C O L O R A D O   P A R K S   &   W I L D L I F E

2024 Mammals Research Summary Report

March 2025

2024 MAMMALS RESEARCH SUMMARY REPORT

JANUARY–DECEMBER 2024

MAMMALS RESEARCH PROGRAM

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

EXECUTIVE SUMMARY

This Mammals Research Summary Report summarizes (≤5 pages each with tables and figures) preliminary results of wildlife research projects and support services updates conducted by the Mammals Research Team of Colorado Parks and Wildlife (CPW) during 2024. These research efforts represent long-term projects (4–10 years) in various stages of completion addressing applied questions to benefit the management and conservation 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 Research Library website at https://cpw.cvlcollections.org/exhibits/show/mammals-research-section/mammals-research-publications 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 conditions, human-wildlife interactions, and investigating improved approaches for wildlife population monitoring and management. The Nongame Mammal Conservation Section addresses ongoing monitoring of lynx in the San Juan mountain range and preliminary results addressing influence of forest management practices on snowshoe hare density in Colorado. The Ungulate Management and Conservation Section includes a pilot evaluation of moose and elk behavioral response to recent wolf establishment in North Park, Colorado, an evaluation of factors influencing elk calf recruitment, and two studies addressing elk response to human recreation. The Predatory Mammal Management and Conservation Section describes onging research addressing bobcat population dynamics and density estimation, mule deer survival and cougar conflict response to changes in cougar harvest, and evaluation of accelerometer collars and methods development for domestic cattle to eventually address cattle response to wolf activity during wolf population establishment. The Support Services section provides annual updates from the CPW Research Library and ongoing database development from the Research and Species Conservation Database Analyst/Manager.

In addition to the ongoing project summaries described above, Appendix A includes research abstracts (<1 page summaries) and citations published by CPW research staff during 2024. These scientific publications provide results from recently completed CPW research projects and other collaborations with universities and wildlife management agencies. Topics addressed include Canada lynx ecology, distribution modelling and habitat use, factors influencing ungulate (elk and mule deer) habitat use and migration patterns, detection of prions from carnivore feces, and evaluation of geostatistical capture-recapture models.

We have benefitted from numerous collaborations that support these projects and the opportunity to work with and train wildlife technicians and graduate students that will likely 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, multiple universities from the U.S. and Canada, U.S. Bureau of Land Management, U.S. Forest Service, CPW big game auction-raffle grants, Species Conservation Trust Fund, Great Outdoors Colorado, CPW Habitat Partnership Program, Rocky Mountain Elk Foundation, and numerous private land owners providing access to support field research projects.

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TABLE OF CONTENTS
2024 MAMMALS RESEARCH & SUPPORT SERVICE SUMMARIES

NONGAME MAMMAL CONSERVATION

CANADA LYNX MONITORING IN COLORADO 2023-2024

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

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Canada lynx monitoring in Colorado 2023 – 2024

Period Covered: December 1, 2023 – December 30, 2024

Principal Investigators: Jake Ivan, Jake.Ivan@state.co.us; Tim Brtis

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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. From 2014–2024 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 the 2023–2024 winter, personnel from CPW and USFS completed the tenth year of monitoring work on this same sample. Fifteen 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 (snow-covered 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. Thirty-five units could not be surveyed via snow tracking. Instead, survey crews deployed 4 passive infrared motion cameras in each of these units during fall 2023. Cameras were lured with visual attractants and scent lure to enhance detection of lynx in the area. Cameras were retrieved during summer or fall 2024 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 826 km during snow tracking surveys and detected 11 lynx tracks at 6 units (Table 1). This is considered a rebound from the program-low of 6 tracks in 4 units observed in 2021–22. Lynx were detected via camera sampling in 3 units during the 2023–24 survey season, which also represents a rebound from the previous program low (1 unit) for cameras, which was observed in 2022–23. In response to program low in camera detections during the 2022-23 winter, and our thinking that a potential explanation could be fatigue to the lured camera sets in use for nearly a decade, 117 cameras were passively (i.e., no lure) deployed along roads, trails, and other potential travel routes during fall 2023 in 16 camera units that have had lynx detections in the past. Deployments followed protocols established by (King et al. 2020) and (Anderson et al. 2023). These cameras were retrieved in summer 2024. During the usual analysis period we recorded 384 lynx detections at 11 units, 35 cameras. That is, the passive sampling scheme produced lynx detection in more units and cameras than at any point during the decade-long sampling using traditional lured sets. It also produced more lynx photos than all but one year during that same timeframe. Coupled with the increased efficiency and reduced cost of deploying passive sets, the monitoring program will transition to this methodology in coming years.

Lynx were once again detected in the upper Rio Grande Reservoir and Conejos Peak areas, after having gone undetected there in 2022–23. However, no lynx were detected near Lizard Head Pass or west of Lake City for the second year in a row (Figure 1).

We used the R package (R Development Core Team 2018) 'RMark' (Laake 2018) to fit multiple-season (i.e., "dynamic") occupancy models (MacKenzie et al. 2006) to our survey data using program MARK (White and Burnham 1999). Thus, we estimated the derived probability of a unit being occupied (ψ), or used, by lynx over the course of the winter, along with the probability of detecting a lynx (p) given that the unit was occupied, the probability a unit that was unused in one year was used the next (i.e., "local colonization," γ), and the probability a used unit became unused from one year to the next (i.e., "local extinction," ε). For each model we fit for the analysis, we specified that the initial ψ in the time series should be a function of the proportion of the unit that is covered by spruce/fir forest – the single most important and consistent predictor of ψ in past analyses. For sake of comparison we fit a base model in which p was specified to be constant for the duration of the survey. However, based on previous work, we considered several other structures for p we anticipated would fit better. We fit models that specified 1) p could vary by survey method (i.e., detection could be different for cameras compared to snowtracking), 2) p could be higher during breeding season when lynx tend to move more and are therefore more likely to be detected by track or at a camera, and 3) p for cameras deployed from 2017–21 could be different than p for other years due to a lure substitution. Additionally we fit a model in which the effect of breeding season was only allowed to act on cameras, not snowtracking. We allowed annual estimates of ε and γ to be different each year (i.e., assuming occupancy dynamics were not random but instead dependent on the year previous and the population is not at equilibrium), which allowed derived ψ to vary as freely as possible given the data. We used Akaike's Information Criterion (AIC), adjusted for small sample size (Burnham and Anderson 2002) to identify the best-fitting model from this small set. Ultimately, we fit a linear model through the time series of ψ estimates to estimate the slope of the trend in occupancy through time. Ideally we would test other predictions of lynx occupancy to see, for instance, if colonization or extinction were influenced by bark beetles, fire, or the presence of competitors or prey species. However, we do not currently have enough data to test these predictions in addition to assessing trend, which is the highest priority.

As has been the case since the inception of our monitoring program, the proportion of the sample unit covered by spruce-fir forest was positively associated with the initial occupancy estimate in the time series. Even though local colonization and extinction were allowed to vary freely from year to year, annual estimates were near zero and varied little (ε = 0.00–0.11; γ = 0.00–0.8) except for the the interval between the 2021–22 and 2022–23 seasons when extinction probability was high ($\varepsilon_{21–22}$ = 0.35, SE = 0.14). Accordingly, derived occupancy was relatively stable across years (ψ = 0.25–0.31), but dropped to a program low the past two winters ($\psi \approx 0.17$, SE = 0.05). The slope of the trend in occupancy through time was slightly negative but not statistically different from zero (β = -0.008, SE = 0.01; Figure 2). Similar to previous years, detection probability was relatively high for snow tracking surveys (p = 0.60, SE = 0.05), lower for camera surveys (p = 0.21, SE = 0.02) using Pikauba, and lowest for camera surveys utilizing Violator 7 (p = 0.07, SE = 0.02). We estimated that 17% of the sample units in the San Juan's were occupied by lynx (95% confidence interval: 6–27%) during 2023–24 (Figure 2).

Table 1. Summary statistics from snow tracking effort.

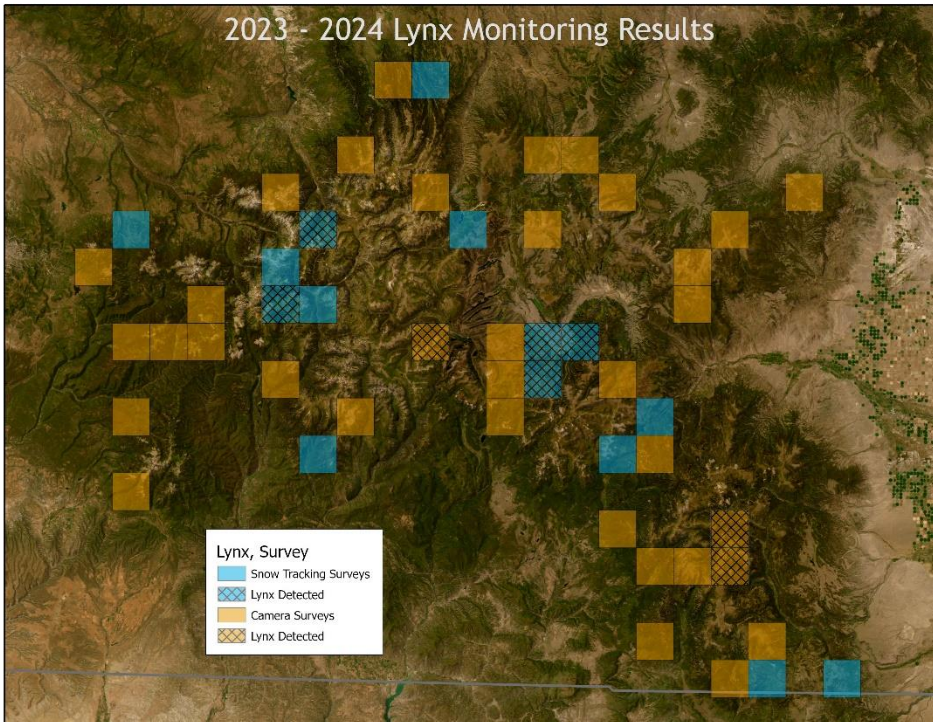
Season	#Units Surveyed	#Units with Lynx	#Lynx Tracks	#Genetic Samples[a]	Lynx DNA[b]	Km Surveyed (Total)	Mean Km Surveyed per Visit	#CPW Personnel[c]	#USFS Personnel[c]
2014-2015	18	7	12	8	8	884	20.1	30	13
2015-2016	17	7	14	9	6	987	21.9	23	6
2016-2017	16	8	13	7	5	703	18.0	20	8
2017-2018	14	7	9	3	1	578	19.3	14	5
2018-2019	14	6	8	2	1	510	19.6	16	5
2019-2020	14	7	11	3	2	640	19.4	15	3
2020-2021	15	9	14	12	7	790	18.8	17	3
2021-2022	13	4	6	5	4	692	18.7	11	3
2022-2023	15	5	10	9	7	730	18.3	15	2
2023-2024	15	6	11	10	6	826	19.7	14	3

[a] Number of genetic samples (scat, hair, or eDNA) collected via backtracking putative lynx tracks
[b] Number of genetic samples that came back positive for lynx
[c] Number of staff that participate in the annual effort

Table 2. Summary statistics from camera effort.

Season	#Units Surveyed	#Units With Lynx	#Photos (Total)	#Photos (Lynx)	#Cameras With Lynx	#CPW Personnel	#USFS Personnel
2014-2015	31	7	133,483	184	11	46	12
2015-2016	31	7	101,534	455	10	33	9
2016-2017	33	6	168,705	251	10	29	9
2017-2018	35	5	173,279	90	8	35	8
2018-2019	35	6	201,782	59	9	31	7
2019-2020	36	4	706,074	36	4	29	6
2020-2021	35	3	347,868	36	3	23	5
2021-2022	35	5	576,288	116	7	23	4
2022-2023	35	1	531,083	4	1	31	3
2023-2024	35	3	601,371	336	4	24	3

a)



b)

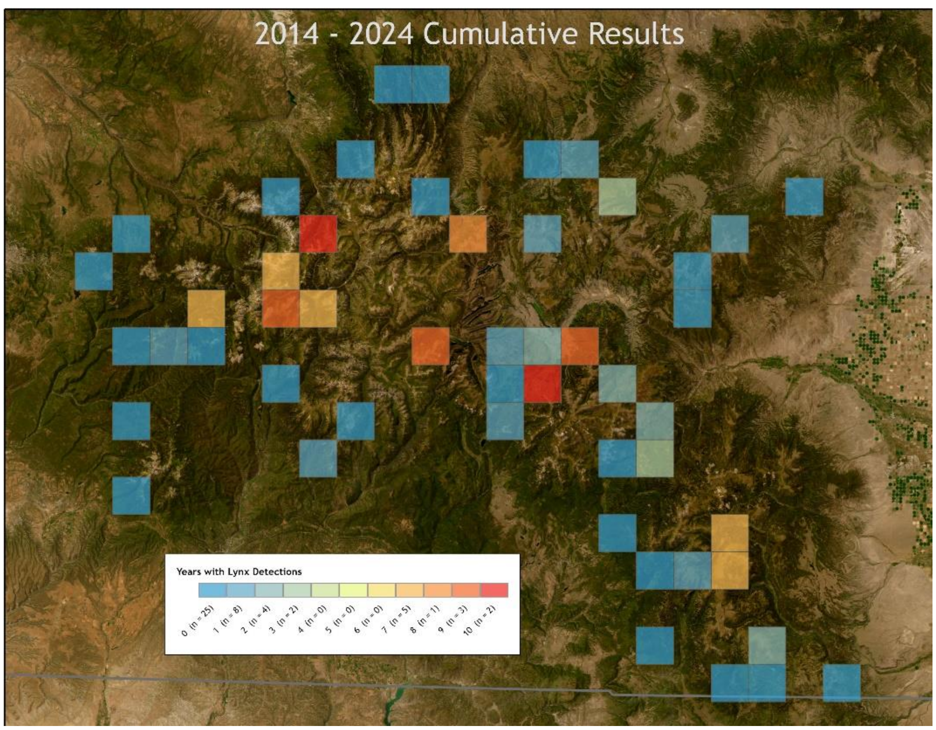


Figure 1. Lynx monitoring results for a) the current sampling season (2023–2024) and b) the cumulative monitoring effort (2014–2024), San Juan Mountains, southwest Colorado. Colored units (*n* = 50) depicted here are those selected at random from the population of units (*n* = 179) encompassing lynx habitat in the San Juan Mountains. Lynx were detected in 8 units in 2023−2024 and 25 units cumulatively since monitoring began in 2014−2015.

