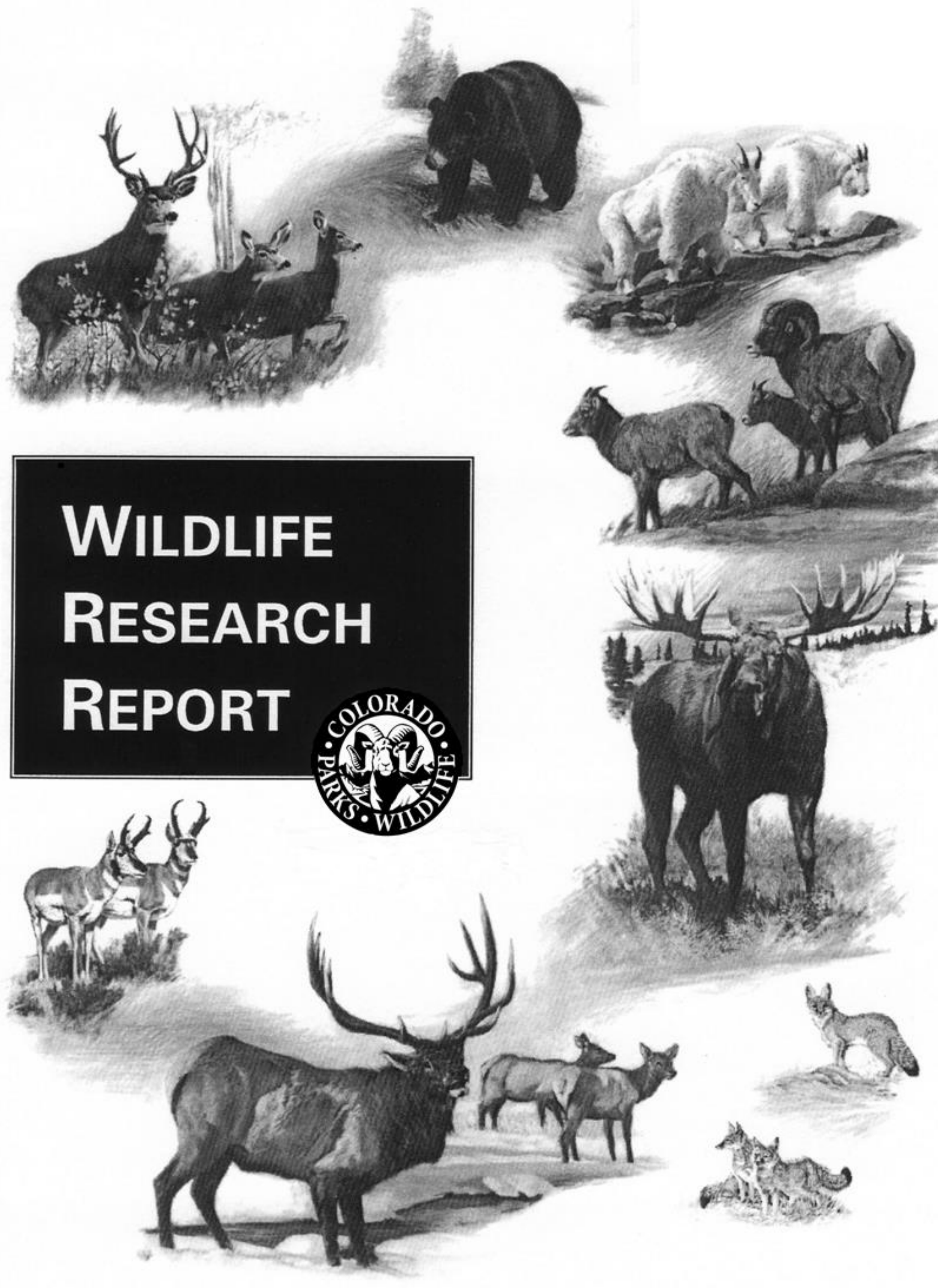
MAMMALS – JULY 2018



WILDLIFE RESEARCH REPORTS

JULY 2017 – JUNE 2018

MAMMALS RESEARCH PROGRAM

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

EXECUTIVE SUMMARY

This Wildlife Research Report represents summaries (≤5 pages each) of wildlife research projects conducted by the Mammals Research Section of Colorado Parks and Wildlife (CPW) from July 2017 through June 2018. These research efforts represent long term projects (4–10 years) in various stages of completion addressing applied questions to benefit the management of various mammal species in Colorado. In addition to the research summaries presented in this document, more technical and detailed versions of most projects (Annual Federal Aid Reports) and related scientific publications that have thus far been completed can be accessed on the CPW website at http://cpw.state.co.us/learn/Pages/ResearchMammalsPubs.aspx or from the project principal investigators listed at the beginning of each summary.

Current research projects address various aspects of wildlife management and ecology to enhance understanding and management of wildlife responses to habitat alterations, human-wildlife interactions, and investigating improved approaches for wildlife and habitat management. The Nongame Mammal Conservation Section addresses preliminary results of lynx prey (snowshoe hare and red squirrel) responses to the recent spruce beetle outbreak in Colorado, lynx population monitoring results from the San Juan Mountain Range in southwest Colorado since 2014, and a recent project addressing influence of forest management practices on snowshoe hare density in Colorado. The Ungulate Conservation Section includes 3 projects addressing development planning and mitigation approaches to benefit mule deer exposed to energy development activity, evaluation of moose demographic parameters that will inform future moose management in Colorado, and a pilot study addressing factors influencing elk calf recruitment. The Predatory Mammal Conservation Section addresses black bear use of urban/exurban environments and approaches for managing black bear-human interactions, and evaluation of harvest management for mountain lions in western Colorado and a literature review evaluating factors that may limit mountain lion populations for management consideration. The Support Services Section describes the CPW library services to provide internal access of CPW publications and online support for wildlife and fisheries management related publications.

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

STATE OF COLORADO
John Hickenlooper, *Governor*

DEPARTMENT OF NATURAL RESOURCES
Bob Randall, *Executive Director*

PARKS AND WILDLIFE COMMISSION

John V. Howard, C*hair*……………………………………………………………………......... Boulder
Michelle Zimmerman, *Vice Chair*.…………………………………………………………Breckenridge
James Vigil, *Secretary*…………………………………………………….………………......Trinidad
Robert Bray……………………………………………………………………………………Redvale
Marie Haskett ……………………………………….……………….….……………….............Meeker
Carrie Besnette Hauser….………………………………………………………………..Glenwood Springs
Marvin McDaniel……………………………………………………………….……………… Sedalia
Dale E. Pizel…………………………………………………………………………………... Creed
Robert “Dean” Wingfield………………………………………………………………………Vernon
Alexander Zipp………………………………………………………………………………… Pueblo
Don Brown, Dept. of Agriculture, *Ex-officio*….………………………………..…….………............Yuma
Bob Randall, Executive Director, *Ex-officio*……….…………………...…………………….…….......Denver

DIRECTOR’S LEADERSHIP TEAM

Bob Broscheid, Director
Reid DeWalt, Heather Dugan, Justin Rutter
Margret Taylor, Gary Thorson, Jeff Ver Steeg,
Patt Dorsey, Dan Prenzlow, JT Romatzke, Mark Leslie

MAMMALS RESEARCH STAFF

Chuck Anderson, Mammals Research Leader
Mat Alldredge, Wildlife Researcher
Alexandria Austermann, Research Librarian
Eric Bergman, Wildlife Researcher
Michelle Gallagher, Program Assistant
Jake Ivan, Wildlife Researcher
Ken Logan, Wildlife Researcher
Nathaniel Rayl, Wildlife Researcher

Colorado Parks and Wildlife
July 2017 – June 2018

TABLE OF CONTENTS
MAMMALS WILDLIFE RESEARCH REPORTS

NONGAME MAMMAL CONSERVATION

NUMERICAL RESPONSE OF SNOWSHOE HARES AND RED SQUIRRELS TO CHANGED FOREST STRUCTURE RESULTING FROM SPRUCE BEETLE OUTBREAKS IN SOUTHWEST COLORADO by J. Ivan and E. Newkirk……………...…………………………………...…………………………………...2

CANADA LYNX MONITORING IN COLORADO by E. Odell, J. Ivan and S. Wait ……….....7

INFLUENCE OF FOREST MANAGEMENT ON SNOWSHOE HARE DENSITY IN LODGEPOLE AND SPRUCE-FIR SYSTEMS IN COLORADO by J. Ivan and E. Newkirk ….12

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 by C. Anderson ……………………………………………………………….16

EVALUATION AND INCORPORATION OF LIFE HISTORY TRAITS, NUTRITIONAL STATUS AND BROWSE CHARACTERISTICS IN SHIRA'S MOOSE MANAGEMENT IN COLORADO by E. Bergman ..………………………………….21

ELK RECRUITMENT AND HABITAT USE IN COLORADO by M. Alldredge, N. Rayl, B. Banulis and A. Vitt ..……………………………………………………………25

PREDATORY MAMMAL CONSERVATION

BLACK BEAR EXPLOITATION OF URBAN ENVIRONMENTS: FINDING MANAGEMENT SOLUTIONS AND ASSESSING REGIONAL POPULATION EFFECTS by H. Johnson…………………………………………………………………… 29

EFFECTS OF PUMA HUNTING ON A PUMA POPULATION IN COLORADO by K. Logan and J. Runge……………………………………………………………...…………………….34

WHAT LIMITS AND REGULATES PUMA POPULATIONS? WHAT MATTERS? by K. Logan ………………………………………………………………………………………….34

SUPPORT SERVICES

LIBRARY SERVICES by A. Austermann.…….……………………………...…………………36

NONGAME MAMMAL CONSERVATION

NUMERICAL RESPONSE OF SNOWSHOE HARES AND RED SQUIRRELS
TO CHANGED FOREST STRUCTURE RESULTING FROM
SPRUCE BEETLE OUTBREAKS IN SOUTHWEST COLORADO

CANADA LYNX MONITORING IN COLORADO

INFLUENCE OF FOREST MANAGEMENT ON SNOWSHOE HARE DENSITY
IN LODGEPOLE AND SPRUCE-FIR SYSTEMS IN COLORADO

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Numerical response of snowshoe hares and red squirrels to changed forest structure resulting from spruce beetle outbreaks in southwest Colorado.

Period Covered: July 1, 2017–June 30, 2018

Principal Investigators: Jake Ivan, Jake.Ivan@state.co.us; Eric Newkirk, Eric.Newkirk@state.co.us

Mountain pine beetle (*Dendroctonus ponderosae*) and spruce beetle (*Dendroctonus rufipennis*) outbreaks have reached epidemic levels in Colorado, impacting over 4 million acres of lodgepole pine (*Pinus contorta*) and Engelmann spruce (*Picea engelmanni*)-subalpine fir (*Abies lasiocarpa*) systems since 1996. Recently, Ivan et al. (2018) completed a large-scale project to assess impacts of beetle outbreaks on occupancy patterns of a suite of wildlife species in Colorado. Among other results, this initial work indicated that snowshoe hare (*Lepus americanus*) occupancy remained largely unchanged during the first decade after beetles impact an area. However, use of beetle impacted stands by red squirrels (*Tamiasciurus hudsonicus*) dropped markedly approximately 4 years post-outbreak and then remained low, especially in stands that had been severely impacted.

Occupancy estimation is a useful metric for determining broad changes in distribution or habitat use by a species through time or by treatment. However, it is also coarse and can be misleading in some cases. For instance, it is possible that snowshoe hare density increased or decreased in response to beetles, yet occupancy remained unchanged because hares did not expand or decrease their distribution. Because snowshoe hares and red squirrels together comprise nearly 100% of the winter diet of federally threatened Canada lynx in Colorado (Ivan and Shenk 2016), it is important understand their response to these outbreaks more thoroughly. Here we describe a follow-up study designed to provide a more detailed assessment of changes in density of these two important prey species in response to spruce beetle outbreaks in core lynx habitat in the San Juan Mountains. Our sampling strategically included sites with and without a strong fir understory, in addition to spruce, in order to assess the importance of this particular habitat feature in dictating hare density. Anecdotal evidence suggests that subalpine fir may be an important determinant. Additionally, we counted snowshoe hare pellets at cleared plots immediately after estimating winter density in order to assess whether the relationship between the two metrics could be relied on to more efficiently sample and monitor hare densities in Colorado.

We used a series of GIS layers depicting forest composition, stand structure and age, spruce beetle extent, and mortality of overstory trees to identify 15 study sites that collectively covered a gradient of years elapsed since initial beetle outbreak (YSO) as well as varied ratios of subalpine fir (ABLA): Engelmann spruce (PIEN) subcanopy. We were careful to control for all other aspects so as to isolate the effects of YSO and fir subcanopy on prey density. That is, the selected sites were comparable with respect to severity of beetle impact (except for control sites), slope, aspect (north facing), elevation, structural stage, lack of previous management, etc.

