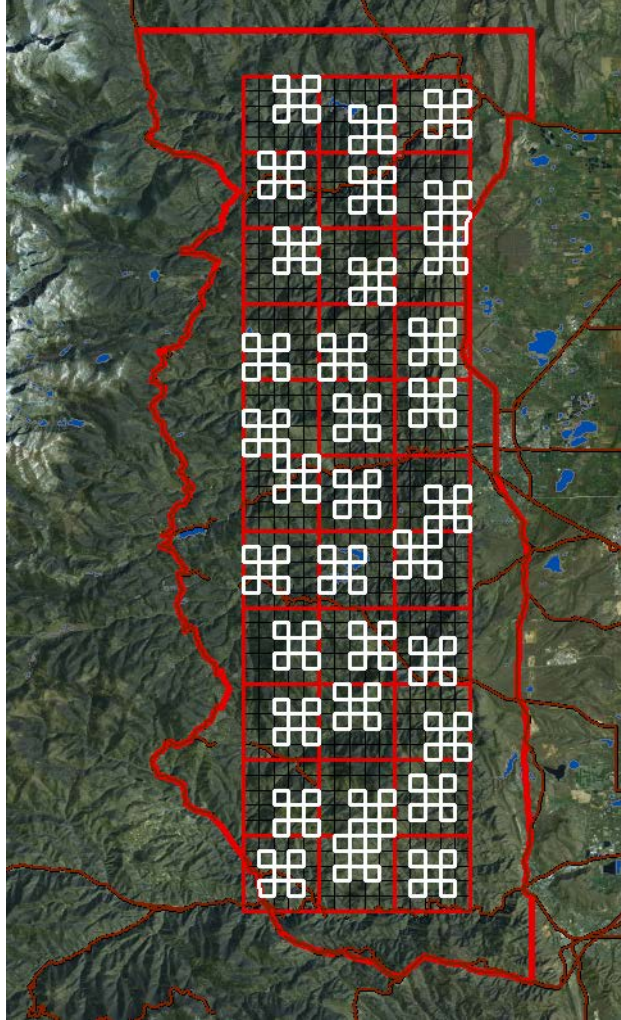| Species	Year	Pictures	Hair Samples	Genotypes
Bobcat	2014	31	5	0
Bobcat	2015	68	12	1
Cougar	2014	86	55	20
Cougar	2015	42	32	11

Figure 1: Study area boundary and grid layout for NGS cougar and bobcat sites. Larger squares represent the 5 km^2 grid overlaid with a 1 km^2 grid. White 1 km^2 cells represent the randomly selected cells where actual lure sites will be placed.

Spatio-temporal patterns of diet and telomere length in Colorado black bears
Becky Kirby (UW-Madison), Jonathan Pauli (UW-Madison), Mat Alldredge (Colorado Parks & Wildlife)

The effect of human-derived food on free-ranging wildlife populations is a growing problem across North America, and is particularly evident among carnivore populations. In Colorado, American black bear (*Ursus americanus*) conflicts have been increasing, and research is focused on elucidating factors that drive such conflicts. Understanding the influences of food availability and population trends is necessary to mitigate risks posed by these conflicts. To this end, this project aims to assess broad-scale patterns of diet and age in black bears across Colorado in hunter-harvested bears.

We are quantifying diet and telomere length of black bears, in relation to geographic and habitat variables. Specifically, we are examining the amount of human food consumption, compared to native foods. Because human food is often underestimated using traditional diet reconstruction analyses due to issues such as digestibility, we are using stable isotope analyses that reflect assimilated diet. Further, we are examining a non-invasive technique related to aging in black bears, using genetic analyses of telomere length measured by qPCR. Telomere length is related to chronological age, but also can be a valuable indicator of fitness and senescence.

We analyzed isotopic signature (δ^{13}C and δ^{15}N) for ~ 300 hunter-harvested bears. Enriched (higher) signatures likely indicate greater consumption of human-derived foods and animal matter, respectively. Adults and eastern bears are significantly enriched in both δ^{13}C and δ^{15}N. Proportional diet estimates from SIAR suggest that northeastern bears consume the greatest amount of human-derived foods compared to other regional bear populations (Table 1). This appears to be driven primarily by availability, as human activity (indexed by road density) is the strongest predictor of human-derived food consumption at a landscape scale (Figure 1). Further, the odds of being a nuisance bear increased by 60% for each per mil increase in δ^{13}C.

