COLORADO PARKS & WILDLIFE

2025 Mammals Research Summary Report

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2025 MAMMALS RESEARCH SUMMARY REPORT

JANUARY–DECEMBER 2025

MAMMALS RESEARCH PROGRAM

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

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EXECUTIVE SUMMARY

This Mammals Research Summary Report summarizes (≤6 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 2025. 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 website at https://cpw.cvlcollections.org/exhibits/show/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, two studies addressing elk response to human recreation, and applying elk sightability for estimating elk abundance. The Predatory Mammal Management and Conservation Section describes onging research addressing bobcat population dynamics and density estimation and mule deer survival and cougar conflict response to changes in cougar harvest. 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. Other ongoing/newly initiated projects without new results to report include evaluation of high-resolution cameras for aerial ungulate surveys, drone applications for wolf monitoring and hazing, predator community effects on prey habitat use/foraging patterns, movement, space use, and social behavior of reintroduced gray wolves, and evaluation of wolf/livestock interactions.

In addition to the ongoing project summaries described above, Appendix A includes research abstracts (<1 page summaries) published by CPW research staff during 2025. These scientific publications provide results from recently completed CPW research projects and other collaborations with universities and wildlife management agencies. Topics addressed include a broad-scale assessment of diel activity patterns for mammal species, factors influencing elk habitat use and migration patterns, an evaluation of antlerless harvest regulations for white-tailed deer management, development of a computer software program to classify ungulate behavior patterns, evaluation of bear behavior patterns during the mating season and relative to infanticide risk, bear response to increased application of bear-resistant garbage storage, and snowshoe hare response to exposure of rabbit hemmorrhagic disease.

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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Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Canada lynx monitoring in Colorado, Winter 2024–2025

Period Covered: January 1, 2025 − December 31, 2025

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

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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 was required. Beginning in 2014 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 2024−2025 winter, personnel from CPW and USFS completed the eleventh year of monitoring work on this same sample. Fourteen units were scheduled for snow-tracking surveys between December 1 and April 30. 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 km (6.2 miles) distributed across at least 2 quadrants of the unit. Thirty-six units could not be surveyed via snow tracking. Instead, survey crews deployed 4 passive infrared motion cameras in each of these units during fall 2024. Cameras were lured with visual attractants and scent lure to enhance detection of lynx in the area. Cameras were retrieved during summer or fall 2025. All photos were archived, filtered to "animals" using the AI platform Pytorch-Wildlife to run MegaDetector v5a (Hernandez et al. 2024) 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 495 km during snow tracking surveys and detected 9 lynx tracks at 4 units (Table 1). This represents the lowest snow-tracking effort (km surveyed) and matches the fewest number of snow-tracking units with lynx, since the inception of the monitoring program. However, 2 units in Area 17 and 1 unit in Area 16 were not surveyed due to a lack of snow and poor tracking conditions. Lynx were detected via camera sampling in 4 units during the 2024–2025 survey season, which represents a continued rebound from the previous program low (1 unit) for cameras, which was observed in 2022–2023 (Table 2). Lynx were detected in the La Garita Mountains northeast of Creede for the first time since the 2021–2022 survey season and were again detected near Lizard Head Pass after having gone undetected there for two winters (Figure 1).

In response to a program low in camera detections during the 2022–2023 winter, and a potential explanation that fatigue to the lured camera sets in use for nearly a decade could be the cause, we initiated a research project to assess an alternate approach to camera sampling for lynx that has been successful elsewhere within their range. Accordingly, 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. These "research deployments" were in addition to our concurrent camera or snow-tracking efforts and followed protocols established by King et al. (2020) and Anderson et al. (2023), including twice the cameras per unit as our traditional approach. Camera data were retrieved in summer 2024, but the cameras were left in place with original batteries to sample through winter 2024–25. During the usual analysis period we recorded 384 lynx detections at 35 cameras in 11 units during 2023–2024 and 691 lynx detections at 32 cameras in 8 units during 2024–2025. Thus, the passive sampling scheme performed as well or better than our traditional lured sets but incurred less effort to deploy and was free from concerns regarding lure fatigue. Therefore, the monitoring program transitioned to this approach for the 2025–2026 deployments. Only 9% of cameras were dead when they were retrieved during summer 2025 after 2 years of deployment as passive sets. Another 25% registered "0 battery" but were still operating.

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. Alternative models to further test predictions relating lynx occupancy to bark beetles, fire, or the presence of competitors or prey species are ongoing but here we focus on status and trend.

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 = 0.00–0.9; γ = 0.00–0.8) except for the intervals between the 2021–22 and 2022–23 seasons when extinction probability was high ($\varepsilon_{21–22}$ = 0.30, SE = 0.14; $\varepsilon_{22–23}$ = 0.20, SE = 0.13). Derived occupancy oscillated between ψ = 0.17–0.32) and appears to be rebounding after hitting a low of 0.17 during winter 2023–2024. The slope of the trend in occupancy through time was slightly negative but not statistically different from zero (β = -0.005, SE = 0.01; Figure 2). Similar to previous years, detection probability was relatively high for snow tracking surveys (p = 0.62, SE = 0.05), lower for camera surveys (p = 0.19, SE = 0.02) using Pikauba lure, and lowest for camera surveys utilizing Violator 7 lure (p = 0.06, SE = 0.02). We estimated that 20% of the sample units in the San Juan's were occupied by lynx (95% confidence interval: 8–32%) during 2024–25 (Figure 2).

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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
2024-2025	11	4	9	9	5	495	18.3	10	2

[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

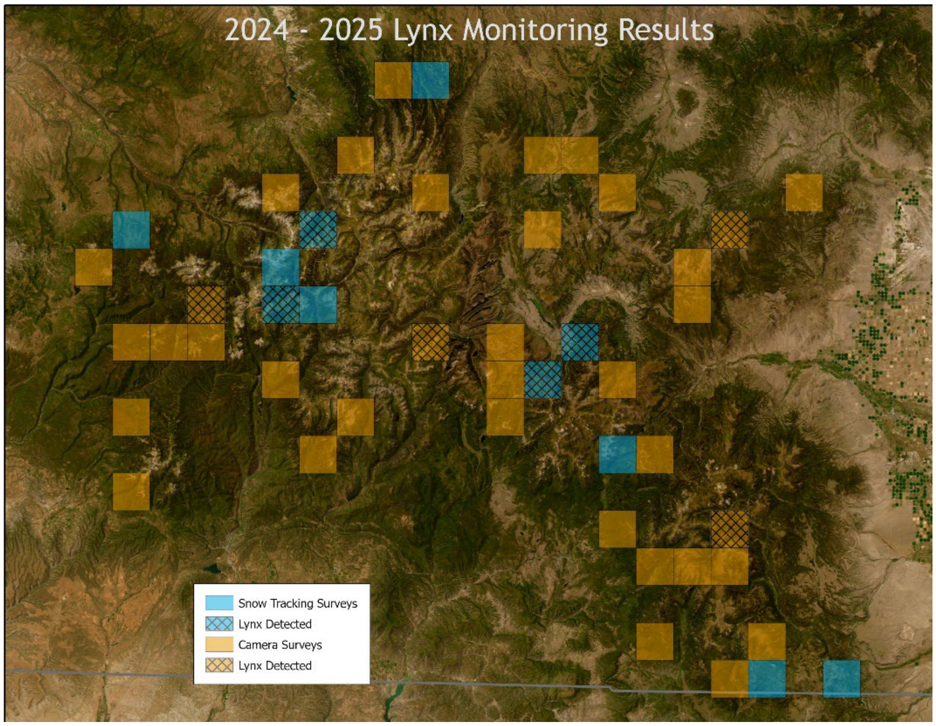
Table 2. Summary statistics from camera effort.

Season	#Units Surveyed	#Units With Lynx	#Photos (Total)[a]	#Photos (Lynx) [a]	#Cameras With Lynx	#CPW Personnel	#USFS Personnel
2014-2015	31	7	29,767	262	11	46	12
2015-2016	31	7	15,357	423	10	33	9
2016-2017	33	6	32,525	227	10	29	9
2017-2018	35	5	65,993	53	8	35	8
2018-2019	35	6	42,796	33	9	31	7
2019-2020	36	4	109,587	21	4	29	6
2020-2021	35	3	69,848	36	3	23	5
2021-2022	35	5	121,076	118	7	23	4
2022-2023	35	1	90,140	4	1	31	3
2023-2024	35	3	85,901	336	4	24	3
2024-2025	36	4	17,924[b]	121	5	24	3

[a] Number photos collected during the survey period (December 1 – April 30). Note that the numbers in these columns are different than those reported from the same columns in previous years. Previously we reported the total photos collected from deployment to retrieval, summed across all cameras. This depiction focuses only on the period of interest and is a fairer comparison between years.