We sampled snowshoe hares at each of the 15 study sites using a combination of mark-recapture and GPS telemetry (Ivan et al. 2013, Ivan et al. 2014) from December 2016–March 2017. Simultaneously, we conducted distance sampling surveys to estimate red squirrel density at the same sites, although that analysis is ongoing and not presented here. We used the 'Density with Telemetry' data type in Program MARK (White and Burnham 1999, Ivan et al. 2013) to obtain density estimates from each of the 15 sites. We then treated these density estimates as response variables and fit linear models through them to test our hypotheses regarding the relationship between snowshoe hare density and YSO or subcanopy. Specifically, we fit an intercept only (mean) model as a point of reference, then fit YSO, PIEN subcanopy, ALBA subcanopy, and total subcanopy singly along with YSO in combination with each. We used Akaike's Information Criterion (AIC, Burnham and Anderson 2002) and precision of coefficients to discern which variables were most associated with hare density. We also fit a simple linear model to relate mean pellets/plot in each stand to estimated snowshoe hare density for that stand. We fit these pellet-plot models with no intercept, thus forcing a relationship in which a mean of zero pellets per plot indicates a density of 0 hares/ha.

The best fitting beetle-habitat model included only total subcanopy as the sole explanatory variable. The model including only ABLA subcanopy was second best, and the effect of ABLA significantly positive. Models that included only YSO and only PIEN subcanopy were actually worse, or only slightly better than the intercept only model, indicating almost no relationship between snowshoe hare density and either of these metrics. Thus, site to site variation subcanopy, especially fir subcanopy (which is likely a function of soils, moisture, and other abiotic factors that determine site potential) is a more important driver of snowshoe hare density than the number of years elapsed since beetles impacted an area (Figures 2–4). Final analyses are ongoing and will include 1) fitting more complicated density models, 2) fitting more and different covariates representing other potentially important attributes of the sampled stands, and 3) fitting weighted linear models to acknowledge that the density response variables are themselves estimates with error around them, and estimates with better precision should carry more weight than those with more uncertainty.

The pellet-plot model showed a strong, positive, linear association between the mean number of pellets counted at a site (index) and the estimated snowshoe hare density at that site (parameter; Figure 5), as has been shown elsewhere (e.g., Berg and Gese 2010) . These results suggest that sampling snowshoe hare pellets, which is inexpensive and efficient compared to capturing and collaring hares, can be a useful tool for indexing snowshoe hare density in Colorado. Final analyses are pending and will include re-fitting the model after standardizing pellet data to pellets/month to account for differing amounts of time elapsed between when plots were cleared and when they were counted.

Literature Cited:

Berg, N. D., and E. M. Gese. 2010. Relationship Between Fecal Pellet Counts and Snowshoe Hare Density in Western Wyoming. Journal of Wildlife Management 74:1745–1751.

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

Ivan, J. S., A. E. Seglund, R. L. Truex, and E. S. Newkirk. 2018. Mammalian responses to changed forest conditions resulting from bark beetle outbreaks in the southern Rocky Mountains. Ecosphere 9:e02369.

Ivan, J. S., and T. M. Shenk. 2016. Winter diet and hunting success of Canada lynx in Colorado. The Journal of Wildlife Management 80:1049–1058.

Ivan, J. S., G. C. White, and T. M. Shenk. 2013. Using auxiliary telemetry information to estimate animal density from capture-recapture data. Ecology 94:809–816.

Ivan, J. S., G. C. White, and T. M. Shenk. 2014. Density and demography of snowshoe hares in central Colorado. Journal of Wildlife Management 78:580–594.

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

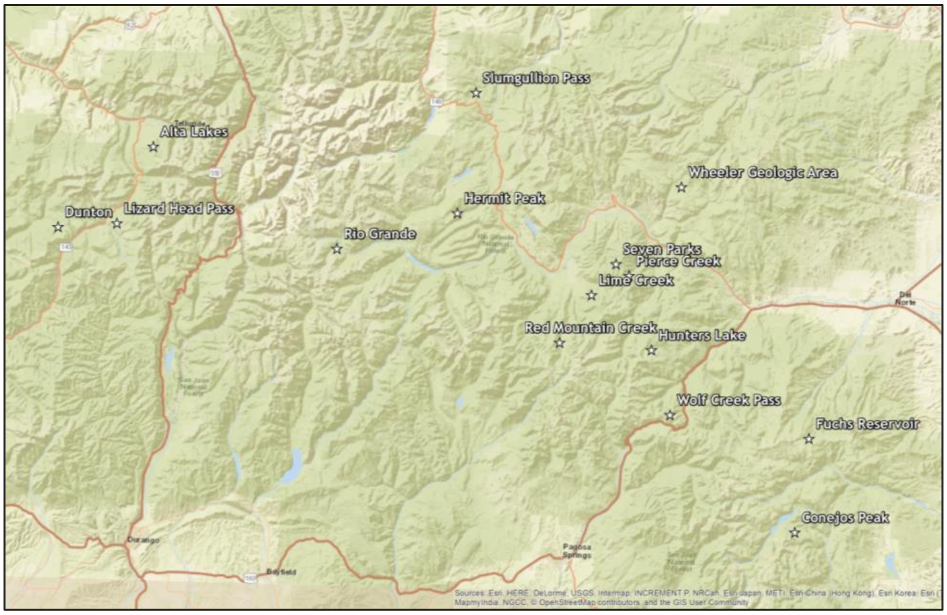


Figure 1. Study sites (n = 15) selected to cover a gradient of years since spruce beetle outbreak in the San Juan Mountains, Colorado, December 2016–January 2017. The 3 western-most sites were green forests that were largely unimpacted at the time of sampling; eastern sites incurred overstory mortality 1–11 years prior to sampling.

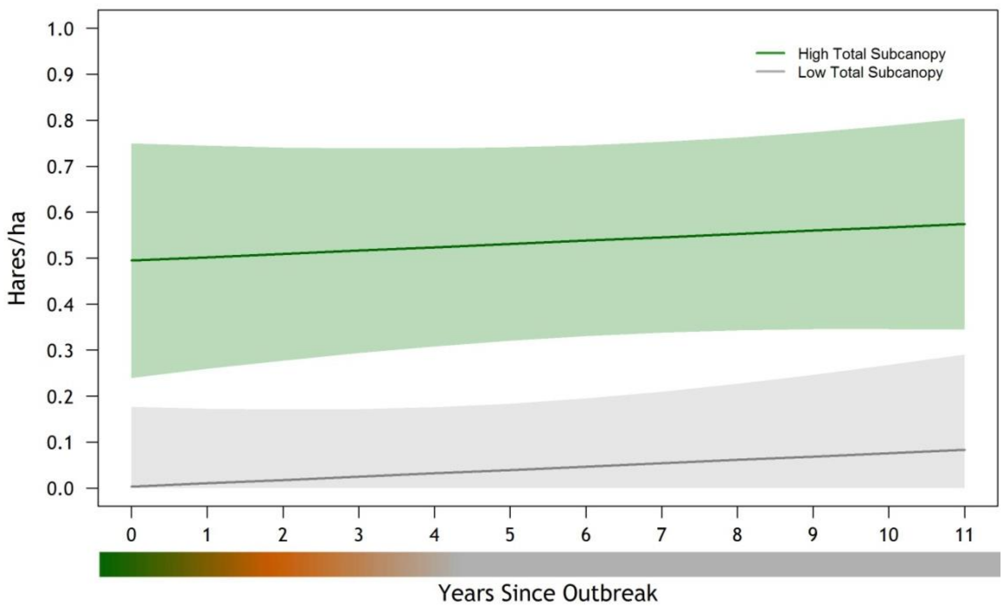


Figure 2. Modeled relationship between snowshoe hare density and years elapsed since spruce beetles first impacted a site. Fitted predictions and 95% CIs are for sites with the highest (e.g., Hunters Lake, Hermit Peak) and lowest (e.g., Wheeler Geologic Area, Wolf Creek Pass) observed subcanopy cover. Note that the difference between low and high subcanopy is associated with a significant difference in snowshoe hare density (~0.0 hares/ha at low subcanopy; ~0.5 hares/ha at high subcanopy), but years since outbreak makes little difference in hares/ha.

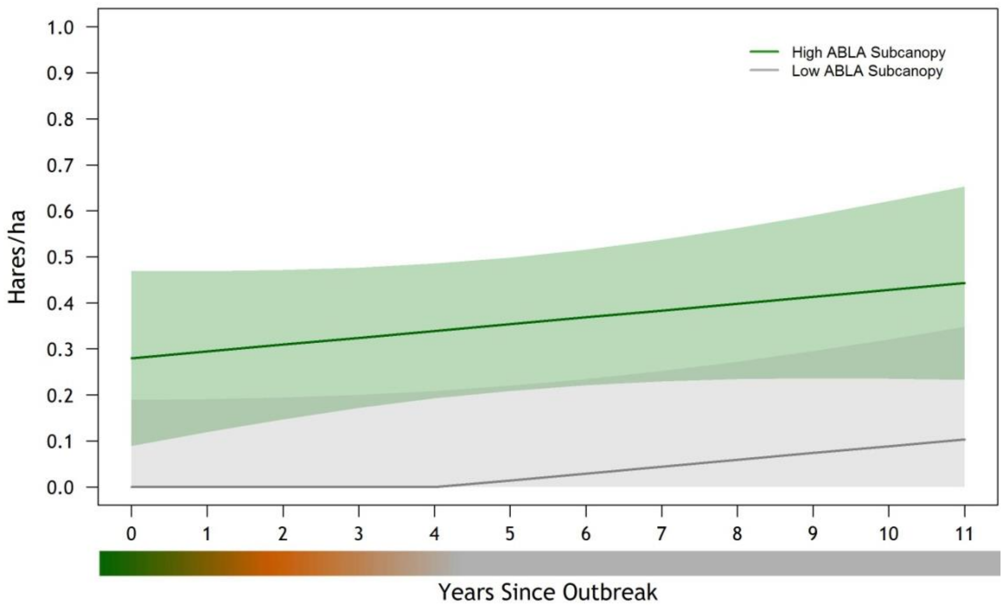


Figure 3. Modeled relationship between snowshoe hare density and years elapsed since spruce beetles first impacted a site. Fitted predictions and 95% CIs are for sites with the highest (e.g., Hunters Lake, Hermit Peak) and lowest (e.g., Wheeler Geologic Area, Wolf Creek Pass) observed subcanopy cover of subalpine fir (ABLA). Note that much of the difference depicted in Figure 2 can be explained by ABLA subcanopy.

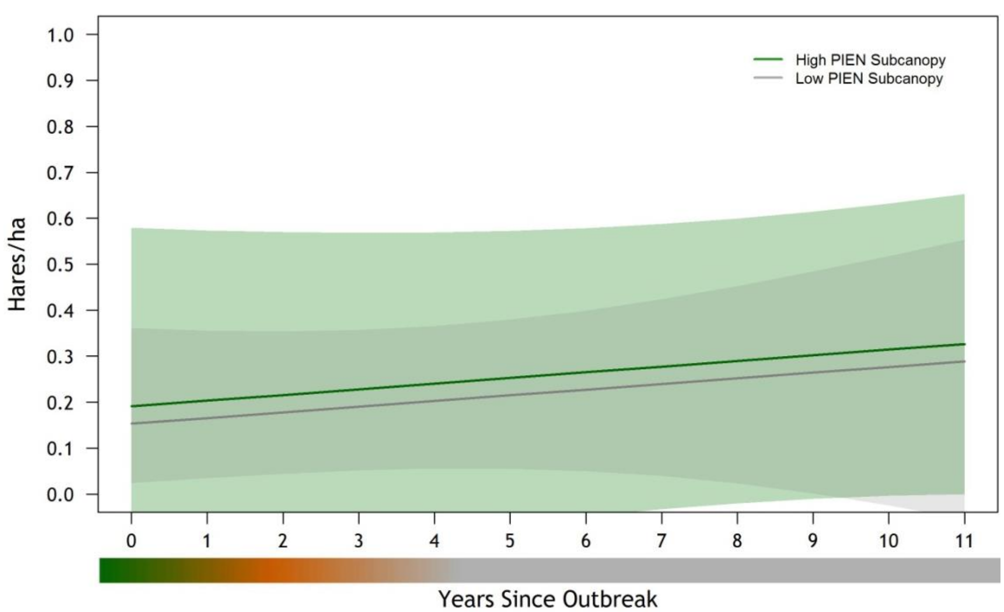


Figure 4. Modeled relationship between snowshoe hare density and years elapsed since spruce beetles first impacted a site. Fitted predictions and 95% CIs are for sites with the highest and lowest observed subcanopy cover of Engelmann spruce (PIEN). Note that the difference between low and high PIEN subcanopy is not strongly associated with a significant difference in snowshoe hare density (means are nearly identical, CIs overlap considerably).