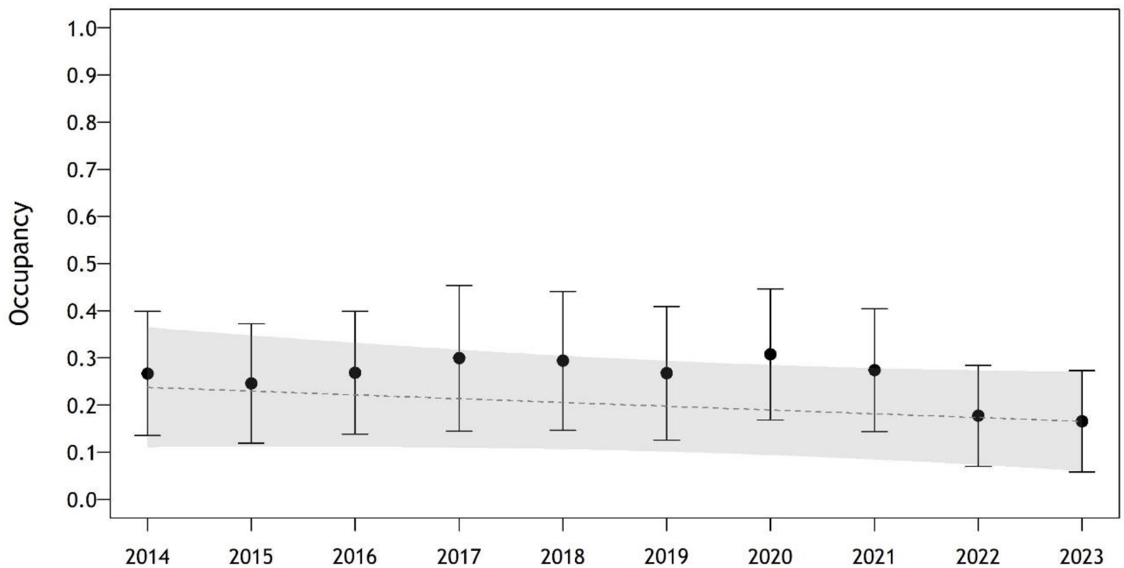


Figure 2. Occupancy estimates (Ψ) and trend (including 95%CI for each) for Canada lynx in the San Juan Mountains, southwest Colorado.

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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: January 1, 2024 – December 31, 2024

Principal Investigator: Jake Ivan, Jake.Ivan@state.co.us;

Understanding and monitoring snowshoe hare (*Lepus americanus*) density in Colorado is imperative 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 obligations. Such activities may depress snowshoe hare density, improve it, or have mixed effects dependent on the specific activity and the time elapsed since that activity was initiated. Here we describe a sampling scheme to assess impacts of common forest management techniques on snowshoe hare density in both lodgepole pine (*Pinus contorta*) and spruce-fir (*Picea engelmannii – Abies lasiocarpa*) systems in Colorado.

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 and USFS Rocky Mountain Research Station, we then grouped relevant forest management activities (stratum 2) into 4 broad categories: even-aged management, uneven-aged management, thinning, and unmanaged controls. We wanted to assess both the immediate and long-term impacts of management on hare densities. Therefore, when selecting stands for sampling, we took the additional step of binning the date of the most recent management activity into 2-decade intervals (i.e., 0-20, 20-40, and 40-60 years before 2018). We then selected a spatially balanced random sample of 5 stands within each combination of forest type × management activity × time interval. This design ensured that we sampled the complete gradient of time since implementation for each management activity of interest in each forest type of interest. There is no notion of "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 (Figure 1).

During summer 2018, we established n = 50 1-m^2 permanent circular plots within each of the stands selected for sampling. Plot locations within each stand were selected in a spatially balanced, random fashion. Technicians cleared and counted snowshoe hare pellets in each plot as they established them. These same plots were re-visited and re-counted during summers 2019 through 2024. In addition to sampling the previously cleared plots from 2018, technicians were able to install plots at 2 more replicate sites for each combination of forest type × management activity × time interval during 2019. In 2021 and 2022, we sampled vegetation metrics in each stand to help account for extraneous noise in the data and allow us to better assess the effects of the treatments themselves. A handful of initially selected stands were re-classified or excluded during 2019–2023 because ground-truthing and/or vegetation metrics revealed they did not actually fit in the stratum for which they were selected. New stands were sampled in their place by pulling the next one from the spatially balanced list. Similarly, 12 new stands were selected to replace those that burned during the 2020 fire season. Currently, inference is based on n = 137 total stands. Finally, prior to the 2023 field season, we computed the sampling variance of the pellet count for each time interval within each treatment. We sampled additional stands in the 3 most variable bins in an effort to reduce variability and improve our understanding of snowshoe hare response to these treatments.

Pellet information from cleared plots is more accurate than that from uncleared plots because uncleared plots usually 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. Data from cleared plots necessarily reflects hare activity from the previous 12 months, and tracks true density more closely. Therefore, we focused the current analysis on the 2019–24 data from previously cleared plots. For each forest type × management activity combination, we plotted mean pellet counts against "year since activity," then fit a curve (e.g., quadratic function) through the data (Figure 2).

Results from this preliminary analysis suggest that on average the highest snowshoe hare densities typically occur in unmanaged spruce-fir forests, and that unmanaged spruce-fir forests are estimated to have more than twice the relative hare density of unmanaged lodgepole pine forests (Figure 2). For both forest types, the fitted line suggests that even-aged management (e.g., clearcutting), immediately depresses relative hare density to near zero, but density rebounds and peaks 20-40 years after management before declining again (lodgepole systems) or leveling off (sprue-fir systems) 40-60 years after. Estimated peak hare densities after even-aged management in lodgepole systems tend to be higher than the control condition. However, in spruce-fir systems the estimated fitted line is flatter and peak densities fell short of the control condition. In both forest types, thinning (which often occurs 20-40 years after stands undergo even-aged management, especially in lodgepole) immediately depresses hare densities. In spruce-fir stands, densities were estimated to slowly recover through time in nearly linear fashion. However, they follow a peaked response in lodgepole pine, similar to the response to even-aged management. Uneven-aged management of spruce-fir forests results in immediate depression of relative hare density, which then recovers back to pre-treatment levels and beyond approximately 40 years after the treatment. The final season of field sampling for this project was summer 2024.

Literature Cited:

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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.

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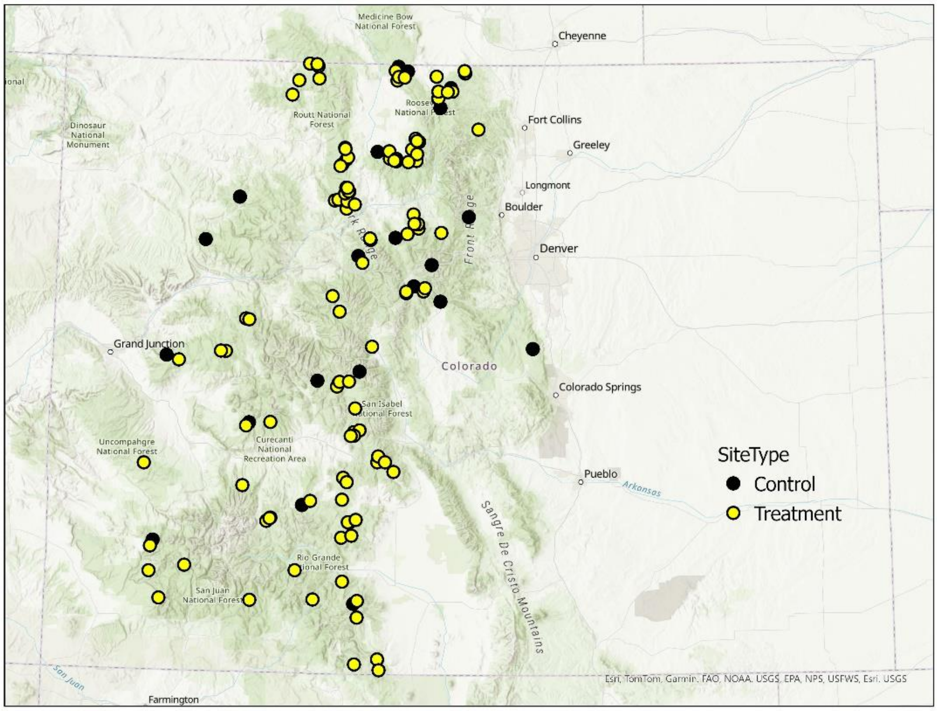

Figure 1. Location of all stands (*n* = 137) resampled for snowshoe hare pellets, June-August 2024.

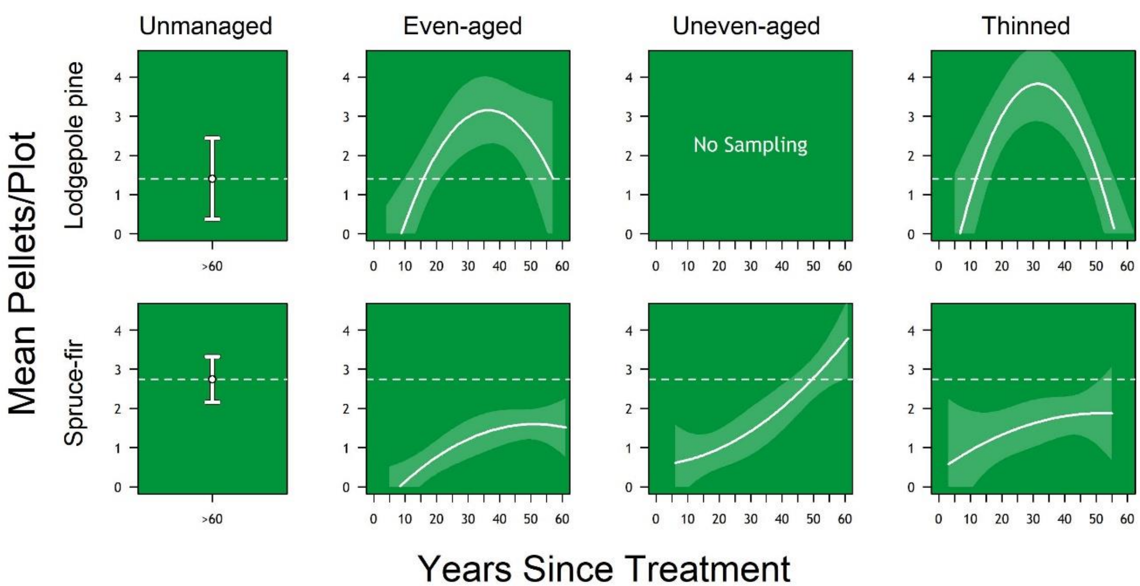

Figure 2. Fitted quadratic function (white line) and 95% CI (shaded polygon) relating pellet counts (i.e., relative snowshoe hare density) to time elapsed since treatment for each forest type × management activity combination. Dotted lines indicate the mean pellets/plot for the unmanaged controls for each forest type.

UNGULATE MANAGEMENT AND CONSERVATION

PILOT EVALUATION OF PREY DISTRIBUTION AND MOOSE RECRUITMENT FOLLOWING EXPOSURE TO WOLF PREDATION RISK IN NORTH PARK, COLORADO

EVALUATING FACTORS INFLUENCING ELK RECRUITMENT IN COLORADO

RESPONSE OF ELK TO HUMAN RECREATION AT MULTIPLE SCALES: DEMOGRAPHIC SHIFTS AND BEHAVIORALLY MEDIATED FLUCTUATIONS IN ABUNDANCE

SPATIOTEMPORAL EFFECTS OF HUMAN RECREATION ON ELK BEHAVIOR: AN ASSESSMENT WITHIN CRITICAL TIME STAGES

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Pilot evaluation of prey distribution and moose recruitment following exposure to wolf predation risk in North Park, Colorado

Period Covered: January 1, 2024 – December 31, 2024

Principal Investigator: Ellen Brandell, ellen.brandell@state.co.us

During November 2020, Colorado voters passed Proposition 114 (subsequently codified as Colorado Revised Statue 33-2-105.8), which directed Colorado Parks and Wildlife (CPW) and the CPW Wildlife Commission to develop a gray wolf (*Canis lupus*) reintroduction and management plan for Colorado by the end of 2023 (CPW 2023). Wolves are a native species to Colorado and prior to westward European expansion they occurred throughout the Rocky Mountains and into Colorado's eastern plains (Feldhamer et al. 2003). Since the 1940s, wolf presence in Colorado has been sporadic (Warren 1942, Lechleitner 1969, Armstrong et al. 2011, CPW 2023). Beginning in the early 2000s, CPW documented occasional wolf presence in Colorado (Colorado Parks and Wildlife 2021), primarily in North Park. During the summer of 2021, a pack comprised of 2 adults and 6 pups was observed in North Park, demonstrating the first wolf reproduction in Colorado in nearly 80 years. In December 2023, CPW introduced 10 wolves into the state from Oregon, fulfilling the December 31, 2023 deadline set in CRS 33-2-105.8. CPW continued their efforts by introducing 15 wolves from British Columbia into Colorado in January 2025. Between immigration, reintroduction, and reproduction, wolves will become a consistent feature on Colorado's landscape, and specifically in North Park. The return of wolves to Colorado's landscape has generated interest in future research projects.

Between the 1940s and present day, and largely in the absence of wolves, Colorado's ungulate prey populations (i.e., elk (*Cervus americanus*), mule deer (*Odocoileus hemionus*), and moose (*Alces alces*)) adapted to many changes. These changes included successional change in vegetation, increases and reductions in competition with other native herbivores and livestock, novel diseases, predation from mountain lions (*Puma concolor*), black bears (*Ursus americanus*), and coyotes (*Canis latrans*), but also increased human activity, human disturbance, and large increases in human infrastructure. Moose experienced deliberate management transplants between the late 1970s (Denney 1976) and mid-2000s. By 2022, Colorado's moose population was estimated to be 3,000–3,500 animals (CPW, unpublished data). Similarly, during the 1940s it was believed there were 45,000 elk in Colorado (Swift 1945) and population growth during the next 6–7 decades led to a peak of ~300,000 animals during the late 1990s and early 2000s (CPW, unpublished data).

This research is generally focused on predator-prey dynamics and how wolves will influence wild prey. Specifically, this research will measure prey survival, productivity, and behavior. To supplement survival and spatial data collected from moose during 2013–2019 (Bergman 2022), we initiated capture and collaring efforts of cow and calf moose during the winter of 2021–2022. These efforts demonstrated that moose calf abundance and subsequent moose calf density in North Park were insufficient to accommodate the necessary sample size for the initial study design of this project. Historically modeled estimates for the North Park moose herd suggest it is comprised of 600–800 animals. Sex and age distribution data from this herd simultaneously indicate there are ~70 bulls/100 cows and ~52 calves/100 cows, thereby suggesting that there are ~140–190 calves in North Park. However, it is likely that >50% of these calves reside on private lands during winter, making their access for capture purposes logistically difficult. Accordingly, there are likely only ~70–95 calves available on public land, of which CPW would need to capture 65%-85% to meet sample size requirements. Capturing such a large proportion of this calf population is both logistically and financially difficult, and preliminary efforts in North Park provided evidence that it would be infeasible to capture 60 moose calves each winter. However, capture efforts of cow moose from 2013–2019 (Bergman 2022), and again during the winter of 2021–2022, provided evidence of adequate densities to accommodate robust capturing and collaring efforts, thereby presenting alternative opportunities to estimate calf survival.

Advancements in satellite collar technology make it feasible for researchers to attain location data from moose that were collected only a few hours earlier. When coupled with VHF capabilities, researchers have the ability to quickly relocate and observe animals. For the purposes of this study, this technology will allow researchers to observe cow moose, but also observe if cow moose are accompanied by a calf (<12 months old). Repeated observations of cows and calves in this manner, and gathered at key points in time, will allow researchers to approximate calf survival by quantifying the decay in calf/cow ratios from birth to the yearling age class (Lukacs et al. 2004). While these data will not provide cause-specific calf mortality estimates, they will improve population models that inform moose ecology and harvest management decision making for the North Park moose herd.

To implement this alternative approach to estimating calf survival, we planned to capture and collar a total of 80 cow moose in North Park. In addition to the previously collared moose, 65 moose were collared for the first time in February 2023. Collars were be deployed in a spatially balanced manner, with approximately 40 collars on both the northern and southern halves of North Park. Three calf-at-heel surveys are to be conducted per biological year during June, December, and April; this allows for calculation of survival post-parturition, prior to their first winter, and at nearly one-year old. Calf-at-heel surveys were conducted for the 2023 biological year in June, December, and May, as well as for the 2024 biological year in June and December so far (Table 1).