[b]The 2024–2025 field season was the first during which the photos collected during the survey period (December 1 – April 30) were initially run through MegaDetector v5a to cull photos of people and vehicles as well as empty photos. We retained and tagged photos for this project with a confidence level for "animal" >0.20. Previous research using training data from this project suggested that this confidence level was useful for improving efficiency, but also conservative. That is, we would miss very few animals at this level of confidence but would remove most non-animal photos from the dataset.

a)



b)

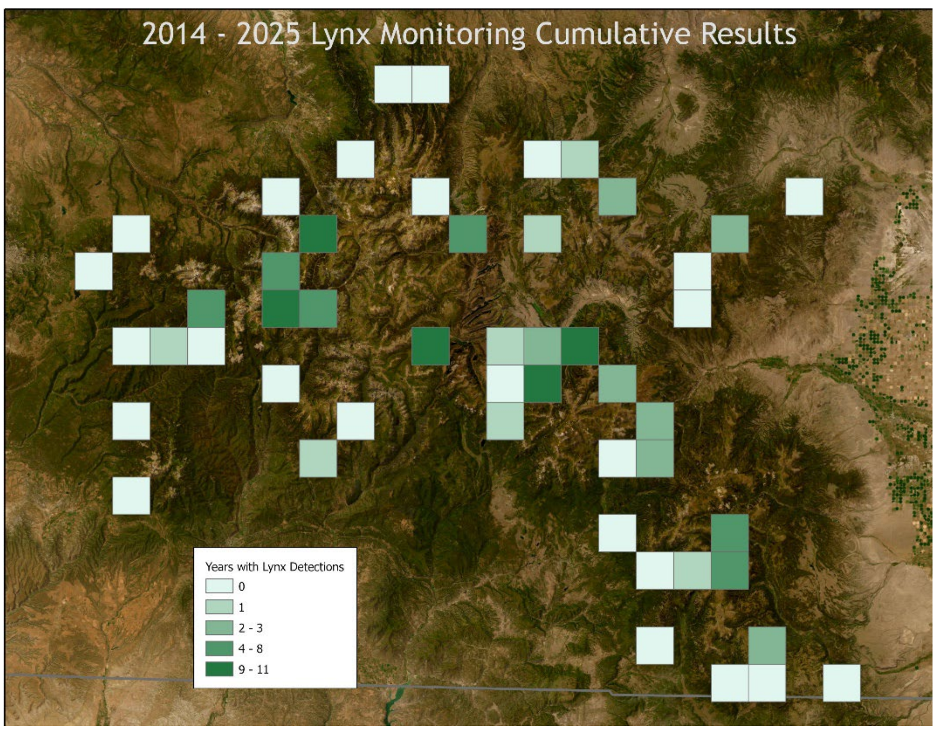


Figure 1. Lynx monitoring results for a) the current sampling season (2024–2025) and b) the cumulative monitoring effort (2014–2025), San Juan Mountains, southwest Colorado. Colored units (*n* = 50) depicted here are those selected at random from the population of units (*n* = 179) encompassing lynx habitat in the San Juan Mountains. Lynx were detected in 8 units in 2024−2025 and 25 units cumulatively since monitoring began in 2014−2015.

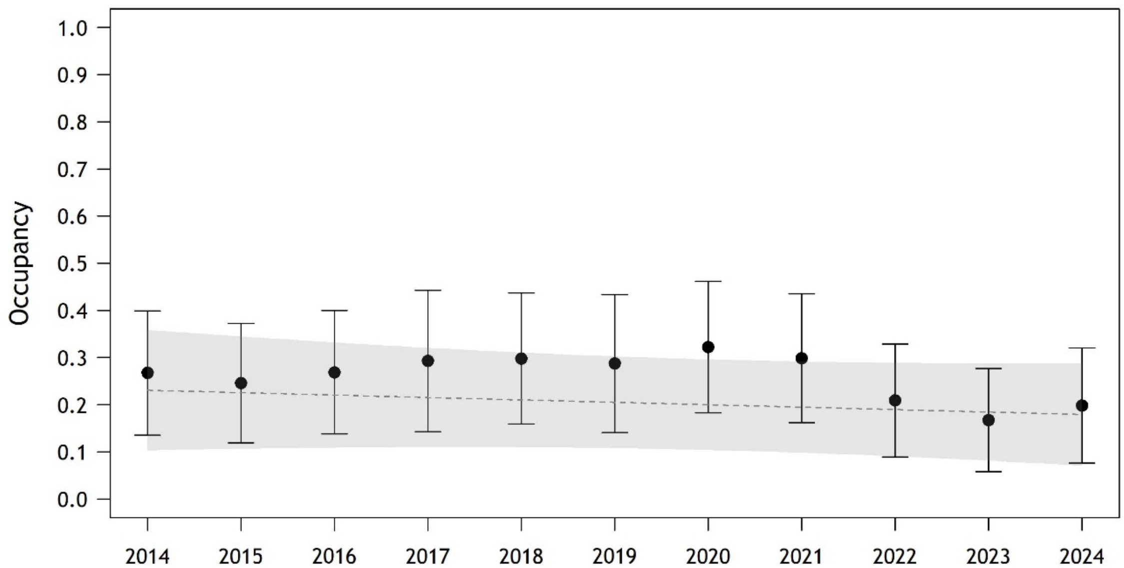


Figure 2. Occupancy estimates (Ψ) and trend (including 95% CI for each) for Canada lynx in the San Juan Mountains, southwest Colorado.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Regional and longitudinal fluctuations in snowshoe hare density in unmanaged spruce-fir forests in Colorado

Period Covered: January 1, 2025 – December 31, 2025

Principal Investigators: Jake Ivan, Jake.Ivan@state.co.us

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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), which were restored to the state from 1999-2006 (Devineau et al. 2010). Regional differences in snowshoe hare density, or changes in density through time, can shape the distribution of lynx in the state and affect lynx abundance and population dynamics. Recent statewide surveys suggest that the distribution of lynx in Colorado is limited, and that abundance (as indexed by occupancy) is weakly cyclic or stable, but also limited ($\hat{n}$ = 65 lynx) (Ivan et al. In Prep). Here I report a preliminary analysis of a statewide sampling scheme designed to 1) assess regional differences in snowshoe hare density and relate those differences to estimated lynx occupancy, and 2) monitor snowshoe hare abundance through time at a broad scale to assess the type and magnitude of fluctuations that occur within the state, which could impact on Canada lynx. This monitoring scheme is an extension of research conducted from 2018–2024 to assess impacts of common forest management techniques on snowshoe hare density in lodgepole pine (*Pinus contorta*) and spruce-fir (*Picea engelmannii – Abies lasiocarpa*) systems in Colorado (Ivan 2024).

For the previous project relating hare density to forest management, forest stands were selected for sampling by first leveraging U. S. Forest Service (USFS) spatial data to delineate all spruce-fir and lodgepole pine stands (stratum 1) on USFS land in Colorado, and to identify all management activities that have occurred in each stand over time. Management activities (stratum 2) were grouped into 4 broad categories: even-aged management, uneven-aged management, thinning, and unmanaged controls. Spatially balanced random samples were selected for each stratum combination, including n = 10 stands that served as spruce-fir controls. During summer 2018, crews established n = 50 1-m^2 permanent circular plots within each of the stands selected for sampling. Plot locations within each stand were also 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 more replicate sites through the years as 1) survey efficiency increased and 2) some stands were transferred from treatment groups to the control group based on ground-truthing. Additionally, after sampling for the previous project concluded in August 2024, more control sites were installed (i.e., counted and cleared) subjectively within occupied lynx range at sites with previous history of snowshoe hare density work (Ivan et al. 2023). The current analysis is based on n = 19 stands, all of which occur within spruce-fir forests with no known management history.

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. To assess regional differences in snowshoe hare density, we computed the mean number of pellets per cleared plot for each stand in each year, then computed a mean for each stand over all years (e.g., 1–7 years). We then plotted these means over estimated lynx occupancy to visually assess whether hare density and lynx occupancy were strongly correlated. To assess trends in snowshoe hare density over time, we computed the mean number of pellets per cleared plot for each stand in each year, then computed a mean for each year over all stands and plotted the changes over time. I only included those stands with >1 year of data for this exercise.

Results from this preliminary analysis suggest little correlation between snowshoe hare density and lynx occupancy; not all stands with high hare density were estimated to have lynx, and not all areas of high estimated lynx occupancy had high hare density (Figure 1). This suggests lynx occupancy is driven by factors outside of local-scale hare density; perhaps hare density across the landscape or other habitat features shape lynx distribution in the state. Snowshoe hare density estimates appeared weakly cyclic through time (Figure 2). However, the current analysis did not standardize raw pellet data to account for disparate timing of surveys year to year, nor did it attempt to account for detection probability of pellets via double observer. I do not expect either issue to have strong effects on inference, but future analyses should account for these issues, nonetheless. Monitoring at these sites is expected to continue indefinitely as funding allows.