We also quantified relative telomere length from these hair follicles in 245 individuals, ranging in age from 1-21 (estimated by cementum annuli). Samples exhibit wide variation among telomere length (T/S) across ages, showing no significant trends. Telomere length declined with increasing latitude and increasing elevation, suggesting a geographical relationship with telomere length (Figure 2). However, telomere length increased with measures of habitat quality, suggesting a positive effect of habitat quality on telomere length. We suspect these patterns reflect differences in important environmental conditions, particularly those driving physiological stress and characteristics of hibernation, that are overwhelming potential relationships to typical predictors of telomere length. Thus, ongoing longitudinal studies are necessary to elucidate rates of change rather than single timepoint samples and increase resolution of covariates.

This study will yield insight into bear foraging ecology and aging, especially how human food and land use impacts both. Further development of these isotopic and molecular techniques will be aid in future bear management and biological studies.

Table 1. Assimilated dietary estimates for black bears in the summer and fall seasons, obtained from the isotopic signatures of hair and blood, respectively. Eastern bears consumed more human-derived foods than western bears, regardless of season, but bears consumed less human-derived foods during the fall than the summer. Estimates provided by region of Colorado.

Diet Groups	Mean Proportion (95% CI)			
	NE CO	SE CO	NW CO	SW CO
Hair (n)	29	71	104	92
Vegetation	0.69 (0.65-0.74)	0.72 (0.69-0.76)	0.83 (0.80-0.85)	0.85 (0.82-0.88)
Animal matter	0.04 (0.02-0.07)	0.06 (0.05-0.08)	0.11 (0.09-0.12)	0.11 (0.10-0.13)
Human-derived foods	0.26 (0.21-0.32)	0.22 (0.18-0.26)	0.07 (0.03-0.10)	0.04 (0.00-0.07)
Blood (n)	9	29	37	38
Vegetation	0.64 (0.53-0.76)	0.77 (0.70-0.84)	0.83 (0.80-0.86)	0.86 (0.83-0.88)
Animal matter	0.07 (0.00-0.13)	0.07 (0.05-0.11)	0.15 (0.12-0.17)	0.13 (0.11-0.15)
Human-derived foods	0.29 (0.14-0.45)	0.15 (0.06-0.24)	0.02 (0.00-0.05)	0.01 (0.00-0.04)

$\delta^{13}C = -21.17 + 0.6442(\ln(\text{road density}))$
$r^2 = 0.11$
$P < 0.001$
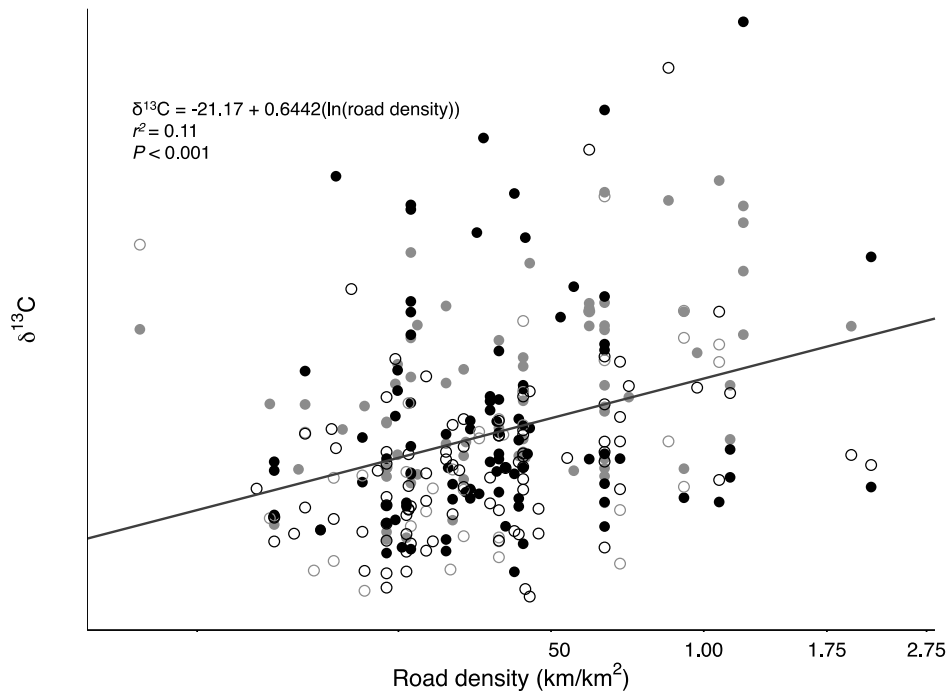
Figure 1. Linear regression of $\delta^{13}C$ on road density (natural-log transformed), showing a positive relationship between increased road density and $\delta^{13}C$ enrichment, with points representing age-sex classes: adult male (*filled black circles*), adult female (*filled gray circles*), subadult male (*open black circles*), subadult female (*open gray circles*).
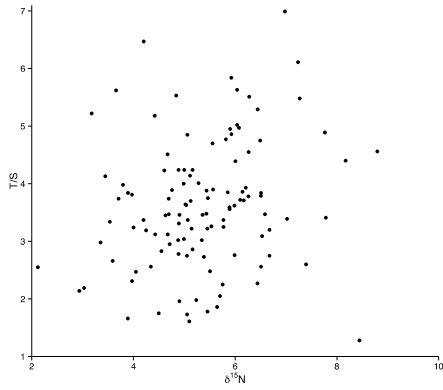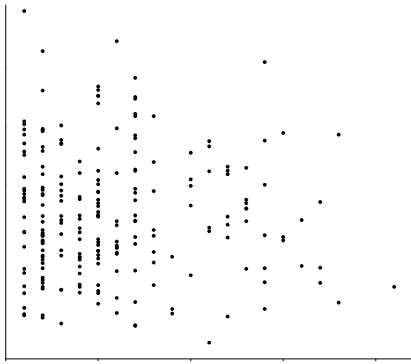
Figure 2. Relationship of relative telomere length (T/S) with individual covariates that we predicted could influence telomere lengths in Colorado black bears. Regression lines shown for significant relationships.