In each survey, cows may not have been located due to dense cover, animal movement from last known GPS location, inaccessible terrain, or collar malfunction. Over time, sample size decreased due to collar failures and harvest. We collared six additional moose in March 2024 to bolster sample size.

Further analysis and estimation of monthly and annual calf survival rates will be done in the future when data collection is complete. Thus far, data collected from cow moose during 2023 and 2024 did not deviate from data collected during 2013–2019. From 2012–2022, survival of cow moose ranged from 91.2%–94.8%. During the same period, pregnancy rates of moose ranged from 54.8%–88.0%.

Table 1. Preliminary summary of calf-at-heel surveys. Cows observed is reported as a proportion and number. Calf:cow ratios are unadjusted and should not be interpreted as survival.

Biological Year	**Month**	**Cows Observed**	**Calf:Cow Ratio**
2023	June	0.93 (n = 53)	0.60
2023	December	0.71 (n = 37)	0.43
2023	May	0.86 (n = 51)	0.30
2024	June	0.82 (n = 46)	0.54
2024	December	0.90 (n = 44)	0.48

To expand this research to include additional prey species, 40 cow elk were collared in February 2023. These elk will serve as sentinel animals that will allow researchers to quantify group size behavior, spatial distribution, and habitat use, relative to any known wolf activity. Collars were be deployed in a spatially balanced manner, with approximately 20 collars on both the northern and southern halves of North Park. Six additional elk were collared in March 2024 to maintain our sample size following harvest.

To collect these data, we aimed to obtain aerial visual observations of all collared elk on a monthly basis and record the habitat type and the elk group size. In addition to estimating group size from the air, we took photographs, allowing us to count elk in groups. We conducted sixteen aerial surveys from March 2023 to December 2024 (7 in 2023, 9 in 2024), and located 58% of collared elk per flight on average. This resulted in an average of 13.13 unique elk groups observed per survey. We will continue approximately monthly elk surveys in addition to the continual locational data collection on GPS collars.

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Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Evaluating factors influencing elk recruitment in Colorado

Period Covered: January 1, 2024-December 31, 2024

Principal Investigators: Nathaniel Rayl, nathaniel.rayl@state.co.us; Mat Alldredge, mat.alldredge@state.co.us; Chuck Anderson, chuck.anderson@state.co.us

In Colorado, elk (*Cervus canadensis*) are an important natural resource that are valued for ecological, consumptive, aesthetic, and economic reasons. In 1910, less than 1,000 elk remained in Colorado (Swift 1945), but today the state population is estimated to be the largest in the country, with more than 290,000 elk. Over the last two decades, however, wildlife managers in Colorado have become increasingly concerned about declining winter elk calf recruitment (estimated using juvenile/adult female ratios) in the southern portion of the state. Although juvenile/adult female ratios are often highly correlated with juvenile elk survival, they are an imperfect estimate of recruitment because they are affected by harvest, pregnancy rates, juvenile survival, and adult female survival (Caughley 1974, Gaillard et al. 2000, Harris et al. 2008, Lukacs et al. 2018). Thus, there is a need for elk research in Colorado based upon monitoring of marked individuals to evaluate factors affecting each stage of production and survival. In 2016, we began a study to investigate factors influencing elk recruitment in 2 elk Data Analysis Units (DAUs; E-20, E-33) with low juvenile/adult female ratios (Figure 1). In 2019, we expanded this study into a 3rd DAU with high juvenile/adult female ratios (E-2), to better determine how predators, habitat, and weather conditions are impacting elk recruitment in Colorado (Figure 2). In 2021, we concluded collaring efforts in E-33.

Since study initiation, we have collared 593 pregnant females in February-March, 901 neonates in May-August, and 299 6-month-old calves in December (Table 1). Averaged across years, we estimated that the annual pregnancy rate of adult female elk was 94% in the Bear's Ears herd (excluding 2019 data where $n = 3$; range = 87-98%), 91% in the Trinchera herd (range = 78-97%), and 93% (range = 81-98%) in the Uncompahgre Plateau herd (Figure 3). Elk populations experiencing good to excellent summer-autumn nutrition typically have pregnancy rates ≥90% (Cook et al. 2013). From 2017-2024, we estimated that the mean ingesta-free body fat (IFBF) of adult female elk was 6.98% (95% CI = 6.81-7.15%) in the Bear's Ears Herd, 7.60% (95% CI = 7.32-7.87%) in the Trinchera herd, and 7.64% (95% CI = 7.44-7.83%) in the Uncompahgre Plateau herd (Figure 4). When late-winter IFBF values are <8-9% for adult female elk that have lactated through the previous growing season, this suggests that there may be nutritional limitations, but it does not identify whether limitations are a result of summer-autumn or winter nutrition (R. Cook, personal communication). Averaged across years, we estimated that the median date of calving was May 31 in the Bear's Ears herd and June 1 in the Trinchera and Uncompahgre Plateau herds (Figure 5). We estimated that the mean weight of 6-month-old elk calves was 223.0 lb (95% CI = 217.8-228.3 lb) from the Bear's Ears herd and 233.6 lb (95% CI = 228.4-238.8 lb) from the Uncompahgre Plateau elk herd.

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Table 1. The number of elk collared in each age class from the Bear's Ears (DAU E-2), Uncompahgre Plateau (DAU E-20), and Trinchera (DAU E-33) herds from 2017-2024.

	Herd							
	E-2 Bear's Ears			E-20 Uncompahgre Plateau			E-33 Trinchera	
Year	Adult	Neonate	6-month	Adult	Neonate	6-month	Adult	Neonate
2017				23	40		23	57
2018				25	48		21	53
2019	2	49	25	30	49	25	30	46
2020	40	54	25	40	52	25	19	21
2021	40	53	25	40	52	25	20	21
2022	40	54	21	40	53	25		
2023	40	43	25	40	54	25		
2024	40	50	27	40	52	26		

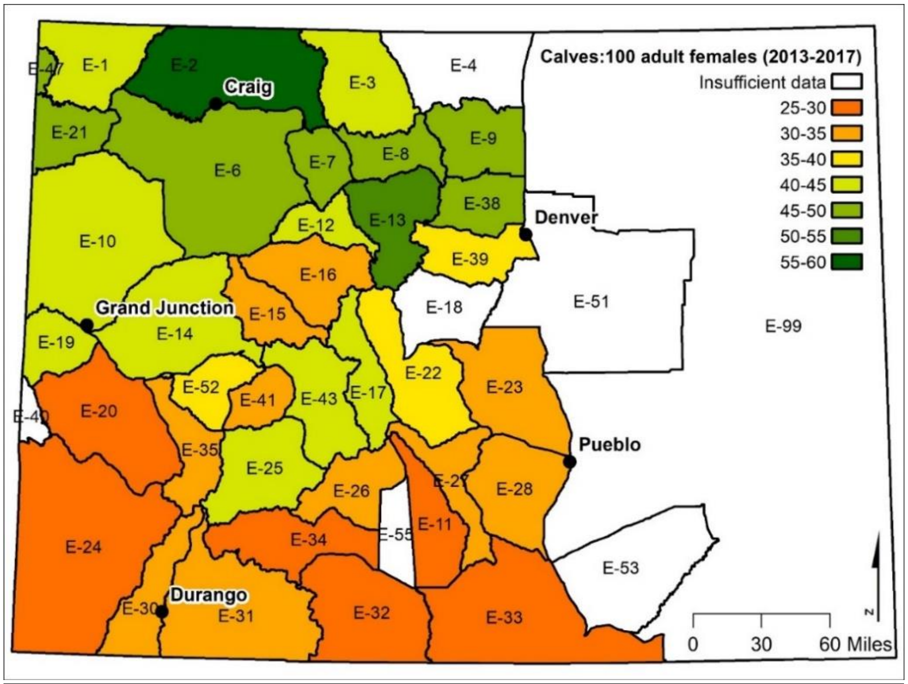

Figure 1. The number of elk calves per 100 adult females observed during December-February aerial surveys (5-year average from 2013-2017) within elk Data Analysis Units (DAUs; labeled with black text).

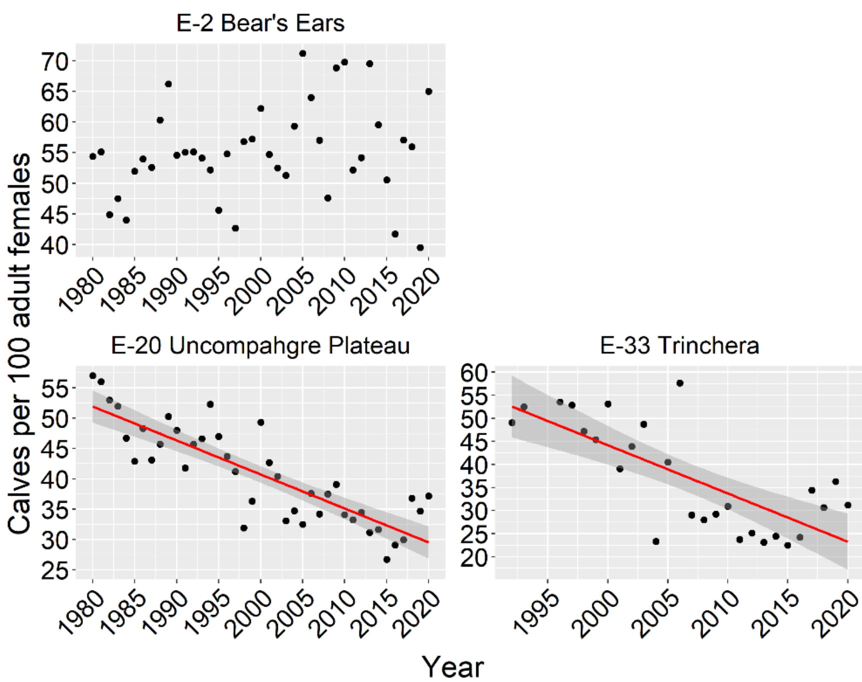

Figure 2. The estimated number of calves per 100 adult females observed annually during winter classification surveys in the Bear's Ears (DAU E-2), Uncompahgre Plateau (DAU E-20), and Trinchera (DAU E-33) elk herds from 1980-2020 (1992-2020 for the Trinchera herd). Red lines and shaded bands represent linear regression trends with 95% confidence intervals, and indicate an average decrease of 0.56 and 1.05 calves per 100 adult females per year in the Uncompahgre Plateau and Trinchera herds, respectively.

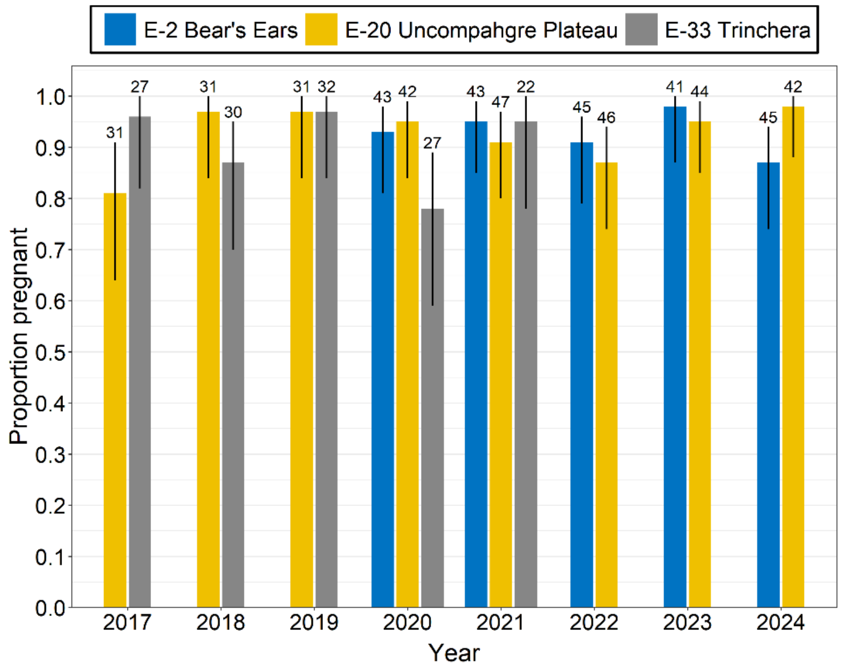

Figure 3. Estimated average pregnancy rates of adult female elk from the Bear's Ears (DAU E-2), Uncompahgre Plateau (DAU E-20), and Trinchera (DAU E-33) herds sampled during late winter 2017-2024. The sample size is given at the top of the 95% binomial confidence intervals (black lines).

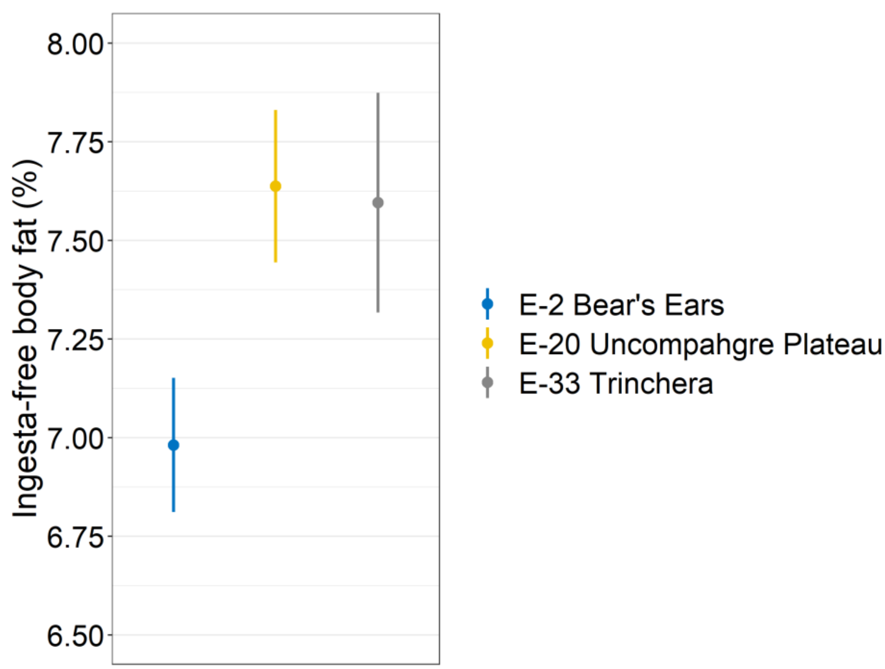

Figure 4. The estimated ingesta-free body fat (%) of adult female elk with 95% confidence intervals from the Bear's Ears (DAU E-2), Uncompahgre Plateau (DAU E-20), and Trinchera (DAU E-33) herds sampled during late winter 2017-2024.