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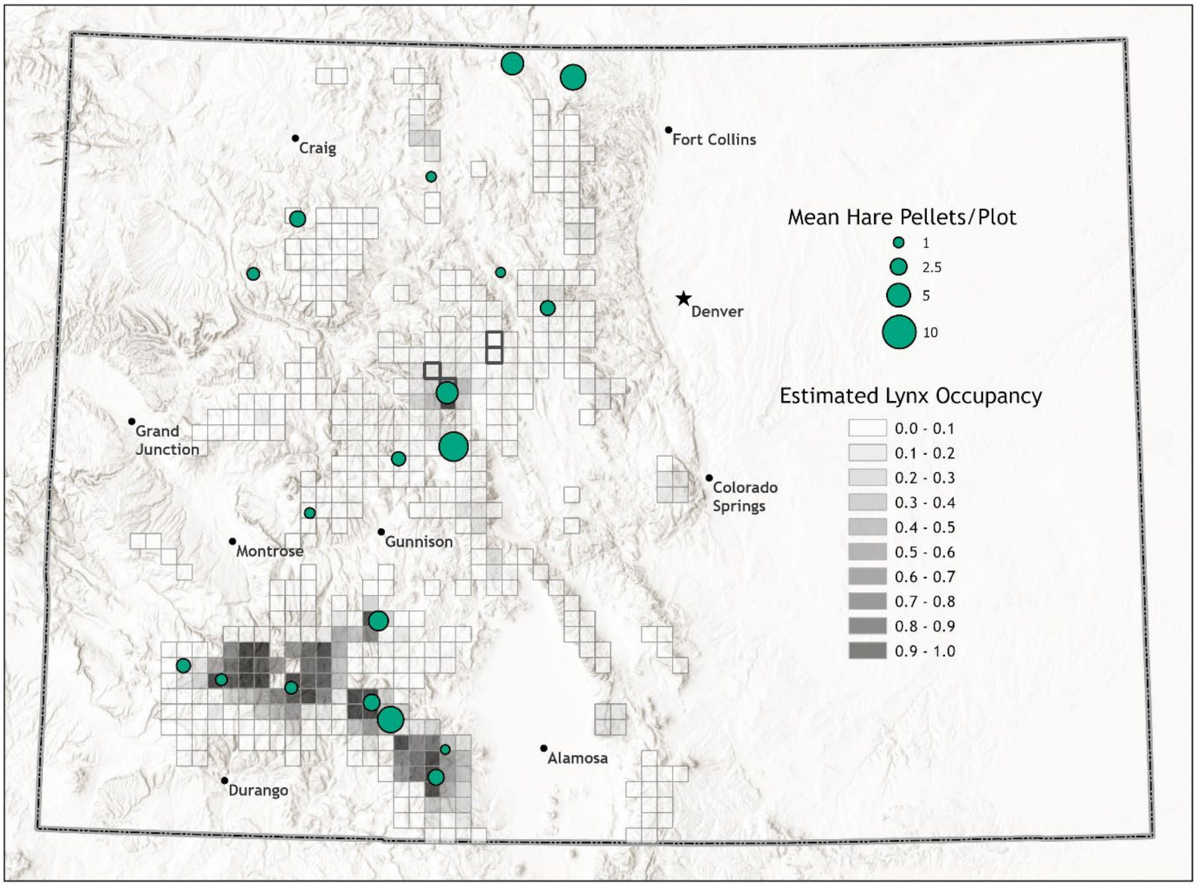

Figure 1. Location of stands (green circles; $n = 19$) sampled for snowshoe hare pellets, June-August 2019–2025 and estimated Canada lynx occupancy based on winter surveys December 2021–April 2024. Larger circles indicate high relative density of hares. Darker cells indicate higher probability of lynx occurrence.

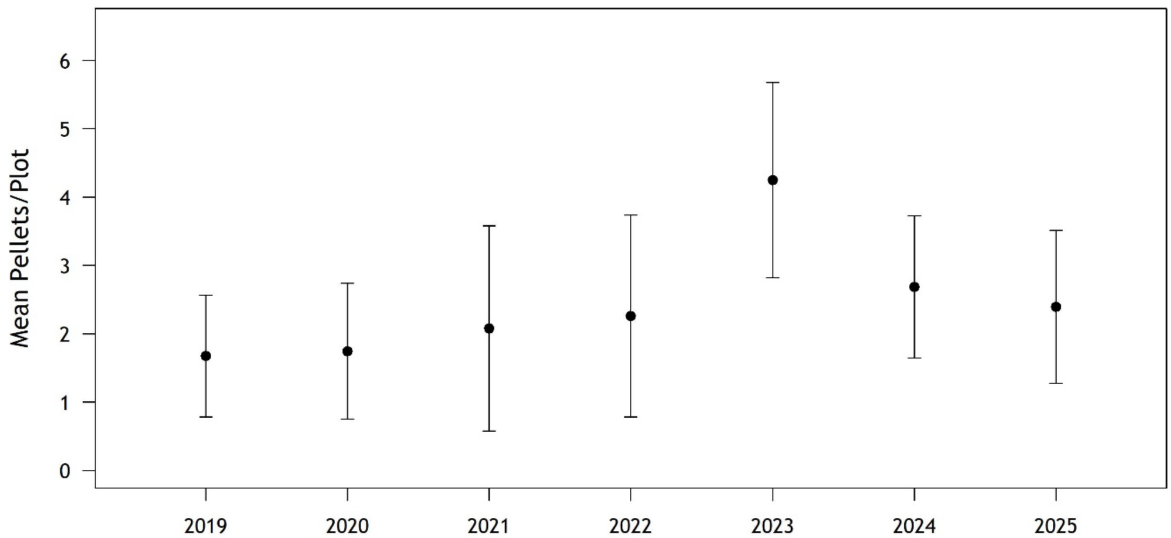

Figure 2. Mean (95% CI) relative density of snowshoe hares through time at sites indicated in Figure 1 above sampled >1 year.

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

ELK SIGHTABILITY FOR ABUNDANCE ESTIMATION IN COLORADO

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, 2025-December 31, 2025

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

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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 lending evidence 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 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 will be conducted per biological year in approximately 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, the 2024 biological year in June, December, and April, and the 2025 biological year in June so far (Table 1). Wind and unfavorable weather conditions pushed the December 2025 survey to January 2026.

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 mortality, which was primary due to harvest. We collared six additional moose in March 2024 to bolster sample size. Attrition can be viewed in Table 1.

Further analysis and estimation of monthly and annual calf survival rates will be done in the future when data collection is complete. 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%. Thus far, data collected from cow moose during 2023 and 2024 did not deviate from data collected during 2013–2019. However, preliminarily, mortality rates appeared to be higher in 2025 due to harvest, vehicle collisions, and natural causes.

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
2024	April	0.96 (n=44)	0.43
2025	June	0.93 (n=42)	0.67

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 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 they occurred in and the size of the elk group they resided in. In addition to estimating group size from the air, we took photographs, allowing us to count elk in groups. We conducted 26 aerial surveys from March 2023 to December 2025 (7 in 2023, 10 in 2024, 9 in 2025) and located 62.4% of collared elk per flight on average. This resulted in an average of 13.0 unique elk groups observed per survey.

Elk collars are scheduled to drop off in January 2026. We will collect all dropped collars in 2026 and begin analysis.

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Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Evaluating factors influencing elk recruitment in Colorado

Period Covered: January 1, 2025-December 31, 2025

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

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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 2017, 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.

From 2017-2024, we collared 593 pregnant females in February-March, 903 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	41	52	26		

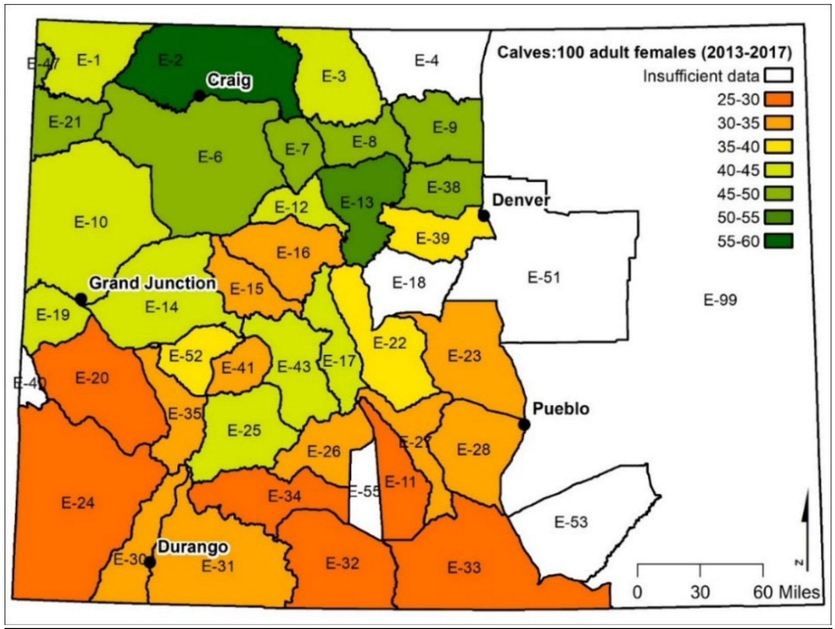

Figure 1. The number of elk calves per 100 adult females observed during December-February aerial surveys (5-year average from 2013-2017) within elk Data Analysis Units (DAUs; labeled with black text).

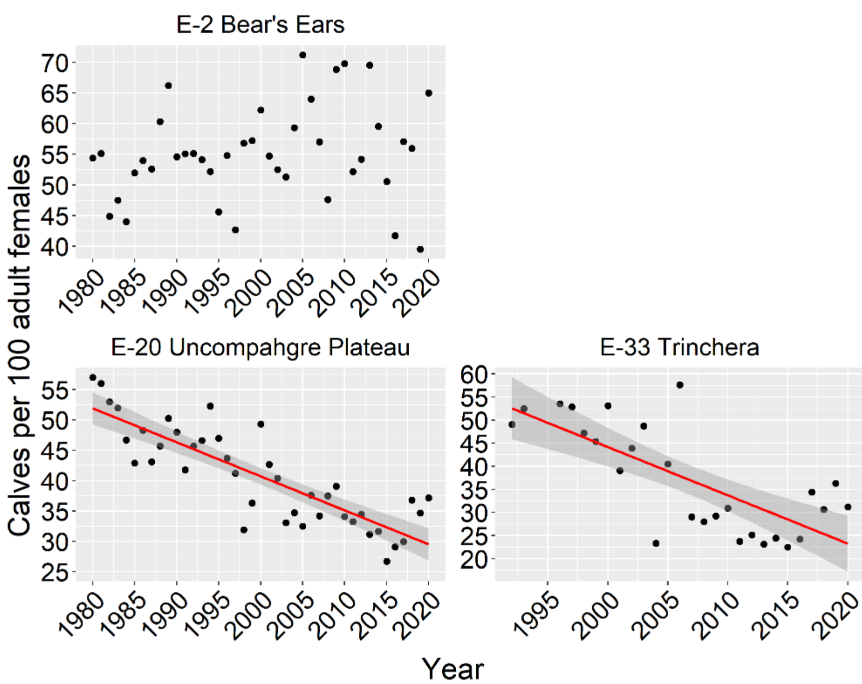

Figure 2. The estimated number of calves per 100 adult females observed annually during winter classification surveys in the Bear's Ears (DAU E-2), Uncompahgre Plateau (DAU E-20), and Trinchera (DAU E-33) elk herds from 1980-2020 (1992-2020 for the Trinchera herd). Red lines and shaded bands represent 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.