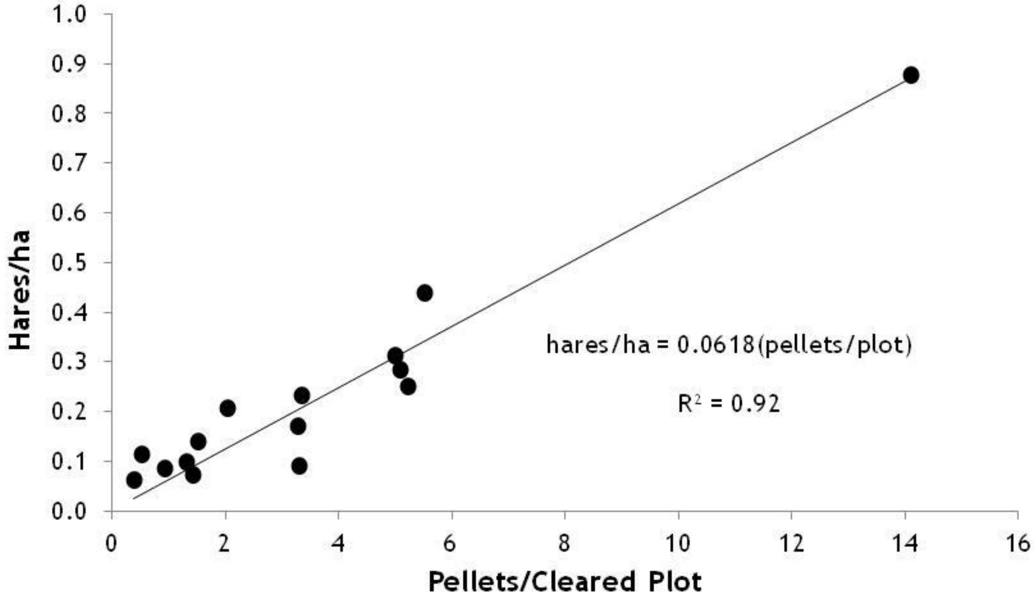


Figure 5. Fitted linear relationship between snowshoe hare density and mean number of pellets per cleared 1-m^2 plot. Note the outlying site (Hunters Lake), which potentially has significant influence on the regression. Removal of this site does not change the slope, but does reduce the R^2 to 0.70, which is still a good fit and indicates a strong association between the index (mean pellets/plot) and estimated parameter (density).

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Canada Lynx Monitoring in Colorado

Period Covered: July 1, 2017–June 30, 2018

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

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

In an effort to restore a viable population of Canada lynx (*Lynx canadensis*) to the southern portion of their former range, 218 individuals were reintroduced into Colorado from 1999–2006. In 2010, the Colorado Division of Wildlife (now Colorado Parks and Wildlife [CPW]) determined that the reintroduction effort met all benchmarks of success, and that the population of Canada lynx in the state was apparently viable and self-sustaining. In order to track the persistence of this new population and thus determine the long-term success of the reintroduction, a minimally-invasive, statewide monitoring program is required. During 2014–2018 CPW initiated a portion of the statewide monitoring scheme described in Ivan (2013) by completing surveys in a random sample of monitoring units (n = 50) from the San Juan Mountains in southwest Colorado (n = 179 total units; Figure 1).

During 2017–2018, personnel from CPW and U.S. Forest Service (USFS) completed the fourth year of monitoring work on this same sample. Specifically, 14 units were sampled via snow tracking surveys conducted between December 1 and March 31. On each of 1–3 independent occasions, survey crews searched roadways (paved roads and logging roads) and trails for lynx tracks. Crews searched the maximum linear distance of roads possible within each survey unit given safety and logistical constraints. Each survey covered a minimum of 10 linear kilometers (6.2 miles) distributed across at least 2 quadrants of the unit. An additional unit was scheduled for snow track surveys but surveys were not completed. The remaining 35 units could not be surveyed via snow tracking. Instead, survey crews deployed 4 passive infrared motion cameras in each of these units during fall 2017. Cameras were baited with visual attractants and scent lure to enhance detection of lynx living in the area. Cameras were retrieved during summer 2018 and all photos were archived and viewed by at least 2 observers to determine species present in each. Camera data were then binned such that each of 10 15-day periods from December 1 through April 30 was considered an 'occasion,' and any photo of a lynx obtained during a 15-day period was considered a 'detection' during that occasion.

Surveyors covered 538 km during snow tracking surveys and detected lynx at 7 units (Table 1). This represents a 4-year low in snow tracking effort and is partially due to switching 4 tracking units to camera units since the beginning of the project, and partially due to lack of snow during the 2017–2018 winter. Surveyors were only able to complete 3 visits to 36% of snow tracking units in 2017–2018, whereas in previous years, 50–71% were surveyed 3 times. The mean distance surveyed as well as the number of units with lynx remained similar to previous years. Surveyors collected more photos during 2017–2018 than in any other year, again due to slowly replacing snow tracking units with camera units over the years. However, we collected <50% of the usual number of lynx photos and the number of units with lynx continued to decline (Table 2). Perhaps this reflects a real decline in lynx abundance or distribution, or perhaps the lack of snow changed lynx behavior and habitat use, resulting in fewer photos. Lack of snow could have altered our detection probability as well (cameras are positioned to account for 1–2 m of snow, which never accumulated). Alternatively, lack of detections could have been due to the new lure (Caven's Violator 7; Minnesota Trapline Products, https://www.minntrapprod.com/Bobcat-and-

Lynx/products/829/) we used in 2017–2018 after the lure we used previously (Pikauba; Luerres Forget's Lures, http://www.leurresforget.com/product.php?id_product=15) became unavailable. Unfortunately, the changes in snow and lure are confounded, thus making it difficult to determine which factor resulted in fewer detections. We will use the Caven's Violator 7 lure in 2018–2019, which, if accompanied by a normal snowfall, may allow us to retrospectively assess the cause of the lack of detections. Compared to previous years, we obtained new lynx detections at a camera unit near Wolf Creek Pass, but failed to detect lynx in the upper Williams Creek or in the La Garita Mountains north of Creede (Figure 1). An adult female with kittens was detected at cameras in a unit near Platoro Reservoir, thus documenting that at least some reproduction occurred in the study area.

We used the R (R Development Core Team 2018) package 'RMark' (Laake 2018) to fit standard occupancy models (MacKenzie *et al.* 2006) to our survey data using program MARK (White and Burnham 1999). Thus, we estimated the probability of a unit being occupied (i.e., used) by lynx over the course of the winter, along with the probability of detecting a lynx (p) given that the unit was occupied. 'Survey method' and 'year' were treated as group variables so that we could, based on previous work, 1) allow detection probability (p) to vary by survey method, 2) allow for detection probability for 2017–18 to differ from other years due to the lack of snow or new lure, and 3) include a breeding season effect for detection at cameras (lynx tend to move more in late winter when they begin to breed, and thus should encounter cameras more often). We also considered a suite of covariates that could potentially explain variation in occupancy (ψ) including proportion of the unit that was covered by spruce/fir forest, average years since bark beetle infestation, variability (standard deviation) in years since bark beetle infestation, proportion of the unit impacted by bark beetles, proportion of the unit that was burned during Summer 2013, and the number of photos of other species that could potentially impact presence of lynx (e.g., snowshoe hares as a food source, coyotes as potential competitors). We limited our model set by first setting a general structure for ψ while assessing fit of various combinations of variables expected to affect p. We then fixed the best-fitting structure for p, and assessed combinations of the covariates expected to influence ψ, allowing up to 2 of these covariates at a time, in addition to the covariates on detection. We included data from the pilot study (2010–2011) as well as the first 4 years of monitoring (2014–2018) to maximize sharing of information across surveys.

As in past years, the best-fitting model characterized occupancy as a function of 2 covariates: the proportion of the sample unit covered by spruce-fir forest and the number of photos of hares recorded at camera stations (Appendix 1). In both cases, the association was positive, indicating that the probability of lynx use increased with more spruce-fir and more hares. Other covariates appeared in top models with spruce-fir, but addition of these covariates did not improve AIC_c scores beyond the model with spruce-fir only (Appendix 1). This phenomenon indicates that these other variables were not informative. Detection probability was relatively high for snow tracking surveys ($p = 0.61$, SE = 0.05), and relatively low for camera surveys ($p = 0.21$, SE = 0.03) during December–February and April, although detection at cameras increased to 0.41 (SE = 0.07) during breeding season (March) as expected. We found a significant, negative effect of the winter of 2017–2018 on detection probability for cameras ($p = 0.05$, SE = 0.03 for December–February and April; $p = 0.13$, SE = 0.04 for breeding season). It is unclear whether this drop in detection probability was due to the lack of snow or the alternate scent lures. We estimated that 38% of the sample units in the San Juan's were occupied by lynx (95% confidence interval: 13–71%). Occupancy estimates from the 2017–2018 monitoring effort were the highest observed to date. However, confidence intervals were quite large, owing to the extra effect needed to model detection in 2017–2018 and to the low, poorly estimated detection probability that resulted (Figure 2). The spatial distribution of lynx in the San Juan's remained largely unchanged (Figure 1).

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

Laake, J. L. 2018. Package 'RMark': R Code for Mark Analysis. Version 2.2.5. https://cran.r-project.org/web/packages/RMark/RMark.pdf.

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.

R Development Core Team. 2018. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org.

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

Table 1. Summary statistics from snow tracking effort.

Season	#Units Surveyed	#Units with Lynx	#Lynx Tracks	#Genetic Samples[a]	Km Surveyed (Total)	Mean Km Surveyed per Visit	#CPW Personnel	#USFS Personnel
2014–2015	18	7	12	8[b]	884	20.1	30	13
2015–2016	17	7	14	9[c]	987	21.9	23	6
2016–2017	16	8	13	7[d]	703	18.0	20	8
2017–2018	14	7	9	3[e]	538	18.5	14	5

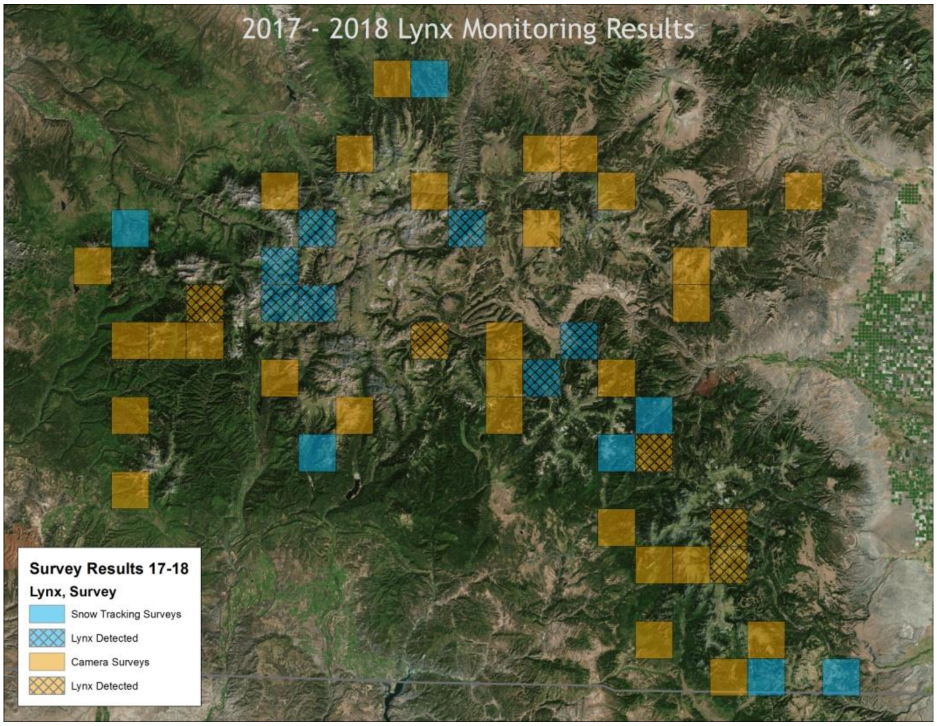
[a] Number of genetic samples (scat or hair) collected via backtracking putative lynx tracks
[b]DNA analysis confirms that all samples collected from putative lynx tracks were lynx
[c]DNA analysis confirms that 6 of 9 samples were lynx (1 coyote, 1 either mule deer or human, 1undetermined)
[d]DNA analyses confirmed that 5 of 7 samples were lynx (1 coyote, 1 snowshoe hare)
[e]DNA confirmation pending

Table 2. Summary statistics from camera effort.

Season	#Units Surveyed	#Units With Lynx[a]	#Photos (Total)	#Photos (Lynx)	#Cameras With Lynx	#CPW Personnel	#USFS Personnel
2014–2015	32	8 (7)	134,694	301	14	46	12
2015–2016	31	7 (6)	101,534	455	10	33	9
2016–2017	33	6 (5)	168,705	251	10	29	9
2017–2018	35	5 (4)	173,279	90	8	35	8

[a] Number in parenthesis indicates units with lynx during the official survey period (Dec 1–Apr 30)

a)



b)

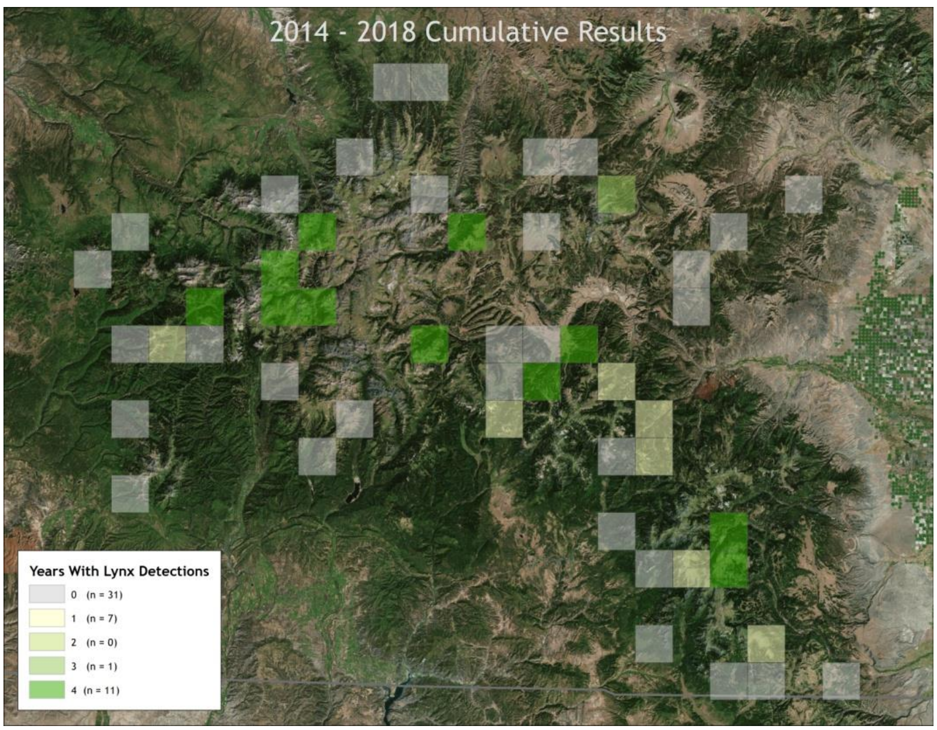


Figure 1. Lynx monitoring results for a) the current sampling season (2017–2018) and b) the cumulative monitoring effort (2014–2018), San Juan Mountains, southwest Colorado. Colored units (*n* = 50) indicate those selected at random from the population of units (*n* = 179) encompassing lynx habitat in the San Juan Mountains. Lynx were detected in 12 units in 2017–2018 and 19 units cumulatively since monitoring began in 2014–2015.