Novel habitats present novel challenges for an apex carnivore (*Puma concolor*)

Wynne E. Moss (UW-Madison), Mathew W. Alldredge (CPW), Jonathan N. Pauli (UW-Madison)

Abstract: Human-modified landscapes are now the most common global cover type. Species persistence in these landscapes hinges upon adaptability, including the capacity to exploit novel food resources and habitats. Yet, for large carnivores, there may be significant costs of such a strategy. Cougars (*Puma concolor*), though generally considered specialists of large ungulates, are capable of preying upon a variety species, which could be advantageous in novel ecosystems like developed landscapes. However, these areas also represent a landscape of heightened risk of conflict with humans. We examined the tradeoff between dietary flexibility and survival in a population of cougars inhabiting Colorado's urban-wildland interface. We monitored space use of GPS-collared cougars and related this to estimates of diet from stable isotope analysis. Our population-wide estimate of diet revealed that native herbivores constituted the bulk of assimilated biomass (64-79%), though there was considerable variation among individuals. Cougars using the most highly developed areas obtained 20% more of their diet from alternative prey (synanthropic wildlife and domestic animals) than those in the least developed areas. Adult males and subadults consumed more alternative prey compared to adult female cougars. Use of developed areas significantly increased risk of mortality for both males and females. Thus, though cougars displayed a highly plastic foraging strategy in developed areas, they were less likely to survive. Our findings reveal that, despite their dietary flexibility, the heightened risk from human conflict is likely to inhibit cougar population recoveries in densely populated areas.

Niche sprawl in an opportunistic apex predator (*Puma concolor*)

Wynne E. Moss (UW-Madison), Mathew W. Alldredge (CPW), Kenneth A. Logan (CPW), and Jonathan N. Pauli (UW-Madison)

Abstract: Urban areas are dramatic examples of landscape change and increasingly identified as systems in which to promote ecological complexity and conservation. Yet, little is known about the processes that regulate highly developed ecosystems, or the behaviours employed by species adapting to them. We evaluated the isotopic niche of an ecologically important apex carnivore, the cougar (*Puma concolor*), over broad spatiotemporal scales and in a region characterized by rapid human growth. We detected a niche expansion, from specialization on native herbivores in wildlands to enhanced reliance on exotic and invasive species by cougars in contemporary urban interfaces. We show that 25 years ago, cougars inhabiting these same urban interfaces possessed diets that more closely resembled their wildland counterparts, suggesting foraging adaptations are recent. Thus, urban sprawl has been accompanied by a niche sprawl over both time and space, indicating that an important top predator is interacting in novel ways. Thus, adaptations to urbanization could alter the ecological role of apex carnivores, and while human-dominated landscapes may maintain these species, their functional relationships are unlikely to remain the same.