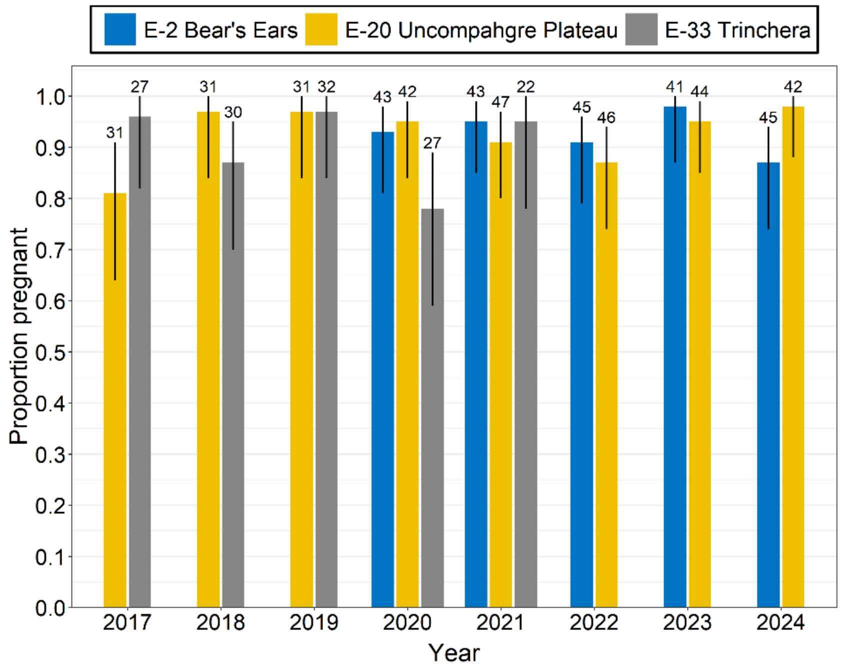

Figure 3. Estimated average pregnancy rates of adult female elk from the Bear's Ears (DAU E-2), Uncompahgre Plateau (DAU E-20), and Trinchera (DAU E-33) herds sampled during late winter 2017-2024. The sample size is given at the top of the 95% binomial confidence intervals (black lines).

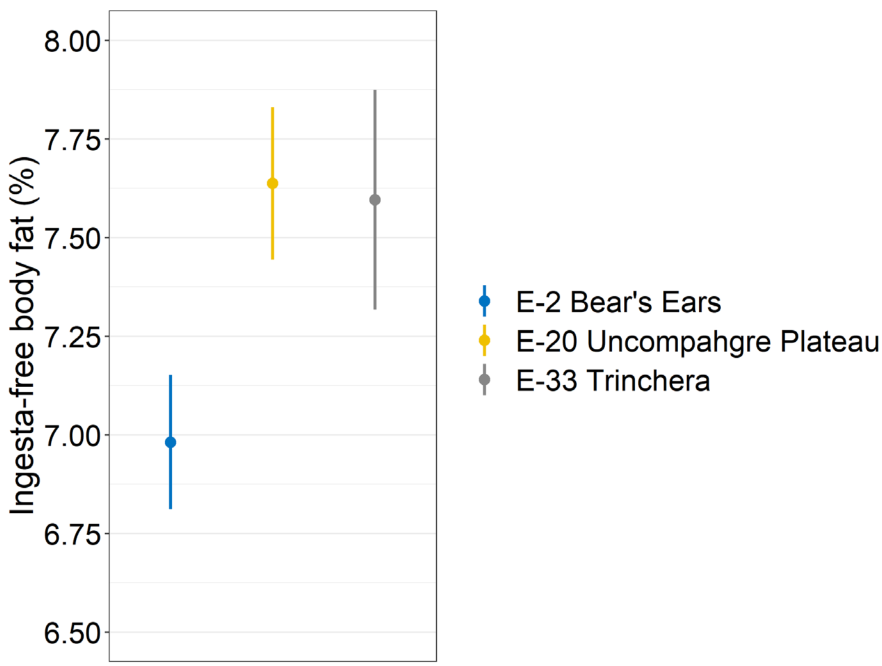

Figure 4. The estimated ingesta-free body fat (%) of adult female elk with 95% confidence intervals from the Bear's Ears (DAU E-2), Uncompahgre Plateau (DAU E-20), and Trinchera (DAU E-33) herds sampled during late winter 2017-2024.

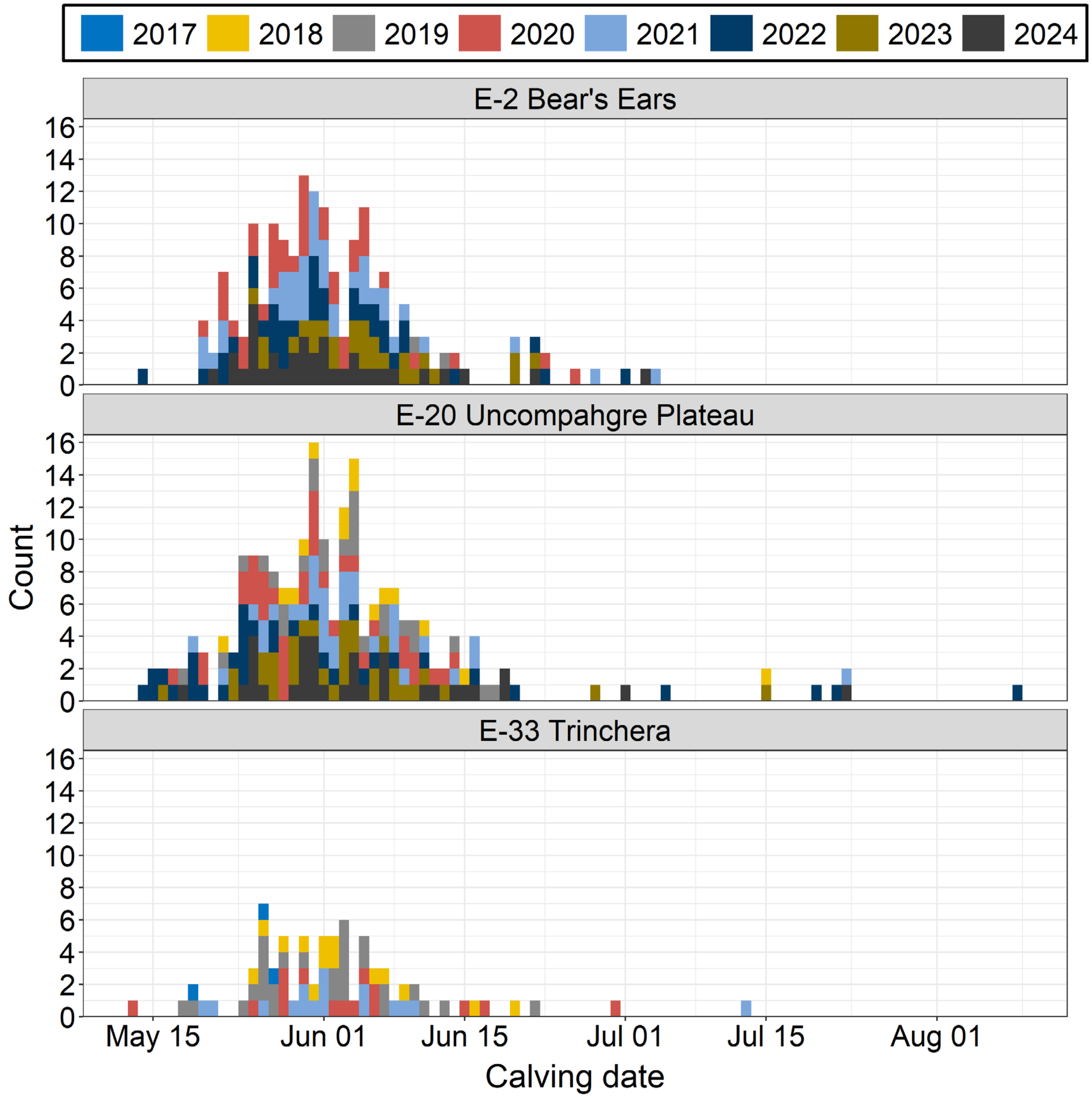

Figure 5. The estimated calving dates of collared female elk from the Bear's Ears (DAU E-2), Uncompahgre Plateau (DAU E-20), and Trinchera (DAU E-33) herds from 2017-2024.

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, 2025-December 31, 2025

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

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This project has objectives at two scales. At the broad, herd-level scale, we are estimating pregnancy, calf survival, and cause-specific mortality rates to identify the primary drivers of declining elk recruitment. 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 adult female elk. At a finer spatiotemporal scale, we are estimating short-term (~3-4 weeks) fluctuations in elk abundance within small study units (<65 km^2 [25 mi^2]) 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 calving, summer, and fall transition ranges. Concurrently, we are evaluating the effectiveness of recreational closures maintained by ski areas, counties, and federal land management agencies.