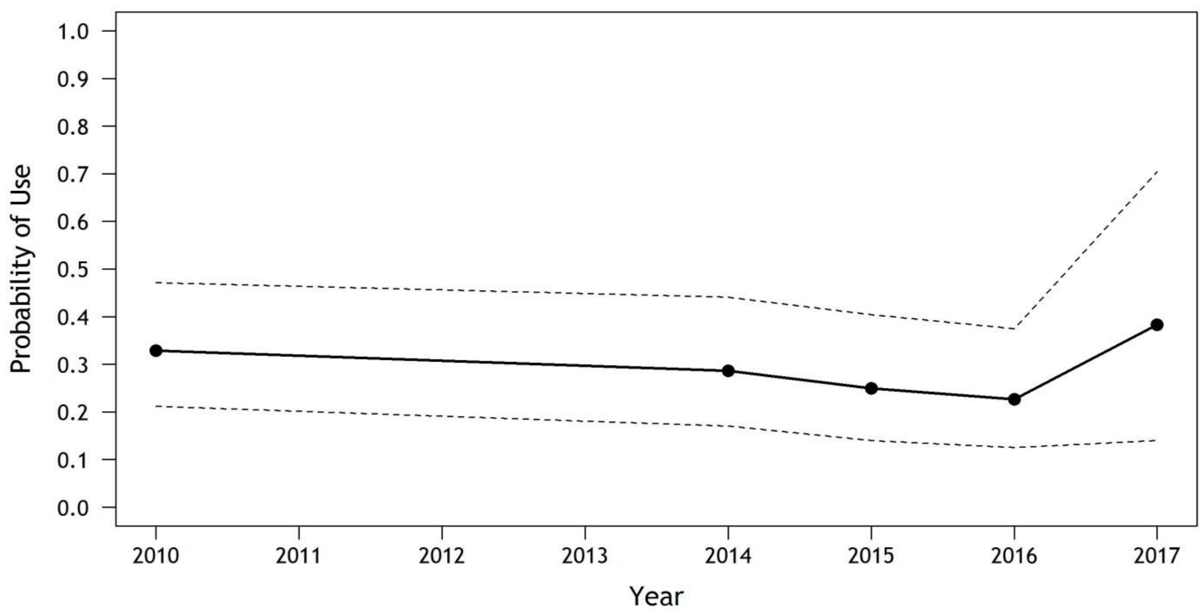


Figure 2. Model-averaged occupancy estimates and 95% confidence intervals for Canada lynx in the San Juan Mountains, southwest Colorado. 'Year' indicates when the efforts were initiated (e.g., 2010–11, 2017–18).

Appendix 1. Model selection results for lynx monitoring data collected in the San Juan Mountains, Colorado, 2010–2018. Rankings are based on Akaike's Information Criterion adjusted for small sample size (AIC_c). Ten variables were considered as covariates to inform estimation of occupancy (ψ). The complete model set (n = 56) included all combinations of two, in addition to modeling detection (*p*) as a function of survey method, breeding season, and the low-snow winter of 2017 for cameras. Only the best 10 models are shown.

Model	AIC_c	ΔAIC_c	AIC_c Wts	No. Par.
p(Best[a])Ψ(Hare + SpruceFir + Year)	746.3	0.0	0.44	11
p(Best)Ψ(Fox + SpruceFir + Year)	749.0	2.7	0.11	11
p(Best) Ψ (SpruceFir + Year)	749.3	3.0	0.10	10
p(Best) Ψ (PropBurn + SpruceFir + Year)	750.3	4.0	0.06	11
p(Best) Ψ (Coyote + SpruceFir + Year)	750.6	4.3	0.05	11
p(Best) Ψ (Bobcat + SpruceFir + Year)	750.8	4.5	0.05	11
p(Best) Ψ (YrsSinceBeetle + SpruceFir + Year)	750.8	4.5	0.05	11
p(Best) Ψ (Cougar + SpruceFir + Year)	750.9	4.6	0.05	11
p(Best) Ψ (SDBeetleKill + SpruceFir + Year)	751.4	5.1	0.03	11
p(Best) Ψ (PropBeetle + SpruceFir + Year)	751.5	5.2	0.03	11

[a]Best-fitting structure for detection probability included effects for survey method, breeding season, and an effect of the low-snow winter of 2017 on cameras.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Influence of forest management on snowshoe hare density in lodgepole and spruce-fir systems in Colorado

Period Covered: July 1, 2017–June 30, 2018

Principal Investigators: Jake Ivan, Jake.Ivan@state.co.us; Eric Newkirk, Eric.Newkirk@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.

Understanding and monitoring snowshoe hare (*Lepus americanus*) density in Colorado is important because hares comprise 70% of the diet of the state-endangered, federally threatened Canada lynx (*Lynx canadensis*; U.S. Fish and Wildlife Service 2000, Ivan and Shenk 2016). Forest management is an important driver of snowshoe hare density, and all National Forests in Colorado are required to include management direction aimed at conservation of Canada lynx and snowshoe hare as per the Southern Rockies Lynx Amendment (SRLA; https://www.fs.usda.gov/detail/r2/landmanagement/planning/?cid= stelprdb5356865). At the same time, Forests in the Region are compelled to meet timber production and management response obligations. Such activities may depress snowshoe hare density, improve it, or have mixed effects dependent on time elapsed since the activity. Here we describe a sampling scheme to assess impacts of common forest management techniques on snowshoe hare density in both lodgepole pine and spruce-fir systems statewide.

To select forest stands for sampling, we first used U. S. Forest Service (USFS) spatial data to delineate all spruce-fir and lodgepole pine stands (stratum 1) on USFS land in Colorado, and identified all of the management activities that have occurred in each stand over time. With consultation from the USFS Region 2 Lynx-Silviculture Team, we then grouped relevant forest management activities (stratum 2) into 4 broad categories: even-aged management, uneven-aged management, thinning, and unmanaged (controls). We then documented the 2-decade window (stratum 3) during which the most recent action was completed. Finally, we selected a spatially balanced random sample of 5 stands within each combination of forest type × management activity × completion date combination to ensure we sampled a complete gradient of time since implementation for each management activity of interest in each forest type of interest (Figure 1, 2). There is no "completion date" for unmanaged controls, so we simply sampled 10 randomly selected stands from this combination. Also, uneven-aged lodgepole pine treatments are rare, so we did not sample that combination, leaving a total of n = 105 stands sampled.

We sampled n = 50 1-m^2 circular plots within each of the n = 105 stands selected for sampling. Plots were also selected in a spatially balanced, random fashion. In 2018, technicians cleared and counted snowshoe hare pellets in each plot. Pellet information from uncleared plots is less accurate than that from previously cleared plots because uncleared plots invariably include pellet accumulation across several years (Hodges and Mills 2008). The degree to which previous years are represented can depend on local weather conditions, site conditions at the plot, and variability in actual snowshoe hare density over previous winters. Nevertheless, data from uncleared plots can be a reasonable indicator of relative snowshoe hare density (Hodges and Mills 2008). Therefore, we computed the mean number of pellets/plot for each forest type × management activity × completion date combination to make an initial assessment of the impacts of forest management on snowshoe hare density (Figure 2). Note that these indices of relative hare density are coarse at best; indices based on data collected from cleared plots in 2019 should more accurately depict snowshoe hare density.

Preliminary results suggest that the highest snowshoe hare densities occur in unmanaged spruce-fir forests. Management of such stands generally leads to lower snowshoe hare densities, although densities comparable to unmanaged stands can be achieved 20–40 years after uneven-aged treatments, or 0–20 years after thinning. Even-aged treatments appear to depress hare densities 0–60 years after treatment. The opposite appears to be true in lodgepole pine systems. That is, thinning a previously unmanaged stand can lead to higher hare densities 0–60 years post-treatment compared to unmanaged stands. Similarly, hare densities in even-aged treatments appear higher than in unmanaged stands 20–60 years post-treatment (Figure 2).

Literature Cited:

Hodges, K. E., and L. S. Mills. 2008. Designing fecal pellet surveys for snowshoe hares. Forest Ecology and Management 256:1918–1926.

Ivan, J. S., and T. M. Shenk. 2016. Winter diet and hunting success of Canada lynx in Colorado. The Journal of Wildlife Management 80:1049–1058.

U.S. Fish and Wildlife Service. 2000. Endangered and threatened wildlife and plants: determination of threatened status for the contiguous U. S. distinct population segment of the Canada lynx and related rule, final rule. Federal Register 65:16052–16086.

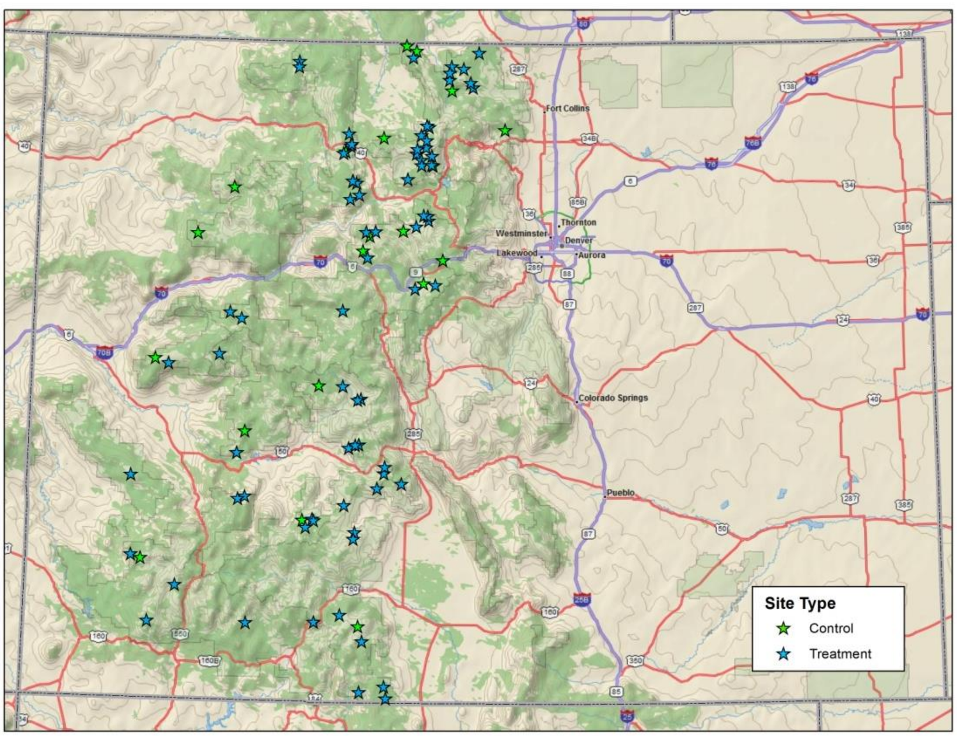


Figure 1. Location of all stands (n = 105) selected for pellet plot sampling, June–September 2018. At each stand, n = 50 1-m^2 permanent pellet plots were installed at random locations, and all snowshoe hare pellets within these were counted and cleared.