Risk-reward tradeoffs in the foraging strategy of cougar (Puma concolor): prey distribution, anthropogenic development, and patch-selection – MS Thesis Abstract
Kevin Blecha (Colo. State Univ.), Mat Alldredge (CPW), and Randy Boone (Colo. State Univ.)

Empirical efforts for understanding whether the space utilization patterns of large elusive carnivores foraging on highly mobile prey are sparse. Having an understanding of the patch choices made by a large carnivore while engaged in foraging behaviors is of particular importance to understanding their conflicts with humans. The over-arching goal of this thesis is to test whether the foraging strategies carried out by a large carnivore inhabiting an area marked by human housing development can be explained by classic optimal foraging theory (OFT). My research takes place in a portion of the Colorado Front Range, which is a foothill-montane system characterized by the urban-wildland interface of the greater Denver metropolitan area and surrounding cities (Boulder, Golden, Evergreen). A matrix of varying levels of rural, exurban, and suburban development are expected to drive the patch-choices made by cougar, a large obligate carnivore that can conflict with human interests when it conducts foraging behaviors.

Before answering questions involving patch choice foraging behaviors, several pieces of information must be acquired. Specifically, Chapter 1 and Chapter 2 take an Eulerian approach to understanding the space utilization patterns of wild prey commonly sought by cougar in this area. Predicted utilization by these prey species is mapped for the study area on a fine (30 m) scale, with the premise that cougar may be attracted to localities where the opportunity of encountering a potential prey item is greater. Appendix 2 provides details on methods used to determine the distribution of housing development, a patch characteristic that cougars may have fear toward. This appendix also provides some discussion on the anthropogenic development experienced in the study area. Appendix 4 provides details on the construction of various "natural" landscape variables from readily available data sources.

Chapter 1 shows that simple encounter measures collected from camera traps can provide a measure of landscape utilization for an animal population at extremely fine scale patch size. I demonstrate that the amount of utilization at a patch, whether by one or many animals, is a function of the abundance of animals within some area around the camera and the micro-habitat utilization patterns of the individuals in that population. However, I show that biases will exist in many situations if certain protocols are not adhered to.

Chapter 2 applies the principle from Chapter 1 to produce a landscape utilization map of common cougar prey species at a fine scale. This was done using a count measure of the amount of time spent by animals within the field-of-view of a sample of 131 camera trap sites monitored over a one year period. While doing so, I accounted for the probability of detection within the camera's field-of-view in the count response. Probability of detection was found to be influenced by several environmental and animal specific variables. A secondary focus was to understand the associations between animal utilization and housing development. The associations found were generally supportive of those found in previous studies using habitat selection, occupancy, and abundance as response variables.

Finally in Chapter 3, using cougar as a model species, I test whether a large carnivore's foraging strategy can be explained by optimal foraging theory, which says that an animal makes decisions while foraging that balances the process of acquiring energy with the process of avoiding risks. In seminal optimal foraging works, authors proposed that an animal will be less cautious in avoiding risks when energetically stressed. I demonstrate that cougars make a tradeoff between choosing locations that would yield a higher encounter rate of prey with choosing safer patches. Cougars were found to show avoidance of higher housing densities, but also shown to be attracted to higher primary prey (mule deer) availability. Support for this tradeoff was shown by demonstrating that hunting success increased as cougars hunted in higher housing densities. Furthermore, the strength of the housing avoidance behavior declined as cougar hunger levels increased. A similar behavior was observed during temporal periods associated with assumingly decreased availability of primary prey; cougars became less cautious when imposed with energetic constraints.

The Use of Lures, Hair Snares, and Snow Tracking as Non-Invasive Sampling Techniques to Detect and Identify Cougars – MS Thesis Abstracts
Kirstie Yeager, (Colo. State Univ.), Mat Alldredge (CPW), and Bill Kendall (Colo. State Univ.)