From 2019-2024, we 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 taken during the 2024 field season, with a goal of completing all classification work by summer 2026. We are also working to make the AI workflow available to all CPW employees to help with photo classification work.

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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

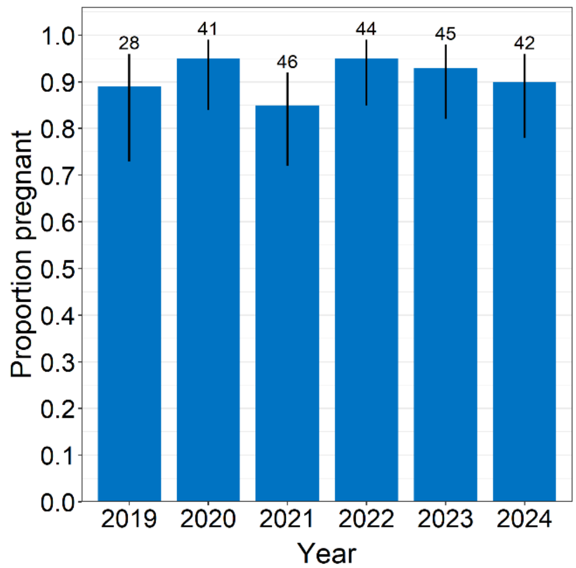

Figure 1. Estimated average pregnancy rates of adult female elk from the Avalanche Creek (DAU E-15) herds sampled during late winter 2019-2024. The sample size is given at the top of the 95% binomial confidence intervals (black lines).

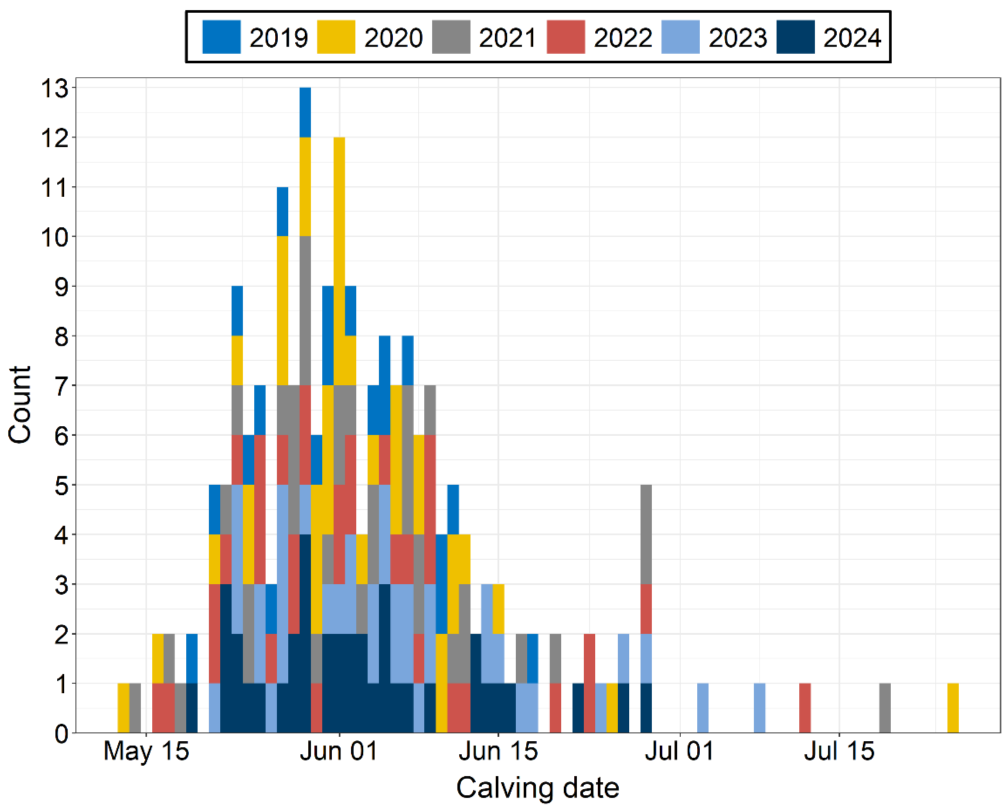

Figure 2. The estimated calving dates of collared female elk from the Avalanche Creek (DAU E-15) herd from 2019-2024.

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, 2025-December 31, 2025

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

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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 impact 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 recreation 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 studied 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 was a collaboration between Colorado Parks and Wildlife (CPW) and the Haub School of Environment and Natural Resources at the University of Wyoming and formed the basis of an M.S. thesis for a graduate student (Eric Van Natta, 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 were deployed on a rotating basis to sample each trail and 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 2025, Eric Van Natta successfully defended his M.S. thesis at the University of Wyoming. We are currently preparing his two thesis chapters for publication.

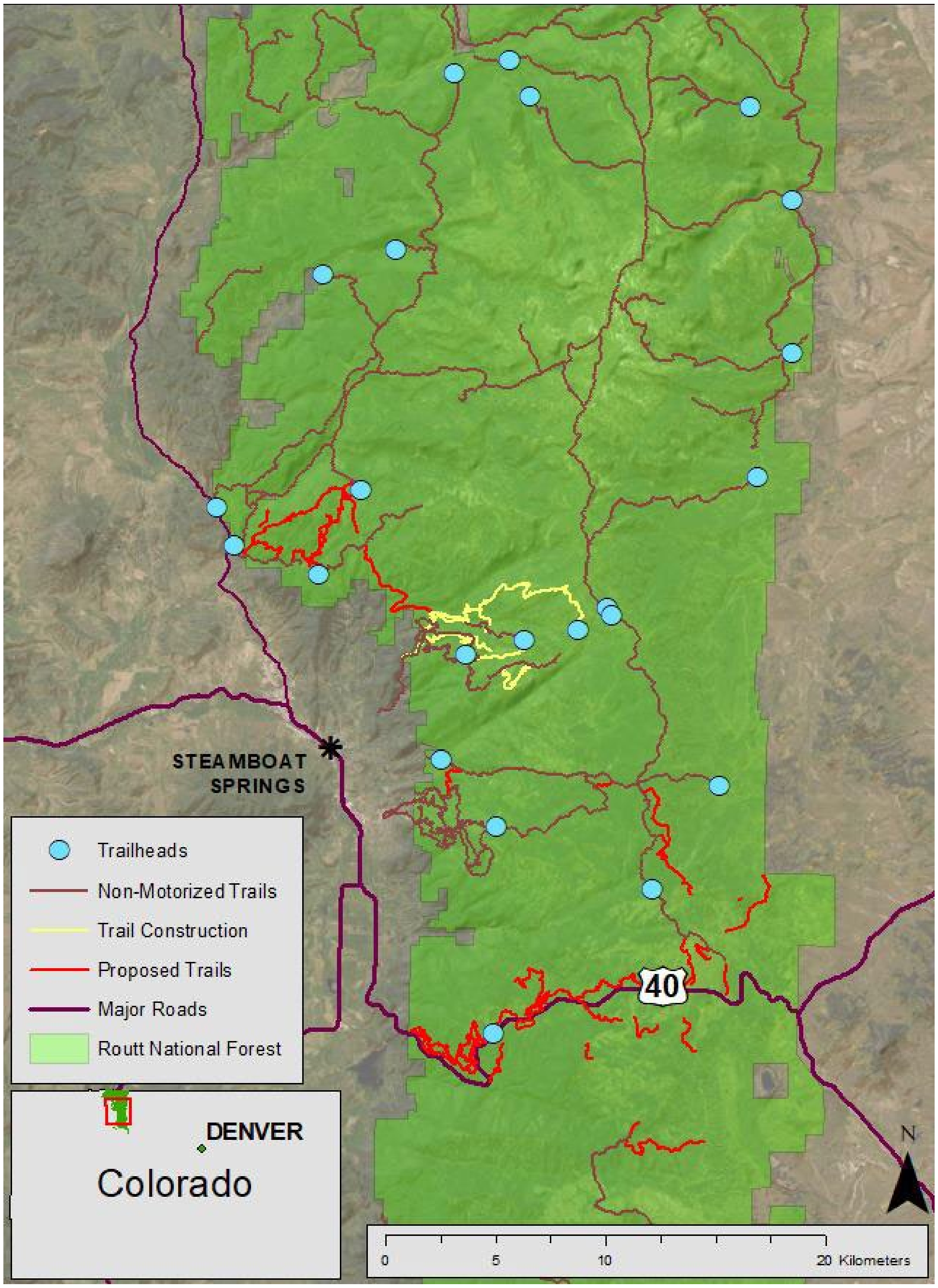

Figure 1. Routt National Forest study area located in northwest Colorado, USA.