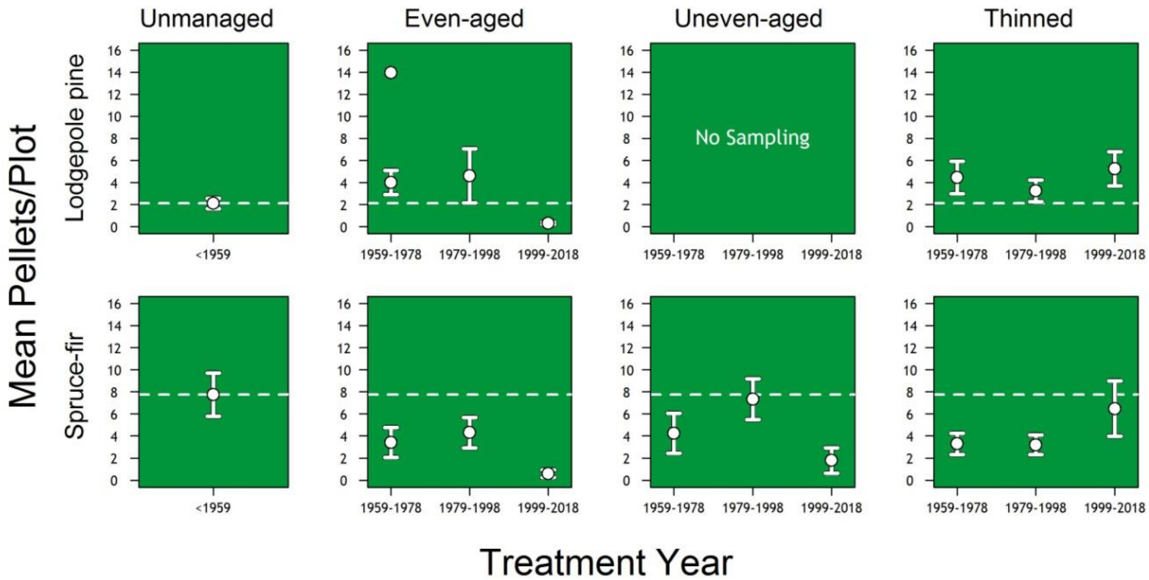


Figure 2. Mean (95% CIs) pellets/plot sampled at each forest type × management activity × completion date combination. Dotted lines indicate the mean pellets/plot for the unmanaged forest type for comparison to management actions. Lodgepole pine stands are rarely managed in uneven fashion, therefore no such stands were sampled. Note the extreme outlier depicted by a single dot in the lodgepole pine, even-aged panel. This is the point estimate derived from all of the data in that completion date bin, including that from a single stand in which the average pellet count was an order of magnitude larger than anywhere else we sampled. These data seem suspect as hares are not thought to reach high densities in very old clearcuts. The data point with associated standard error is the estimate if this potential outlier is omitted.

UNGULATE AND HABITAT CONSERVATION

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

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

ELK RECRUITMENT AND HABITAT USE IN COLORADO

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

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, 2017–June 30, 2018

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

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

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 preliminary and final results of a 10-year research project 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, estimated neonatal, overwinter fawn and annual adult female survival, estimated early and late winter body condition of adult females, and estimated annual abundance among study areas. During this research segment, we targeted 240 fawns (60/study area) and 120 does (30/study area) in early December 2017 for VHF and GPS radiocollar attachment, respectively, and attempted recapture of 120 does (30/study area) and 40 fawns (20 in 2 study areas) in March 2018 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.

Based on final (migration, mule deer behavioral responses, reproductive success and neonate survival) and preliminary data analyses for this 10-year project: (1) annual adult female survival was consistent among areas averaging 79–87% annually, but overwinter fawn survival was variable, ranging from 31% to 95% within study areas, with annual and study area differences primarily due to early winter fawn condition (Dec fawn mass), annual weather conditions, and factors associated with predation on winter range; (2) mule deer body condition early and late winter was generally consistent within areas, with higher variability among study areas early winter, primarily due to December lactation rates, and late winter condition related to seasonal moisture and winter severity; (3) late winter mule deer densities increased through 2016 in all study areas, ranging from a 50% increase in North Ridge to a 103% increase in North Magnolia, however densities have stabilized recently in 3 of the 4 study areas and a recent decline in density was evident in North Ridge (Fig. 3); (4) 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. 4); (5) mule deer exhibited behavioral plasticity in relation to energy development, where disturbance distance varied relative to diurnal extent and magnitude of development activity, which may provide for several options in future development planning (Fig. 5); and (6) energy development activity under existing conditions did not influence pregnancy rates, fetal rates or early fawn survival (0–6 months), but may have reduced neonatal survival (March until birth) when drought conditions persisted during the third trimester of doe parturition (Fig. 6).

Final results are pending to address vegetation and mule deer responses to assess habitat treatment mitigation options for energy development planning, and final results addressing the interaction of mule deer behavioral and demographic factors associated with energy development activity have recently been submitted for scientific peer-review and publication. Completion of this project, including final data collection, analyses and interpretation of results, is anticipated by fall/winter 2020.

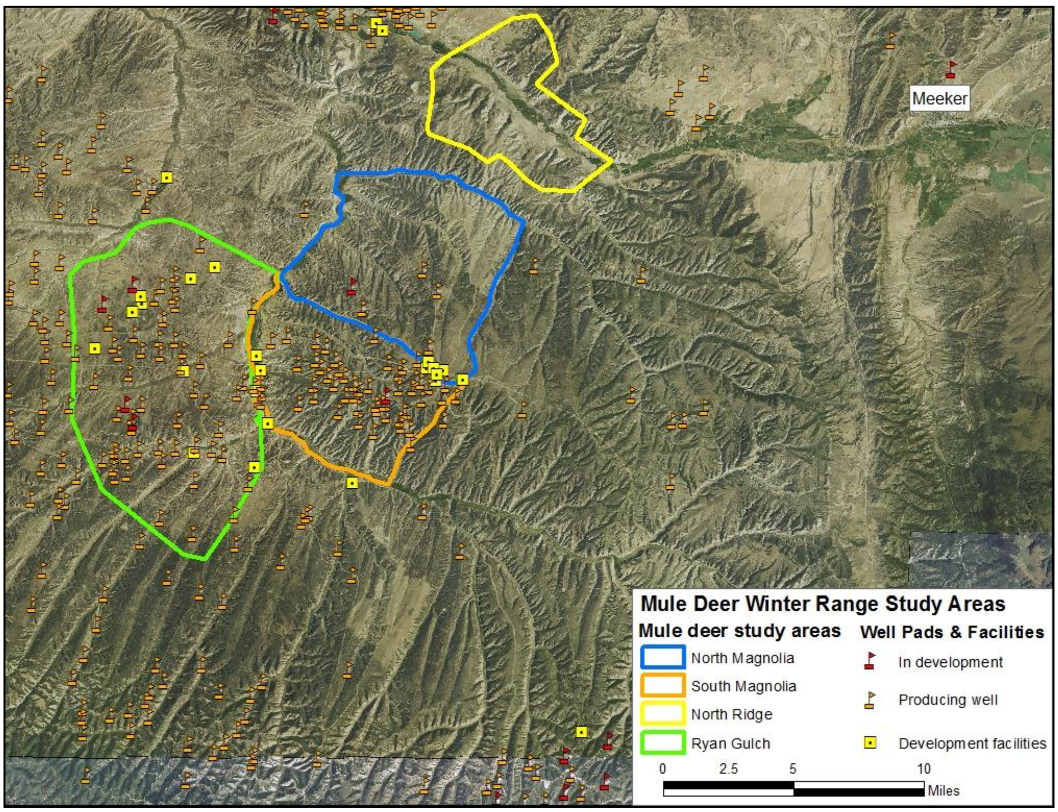


Figure 1. Mule deer winter range study areas relative to active natural gas well pads and energy development facilities in the Piceance Basin of northwest Colorado, winter 2013/14 (Accessed http://cogcc.state.co.us/ December 31, 2013; energy development activity has been minor since 2013).

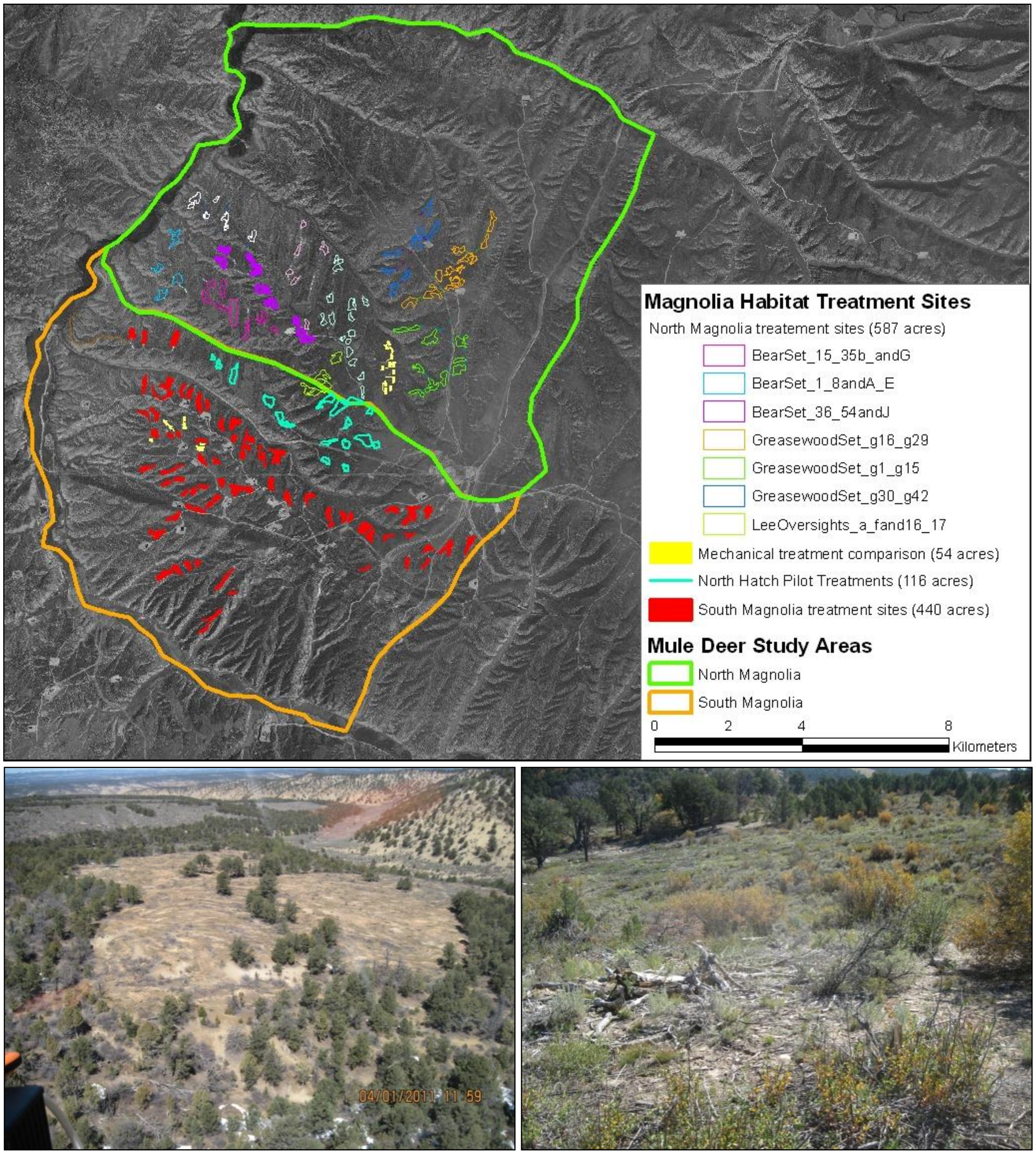


Figure 2. Habitat treatment site delineations in 2 mule deer study areas (604 acres each) of the Piceance Basin, northwest Colorado (Top; cyan polygons completed Jan 2011 using hydro-axe; yellow polygons completed Jan 2012 using hydro-axe, roller-chop, and chaining; and remaining polygons completed Apr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

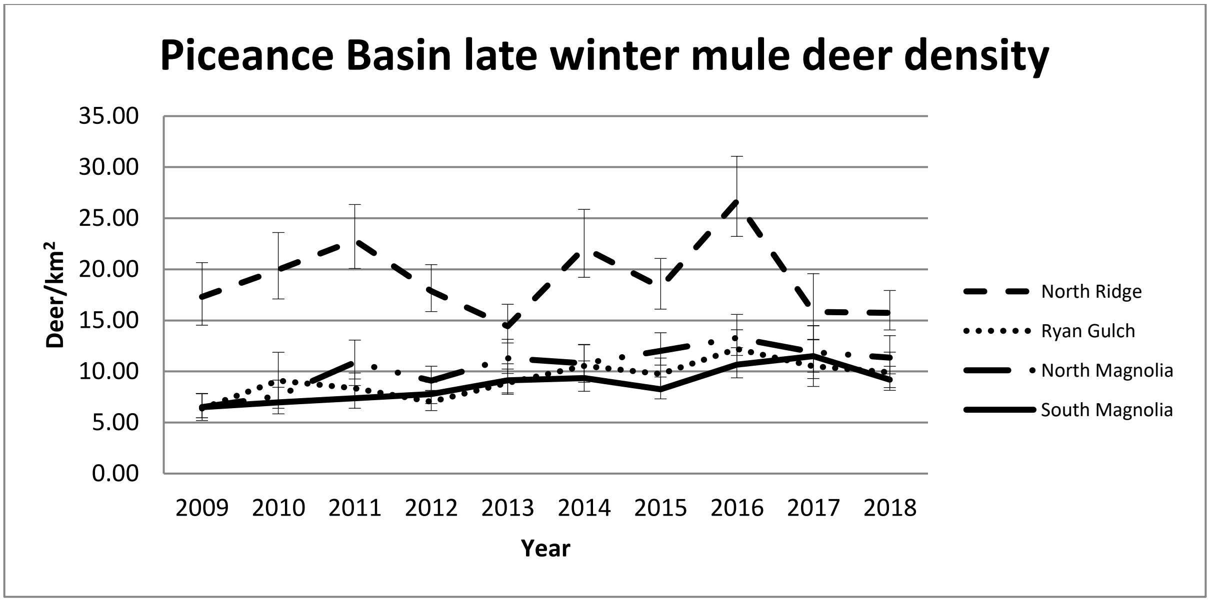


Figure 3. Mule deer density estimates and 95% CI (error bars) from 4 winter range herd segments in the Piceance Basin, northwest Colorado, late winter 2009–2018.