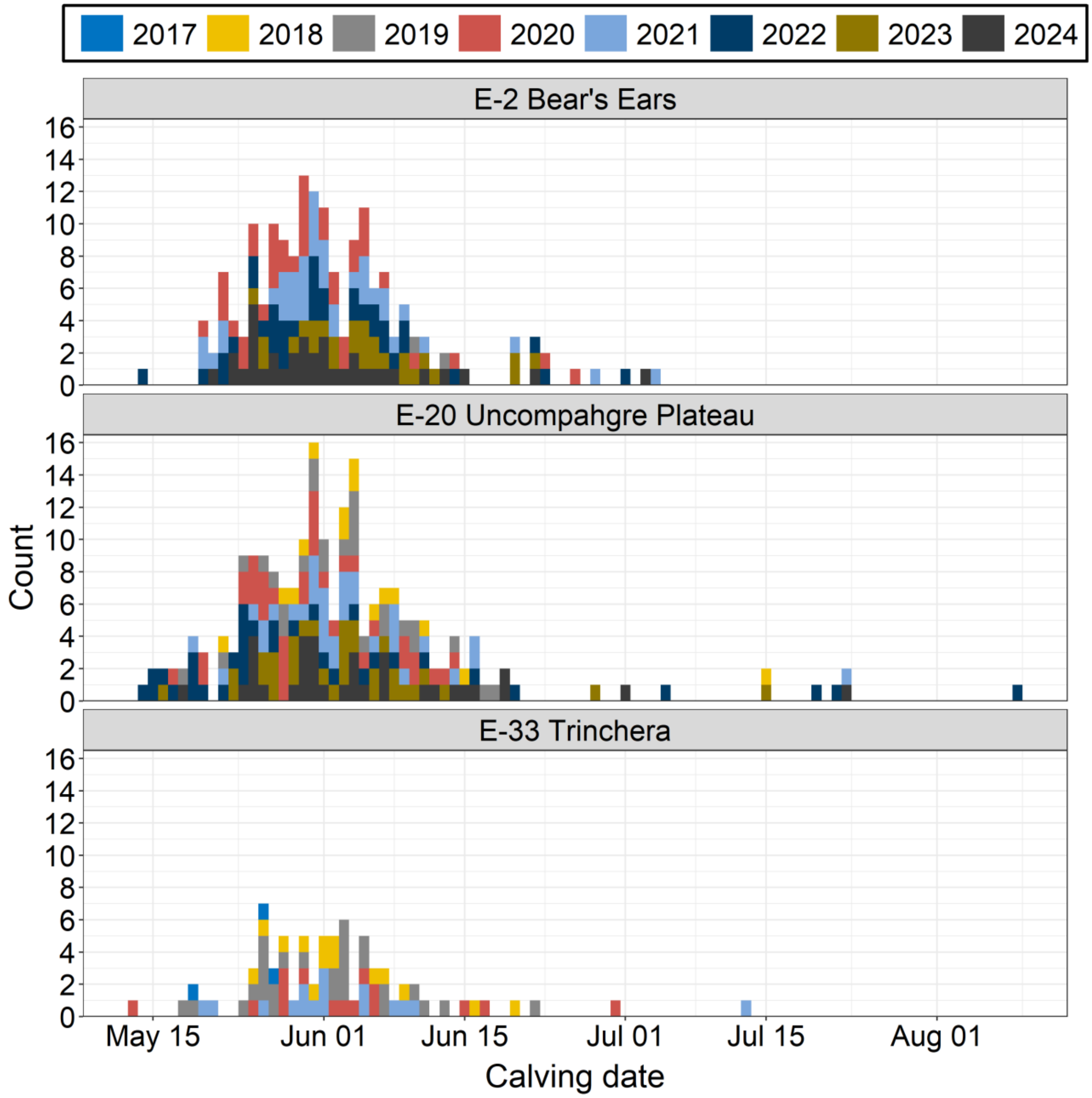

Figure 5. The estimated calving dates of collared female elk from the Bear's Ears (DAU E-2), Uncompahgre Plateau (DAU E-20), and Trinchera (DAU E-33) herds from 2017-2024.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Response of elk to human recreation at multiple scales: demographic shifts and behaviorally-mediated fluctuations in local abundance

Period Covered: January 1, 2024-December 31, 2024

Principal Investigators: Eric Bergman, eric.bergman@state.co.us; Nathaniel Rayl, nathaniel.rayl@state.co.us

This project has objectives on 2 scales. At the broad, elk herd-level scale, we are estimating pregnancy rates, calf survival rates, and cause-specific mortality rates to evaluate the importance of mortality sources for elk calf survival. More specifically, we are evaluating the influence of biotic (birth date, birth mass, gender, maternal body condition, habitat conditions), abiotic (previous and current weather conditions), and human-induced factors (i.e., relative exposure to recreational activities) on seasonal mortality risk of elk calves from birth to age 1 and on pregnancy rates of mature female elk. At the narrower geographic and temporal scale, we are using short-term (~3-4 weeks) changes in elk abundance within small study units (<65 km^2 [25 mi^2]) as a tool to evaluate the influence of human recreation on elk distribution. At this narrower scale, the primary objective is to evaluate the role that human recreation (e.g., hiking, mountain biking, horseback riding, trail running, hunting, etc.) has on the behavioral distribution of elk on spring calving, summer, and fall transition ranges. Coupled to the objective of detecting behaviorally influenced changes in abundance and density, we are evaluating the effectiveness of current recreational closures maintained by ski areas, counties, and federal land management agencies.

From 2019-2024, we have collared 224 pregnant females in March, 299 neonates in May-July, and 151 6-month-old calves in December from the Avalanche Creek elk herd (Data Analysis Unit E-15; Table 1). Averaged across years, we estimated the annual pregnancy rate of adult female elk was 91% (95% CI = 87-94%; Figure 1). Elk populations experiencing good to excellent summer-autumn nutrition typically have pregnancy rates ≥90% (Cook et al. 2013). We estimated that the mean ingesta-free body fat (IFBF) of adult female elk was 8.25 (95 CI = 7.95-8.55%). When late-winter IFBF values are <8-9% for adult female elk that have lactated through the previous growing season, this suggests that there may be nutritional limitations, but it does not identify whether limitations are a result of summer-autumn or winter nutrition (R. Cook, personal communication). Averaged across years, we estimated that the median date of calving was June 1 (Figure 2). We estimated that the mean weight of 6-month-old elk calves was 245.0 lb (95% CI = 239.7-250.3).

From 2019-2023, 20,021,930 photos were taken at 1,081 camera sites deployed across eight study units (Table 2). We have developed a workflow that uses Artificial Intelligence (AI) photo recognition software to identify photos that the AI software has a >20% confidence contains an object (animal, person, or vehicle). This has reduced the number of photos we need to classify manually by more than 90% (Table 2). We are in the process of manually classifying the remaining two million photos, with a goal of completing all classification work by fall 2025.

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Cook, R. C., J. G. Cook, D. J. Vales, B. K. Johnson, S. M. McCorquodale, L. A. Shipley, R. A. Riggs, L. L. Irwin, S. L. Murphie, B. L. Murphie, K. A. Schoenecker, F. Geyer, P. B. Hall, R. D. Spencer, D. A. Immell, D. H. Jackson, B. L. Tiller, P. J. Miller, and L. Schmitz. 2013. Regional and seasonal patterns of nutritional condition and reproduction in elk. Wildlife Monographs 184:1–44.

Table 1. The number of elk collared in each age class from the Avalanche Creek elk herd (DAU E-15) from 2019-2023.

	Age class		
Year	Adult	Neonate	6-month
2019	24	26	25
2020	40	54	25
2021	40	51	25
2022	40	53	25
2023	40	60	25
2024	40	55	26

Table 2. The number of camera sites, photos, and photos that were classified as containing objects (animal, human, or vehicle) with a >20% confidence by Artificial Intelligence photo recognition software from 2019-2023.

Year	Sites	Photos	Photos with objects (>0.20 confidence)
2019	116	394,024	53,663
2020	254	5,345,029	518,118
2021	237	4,856,986	483,047
2022	237	4,241,615	406,446
2023	237	5,184,276	465,261
Total:	1,081	20,021,930	1,926,535

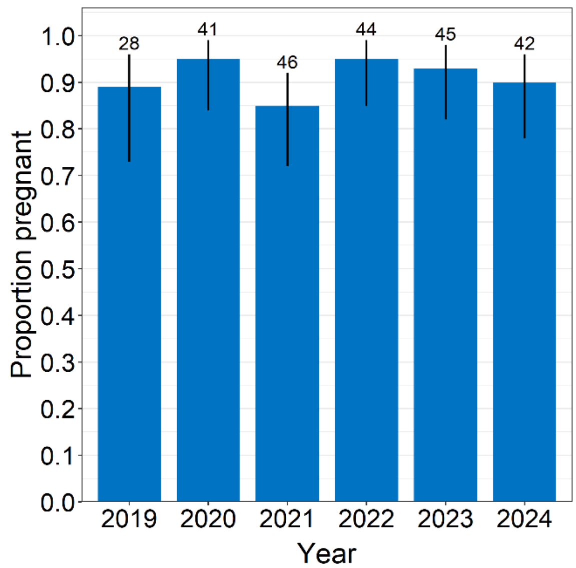

Figure 1. Estimated average pregnancy rates of adult female elk from the Avalanche Creek (DAU E-15) herds sampled during late winter 2019-2024. The sample size is given at the top of the 95% binomial confidence intervals (black lines).

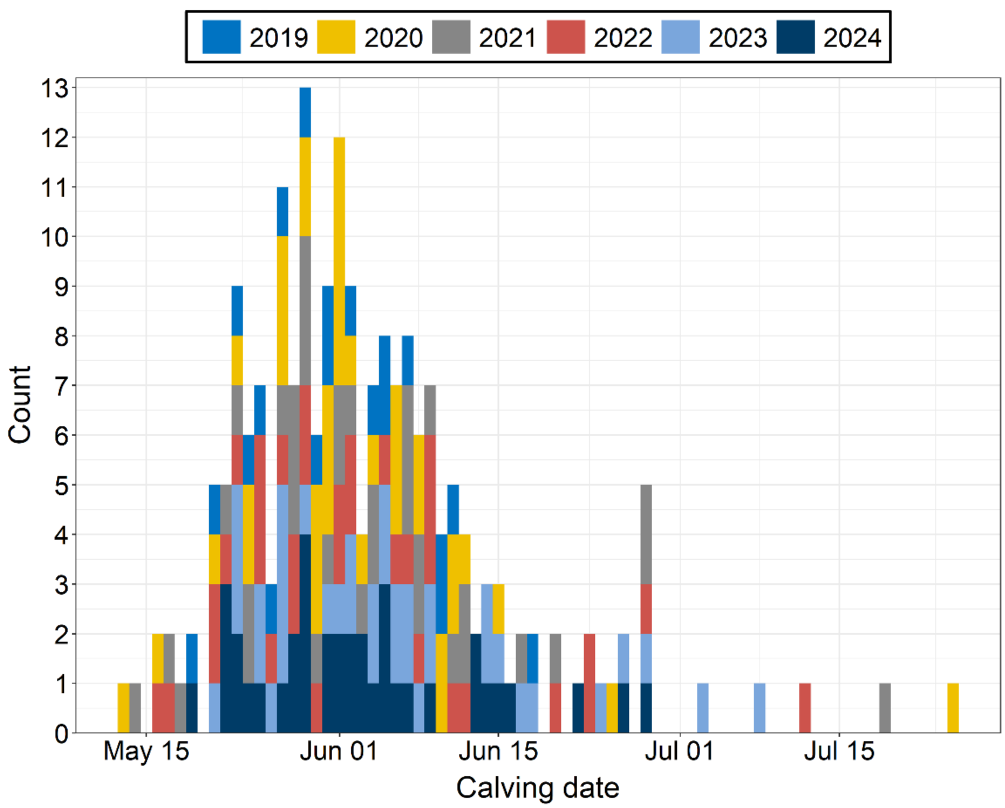

Figure 2. The estimated calving dates of collared female elk from the Avalanche Creek (DAU E-15) herd from 2019-2024.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Spatiotemporal effects of human recreation on elk behavior: an assessment within critical time stages

Period Covered: January 1, 2024-December 31, 2024

Principal Investigators: Nathaniel Rayl, nathaniel.rayl@state.co.us; Eric Bergman, eric.bergman@state.co.us; Joe Holbrook, Joe.Holbrook@uwyo.edu

The influence of recreational disturbance on ungulate populations is of particular interest to wildlife managers in Colorado, as there is growing concern about its potential impacts within the state. Currently, the western United States is experiencing some of the highest rates of human population growth in the country, with growth in rural and exurban areas frequently outpacing growth in urban areas. Additionally, participation in outdoor recreation is also increasing. In Colorado, the number of individuals participating in recreational activities, and the associated demand for recreational opportunities, appear to be increasing. Understanding potential impacts of recreational activity on elk spatial ecology in Colorado is critical for guiding management actions, as altered movements may result in reduced foraging time and higher energetic costs, which may decrease fitness.

We are studying elk from the resident portion of the Bear's Ears elk herd (DAU E-2) in Colorado to determine potential impacts of recreational activities on this population. This research project is a collaboration between Colorado Parks and Wildlife (CPW) and the Haub School of Environment and Natural Resources at the University of Wyoming, and forms the basis of an M.S. thesis for a graduate student (Eric VanNatta, also CPW Area 10 Terrestrial Biologist) enrolled at the Haub School.

In January 2020 and January 2021, we collared 30 and 26 adult female elk, respectively, from the resident portion of the Bear's Ears elk herd on U.S. Forest Service (USFS) land near Steamboat Springs. We estimated pregnancy rates of 93% (95% CI: 79-98%) in 2020 and 96% (95% CI: 81-100%) in 2021.

From May-October 2020 we deployed trail counters at 22 trailheads in the Routt National Forest (Figure 1). We recorded roughly 100,000 people departing and returning from these trailheads. Among individual trailheads, we documented average daily traffic counts ranging from 2-325 people (Figure 2). Most traffic was recorded on weekends with noticeable lulls in traffic frequency observed during weekdays. During the 2021 field season, we again deployed trail counters at the 22 trailheads, and also added additional trail counters at 1-km intervals along each trail for up to 5-km from the trailhead. These additional trail counters are being deployed on a rotating basis to sample each trail. Data collected from these additional trail counters will provide an estimate of the decay of traffic along trails.

During the 2020 and 2021 field season, we distributed handheld GPSs to recreationists (hikers, bikers, hunters) to record detailed tracks of human use within this trail system (Figure 3). In 2020, we collected over 100 GPS tracks. These tracks from recreationists and hunters will allow us to better quantify human recreation on the landscape and evaluate how elk respond to recreationists. In fall 2023, Eric VanNatta successfully completed and defended his M.S. proposal at the University of Wyoming and finished processing and cleaning the trail counter dataset. In 2024, Eric worked on analyses for the first chapter of his thesis, which should be completed in early 2025.