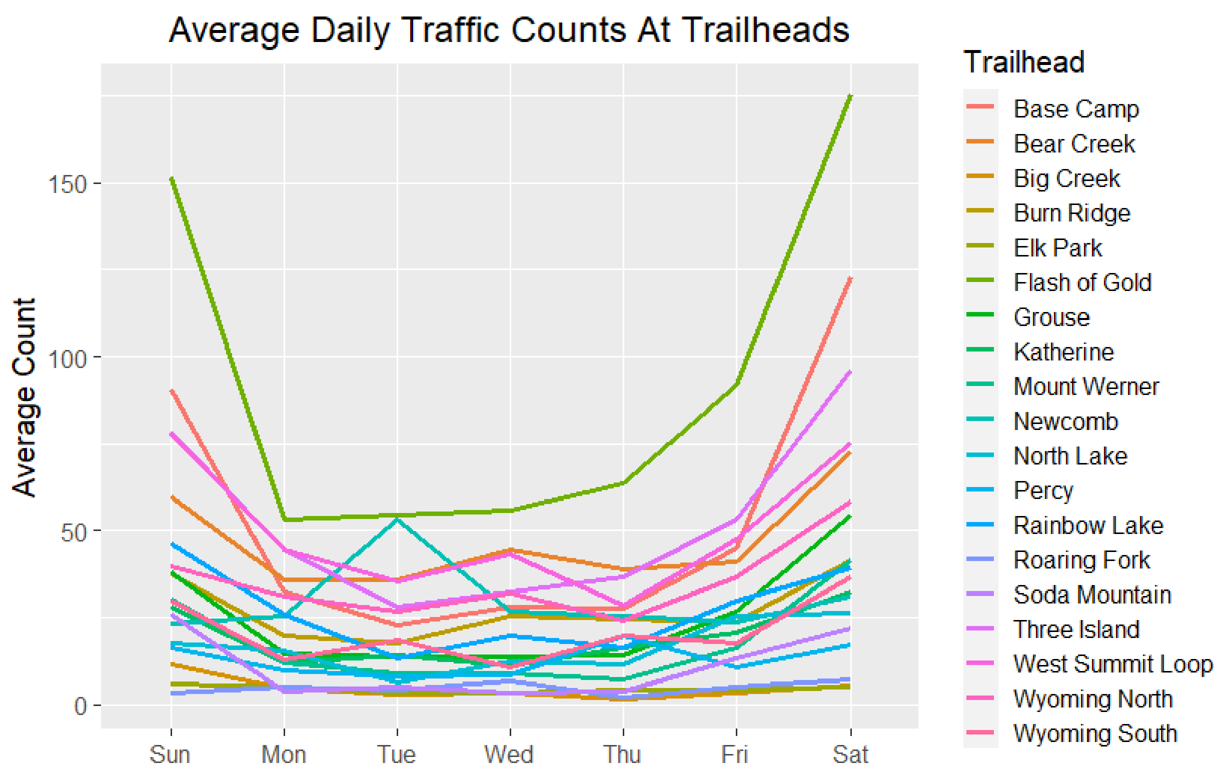

Figure 2. Daily trends in trailhead traffic documented with trail counters from June through October 2020, excluding Fish Creek Falls, Mad Creek, and Red Dirt trailheads, which received average daily counts >200.

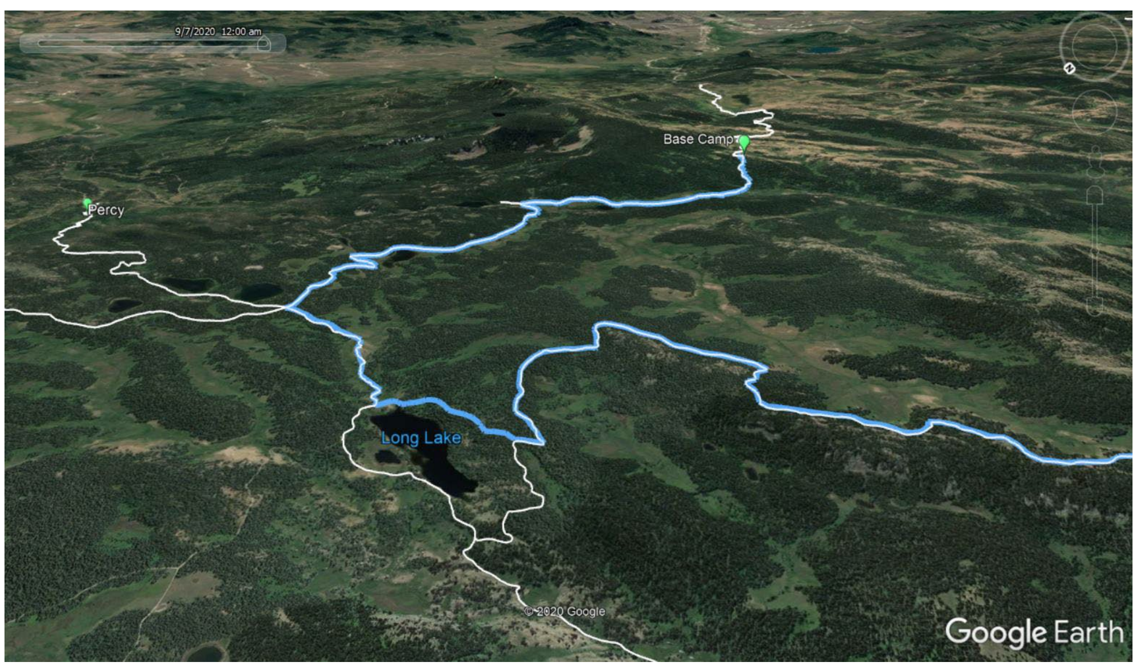

Figure 3. GPS track (blue) recorded from recreational mountain biker on trail system (white) in August 2020. Note the off-trail use near Long Lake.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Elk sightability for abundance estimation in Colorado

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

Principal Investigators: Rachel Smiley, rachel.smiley@state.co.us; Mat Alldredge, mat.alldredge@state.co.us; Chuck Anderson, chuck.anderson@state.co.us; Andy Holland, andy.holland@state.co.us; Jon Runge, jon.runge@state.co.us

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Rocky Mountain Elk (*Cervus canadensis*) is an iconic species throughout western North America and especially in Colorado, with high recreational value to hunters, photographers, artists and wildlife enthusiasts in general. Elk populations can fluctuate greatly and are responsive to ecological conditions such as habitat succession, wildfires, climatic conditions, harvest regimes, and predation pressure (Wang et al. 2002, Brodie et al. 2013, Paterson et al. 2022). To maintain sustainable populations, managers must understand the various factors that influence population dynamics and use the best available information to set herd objectives, harvest strategies, and monitoring programs. Estimates of animal abundance are critical for understanding changes in population size and proximity to objectives. In Colorado, growing interest in elk population size and concern over the factors that may impact populations emphasizes the need for estimates of elk abundance.

The myriad of factors that can influence population dynamics of elk highlight the need for estimates of abundance to understand the overall population status and when management intervention is warranted. Understanding wildlife population dynamics allows managers to estimate population size from one year to the next. If population size is reliably estimated for one year and the future number of losses and gains are monitored, then the population size and trend can be estimated and modeled into the future. Conducting yearly population counts via aerial surveys is expensive and not practical across the entire state on an annual basis. Reliable population models, however, require estimates of population size as a starting point and periodic re-estimation of population size can help anchor models over long time periods (Lukacs and Nowak 2023).

Sightability surveys are a relatively time- and cost-effective approach with demonstrated utility for estimating abundance (Anderson et al. 1998, Wal et al. 2011, Fieberg 2012, Phillips et al. 2019). To parameterize sightability models, observers conduct trial flights to determine whether marked animals are seen or not seen in a variety of sighting conditions. Using data collected during the trial flights we will model how factors influence sightability, such as group size, vertical cover, and snow cover. Once the model is parameterized, biologists can conduct sightability surveys, in which they count and classify groups of elk and record the variables that influence sightability. When applied to sightability surveys, the sightability model uses detection probabilities for groups of animals seen and missed during development to correct for sighting conditions influencing detection and provides corrected abundance estimates.

Development of an elk sightability model will give the state a tool to obtain periodic elk estimates at the DAU level. For this study, we are using females collared in the Elk Monitoring areas. Additionally, we are including males in the study to account for differences in habitat or group characteristics between sexes. In winter 2024-2025 we collared 15 male elk in the South Park study area (DAU E-18, E- 22, and E-23) and 15 male elk in the Gunnison study area (DAU E-5, E-25, and E-43). In February 2025, we completed 37 sightability trials on collared elk between the two study areas (Figures 1, 2). The trials included groups that ranged from 1 to 150 elk in a variety of vegetation and snow cover classes, which will allow for evaluation of how these variables influence the detection of elk. We will deploy 30 more collars on male elk in winter 2025-2026 in the Piney River (DAU E-12) and Middle Park (DAU E-13, E-8) and continue trials to get a large enough sample size for a robust sightability model.

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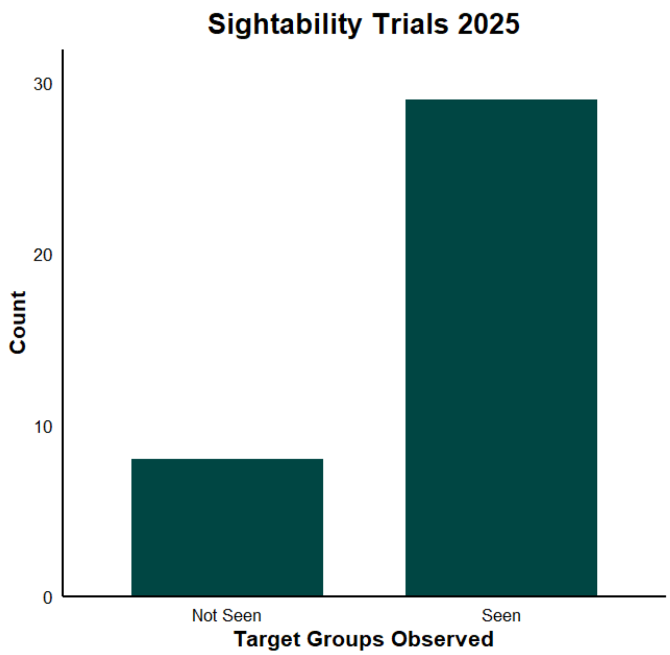

Figure 1. Number of trials where target elk were seen and not seen in Gunnison and South Park study areas in 2025.