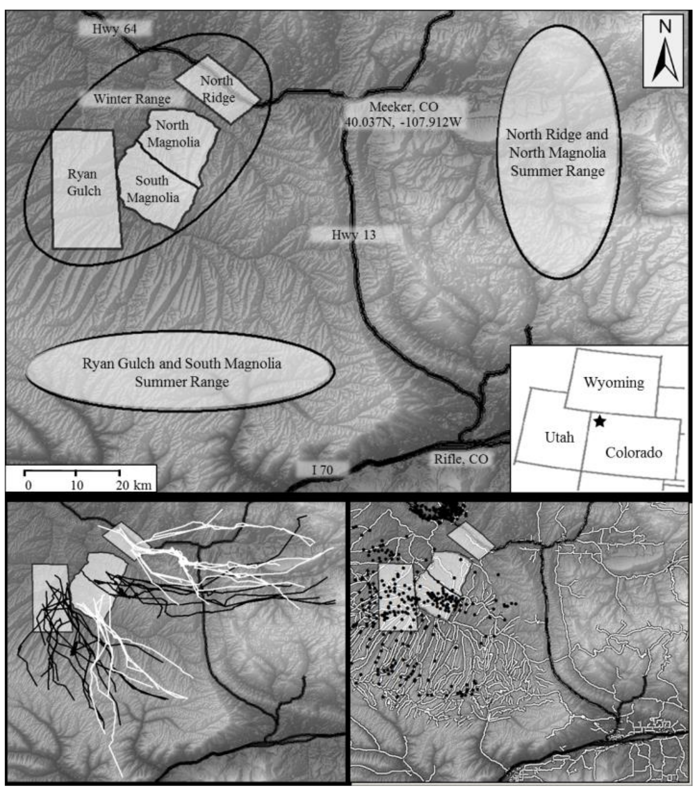


Figure 4. Mule deer study areas in the Piceance Basin of northwestern Colorado, USA (Top), spring 2009 migration routes of adult female mule deer (n = 52; Lower left), and active natural-gas well pads (black dots) and roads (state, county, and natural-gas; white lines) from May 2009 (Lower right; from Lendrum et al. 2012; http://dx.doi.org/10.1890/ES12-00165.1).

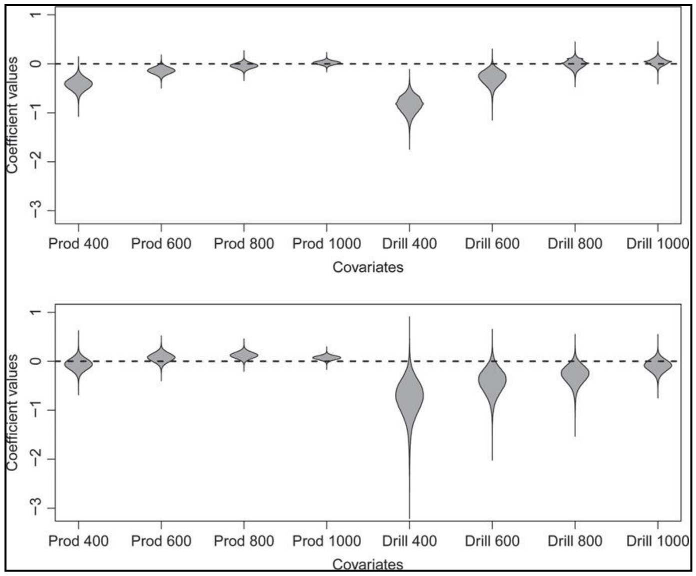


Figure 5. Posterior distributions of population-level coefficients related to natural gas development for RSF models during the day (top) and night (bottom) for 53 adult female mule deer in the Piceance Basin, northwest Colorado. Dashed line indicates 0 selection or avoidance (below the line) of the 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).

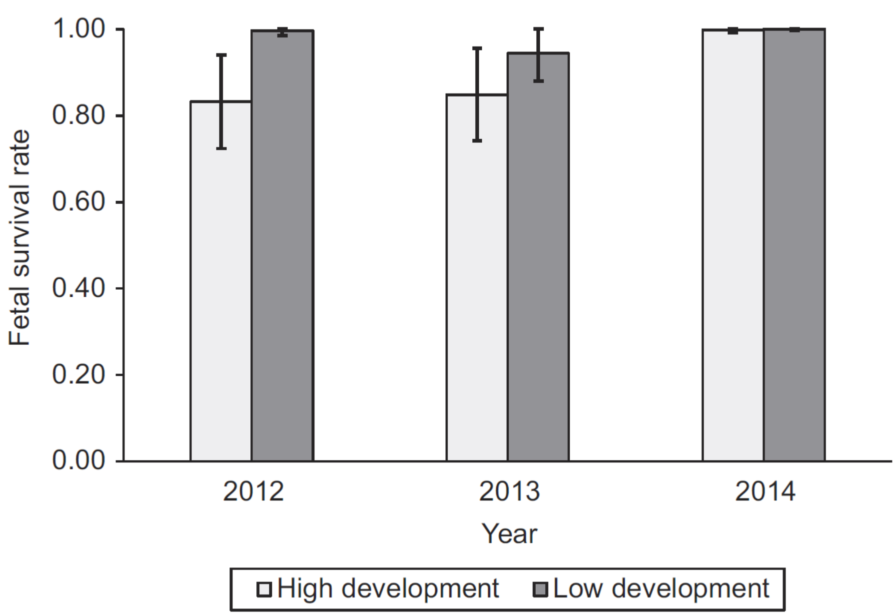


Figure 6. Model averaged estimates of mule deer fetal survival from early March until birth (late May–June) in high and low energy development study areas of the Piceance Basin, northwest Colorado, 2012–2014 (from Peterson et al. 2017; http://www.bioone.org/doi/pdf/10.2981/wlb.00341)

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, 2017–June 30, 2018

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 2017–2018 fiscal year. A primary objective during all years of this project has been the capture of adult female moose for the purposes of deploying VHF and GPS collars, collecting pregnancy data via blood serum, evaluating body condition via ultrasonography, and collecting early winter calf-at-heel ratios. Beginning in 2014–2015 and continuing through 2017–2018, summer field efforts focused on estimation of parturition rates. During the 2017–2018 year, all captures occurred during the first week of January and occurred in the Laramie River (NE Colorado) and North Park (NW Colorado) areas.

During 2017–2018, 38 cow moose were captured and collared. Of these 38 animals, 15 were recaptures of animals that had been captured during previous winters of the study. Nine of these recaptures occurred along the Laramie River and 6 recaptures occurred in North Park. Individual animals were recaptured to meet 2 objectives. First, many animals wore GPS collars that stored location data within the collar. Those data could not be retrieved without retrieving the collar. These animals were subsequently re-collared with satellite collars that are now capable of transmitting location data. The second objective was to establish a longitudinal data set that will allow us to determine long-term productivity of individual animals. In particular, repeated measurements of individuals will allow us to evaluate if different reproductive strategies occur within moose, and if those strategies can be linked to annual variation within individual condition.

During the 2017–2018 winter, measured rump fat at the time of capture ranged between 0–23 mm among study areas. Measured loin depth at the time of capture ranged between 29–55 mm among study areas. Measured loin fat, at the time of capture, ranged between 0–9 mm. When data from 2013–2018 were pooled, pregnancy probability was best predicted by simply considering maximum loin depth. Due to the unbalanced sampling design, regional and annual effects in pregnancy rates were not evaluated. As has been the case during all years of the study, survival of radio collared animals was high in all study areas (85%–96%). During 2017–2018 pregnancy rates were invariant between areas (67% in NW Colorado, 63% in NE Colorado). However, during the 5 winters of data collection, a large amount of variation in pregnancy rates has been observed. Over the course of this study, calf-at-heel estimates at the time of capture have average 0.59. During 2017–2018, the measured calf-at-heel rate in NW Colorado was slightly lower than average (0.50), but no difference from the long term average was observed in NE Colorado (0.59).

Beginning during the summer of 2017 and continuing into the summer of 2018, vegetation sampling occurred in NW and NE Colorado. These efforts are directed at: 1) identifying willow community diversity at known moose locations, 2) determining if moose demonstrate preference among willow species while browsing, and 3) to determine the nutritional quality of willows throughout the summer period. Ultimately, these data will be used to develop a linkage between moose body condition, pregnancy, and habitat conditions.

Thus far, data collected during this project have met expectations. In particular, survival rates have been consistently high in all study areas. However, a large degree variation within pregnancy rates have been observed, which is intriguing. During coming years, the relationship between moose pregnancy and browse availability and browse nutritional character will be discerned to help biologists project moose population trajectory and to refine moose herd management objectives.

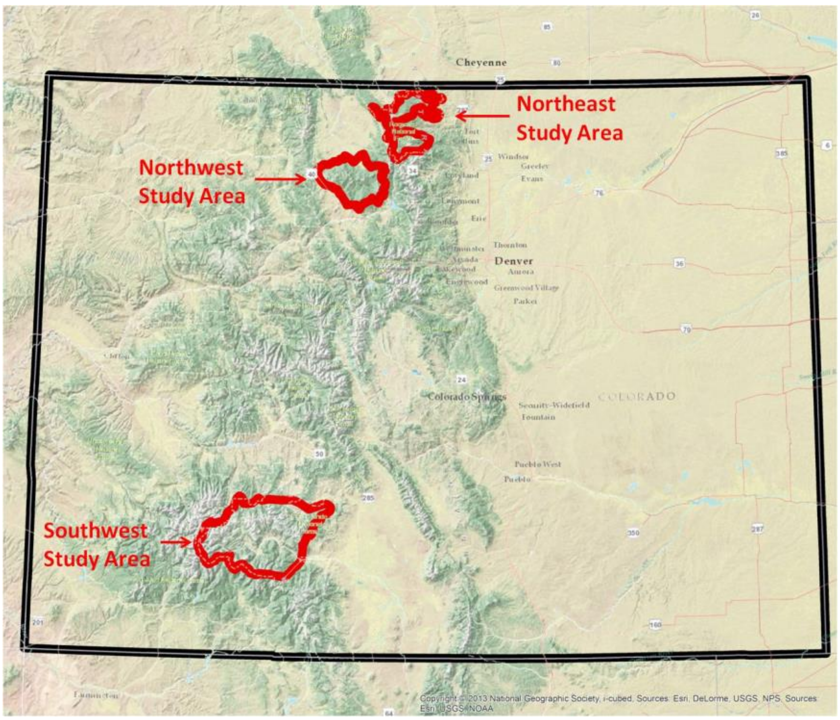


Figure 1. Moose research study areas, located in 3 regions in Colorado. A total of 219 moose were captured during winters between 2013–2014 and 2017–2018. During the winter of 2017–2018, a total of 38 moose were captured in the Northeast and Northwest study areas. Survival of moose was high in all study areas and during all years of the study.

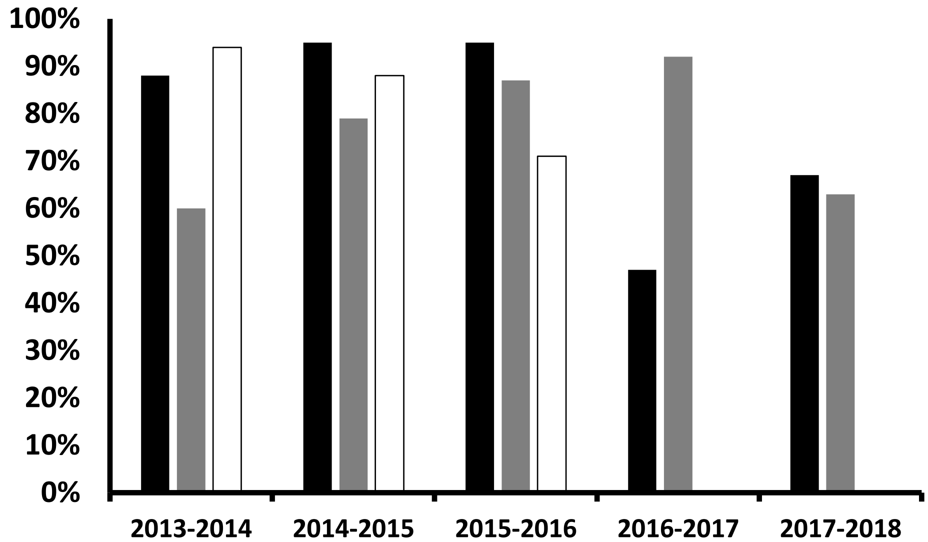


Figure 2. Pregnancy data were collected for all moose at the time of capture. Data from northwest Colorado are depicted by black bars, data from northeast Colorado are depicted by gray bars, and data from southwest Colorado are depicted by white bars. Data from southwest were sparse during 2015–2016 (*n* = 7 animals) and not collected during 2016–2017 or 2017–2018. The cause and consequences of the low pregnancy rate observed in northwest Colorado during 2016–2017 were never determined and that was considered to be an outlier event.