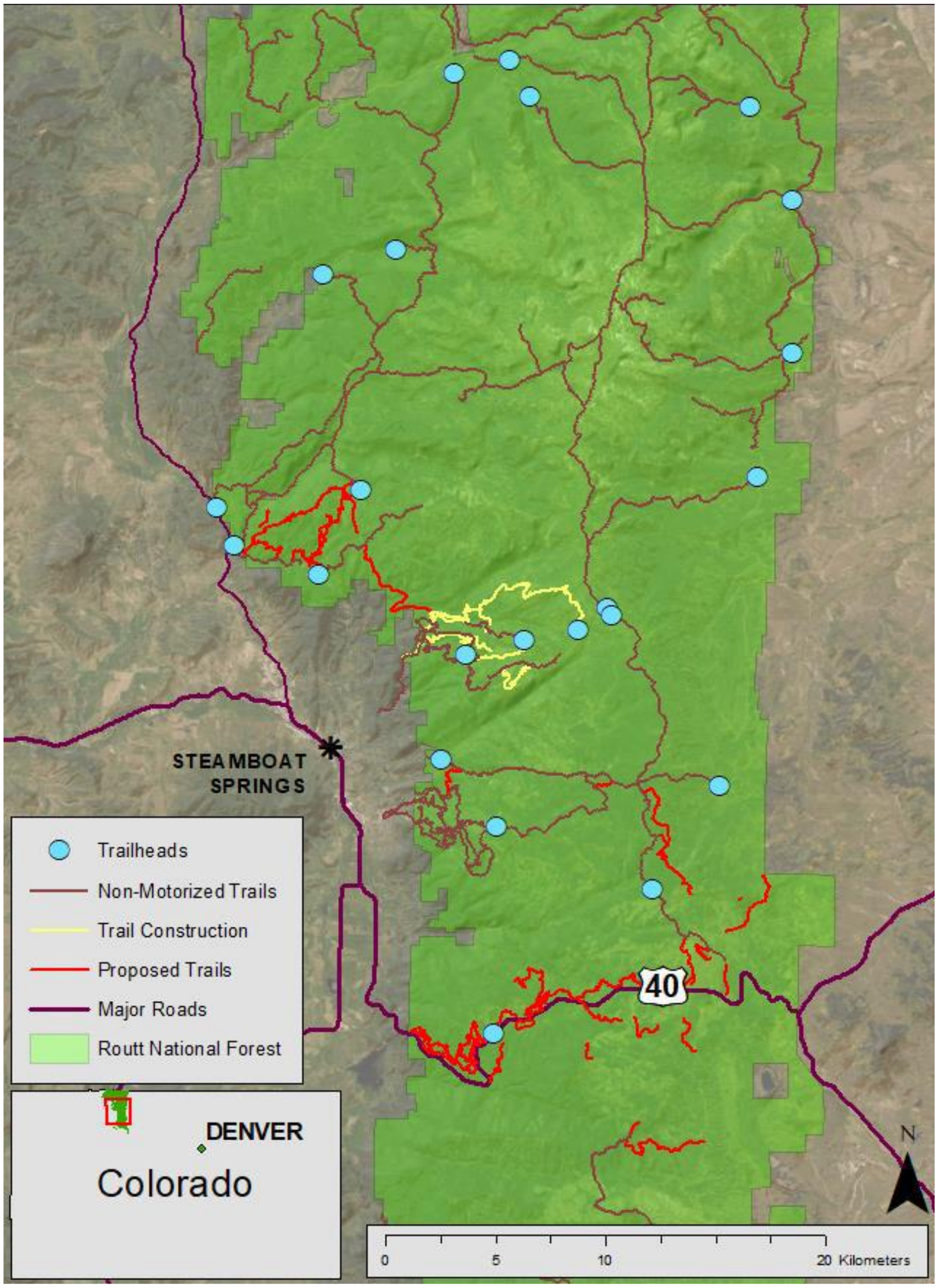

Figure 1. Routt National Forest study area located in northwest Colorado, USA.

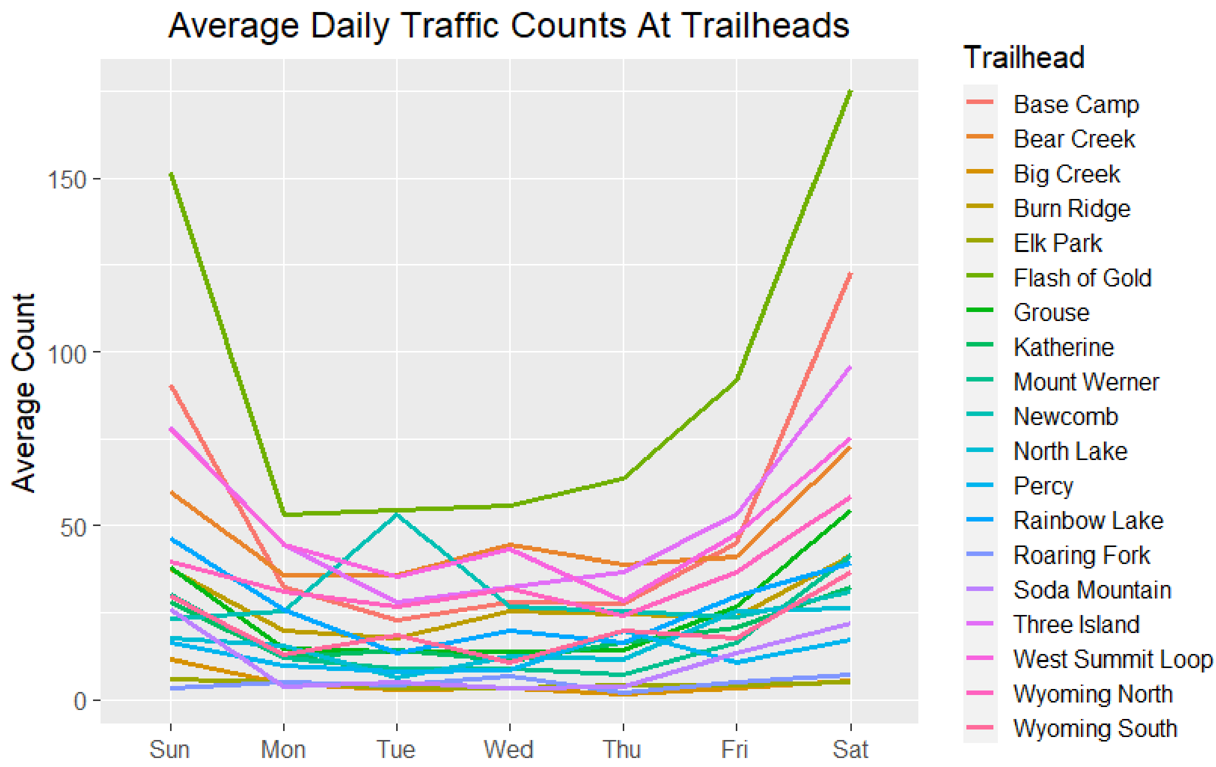

Figure 2. Daily trends in trailhead traffic documented with trail counters from June through October 2020, excluding Fish Creek Falls, Mad Creek, and Red Dirt trailheads, which received average daily counts >200.

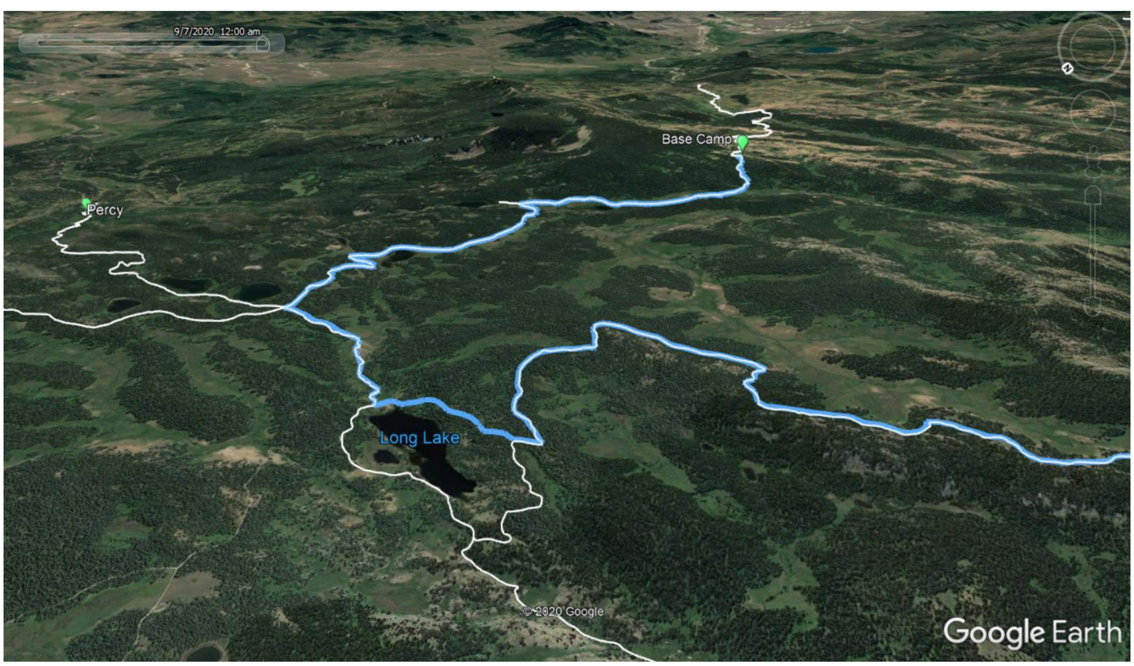

Figure 3. GPS track (blue) recorded from recreational mountain biker on trail system (white) in August 2020. Note the off-trail use near Long Lake.

PREDATORY MAMMAL MANAGEMENT AND CONSERVATION

BOBCAT POPULATION DYNAMICS AND DENSITY ESTIMATION

MULE DEER POPULATION RESPONSE TO COUGAR POPULATION MANIPULATION

EVALUATION OF ACCELEROMETER COLLARS AND METHODS DEVELOPMENT FOR DOMESTIC CATTLE

Colorado Parks and Wildlife
WILDLIFE RESEARCH PROJECT SUMMARY

Bobcat population dynamics and density estimation

Period Covered: January 01, 2024 – December 31, 2024

Principal Investigators: Shane Frank, shane.frank@state.co.us; Jake Ivan, jake.ivan@state.co.us; Mark Vieira, mark.vieira@state.co.us; Jon Runge, jon.runge@state.co.us

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To enhance our understanding of bobcat (*Lynx rufus*) population dynamics and the relative influence of bobcat harvest on bobcat densities in Colorado, we initiated a research project late September 2022 in 2 study areas with similar habitat types but differing harvest levels (1 high, 1 low) to (1) capture and mark bobcats with ear tags and GPS collars to be used in remote camera mark-resight analysis for population density estimation; and (2) address population dynamics of populations exposed to different mortality factors. Field seasons for this project start in fall (~October) and continue into early spring (~March). This report includes two full capture seasons (2022-2023 and 2023-2024) and partially covers a 2024-2025 capture season (Oct-Dec 2024).

We selected two study areas, 'Piceance' and 'Skull Creek,' in the northwest region within GMUs 10 and 22 (Figure 1). Each area was 20 x 20 km (400 km2 area) in extent, with similar topography and habitat composition. Piceance had higher historical bobcat harvest (>2.55 bobcats/100 km2) than Skull Creek (nearly 0 bobcats/100 km2). Habitat type composition was predominated by pinyon (Pinus spp.)-juniper (Juniperus spp.) and sagebrush (Artemisia spp.) communities in both study areas. A grid of 100 cameras arranged in a 2x2 km spacing or 100 cells total was maintained in each study area (Figure 1). Cumulatively, as of 12/31/2024, CPW has had 74 bobcat captures (52 males, 22 females), of which 50 were new captures/individuals and 24 were recaptures (Figure 2, top row). The majority of captures are adults in each study area (>70%). The captures in the high harvest area had a higher proportion (~30%) of subadults compared to the low harvest area (~5%). Of the 50 newly marked bobcats, 40 were collared. On average, an unmarked bobcat required approximately 300 trap nights for capture during the early 2024 and then only 31 trap nights in late 2024. This variation in success rate is hypothesized to be a difference in winter conditions, prey availability, and potentially increasingly consistent trapping pressure over time. Dietary work and subsequent spatial analysis will help elucidate influences on capture success, but this is part of an on-going master thesis and has not been completed.

We have recorded ~30,000 GPS locations from the 40 collared bobcats. Nearly a quarter of the collared GPS-collared bobcats (*n* = 12) have died with mortality sources stemming from harvest (*n* = 7), potentially illegal take (*n* = 2), natural mortality (*n* = 2), and capture-related (*n* = 1) which appeared to be from a pre-existing pathology. There are currently 17 collared bobcats in Piceance (high harvest) and 12 collared bobcats in Skull Creek (low harvest). We are currently halfway through identifying animal detections on 800,000+ camera photos for the purpose of mark-resight bobcat population estimation. Preliminary analysis suggests that collared bobcats on the low harvest study area have more time on survey grids. This might have implications for differences in probability of detection (rates) or resights between the study areas for GPS-collared bobcats since fall of 2022 until present. Here each polygon is an individual bobcat's space use and has a minimum of 100 locations (21 Males, 8 Females).

In fall of 2024, CPW personnel checked and refreshed 100 camera traps within each study area (Figure 1). Camera trap checks included replacing visual attractants and scent lure to draw bobcats for photo detections or 'resights' in the case of marked bobcats. This year we conducted rabbit and deer pellet plot survey counts (*n* = 5, Figure 2) at each camera location to be associated with leporid and deer camera detection rates. This information will aid in giving a relative abundance of potential prey items between the study areas, in addition to a potential spatial distribution of prey within each area. Live-trapping efforts in both study areas will continue through spring and camera image collection will continue through late summer of 2025, at which point photo identification and mark-resight analysis will be performed for the new complete data set (2023-2025). Study areas will move from pinyon-juniper/sagebrush communities to a new habitat type (e.g., ponderosa pine) beginning fall of 2025 to address bobcat density/habitat relationships.

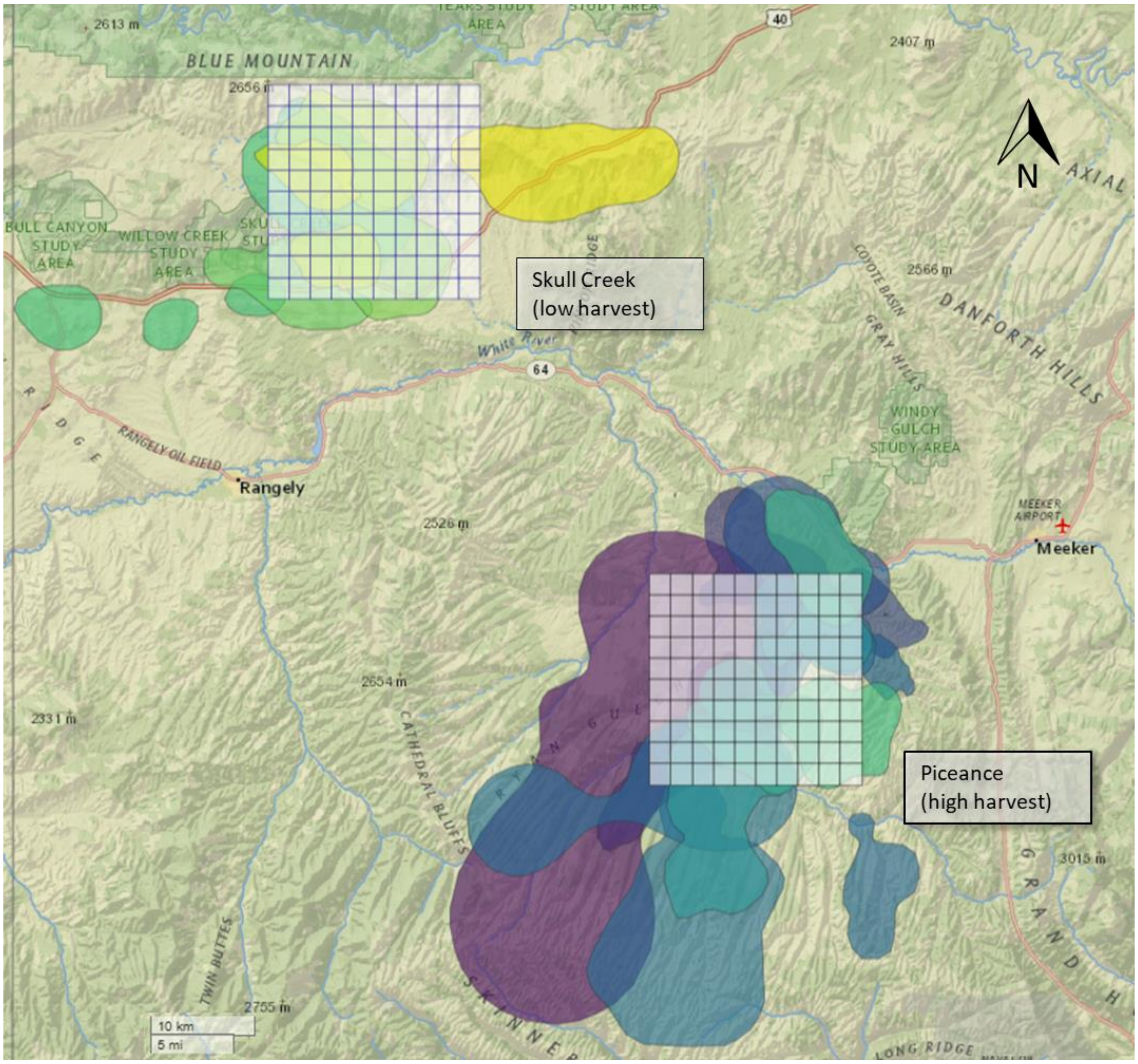

Figure 1. Bobcat study areas (20 x 20 km) in northwest Colorado include the high bobcat harvest study area (Piceance) as the southernmost grid and the low bobcat harvest study area (Skull Creek) as the northernmost grid, which is bordered by Dinosaur National Monument (green shaded area) to the north. Bobcat study areas are subdivided into 100 2 x 2 km cells, each containing one camera trap (not shown). Colored background polygons represent individual bobcat annual ranges.