Development of a Noninvasive Method to Sample Cougars (*Puma concolor*)

A noninvasive method that will sample all individuals in a population over multiple occasions is a useful tool in assessing population demographics with little disturbance to the target animals; however, finding such a method for large carnivores, such as cougars, is challenging due to their elusive nature and large home-range sizes. Current methods to sample cougars usually involve a physical capture component, but obtaining reliable estimates can be difficult and cost prohibitive when using capture as the sole sampling method. Because cougars leave sign, and exhibit behaviors like territoriality and curiosity, a noninvasive-genetic-sampling (NGS) method may be a plausible alternative. Hair contains DNA, which can be genetically analyzed to yield the individual identification necessary for population assessments and can be obtained without handling the animal. I tested NGS techniques using attractants, specifically scent lures and auditory calls, and hair snares to sample cougars at lure sites on the Front Range, Colorado during February – April, 2012 and November, 2012 – April, 2013. I established 16 – 20 sites over four ≈ 30-day sampling periods. In general, my results suggest calls are more effective attractants than scents. At sites with auditory calls, photographs documented 40 visits by ≥ 13 individual cougars, and I obtained 14 hair samples. Only 2 hair samples were collected using scented scratch pads and no samples were acquired via a novel hair snare. I conclude that given the ability to successfully genotype the hair samples collected, auditory calls and hair snares may be an effective way to assess the various population demographics that are needed to inform management decisions.

Assessing the Probability of Identifying Cougars by Noninvasive-Genetic Sampling with Auditory Predator Calls and Hair Snares

Detecting all individuals in a population equally and with certainty will yield unbiased population estimates; however, many current sampling techniques for cougars have inherent variation, such as a trap response or individual heterogeneity in detection probability. From November, 2012 – April, 2013, I applied a noninvasive method to sample cougars and assessed variation in detection in 2 study areas in Colorado, one on the Front Range (FR; 1,270 km²) and one on the Uncompahgre Plateau (UP; 540 km²). In total, I established 148 lure sites with auditory predator calls and hair snares over 3 (UP) and 4 (FR) sampling periods. Each site was active an average of 28.5 days (4,214 sampling nights). On the FR, I observed 98 detections by 13 independent marked cougars, 2 sibling groups, and ≥ 16 unique unmarked animals. On the UP, I documented 18 detections by 7 independent marked cougars and no unmarked animals. Collectively, 14 of the 20 marked cougars detected were observed multiple times. I used the GPS location data of 27 previously marked cougars to determine availability and estimated detection probabilities. The probability of detecting an independent marked cougar at least once during the study adjusted for partial availability was 0.83 ± 0.10 (FR) and 1.00 (UP). I collected 59 hair samples. Thirty-two were genotyped at ≥ 8 loci identifying 26 unique cougars. I concluded that a noninvasive-sampling technique using auditory calls and hair snares can be a useful tool in assessing population demographics of cougar populations.

SUPPORT SERVICES

RESEARCH LIBRARY ANNUAL REPORT

<div align="center">**Colorado Parks and Wildlife**</div>

<div align="center">**WILDLIFE RESEARCH REPORT SUMMARY**</div>

<div align="center">**Research library, annual report**</div>

Period Covered: July 1, 2014 – June 30, 2015

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

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 77 years of Federal Aid reports, 7 decades of 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, 2015, the Research Library held 19,464 titles and 32,170 items (these are the multiple copies of a title) and had 172 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 WildPoint (intranet) eliminating the need for individual usernames and passwords.

An on-going project has been the digitization of Colorado Parks and Wildlife publications. This year the Aquatic Federal Aid reports were scanned and the resulting PDFs made available via the Library catalog. At CPW staff request, digital scans of Big Game Hunting brochures from 1949-1996 were made at a local commercial vendor. Due to the large file size, extensive work was required to make the PDFs both word-searchable and transferable. CPW staff can now access these historic files on WildPoint.

In the Fall of 2014, an astute new employee in the Denver office of CPW found several boxes of diaries and logbooks. The boxes made their way to the Library in Ft. Collins where they were discovered to be the extensive hand-written daily logs (1929-1984) of John D. Hart. Hart was a long-time employee who started as a game warden and then served as Assistant Director of Colorado Division of Wildlife. As a collection, the logbooks constitute valuable primary-source material. They were donated to the Western Heritage Collection of Denver Public Library where they will be properly preserved and used by researchers of Colorado's natural resources history.

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 7 years. Please note that one request from a CPW staff member may be for multiple journal or book titles. Even though the

<div align="center">44</div>

total number of requests dropped slightly this year, it is interesting that the current record for number of requests per month was set in January 2015 and then immediately increased in February 2015.

Table 1. Monthly CPW Research Library reference requests August 2008 – July 2015.

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