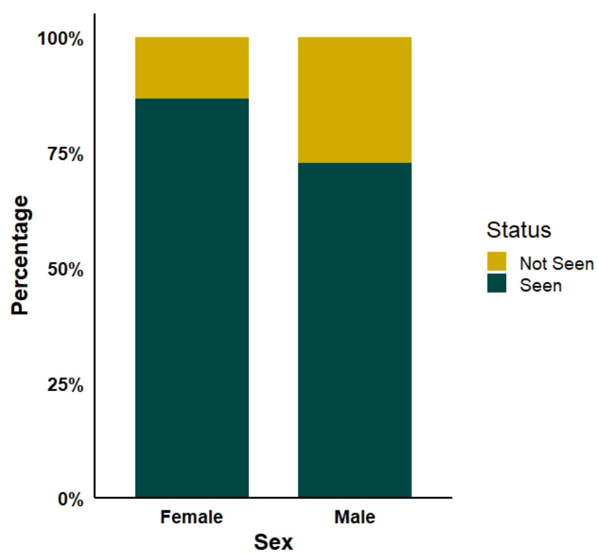

Figure 2. Percent of trials where male and female elk were seen and not seen in Gunnison and South Park study areas in 2025.

PREDATORY MAMMAL MANAGEMENT AND CONSERVATION

BOBCAT POPULATION DYNAMICS AND DENSITY ESTIMATION

MULE DEER POPULATION RESPONSE TO COUGAR POPULATION MANIPULATION

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Bobcat population dynamics and density estimation

Period Covered: January 01, 2025 – December 31, 2025

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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 two study areas with similar habitat types (Pinyon-Juniper and Sagebrush) 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 potential population dynamics of populations exposed to different mortality factors. The Pinyon-Juniper/Sagebrush study areas were completed in summer of 2025 and the study areas shifted to another habitat type, Ponderosa Pine/Mixed Conifer, along the Front Range. The new study areas have the same objectives as above. Field seasons for this project start in fall (~October) and continue into early spring (~March). This report includes three full capture seasons (2022-2023, 2023-2024, 2024-2025) in the Pinyon-Juniper/Sagebrush study areas and partial covers a 2025-2026 capture season (Oct-Dec 2025) in the new Ponderosa Pine/Mixed Conifer study areas.

We selected two study areas, 'Piceance' and 'Skull Creek,' in the northwest region within GMUs 10 and 22 for years 2022-2025 and two study areas, 'Westcreek' and 'Deckers', along the Front Range in GMUs 501 51, 511, and 461 for years 2025-2027 (Figure 1; GMUs not shown). Each area was 20 x 20 km (400 km^2 area) in extent, with similar topography and habitat composition between pairs. Piceance had higher historical bobcat harvest (>2.55 bobcats/100 km^2) than Skull Creek (nearly 0 bobcats/100 km^2). Westcreek had a higher historical bobcat harvest (2.0/100 km^2) than Deckers (0.25/100 km^2). Habitat type composition of the overstory was predominated by pinyon (*Pinus* spp.)-juniper (*Juniperus* spp.) and sagebrush (*Artemisia* spp.) communities in the northwest study areas and by ponderosa pine (*Pinus ponderosa*) and mixed conifers, such as spruce-fir (*Picea* spp. and *Abies* spp.). 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 12/31/2025, CPW has had 111 bobcat captures (66 males, 45 females), of which 71 were new captures/individuals and 40 were recaptures. 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%) for the Pinyon-Juniper/Sagebrush study areas. There have only been six captures in the Ponderosa Pine/Mixed Conifer study areas, as only a partial single capture season is reported here. Of the 71 newly marked bobcats, 61 were collared. On average, an unmarked bobcat required approximately 300 trap nights for capture during early 2024, only 31 trap nights in late 2024, and >100 trap nights in 2025 through December. This variation in success rate is hypothesized to be a difference in winter conditions, prey availability (see below) potentially increasingly consistent trapping pressure over time, and potential bobcat abundance differences between habitat types. 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. Preliminary analysis suggests that there might be a difference in female space use and dietary niche between low and high harvest study areas of Pinyon-Juniper/Sagebrush habitat, but not for males.

We have recorded ~50,000 GPS locations from the 50 collared bobcats. Nearly a half of the GPS-collared bobcats (n = 25) have died and with mortality from various sources: harvest (n = 15), other human-related (n = 5), potentially illegal take (n = 3), natural mortality (n = 5), and capture-related (n = 1) which appeared to be from a pre-existing pathology. These mortalities have accumulated over four years. There are currently 14 collared bobcats in Piceance (high harvest), but only ½ of those are delivering data, suggesting some collars have likely dropped off the bobcats with exhausted battery life. There are 12 collared bobcats in Skull Creek (low harvest), with only two collars not delivering locations.

We have amassed ~3.3 million camera grid photos from Piceance and Skull Creek, of which ~2 million have been processed down to animal detections. Of those, 30% have been processed to species level. Preliminary analysis suggests that collared bobcats on the low harvest study area have more time on survey grids across all study areas and habitat types. 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.

In summer of 2025, CPW personnel removed all cameras from Piceance and Skull Creek study areas. The Lee Fire burned roughly a third of the cameras in Piceance, destroying camera image data collected from March 2025-August 2025 at those sites. This might affect our ability to estimate a precise population density for that season. The remaining cameras from both study areas were relocated to the Front Range in fall of 2025 to north of Woodland Park and west of Rampart Range at two new study areas within ponderosa pine habitat. Camera trap set-ups included the placement of visual attractants and scent lure to draw bobcats for photo detections or 'resights' in the case of marked bobcats, following the same protocol as the previous study areas. In fall of 2025, we conducted rabbit and deer pellet plot survey counts (n = 5, Figure 2) during set-up at each camera location to be associated with rabbit 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. Rabbit pellet plots were significantly different between the two habitat types, with more mean pellet plot counts in the Pinyon-Juniper/Sagebrush than in the Ponderosa Pine/Mixed Conifer study areas (Tukey Multiple Comparison; $P < 0.001$), but not between low and high harvest study areas within each habitat type ($P > 0.9$). Mean deer pellet plot counts were similar among all habitat types and between bobcat harvest levels, except between Piceance-Deckers ($P < 0.01$) and Piceance-Westcreek ($P < 0.05$), where Piceance had more deer pellets than both. Live-trapping efforts in both study areas will continue through spring and camera image collection will continue through late summer of 2027, with camera visits and image collection occurring spring and fall (e.g. this March).

Figure 1. Bobcat study areas (20 x 20 km) in northwest Colorado and along the Front Range, including the high bobcat harvest (Piceance in red), and low bobcat harvest (Skull Creek in blue) study areas in Pinyon-Juniper/Sagebrush habitat types and the high bobcat harvest (Westcreek in green) and low bobcat harvest (Deckers in orange) study areas in Ponderosa Pine/Mixed Conifer study areas. Example pictures of the habitat types are shown. Bobcat study areas are subdivided into 100 2 x 2 km cells (square grids), each containing one camera trap (small dots).