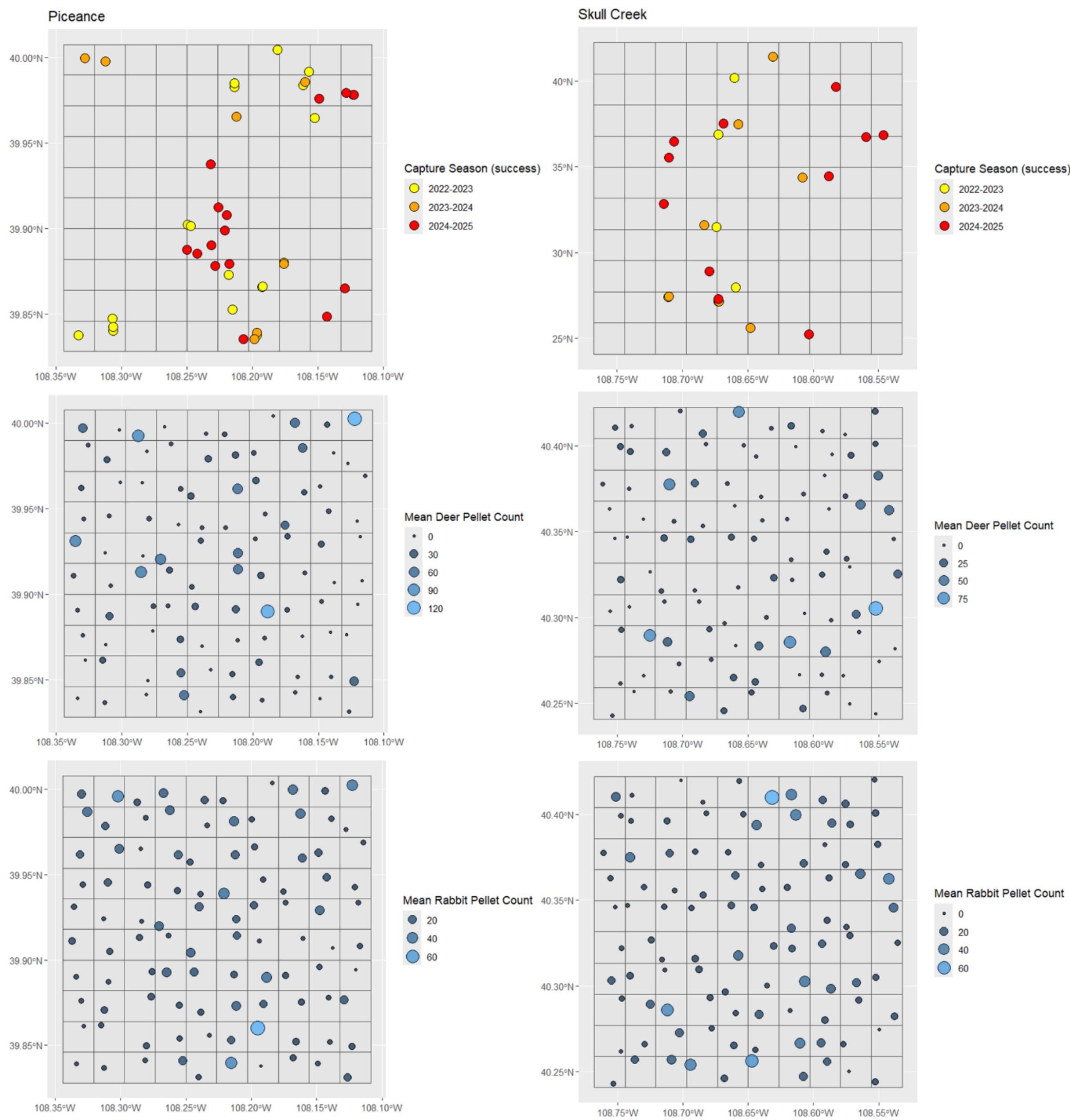

Figure 2. Each panel is a bobcat study area grid, with the left column High Harvest/Piceance and right column Low Harvest/Skull Creek. The top row depicts all the successful capture locations across trapping seasons (yellow: 2022-2023, orange: 2023-2024, red: 2024-2025). The middle row depicts the mean pellet count of deer pellets (variably sized blue dots) at each of the camera sites. The bottom row depicts the mean pellet count of leporid, i.e. cottontail and jackrabbit, pellets (variably sized blue dots) at each of the camera sites. For both deer and leporids, we used five pellet plots at each of the camera sites (n = 500 pellet plots per study area).

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Mule deer population response to cougar population manipulation

Period Covered: January 1, 2024 – December 31, 2024

Principal Investigators: Mat Alldredge, mat.alldredge@state.co.us; Allen Vitt, allen.vitt@state.co.us; Bryan Lamont, bryan.lamont@state.co.us; Ty Woodward, tyrel.woodward@state.co.us; Jamin Grigg, jamin.grigg@state.co.us; Chuck Anderson, chuck.anderson@state.co.us

The adopted Colorado mule deer (*Odocoileus hemionus*) strategy identified predation as one of the potential factors limiting Colorado mule deer populations. Since the adoption of the mule deer strategy by the Colorado Parks and Wildlife (CPW) Commission, members of the CPW Leadership Team developed a plan to implement the strategy. To inform predator harvest and management decisions, staff examined existing data sets related to predator and deer relationships. In June 2015, CPW personnel from the SE Region, Terrestrial, and Research branches met to explore the concept for a project that examines how deer demographic parameters may change following cougar population suppression. Deer Data Analysis Unit (DAU) D-16 had experienced significant deer mortality from cougars. This study initiated in 2017 in D-16 and the adjacent D-34 as a manipulative study to examine the effects of cougar predation on mule deer and simultaneously examine the effects of cougar harvest on the cougar population.

To assess the effect of management manipulations, it was necessary to develop an experimental framework including a control and treatment study area. Otherwise, the magnitude of the effect would be unknown as other limiting factors fluctuate. D-34 is an adjacent mule deer DAU to the south of D-16, which has a similar mule deer population size and habitat. Using D-16 and D-34 in a crossover design allowed for the manipulation of a potential limiting factor for mule deer population growth or survival and examine similarities in the response as the control and treatment are switched between the areas. The study's first objective was to assess the impact of cougar predation on mule deer survival and determine if this impact could be manipulated by altering cougar densities. The second objective was to assess how this manipulation would affect the cougar population in terms of intraspecific mortality and human conflict.

The manipulation involved increasing cougar harvest in D-16 for the first 3 years of the study and then reducing harvest to a low level for the following 6 years and doing the reverse in D-34 with reduced harvest for the first 6 years and increased harvest in the last 3 years. During this time we would monitor deer mortality from cougars, measure cougar density, and assess intraspecific cougar mortality and cougar/human conflict in both study areas.

To date, deer survival has been relatively high (86% average doe survival D-16 and D-34; 64% average winter fawn survival D-16; 84% average winter fawn survival D-34) in both study areas across years and deer mortality associated with cougars has been low (5.6% does D-16; 7.2% does D-34; 4.2% fawns D-16; 2.1% fawns D-34). Because deer survival was relatively high in the area and mortality associated with cougars was relatively low during the first 6 years of the study, we stopped investigating the impact of cougar predation on deer survival. The remaining treatment was to increase cougar harvest in D34, which presumably would increase deer survival. However, it was decided that it would not be possible to measure an effect if it did occur with relatively high deer survival evident during the period of low cougar harvest/relatively high cougar density.

Graduate student, Annie Hart, at Colorado State University finished her Master's project examining the deer data. The first part of her project examined how variation in natural forage abundance influenced mule deer selection of agricultural resources. The other part of her project modeled adult and juvenile survival to help understand the costs and benefits of migration. This used a state uncertainty modeling approach to estimate survival of migrant and resident fawns, which incorporates the survival of individuals that die before their movement strategy is classified.

The cougar population component of the study is continuing with assessing impacts of cougar harvest in D-16 and D-34. We continue to estimate cougar density in both study areas and are monitoring intraspecific effects and cougar/human conflict. As this continues, we will maintain a low cougar harvest (quota of 12) in D-16 but need to increase the cougar quota in D-34. The quota in D-34 had been reduced to 15 since the study started, but we increased the quota to 35 cougars to start in the 2023-2024 hunting season, which was approved by the CPW Wildlife Commission in 2023 and will continue through the 2025-2026 hunting season. This total harvest of 35 was achieved in the 2023-2024 hunting season.

During the study we have captured and collared 124 cougars in D-16 and 129 in D-34. Last year we captured 11 in D-16 and 20 in D-34. The higher captures in D-34 were related to increased sample size requirements for the cougar survey in D-34. Over the last two years collars have been failing sooner than expected, presumably because collar batteries are not lasting as long as they used to.

To date, we have completed 4 density estimates in each D16 and D34 with preliminary estimates ranging from 2.7 to 3.1 independent cougars per 100 km^2. This does not account for any cougars that may have been harvested prior to the initiation of the survey each year. We have not detected a significant change in density relative to changes in harvest quotas or achieved harvest. In 2024 the density estimate was conducted in D16, which is the final estimate for this area.

Cougar mortality has been relatively low throughout the study, with the majority of this attributable to hunting mortality. Other sources of mortality include disease, intraspecific killing, human conflict removal and unknown. Intraspecific mortality has ranged from 1 to 2 incidences yearly in D16 and 1 to 3 in D34 for collared cougars.

Cougar/human conflict is variable between years and study areas. This conflict may include livestock depredation, pet depredation, being in unacceptable locations, or aggressive behaviors toward humans. We show conflict rates from 2000-2023 (Figure 1) which shows the variability across time. There may also be variability in these data from how it was reported and recorded, most notably the switch to an electronic/online approach of the conflict app in 2019. D34 had some of the highest conflict, especially in 2021 and 2023, but historical conflict rates also had occasional high years as well.

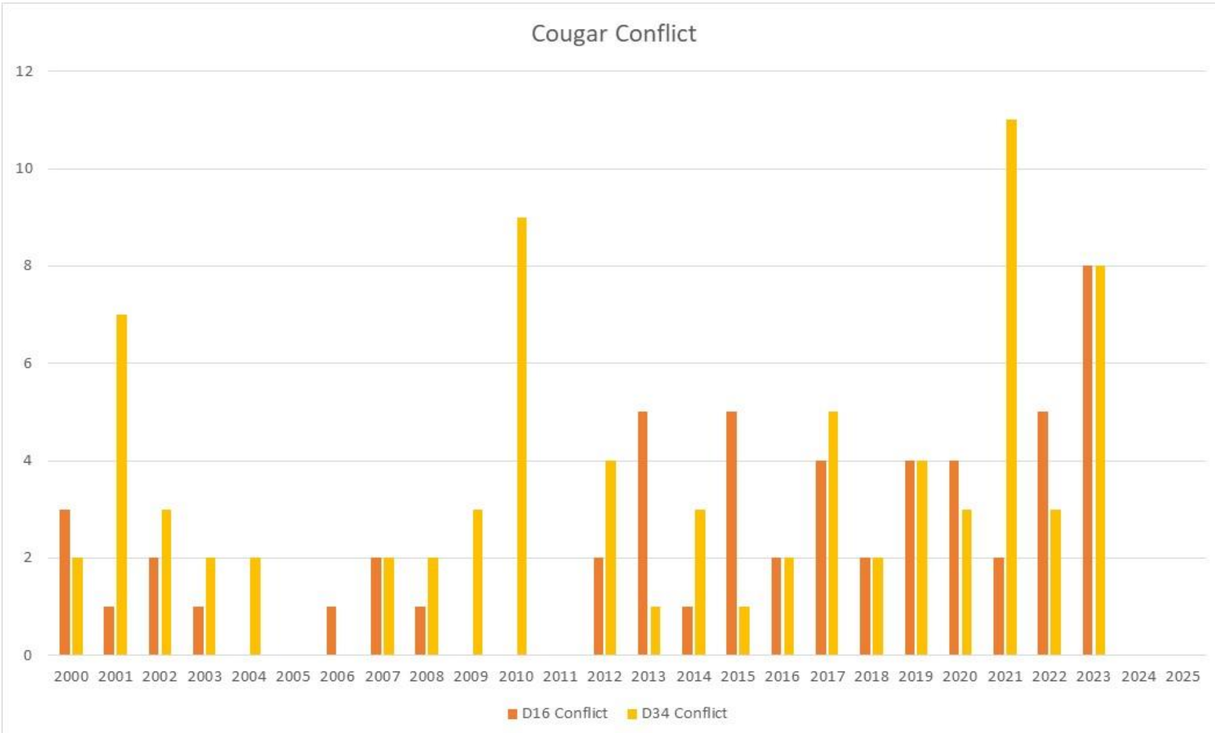

Figure 1: Number of human/cougar conflicts in DAUs D-16 and D-34 by year. This does not include sightings.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Evaluation of accelerometer collars and methods development for domestic cattle

Period Covered: January 1, 2024-December 31, 2024

Principal Investigator: Ellen Brandell, ellen.brandell@state.co.us

Livestock production is an important component of Colorado's economy (University of Arkansas, Bureau of Land Management), as well as ingrained in the state's culture and heritage– cattle production in particular. Colorado citizens are concerned about the effects of re-establishing gray wolves (*Canis lupus*) on livestock (Niemiec et al. 2022), and given the geographic constraints of CRS 33-2-105.8 (Colorado General Assembly 2020, CPW 2023) and suitable wolf habitat in Colorado (Ditmer et al. 2022), wolves and livestock will spatially overlap in western Colorado. Wolves may affect livestock both directly and indirectly; direct effects include depredation, which has already occurred in the state. Indirect effects, such as increased stress or vigilance behavior, are much more difficult to observe and quantify.