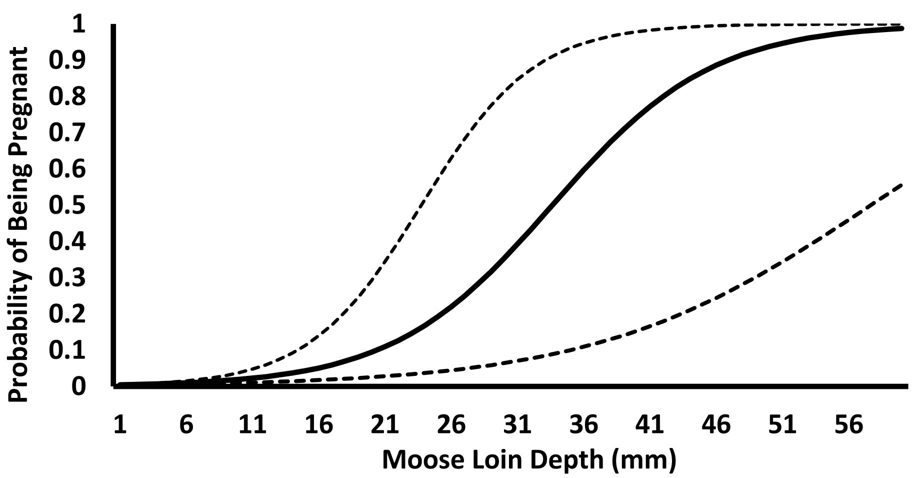


Figure 3. During the course of this study, probability of moose pregnancy has been best predicted by measured loin depth. The relationship between body condition and pregnancy status is reflected by the solid black line and from data collected during all 5 years of the study (dotted lines represent 95% confidence intervals for moose pregnancy probability). No regional effects were found in our data, and the lack of significance of annual effects in our best performing models is likely driven by small sample sizes.

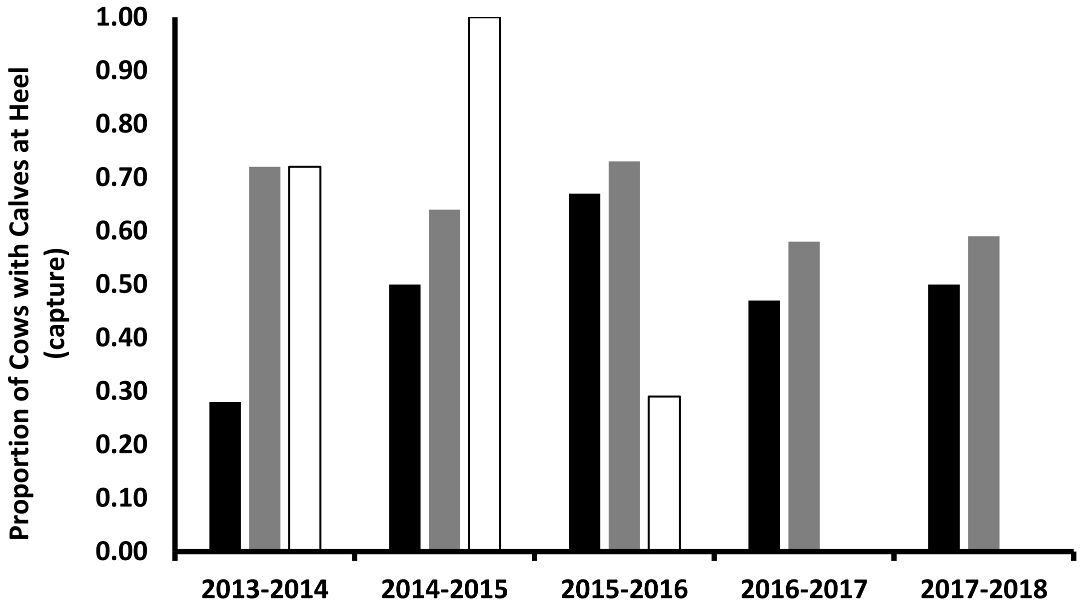


Figure 4. Moose calf-at-heel data were collected for all cow moose at the time of capture. Data from northwest Colorado are depicted by black bars, data from northeast Colorado are depicted by gray bars, and data from southwest Colorado are depicted by white bars. Data from southwest were sparse during 2015–2016 (n = 7 animals) and not collected during 2016–2017 or 2017–2018. Overall, recruitment of moose calves into the winter time period has consistently exceeded 50%. Anecdotal evidence suggests that overwinter survival of moose calves in Colorado is high, thereby lending evidence moose herds are likely stable or increasing despite documented highly variable pregnancy rates.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

PILOT STUDY—Elk recruitment and habitat use in Colorado

Period Covered: July 1, 2017–June 30, 2018

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

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

ABSTRACT

Our principal research objective is to address elk recruitment across southern Colorado in response to declining December calf:cow ratios. These ratios have been declining for more than a decade in the majority of the data analysis units (DAUs) across the southern half of Colorado. We have specifically focused on DAUs E-20 and E-33 as these two analysis units have some of the lowest reported ratios in the state, around 30 calves per 100 cows in December. To address this, we have initiated a pilot study to examine potential drivers of low recruitment. This includes examining body condition and pregnancy rates of cow elk and cause specific mortality of calves. There is some indication that mortality of calves in E-33 is a contributing factor to low recruitment rates, but retention of calf collars during the first year limited analysis and calf survival for the current year is not complete.

PROJECT NARRITIVE OBJECTIVES

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

SEGMENT OBJECTIVES

Elk Recruitment

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

2017–2018 Project Overview

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

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

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

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

Cow elk capture was initiated in late February, 2017 and 2018, in E-20 and E-33. In 2017, body condition was estimated for 32 and 29 elk in E-20 and E-33 respectively and 23 were GPS collared in each area. Similarly, in 2018, body condition was estimated for 30 elk in E-20 and 31 elk in E-33 and 20 were collared in each area. Body condition of elk, based on loin thickness, rump fat and a body condition score was reasonably good in both study areas (Table 1). Vaginal implant transmitters (VITs) were placed in pregnant elk. Ingesta-free body fat was estimated from these measures for each study area and year with an average near 7.5% each year. Pregnancy rates were higher in 2018 at 96.7% and 87.1% in E-20 and E-33 respectively (Table 1).

Calf capture began in the middle of May, 2017 and 2018. Only 2 of 40 VITs worked in 2017, so capture was primarily opportunistic. A total of 40 and 55 calves were caught in E-20 and E-33 during 2017, respectively (Table 2). VITs worked reliably in 2018 allowing for numerous captures shortly after parturition for calves from collared cows. Additional calves were also captured opportunistically. A total of 47 and 54 calves were captured in E-20 and E-33 respectively. Average capture weight was similar across years but average weight was slightly less during the second year.

Retention issues for calf collars during the first year of the study limits the results for assessing recruitment. Mortality during the first few months (prior to collar retention issues) indicated 10% known predation mortality in E-20 and 27% known predation mortality in E-33. There was an additional mortality from malnutrition and one unknown cause in E-20 and 2 unknown mortalities in E-33. In E-33, 26% of the calf mortality was attributed to bears and 32% to cougars. As of June 30, 2018, similar patterns were being observed during this second year with potentially higher bear predation in E-33, but this only represents a few weeks of data for this year.

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

	Year	n	Loin	Rump	BCS	% Pregnant
E-20	2017	32	48.7	7.1	3.4	77.4
	2018	30	53.7	7.1	3.9	96.7
E-33	2017	29	52.0	5.7	3.4	79.3
	2018	31	51.4	5.2	3.2	87.1

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

	Year	n	F:M	Age	Weight
E-20	2017	40	20:20	2.3	17.3
	2018	47	24:23	1.6	17.9
E-33	2017	55	29:26	2.6	17.3
	2018	54	25:29	2.2	18.7

PREDATORY MAMMAL CONSERVATION

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

EFFECTS OF PUMA HUNTING ON A PUMA POPULATION IN COLORADO

WHAT LIMITS AND REGULATES PUMA POPULATIONS? WHAT MATTERS?

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, 2017–June 30, 2018

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

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

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

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

Publications in Progress:

Kirby, R., H.E. Johnson, M.W. Alldredge, and J.N. Pauli. The tension between foraging and hibernation shapes biological aging in bears. *In Review* with *Scientific Reports.*

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

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

Published Abstracts:

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

Heather E. Johnson[1], David L. Lewis[1], Tana L. Verzuh[1], Cody F. Wallace[1], Rebecca M. Much[1], Lyle K. Willmarth[1], Stewart W. Breck[2]
[1]Colorado Parks and Wildlife, Durango CO, USA
[2]USDA National Wildlife Research Center, Fort Collins, CO, USA

Citation: Johnson, H. E., D. L. Lewis, T. L. Verzuh, C. F. Wallace, R. M. Much, L. K. Willmarth and S. W. Breck. 2017. Human development and climate affect hibernation in a large carnivore with implications for human-carnivore conflicts. Journal of Applied Ecology, DOI:10.1111/1365-2664.13021

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

Experience, attitudes, and demographic factors influencing the probability of reporting human-black bear interactions

Ryan C. Wilber[1], Stacy A. Lischka[2], Jessica R. Young[1], Heather E. Johnson[3]
[1]Western State Colorado University, 600 N. Adams St., Gunnison, CO 81231, USA
[2]Colorado Parks and Wildlife, 317 W. Prospect Ave., Fort Collins, CO 80526, USA
[3]Colorado Parks and Wildlife, 415 Turner Drive, Durango, CO 81303, USA

Citation: Wilber, R. C., S. A. Lischka, J. R. Young and H. E. Johnson. 2018. Experience, attitudes, and demographic factors influencing the probability of reporting human-black bear interactions. Wildlife Society Bulletin; DOI: 10.1002/wsb.854

ABSTRACT Interactions between people and American black bears (Ursus americanus) have been increasing throughout the United States, with negative interactions becoming a major management challenge for wildlife agencies. To monitor the number, location, and severity of these conflicts, wildlife agencies typically rely on voluntary public reports. Although trends in voluntary reports are commonly assumed to reflect actual trends in human-bear interactions, recent research suggests an individual's likelihood of reporting interactions may be biased, influenced by attitudes toward the species and its management, previous experiences with wildlife, or demographic factors. During 2012, we used a mail survey of residents in the vicinity of Durango, Colorado, USA, (n = 1,667) to explore the relative importance of tolerance for black bears, satisfaction with bear management, personal experience with

bears, and demographic traits as predictors of a resident's decision to report interactions to the authorities. We found that residents' experiences with bears were most important in predicting reporting behavior, followed closely by attitudes related to tolerance for bears, and satisfaction with management; demographic factors had relatively little influence. Respondents were more likely to report when they had seen black bears near their homes, had been threatened by bears, were intolerant of bears, dissatisfied with management, and were female. Although several variables in our analyses were influential in explaining reporting behavior, the overall predictive power of our models was low ($R^2 = 0.17$), suggesting future investigations of reporting behavior should include a broader set of covariates. Our results indicate that public reports represent a biased measure of human-bear interactions, and management agencies should either account for bias, or collect different types of interaction data, when assessing patterns of bear activity.

Compounding effects of human development and a natural food shortage on a black bear population along a human development-wildland interface

Jared S. Laufenberg[a], Heather E. Johnson[b], Paul F. Doherty Jr.[a], Stewart W. Breck[c]
[a]Department of Fish, Wildlife, and Conservation Biology, Colorado State University, Fort Collins, CO 80523, USA
[b]Colorado Parks and Wildlife, 415 Turner Drive, Durango, CO 82303, USA
[c]USDA-Wildlife Services, National Wildlife Research Center, 4101 La Porte Ave., Fort Collins, CO 80521, USA

Citation: Laufenberg, J. S., H. E. Johnson, P. F. Doherty Jr., and S. W. Breck. 2018. Compounding effects of human development and a natural food shortage on a black bear population along a human-wildland interfact. Biological Conservation 224:188-198; doi.org/10.1016/j.biocon.2018.05.004

Abstract
Human development and climate change are two stressors that threaten numerous wildlife populations, and their combined effects are likely to be most pronounced along the human development-wildland interface where changes in both natural and anthropogenic conditions interact to affect wildlife. To better understand the compounding influence of these stressors, we investigated the effects of a climate-induced natural food shortage on the dynamics of a black bear population in the vicinity of Durango, Colorado. We integrated 4 years of DNA based capture-mark-recapture data with GPS-based telemetry data to evaluate the combined effects of human development and the food shortage on the abundance, population growth rate, and spatial distribution of female black bears. We documented a 57% decline in female bear abundance immediately following the natural food shortage coinciding with an increase in human-caused bear mortality (e.g., vehicle collisions, harvest and lethal removals) primarily in developed areas. We also detected a change in the spatial distribution of female bears with fewer bears occurring near human development in years immediately following the food shortage, likely as a consequence of high mortality near human infrastructure during the food shortage. Given expected future increases in human development and climate-induced food shortages, we expect that bear dynamics may be increasingly influenced by human-caused mortality, which will be difficult to detect with current management practices. To ensure long-term sustainability of bear populations, we recommend that wildlife agencies invest in monitoring programs that can accurately track bear populations, incorporate non-harvest human-caused mortality into management models, and work to reduce human-caused mortality, particularly in years with natural food shortages.