Indirect effects of wolves on cattle have been documented in other western states or laboratory experiments, such as decreased weight gain (Ramler et al. 2014) and increased stress (Cooke et al. 2013). However, these negative effects are not ubiquitous across studies, and the majority of published literature on this topic lacks a mechanistic understanding. For example, cattle movement rates (Laporte et al. 2010, Bailey et al. 2018) and physiology (Cooke et al. 2013) in response to wolf presence have been studied, but unless changes in movement rates or physiology have direct implications for weight gain, pregnancy rates, or animal health, it might not be important to a producer or impact the operation's economics.

In a future research project, we aim to link cattle behavior and movement in response to wolf presence to cattle stress levels, weight gain, and pregnancy rates. Quantifying the mechanisms of changes in cattle stress, weight gain, and pregnancy rates is critical for identifying whether a causal relationship exists between wolf exposure and cattle responses, the magnitude of this effect, and subsequent consequences for producers' bottom line. However, before we can launch a research project, we need to test the field equipment and develop data collection methods.

In spring 2023, we began a methods testing project is to evaluate GPS and accelerometer collars on beef cattle. We had three goals of this methods testing project: (1) Assess proper fit of GPS/accelerometer collars on both adult female cows and calves throughout the grazing season; (2) develop methods to calibrate accelerometer data to common cattle behaviors; and (3) test field equipment, and improve equipment as needed. We applied what we learned in 2023 to a 2024 field season where we refined our data collection protocols.

We outfitted 20 cows with collars in May and June 2023. More specifically, we collared and monitored 10 cow-calf pairs from two cattle operations (one in Northeast Colorado, one in Northwest Colorado). Cow-calf pairs are of interest as calves are the most vulnerable to predation. In May 2024, we outfitted collars on 8 cows from one operation in Northwest Colorado. Data collection ranged from approximately 1-5 months while cattle were grazing on allotments (e.g., USFS, BLM) or privately owned pastures. We obtained a high-quality visual observation of all collared animals at least twice per month, and often multiple times a week. Visual observations were obtained by CPW staff, the livestock owner, or ranch personnel. Animal condition and collar fit was assessed visually, and with associated photos and video where possible. We used this information to determine if collars needed to be periodically adjusted. Calf collars had a section of elastic to allow for growth in between adjustments.

Accelerometers collected triaxial data (x, y, and z axes) 8 times per second (8 Hz). Accelerometers have been used on cattle and other grazing species to identify behaviors and quantify time budgets (Riaboff et al. 2020, Riaboff et al. 2022). We will create time budgets by specifying cattle behaviors such as feeding, resting, ruminating, moving, acting vigilant, and grooming. We will calibrate cattle behavior by correlating observer behavior with accelerometer data. We performed focal follows, where an individual cow or calf is observed for a predetermined amount of time (20 minutes), and recorded the timing of different behaviors (Riaboff et al. 2022). In 2023, one adult female cow per operation was outfitted with a camera collar as well to provide constant behavioral validation data. Currently, we are assessing the observation data and labeling as specific behaviors; the next step is to use machine learning algorithms to correspond these behaviors with triaxial data patterns (Riaboff et al. 2020, Riaboff et al. 2022).

Collars also collected geospatial data at short, regular intervals (5 minutes), which will be used to calculate distance moved and movement rates (Bailey et al. 2018). We are currently organizing and cleaning these locational data.

Experiences from this methods testing project will help guide equipment decisions, data collection methods, and fieldwork as we develop a larger-scale research project focusing on indirect effects of predators on livestock. Data collected in 2023 and 2024 should be adequate to develop time budgets and behavioral models. We plan to analyze these data before moving forward with a full research project. The timeline for this research is also dependent on wolf activity in the state and partnerships with livestock producers, and therefore we will be adaptable moving forward.

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SUPPORT SERVICES

RESEARCH LIBRARY SUPPORT SERVICES

RESEARCH DATABASE SUPPORT SERVICES

Colorado Parks and Wildlife

RESEARCH LIBRARY SUPPORT SERVICES

Period Covered: January 1, 2024 – December 31, 2024

Author: Karen Hertel, Karen.Hertel@state.co.us

The Colorado Parks and Wildlife Research Center Library, in existence since the 1960s in the Fort Collins office, serves all CPW staff regardless of location. Primary functions of the library are to 1) support wildlife research and management by providing research assistance and full-text information resources, and 2) serve as an institutional repository by archiving and providing access to documents produced by agency staff.

The primary activities in 2024 carried out by the research librarian, Karen Hertel, were:

- Implementation of new EBSCO Discovery Service (EDS) library platform.
- Updating of MARC records with the 856 tag to provide electronic access to documents.
- Addition of 122 items, collections, or exhibits to the Omeka CPW Digital Collections.
- Completion of the CPW and monograph collection analyses, resulting in the withdrawal of 1,654 obsolete, duplicate, or seldom-used items.
- Continued digitization of CPW documents, adding 191 new pdfs to the collection.

As of December 2024, the CPW Library Catalog contains 7658 records (unique titles) and 18,802 items (many titles have more than one item; for example, a report that is produced multiple years). CPW Digital Collections, part of the Plains to Peaks Collective, grew to 519 items, accessible through the catalog or the public-facing website. There are 273 registered patrons (CPW staff).

Approximately 90% of the library budget was used for electronic journal and database subscriptions. To facilitate access to all library resources, including the journals and databases, the decision was made to return to Ebsco (cancelled in 2020) as the vendor for the public-facing discovery layer of the catalog and retain the underlying integrated library system (ILS) with the current AspenCat consortium. The response to the new catalog has been positive and journal usage has increased.

Current subscription databases include BioOne, Birds of North America, ProQuest Dissertations and Theses, EBSCO Environment Complete, JSTOR Life Sciences, and curated collections from Wiley Online Library and Canadian Science Publishing. The majority of journal titles in these databases are now searchable in EDS, a vast improvement over the previous access which required going to each database/journal separately.

A major role of the librarian is to assist CPW staff with document delivery and research assistance. Document requests are filled through CPW subscriptions, interlibrary loan privileges at the University of Wyoming Library, and on-site only (not remote) access at CSU Morgan Library. This year, 279 reference requests were received. The majority were document delivery requests; other assistance included compiling literature reviews, looking for information in library materials, questions on copyright, use of library resources, etc.

Collaboration continues with the Colorado State Library (CSL) staff to facilitate sharing of print and digital items and utilize their cataloging records for CPW items when feasible. CPW publications issued in print are sent to CSL for distribution to state depository libraries.

Colorado Parks and Wildlife

RESEARCH DATABASE SUPPORT SERVICES

Period Covered: January 1, 2024 – December 31, 2024

Author: Benjamin Wasserstein, Research & Species Conservation Database Analyst/Manager, Benjamin.Wasserstein@state.co.us

The Research & Species Conservation Database Analyst/Manager serves as CPW's operational professional for statewide activities on research, wildlife health, species conservation, and terrestrial data analysis and summarization. Duties and goals for this role involve developing and maintaining custom database solutions for research and management projects, providing custom applications for analysis and reporting, and administering data and database systems in an organized and efficient manner. This annual report provides a detailed summary of managed database systems and provides a snapshot of totals at the end of the 2024 calendar year (Figure 2).

Newly Developed Databases

Four new databases were implemented in 2024 to support specific CPW research and species conservation projects: PH1, ElkSightability, GRSG, and Bioacoustics. Each of these new databases also have supporting applications that empower users with data visualization and data management functionality. The PH1 database supports a five year collaborative research project that was initiated in February 2024 with the deployment of 200 GPS collars on Pronghorn and Mule Deer in the PH1 management area. The ElkSightability database was created to support a Mammals Research project that will begin in early 2025, investigating elk sightability in different cover types during aerial surveys. GRSG is a database created to house Greater Sage-grouse telemetry data collected from one of CPW's Avian Researchers. Lastly, the Bioacoustics database is designed as a warehouse to store data collected from autonomous recording units (ARUs) deployed throughout the state for monitoring wildlife populations through audio recordings. While the Bioacoustics database will store acoustic data from bat monitoring efforts in the near future, the structure of the database is designed to accommodate acoustic data collected from monitoring other species such as birds and amphibians.

Custom Applications

The Research & Species Conservation Database Analyst develops custom database applications for Mammals/Avian Research, Wildlife Health, and Species Conservation staff. These applications offer data management and analysis solutions that are tailored to specific research and species conservation projects. Software programs and platforms such as Microsoft Access, Tableau, ArcGIS, and R Shiny web applications are utilized to provide users with tailored views into CPW research and species conservation data. A select few custom applications and notable developments are highlighted below.

GPS Collar Continuity Charts

- A new visualization tool is being incorporated into our database applications pertaining to GPS collar data – collar continuity charts (Figure 1). GPS collars are great at providing near real-time locational data and are a vast improvement over VHF collars in many respects, however, they are imperfect and are subject to issues such as satellite transmission anomalies and malfunctioning hardware. Collar continuity charts are being incorporated into our data visualization products to allow CPW Researchers and Biologists to visualize the functionality of any particular GPS collar by displaying successful GPS positions, failed GPS positions, and mortality alerts over time. These visualizations serve to help monitor collar functionality throughout its lifecycle – from initial pre-deployment testing to post-deployment monitoring.

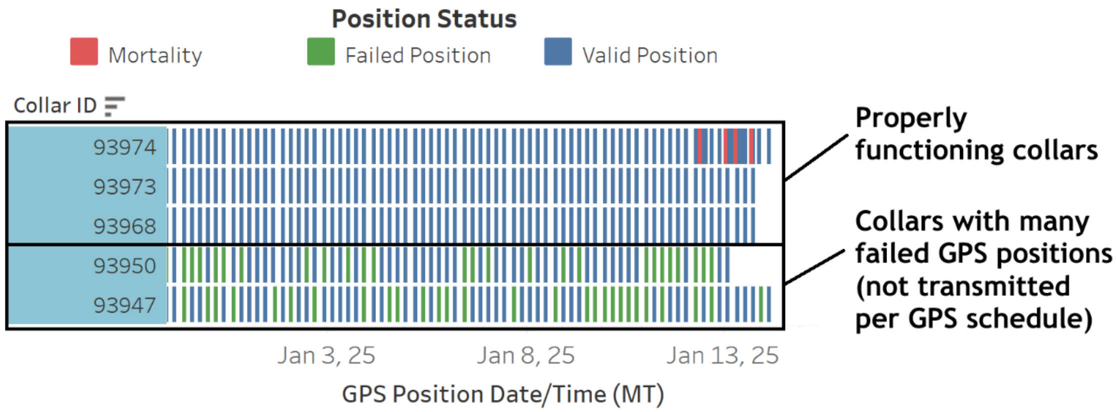


Figure 1. An example of a collar continuity chart displaying properly functioning collars and improperly functioning collars. Mortality alerts (red), successful GPS positions (blue), and failed GPS positions (green) are displayed over time, allowing CPW staff to monitor collar functionality throughout its lifecycle.

Gray Wolf R Shiny Web Application

- This custom web application (coded in Program R) allows relevant researchers and biologists to view GPS collar data from the "WolfMonitoring" SQL Server database alongside helpful reference layers such as wildlife crossings and NPS land parcels. Staff can access admin functions through this dashboard such as the ability to manually download new GPS collar data and to view "missed GPS fixes" – an anomaly that may stem from a malfunctioning collar or a wolf that is out of view of satellites (e.g., a denning female). Other custom functionality is built into this web app, such as the ability to calculate distances traveled by individual wolves over time.

Seed Mix Data Entry R Shiny Web Application

- This web application (coded using Program R) provides CPW research staff with data entry functionality tied to the "Colorado Seed Tool" phone application, which assists the public with verifying seed mixes and generating seed menus to assist with seeding projects. The Seed Mix Data Entry R Shiny web application underwent various changes in 2024 to accommodate improvements to the phone app. The "Colorado Seed Tool" app can be downloaded from the Apple or Google Play app stores and serves to help increase the success of seeding projects by allowing the public to tap into the wealth of information captured in CPW's "SeedMix" database.

2025 State Wildlife Action Plan (SWAP)

In preparation for the 2025 SWAP, CPW took on the task of ranking 300+ vertebrate species to determine whether they are a species of greatest conservation need (SGCN) or a species of greatest information need (SGIN). This position supported this effort by creating a web form that allowed experts to rank each of those species by filling out a questionnaire. The answers recorded in the questionnaire were sent through a ranking algorithm that determined whether a species should be ranked as SGCN Tier 1, SGCN Tier 2, SGIN, or Not SGCN. One goal with the SWAP ranking form is to make this process as objective as possible by requiring experts to answer specific questions, but letting the algorithm/decision matrix provide for the actual scoring and ranking. Additional plant and invertebrate species are being ranked by CPW and its partners and will be incorporated into a dashboard that allows the public to view species' SGCN/SGIN rankings. That dashboard can be viewed at the URL below.
https://lookerstudio.google.com/reporting/590a929e-cd66-4d95-9fc4-3bdac550f416

Comprehensive Wildlife Health Database System

Preparations began in 2024 to develop a comprehensive database for CPW's Wildlife Health Team within the Terrestrial Section. To date, a centralized database solution does not exist for the Wildlife Health Team apart from our CWD database, however, an abundance of data is collected for other wildlife diseases. Big changes are coming in 2025 as we aim to ramp up development on a new comprehensive database for our Wildlife Health program.

Database Dictionaries

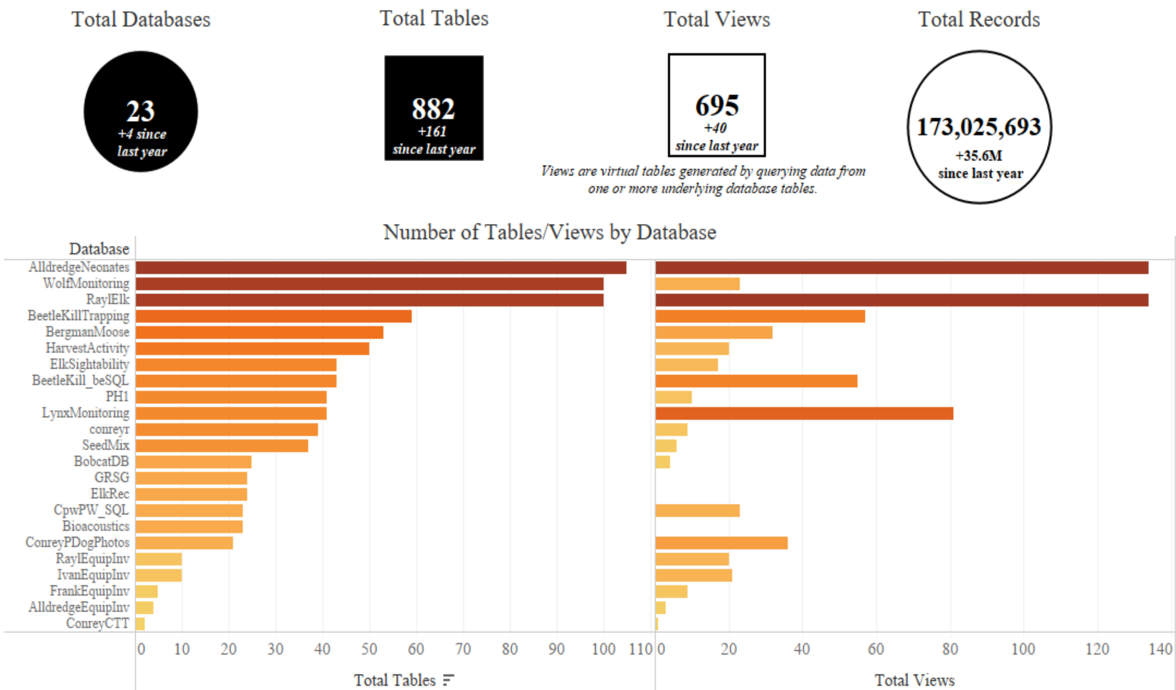
In order to better document research databases and to maximize their usability, the Research & Species Conservation Database Technician began an effort to draft database dictionaries in 2024. These are living documents that detail specific information regarding the structure and functionality built into each database on CPW's mammals/avian research SQL Server instance (Figure 2). One goal with this effort is to empower CPW staff with documentation that allows them to develop their own custom queries and analyses using data within research databases. These documents will be updated as database modifications are made, and database dictionaries will continue to be drafted and reviewed into 2025.

Technical Adjustments and New Data Pipelines

2024 brought many technical challenges and new requirements to light, and a few of those challenges are worthy of highlighting in this report. Data downloads for ATS collars had been disabled in late 2022 amidst a technical challenge with ATS collar data – timestamps for GPS collar data were found to be incorrect in many instances where collars were programmed to local time (GMT-7 for MST) and/or UTC (GMT-0). In re-vamping the ATS data download routine to pull the GMT time offset from a GPS position's transmission record, we were able to correct the issue of ATS collar data timestamps improperly being converted to UTC or Mountain Time. Collar data downloads for ATS collars within research SQL server databases were re-enabled in 2024 following this fix.

In preparation to deploy Telonics GPS collars in early 2025, a new data pipeline was created by the Research & Species Conservation Database Analyst to download and ingest Telonics collar data into our research databases. This workflow was built from the ground-up and is scheduled to run automatically at regular intervals, multiple times per day. With this new pipeline, our research databases are now equipped to automatically download and ingest GPS collar data from four major collar companies: ATS, Lotek, Telonics, and Vectronic.

CPW Mammals/Avian Research SQL Server Database Summary - January 2025



Database	# Records (Tables)	# Records (Views)	Total Record Count
RaylElk	22,754,059	58,711,259	81,465,318
ConreyPDogPhotos	10,506,215	22,843,589	33,349,804
AlldredgeNeonates	3,756,000	21,072,879	24,828,879
LynxMonitoring	8,328,680	13,720,067	22,048,747
ElkSightability	795,178	1,751,798	2,546,976
BergmanMoose	499,239	1,742,465	2,241,704
BeetleKill_beSQL	848,302	1,240,986	2,089,288
ElkRec	1,211,849	0	1,211,849
PH1	307,921	852,232	1,160,153
HarvestActivity	678,910	257,525	936,435
SeedMix	196,338	139,384	335,722
CpwPW_SQL	58,291	123,815	182,106
conreyr	167,134	1,301	168,435
WolfMonitoring	35,315	121,781	157,096
BeetleKillTrapping	56,307	32,877	89,184
ConreyCTT	44,118	44,096	88,214
BobcatDB	28,621	27,609	56,230
IvanEquipInv	8,148	25,474	33,622
GRSG	24,747	0	24,747
RaylEquipInv	2,025	7,428	9,453
FrankEquipInv	337	1,324	1,661
AlldredgeEquipInv	67	3	70
Bioacoustics	0	0	0
Grand Total	*50,307,801*	*122,717,892*	*173,025,693*

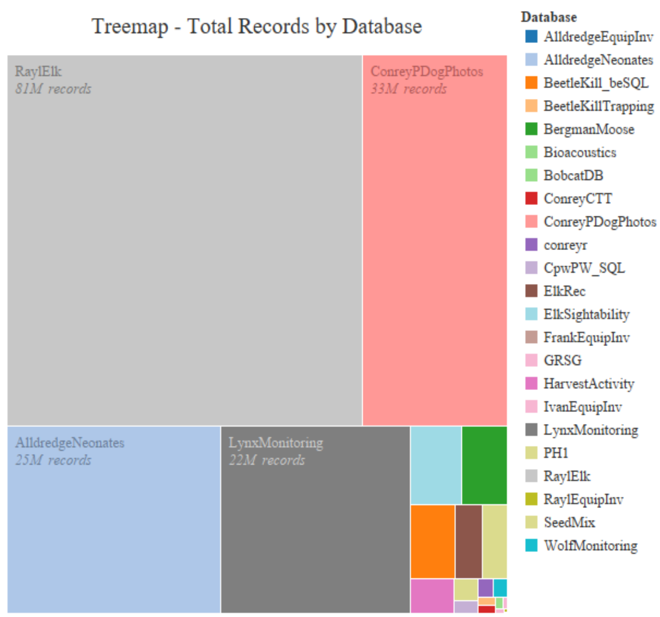


Figure 2. The 2024 end of year summary containing total counts of tables, views, and records from all SQL Server databases managed by the Research & Species Conservation Database Analyst.

APPENDIX A. CPW mammal research citations and abstracts accepted for publication January – December 2024.

Canada Lynx (*Lynx canadensis*)

Jacob S. Ivan
Colorado Parks and Wildlife, 317 W. Prospect Road, Fort Collins, CO, USA

Citation: Ivan, J. S. (2024). Canada Lynx (*lynx Canadensis*). Pages 129-152 *in* J. E. Cartron and J. K. Frey, Eds. Wild Carnivores of New Mexico. 1144pp. https://www.unmpress.com/9780826351517/wild-carnivores-of-new-mexico/

No Abstract. Published February 2024.

Reply to Thornton and Murray: Models for Canada lynx conservation planning require nuance

Jacob S. Ivan[a], Karen E. Hodges[b], Joseph D. Holbrook[c], Ron A. Moen[d], Lucretia E. Olson[e], John R. Squires[e], Jennifer H. Vashon[f]
[a] Colorado Parks and Wildlife, 317 W. Prospect Rd., Fort Collins, CO, USA
[b] Department of Biology, University of British Columbia Okanagan, Kelowna, British Columbia, Canada
[c] Haub School of Environment and Natural Resources, Department of Zoology and Physiology, University of Wyoming, Laramie, WY, USA
[d] Natural Resources Research Institute, University of Minnesota, Duluth, MN, USA
[e] USDA Forest Service, Rocky Mountain Research Station, Missoula, MT, USA
[f] Maine Department of Inland Fisheries and Wildlife, Bangor, ME, USA

Citation: Ivan, J. S., Hodges, K. E., Holbrook, J. D., Moen, R. A., Olson, L. E., Squires, J. R., and Vashon, J. H. 2024. Reply to Thornton and Murray: Models for Canada lynx conservation planning require nuance. Biological Conservation 299: 110836. https://doi.org/10.1016/j.biocon.2024.110836

No Abstract. Published November 2024.

Anthropogenically protected but naturally disturbed: a specialist carnivore at its southern range periphery

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ABSTRACT Understanding how species distributions and associated habitat are impacted by natural and anthropogenic disturbance is central for the conservation of rare forest carnivores dependent on subalpine forests. Canada lynx at their range periphery occupy subalpine forests that are structured by large-scale fire and insect outbreaks that increase with climate change. In addition, the Southern Rocky Mountains of the western United States is a destination for winter recreationists worldwide with an associated high degree of urbanization and resort development. We modeled habitat for a reintroduced population of Canada lynx in the Southern Rocky Mountains using an ensemble species distribution model built on abiotic and biotic covariates and validated with independent lynx locations including satellite telemetry, aerial telemetry, camera traps, den locations, and winter backtracking. Based on this model, we delineated Likely and Core lynx-habitat as thresholds that captured 95% and 50% of testing data, respectively. Likely (5727 km^2) and Core (441 km^2) habitat were spatially limited and patchily distributed across western Colorado, USA. Natural (e.g., insect outbreaks, fire) and anthropogenic (e.g., urbanization, ski resort

development, forest management) disturbance overlapped 37% of Likely lynx-habitat and 24 % of highest quality Core. Although overlap with fire disturbance was low (5%), future burns likely represent the greatest potential impact over decades-long timeframes. The overlap of publicly owned lands administratively classified as "protected" with Likely (62% overlap) and Core (49%) habitat may insulate lynx from permanent habitat conversion due to direct human disturbance (urbanization, ski resort development). Published December 2024.

A multi-property assessment of intensity of use provides a functional understanding of animal movement

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ABSTRACT
1. The intensity of use of a location is one of the most studied properties of animal movement, yet movement analyses generally focus on the overall use of a location without much consideration of how patterns in intensity of use emerge. Extracting properties related to intensity of use, such as the number of visits, the average and variation in time spent and the average and variation in time betwen visits, could help provide a more mechanistic understanding of how animals use landscape. Combining and synthesizing these properties into a single spatial representation could inform the role that a location plays for an animal.
2. We developed an R package named 'UseScape' that allows the extraction of these metrics and then clustered them using mixture modelling to create a spatial representation of the type of use an animal makes of the landscape. We illustrate applications of the approach using datasets of animal movement from four taxa and highlight species-specific and cross-species insights.
3. Our framework highlights properties that functionally differ in how animals use them, contrasting, for example, heavily used locations that emerge because they are frequented for long durations, locations that are repeatedly and regularly visited for shorter durations of time or locations visited irregularly. We found that species generally had similar types of use, such as typical low, mid and high use, but there were also species-specific clusters that would have been ignored when only focusing on the overall intensity of use.
4. Our multi-system comparison highlighted how the framework provided novel insights that would not have been directly obtainable by currently available approaches. By making the framework available as an R package, these analyses can be easily applicable to a myriad of systems where relocation data are available. Published Feb. 2024

Some memories never fade: inferring multi-scale memory effects on habitat selection of a migratory ungulate using step-selection functions

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ABSTRACT Understanding how animals use information about their environment to make movement decisions underpins our ability to explain drivers of and predict animal movement. Memory is the cognitive process that allows species to store information about experienced landscapes, however, remains an understudied topic in movement ecology. By studying how species select for familiar locations, visited recently and in the past, we can gain insight to how they store and use local information in multiple memory types. In this study, we analyzed the movements of a migratory mule deer (*Odocoileus hemionus*) population in the Piceance Basin of Colorado, United States to investigate the influence of spatial experience over different time scales on seasonal range habitat selection. We inferred the influence of short and long-term memory from the contribution to habitat selection of previous space use within the same season and during the prior year, respectively. We fit step-selection functions to GPS collar data from 32 female deer and tested the predictive ability of covariates representing current environmental conditions and both metrics of previous space use on habitat selection, inferring the latter as the influence of memory within and between seasons (summer vs. winter). Across individuals, models incorporating covariates representing both recent and past experience and environmental covariates performed best. In the top model, locations that had been previously visited within the same season and locations from previous seasons were more strongly selected relative to environmental covariates, which we interpret as evidence for the strong influence of both short- and long-term memory in driving seasonal range habitat selection. Further, the influence of previous space uses was stronger in the summer relative to winter, which is when deer in this population demonstrated strongest philopatry to their range. Our results suggest that mule deer update their seasonal range cognitive map in real time and retain long-term information about seasonal ranges, which supports the existing theory that memory is a mechanism leading to emergent space-use patterns such as site fidelity. Lastly, these findings provide novel insight into how species store and use information over different time scales. Published February 2024

Estimating encounter-habitat relationships with scale-integrated resource selection functions

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ABSTRACT
1. Encounters between animals occur when animals are close in space and time. Encounters are important in many ecological processes including sociality, predation and disease transmission. Despite this, there is little theory regarding the spatial distribution of encounters and no formal framework to relate environmental characteristics to encounters. The probability of encounter could be estimated with resource selection functions (RSFs) by comparing locations where encounters occurred to available locations where they may have occurred, but this estimate is complicated by the hierarchical nature of habitat selection.
2. We developed a method to relate resources to the relative probability of encounter based on a scale-integrated habitat selection framework. This framework integrates habitat selection at multiple scales to obtain an appropriate estimate of availability for encounters. Using this approach, we related encounter probabilities to landscape resources. The RSFs describe habitat associations at four scales, home ranges within the study area, areas of overlap within home ranges, locations within areas of overlap, and encounters compared to other locations, which can be combined into a single scale-integrated RSF. We apply this method to intraspecific encounter data from two species: white-tailed deer (*Odocoileus virginianus*) and elk (*Cervus elaphus*) and interspecific encounter data from a two-species system of caribou (*Rangifer tarandus*) and coyote (*Canis latrans*).
3. Our method produced scale-integrated RSFs that represented the relative probability of encounter. The predicted spatial distribution of encounters obtained based on this scale-integrated approach produced distributions that more accurately predicted novel encounters than a naïve approach or any individual scale alone.

4. Our results highlight the importance of accounting for the conditional nature of habitat selection in estimating the habitat associations of animal encounters as opposed to ‘naïve’ comparisons of encounter locations with general availability. This method has direct relevance for testing hypotheses about the relationship between habitat and social or predator–prey behaviour and generating spatial predictions of encounters. Such spatial predictions may be vital for understanding the distribution of encounters driving disease transmission, predation rates and other population and community-level processes. Published August 2024

CARNIVORE ECOLOGY AND MANAGEMENT

Detection of prions from spiked and free-ranging carnivore feces

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ABSTRACT Chronic wasting disease (CWD) is a highly contagious, fatal neurodegenerative disease caused by infectious prions (PrP CWD) affecting wild and captive cervids. Although experimental feeding studies have demonstrated prions in feces of crows (*Corvus brachyrhynchos*), coyotes (*Canis latrans*), and cougars (*Puma concolor*), the role of scavengers and predators in CWD epidemiology remains poorly understood. Here we applied the real-time quaking-induced conversion (RT-QuIC) assay to detect PrP CWD in feces from cervid consumers, to advance surveillance approaches, which could be used to improve disease research and adaptive management of CWD. We assessed recovery and detection of PrP CWD by experimental spiking of PrP CWD into carnivore feces from 9 species sourced from CWD- free populations or captive facilities. We then applied this technique to detect PrP CWD from feces of predators and scavengers in free-ranging populations. Our results demonstrate that spiked PrP CWD is detectable from feces of free-ranging mammalian and avian carnivores using RT-QuIC. Results show that PrP CWD acquired in natural settings is detectable in feces from free-ranging carnivores, and that PrP CWD rates of detection in carnivore feces reflect relative prevalence estimates observed in the corresponding cervid populations. This study adapts an important diagnostic tool for CWD, allowing investigation of the epidemiology of CWD at the community-level. Published February 2024.

Geostatistical capture–recapture models

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ABSTRACT Methods for population estimation and inference have evolved over the past decade to allow for the incorporation of spatial information when using capture–recapture study designs. Traditional approaches to specifying spatial capture–recapture (SCR) models often rely on an individual-based detection function that decays as a detection location is farther from an individual's activity center. Traditional SCR models are intuitive because they incorporate mechanisms of animal space use based on their assumptions about activity centers. We modify the SCR model to accommodate a wide range of space use patterns, including for those individuals that may exhibit traditional elliptical utilization distributions. Our approach uses underlying Gaussian processes to characterize the space use of individuals. This allows us to account for multimodal and other complex space use patterns that may arise due to movement. We refer to this class of models as geostatistical capture–recapture (GCR) models. We adapt a recursive computing strategy to fit GCR models to data in stages, some of which can be parallelized. This technique facilitates implementation and leverages modern multicore and distributed computing environments. We demonstrate the application of GCR models by analyzing both simulated data and a data set involving capture histories of snowshoe hares in central Colorado, USA. Published January 2024.