Assessing ecological and social outcomes of a bear-proofing experiment

Heather E. Johnson[1], David L. Lewis[1], Stacy A. Lischka[2], Stewart W. Breck[3]
[1]Colorado Parks and Wildlife, 415 Turner Drive, Durango, CO 81303, USA
[2]Colorado Parks and Wildlife, 317 W. Prospect Ave., Fort Collins, CO 80526, USA
[3]U. S. Department of Agriculture National Wildlife Research Center, 4101 LaPorte, Ave., Fort Collins, CO 80521, USA

Citation: Johnson, H. E., D. L. Lewis, S. A. Lischka, and S. W. Breck. 2018. Assessing ecological and social outcomes of a bear-proofing experiment. Journal of Wildlife Management 82:1102-1114; DOI: 10.1002/jwmg.21472

ABSTRACT Human-black bear conflicts within urban environments have been increasing throughout North America, becoming a high priority management issue. The main factor influencing these conflicts is black bears foraging on anthropogenic foods within areas of human development, primarily on residential garbage. Wildlife professionals have advocated for increased bear-proofing measures to decrease the accessibility of garbage to bears, but little research has been conducted to empirically test the effectiveness of this approach for reducing conflicts. Between 2011 and 2016, we conducted a before-after-control-impact experiment in Durango, Colorado where we distributed 1,110 bear-resistant trash containers, enhanced education, and increased enforcement to residents in 2 treatment areas, and monitored 2 paired control areas. We examined the ecological and social outcomes of this experiment, assessing whether bear-resistant containers were effective at reducing conflicts; the level of public compliance (i.e., properly locking away garbage) needed to reduce conflicts; whether the effectiveness of bear-resistant containers increased over time; and if the distribution of bear-resistant containers changed residents' attitudes about bear management, support for ordinances that require bear-proofing, or perceptions of their future risk of garbage-related conflicts. After the bear-resistant containers were deployed, trash-related conflicts (i.e., observations of strewn trash) were 60% lower in treatment areas than control areas, resident compliance with local wildlife ordinances (properly locking away trash) was 39% higher in treatment areas than control areas, and the effectiveness of the new containers was immediate. Conflicts declined as resident compliance with wildlife ordinances increased to approximately 60% (by using a bear-resistant container or locking trash in a secure location), with minor additional declines in conflicts at higher levels of compliance. In addition to these ecological benefits, public mail surveys demonstrated that the deployment of bear-resistant containers was associated with increases in the perceived quality of bear management and support for ordinances that require bear-proofing, and declines in the perceived risk of future trash-related conflicts. Our results validate efforts by wildlife professionals and municipalities to reduce black bear access to human foods, and should encourage other entities of the merits of bear-proofing efforts for reducing human-bear conflicts and improving public attitudes about bears and their management.

A conceptual model for the integration of social and ecological information to understand human-wildlife interactions

Stacy A. Lischka[a,b], Tara L. Teel[c], Heather E. Johnson[d], Sarah E. Reed[b,e], Stewart Breck[f], Andrew Don Carlos[c], Kevin R. Crooks[b]

[a]Research, Policy, and Planning Branch, Colorado Parks and Wildlife, 317 W. Prospect Road, Fort Collins, CO 80526, USA
[b]Department of Fish, Wildlife, and Conservation Biology, Colorado State University, Fort Collins, CO 80523, USA
[c]Department of Human Dimentions of Natural Resources, Colorado State University, Fort Collins, CO 80523, USA
[d]Research, Policy, and Planning Branch, Colorado Parks and Wildlife, 415 Turner Dr., Durango, CO 81303, USA
[e]Americas Program, Wildlife Conservation Society, 2300 Southern Blvd., Bronx, NY 10460, USA
[f]National Wildlife Research Center, USDA Wildlife Services, 4101 Laporte Ave., Fort Collins, CO 80521, USA

Citation: Lischka, S. A., T. L. Teel, H. E. Johnson, S. E. Reed, S. Breck, A. D. Carlos, and K. R. Crooks. 2018. A conceptual model for the integration of social and ecological information to understand human-wildlife interactions. Biological Conservation 225:80-87; doi.org/10.1016/j.biocon.2018.06.020

Abstract

There is growing recognition that interdisciplinary approaches that account for both ecological and social processes are necessary to successfully address human-wildlife interactions. However, such approaches are hindered by challenges in aligning data types, communicating across disciplines, and applying social science information to conservation actions. To meet these challenges, we propose a conceptual model that adopts a social-ecological systems approach and integrates social and ecological theory to identify the

multiple, nested levels of influence on both human and animal behavior. By accounting for a diverse array of influences and feedback mechanisms between social and ecological systems, this model fulfills a need for approaches that treat social and ecological processes with equal depth and facilitates a comprehensive understanding of the drivers of human and animal behaviors that perpetuate human-wildlife interactions. We apply this conceptual model to our work on human-black bear conflicts in Colorado, USA to demonstrate its utility. Using this example, we identify key lessons and offer guidance to researchers and conservation practitioners for applying integrated approaches to other human-wildlife systems.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Evaluation of mountain lion management in Colorado

Period Covered: July 31, 2017–June 30, 2018

Effects of Puma Hunting on a Puma Population in Colorado

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

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

We examined effects of regulated hunting on a puma *(Puma concolor)* population on the Uncompahgre Plateau, Colorado for 10 years (2004–2014). The study was designed with a reference period (years 1–5) without puma hunting and a treatment period (years 6–10) with puma hunting. We captured and marked pumas on the study area (UPSA) and monitored them year-round for data on puma demographics. Abundance of independent pumas was estimated on the UPSA each winter during the Colorado puma hunting season from reference year 4 (RY4) to treatment year 5 (TY5) using the Lincoln-Petersen method. In addition, we surveyed puma hunters to learn how hunter behavior influenced harvest and the puma population. In the reference and treatment periods, 110 and 116 individual pumas were captured and marked, respectively, during 440 total capture events. Data analyses have been completed and results and conclusions have been submitted for scientific peer-review and publication to *Wildlife Monographs*.

What Limits and Regulates Puma Populations? What Matters?

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

Wildlife managers require reliable information on factors that influence animal populations in order to develop successful management programs. Such is the case with the puma (*Puma concolor*) in western North America, where populations have recovered in recent decades primarily due to restrictions on human-caused mortality. Managers need a clear understanding of the factors that limit or regulate puma populations and how those factors might be manipulated to achieve management objectives, including: sustaining puma and other wildlife populations, providing hunting opportunity, and reducing puma conflicts with people. In this paper, I present relevant technical literature on puma populations, behavior, and relationships with prey that has contributed to establishing hypotheses on puma population limitation and regulation. Current hypotheses include: the social limitation hypothesis, and the food limitation hypothesis. Associated with each of those are 2 hypotheses on puma population regulation: the social regulation hypothesis and the regulation by competition hypothesis. I discuss management implications framed by these hypotheses as they pertain to puma hunting, conflicts, and relationships with ungulate prey. Finally, I discuss environmental and societal issues that determine puma management objectives and challenge puma conservation. Internal CPW peer review has been completed for this manuscript and the revised manuscript is planned to be submitted for scientific peer-review and publication to *Wildlife Biology*.

SUPPORT SERVICES

RESEARCH LIBRARY ANNUAL REPORT

Colorado Parks and Wildlife

WILDLIFE RESEARCH REPORT SUMMARY

Research library, annual report

Period Covered: July 1, 2017–June 30, 2018

Author: Alexandria Austermann, alexandria.austermann@state.co.us

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

The Colorado Parks and Wildlife (CPW) Research Library was created in the late 1960s, at the Fort Collins office, to provide support primarily to the wildlife research sections. With the changing needs of CPW, the mission of the Library has expanded to serve all CPW staff regardless of location. The Library is now vital to the science-driven wildlife management work of the agency. The Librarian has become a valued partner in assisting with research and supplying full-text reference resources for the work done by biologists, researchers and wildlife managers across the state.

Under the capable oversight of past librarians Jackie Boss, Marian Hershcopf and Kay Knudsen, the Library specialized in collections that are focused on wildlife ecology and associated ecological information and CPW public historical records. These librarians can be credited with the physical organization of the Library which continues to serve as the center for effective research services for employees, cooperators and wildlife educators. The Library is also affiliated with several large universities and a network of public libraries that provide access to a much larger pool of information and resources at no cost to the Library. This allows the Library to better serve the agency while still being budget conscious. In March of 2018, a new librarian, Alexandria Austermann, was hired.

The Library is changing with the digital information age and I am constantly working with vendors to expand our online resources and capabilities. The goal of outreach and support is today fulfilled using a library website and online catalog. The online catalog contains links to scholarly journals, wildlife databases and digitized documents that are available, through the CPW intranet, 24/7 to staff. The online catalog serves a directory to the unique wildlife management-centered book collection that the Library has amassed over the last 55+ years. A modified version of the library catalog is available to the public from the public CPW website. Due to licensing restrictions, the public is not able to access the journals or databases that are available to CPW staff, but the public can still search the catalog and download any PDFs that are attached to a catalog record.

The library catalog also provides access to the Federal Aid reports that are required by the Pittman-Robertson (Terrestrial) and Dingell-Johnson (Aquatic) Acts. Federal funding from these Acts is awarded to the State of Colorado for wildlife and sport fish restoration. CPW may be the only wildlife agency to have digital access in the form of full-text, word-searchable PDFs, for this important collection of Federal Aid reports. The Library is also an archive for historic CPW publications including 80 years of Wildlife Commission minutes and Director's reports dating back to 1877 and the special collection of original Colorado hunting and fishing brochures, many digitized, that serve as a history of our rules and regulations and are often accessed by staff.

As part of the project to digitize CPW documents, the equivalent of 9GB of data have been scanned and uploaded to the library catalog through the catalog vendor. As part of a new digitizing initiative, I'm partnering with the Colorado State digital library to upload PDFs of CPW's published works to make them digitally available to any interested parties. This will mean that CPW doesn't need to maintain a server to store the terabytes of PDFs that will be produced when digitizing the reports generated over the last almost 60 years and we won't pay the fee to the cataloging vendor to store the reports in their cloud. This will minimize the costs of digitizing and storing the reports while still allowing them to be publicly accessible.

As a form of outreach to staff and stakeholders, the Research branch has made an effort to restart the Technical Publication series. Kay was involved in editing and proofreading as well as coordinating publications on reports published in 2017 and early 2018. I will continue this effort in a similar manner.

As of October 2018, the Library held 19,934 cataloged titles and 31,070 items (these are the multiple copies of a title) and had 185 registered patrons (CPW staff). Current wildlife databases available to all CPW staff include BioOne, four of EBSCO's specialty databases (Environment Complete, Fish and Fisheries Worldwide, Wildlife and Ecology Studies Worldwide and CAB Abstracts), Birds of North America, ProQuest Dissertations and Theses and the JSTOR Life Sciences collection. Online access to the major wildlife journals continue to be a primary usage entry point. CPW staff statewide are authenticated through the CPW intranet eliminating the need for individual usernames and passwords.

As of January 2019, I will be changing our subscription from EBSCO's databases to the ProQuest Natural Science collection, which also includes four databases: Agricultural & Environmental Science Database, Biological Science Database, Earth, Atmospheric & Aquatic Science Database and Aquatic Science & Fisheries Abstracts. This is a substantial cost savings and I believe that ProQuest has a superior search interface that returns better, more relevant results and makes it easier to share those results with the researcher. ProQuest also has a better system for setting up and sharing research alerts that help keep wildlife researchers appraised of the latest articles published in their field of study. I am also subscribing directly to the publisher John Wiley and Sons for their journals rather than using a third-party vendor for Wiley journals. This will be a cost savings on our current Wiley subscriptions. The representative from Wiley that I am working with is putting together an additional custom collection for the Library that will vastly expand our access to Wiley journals at a substantially reduced cost.

One of my major roles is to assist CPW staff with document delivery and research assistance, including literature searches. The Library is not open on a walk-in basis to the general public but I do assist the Denver Help Desk and area staff with questions they receive from citizens. I also receive and fill requests, time permitting, from wildlife researchers outside of CPW and retired staff members who are still active in the wildlife community.

The chart below shows the number of reference questions, literature searches and document requests I have handled since I started in March of 2018 and Kay filled in for the years before that.

Month/ Year	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014	2014–2015	2015–2016	2016–2017	2017–2018
July	20	45	28	37	60	44	64	49	
August	25	34	52	44	45	25	39	40	
September	30	37	53	48	46	42	59	48	
October	38	41	42	39	74	37	46	57	
November	28	46	52	51	48	47	48	59	
December	32	34	52	49	46	35	56	69	
January	62	48	64	46	53	75	56	90	
February	43	43	43	54	62	77	67	68	
March	36	46	36	53	48	70	79	82	31
April	23	30	42	70	57	58	45	49	65
May	17	51	53	65	39	58	54	68	66
June	26	27	36	35	34	34	37	55	38
Total	380	482	553	591	612	602	650	734	200