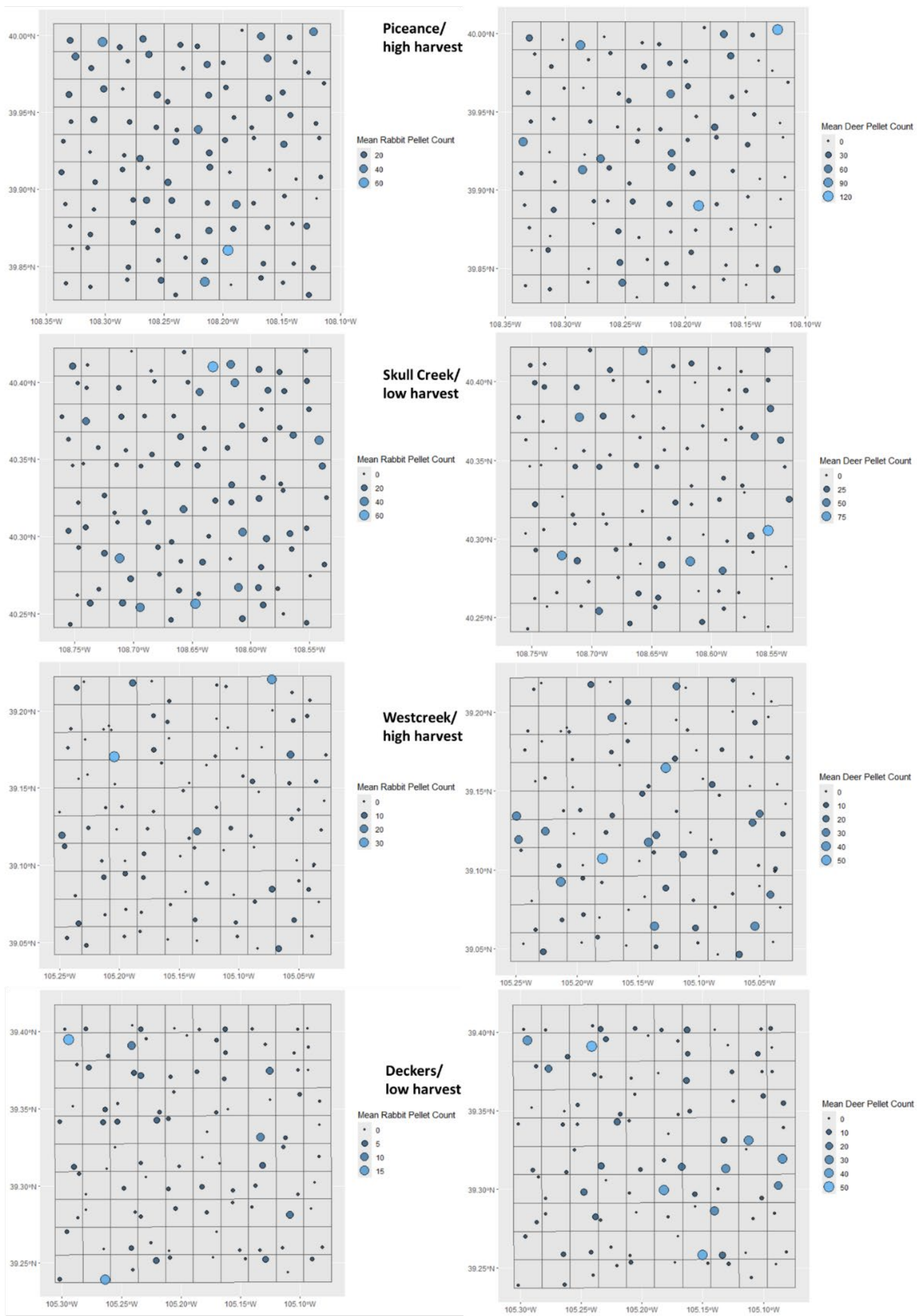

Figure 2. Each panel is a bobcat study area grid depicting mean pellet counts at plots (*N* = 5 plots) at each camera site (*N* = 500) for both rabbits (i.e., cottontail and jackrabbits; left column) and deer (right column). Piceance/high harvest and Skull Creek/low harvest from Pinyon-Juniper/Sagebrush habitat type study areas were counted in fall of 2024, whereas Westcreek/high harvest and Deckers/low harvest Pondera Pine/Mixed Conifer habitat type study areas were counted in fall of 2025.

Colorado Parks and Wildlife

WILDLIFE RESEARCH PROJECT SUMMARY

Mule deer population response to cougar population manipulation

Period Covered: January 1, 2025-December 31, 2025

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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 and is currently working on publishing these results. 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 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 proposed an increase in the quota to 35 cougars to start in the 2023-2024 hunting season, which was approved by the CPW Wildlife Commission in 2023. This total harvest was achieved in the 2023-2024 and 2024-2025 hunting seasons.

To date, we have completed 4 density estimates in each D-16 and D-34 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 D-16, which is the final estimate for this area. No population estimate was done during 2025 with the final population estimate being scheduled for D-34 in winter of 2026.

During the study we captured and collared 124 cougars in D-16 and 133 in D-34. Last year we did not capture in D-16 as population estimates are completed there. Five cougars were captured in D-34 last year to maintain sample size. Over the last couple of years collars have been failing sooner than expected, presumably because collar batteries are not lasting as long as they used to.

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 incidents 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. D-34 had some of the highest conflict, especially in 2021 and 2023, but historic conflict rates also had occasional high years as well.

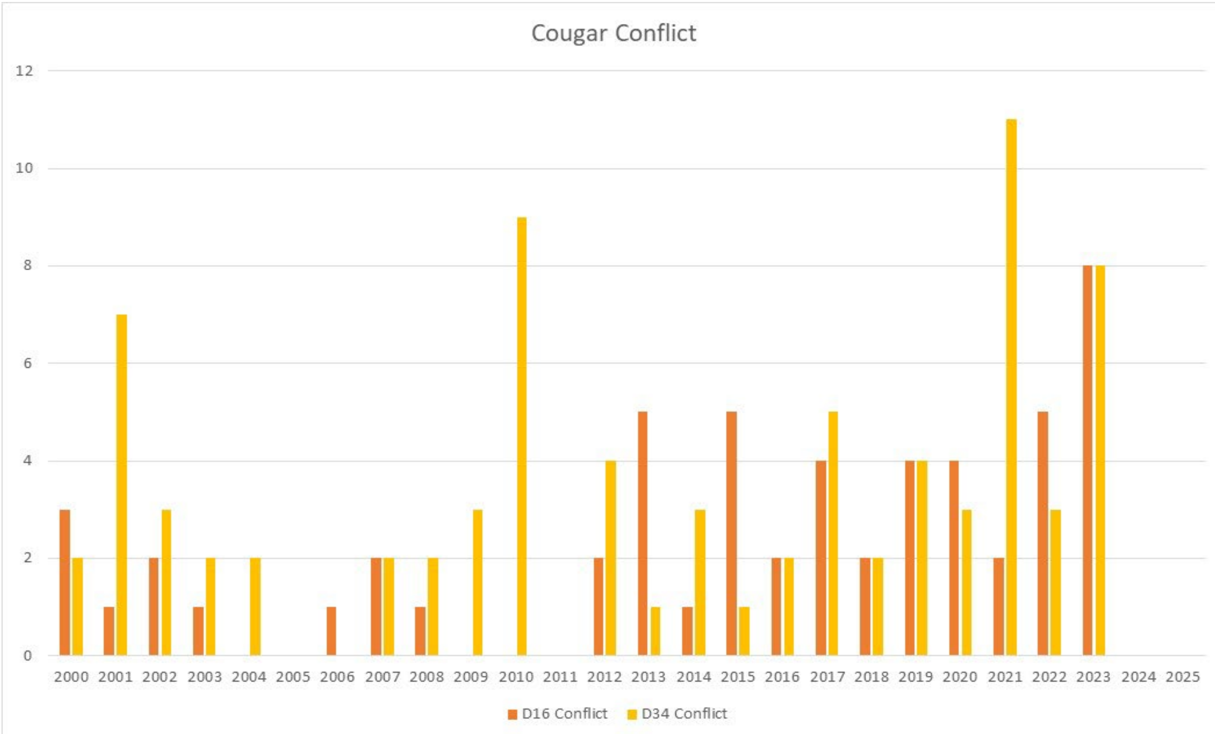


Figure 1: Number of human/cougar conflicts in DAUs D-16 and D-34 by year. This does not include sightings.

SUPPORT SERVICES

RESEARCH LIBRARY SUPPORT SERVICES

RESEARCH DATABASE SUPPORT SERVICES

Colorado Parks and Wildlife

RESEARCH LIBRARY ANNUAL REPORT

Period Covered: January 1, 2025 – December 31, 2025

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 2025 carried out by the research librarian, Karen Hertel, were:

- Creation of two digital exhibits for researchers and the public–CPW Mammals Research and CPW Aquatics Research–that provide a landing page for access to CPW Library research resources, researcher bios, and relevant publications
- Cataloging of 98 items from the uncatalogued collection, the majority CPW publications
- Digitization and adding access link to the catalog record of 458 items, the majority CPW publications
- Creation of new digital collections of 1) CPW Regulation Brochures and 2) Harvest Statistics for Big Game and Small Game. Collections include historical reports, previously uncatalogued and undigitized.
- Withdrawing 3,285 issues of print journals, available through our e-subscriptions and 127 print monographs from the collection.
- Collating federal aid reports for 122 Mammals Research projects and providing access by project title. These reports were previously uncatalogued at the title level, thereby difficult to know about and find.
- Changing call number of items classified with Colorado State Classification to Library of Congress Classification so that items could be located within the print collection.

As of December 2025, the CPW Library Catalog contains 7,553 records (unique titles) and 15,536 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 573 items, accessible through the catalog or the public-facing website. There are 288 registered patrons (CPW staff).

Approximately 90% of the library budget was used for electronic journal and database subscriptions. Current subscription databases include the EBSCO Discovery Service (EDS) catalog, Colorado Library Consortium (CLiC) Koha ILS and Cloud Library, BioOne, Birds of North America, ProQuest Dissertations and Theses, EBSCO Environment Complete, JSTOR Life Sciences, and curated collections from Oxford University Press, Wiley Online Library and Canadian Science Publishing. The majority of journal titles in these databases are searchable in EDS.

A major role of the librarian is to assist CPW staff with document delivery and research assistance. Document requests are filled through CPW subscriptions, article purchases, interlibrary loan privileges at the University of Wyoming Library, and on-site only (not remote) access at CSU Morgan Library. This year, 217 requests for articles, book chapters, etc. were filled. Other library reference services included compiling literature reviews, looking for information in library materials, questions on copyright, use of library resources, etc. The librarian assisted with 57 requests, totaling approximately 70 hours of research time.

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: January 1, 2025 – December 31, 2025
Author: Benjamin Wasserstein, Research and Species Conservation Database Analyst/Manager, Benjamin.Wasserstein@state.co.us

The Research and 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 serves to highlight this role's work in the 2025 calendar year.

Newly Developed Databases

Two new databases were implemented in 2025 to support CPW species conservation projects: SWAP_2025 and SCT. The SWAP_2025 database was developed as a long-term database management system for Colorado's 2025 State Wildlife Action Plan (SWAP). This database was modeled around the required elements for SWAPs (identifying species of greatest conservation need (SGCN), key habitat types, threats, actions, etc.) with the goal of standardizing data in a manner that enables staff and stakeholders to explore the relationships between habitats, species, threats, and conservation actions. For more information regarding the SWAP database and Colorado's digital SWAP, see the dedicated 2025 SWAP section below.

The SCT database was also newly implemented in 2025 and acts as a primary data store for a variety of different projects from CPW's Species Conservation Team (SCT) with the goal of centralized data management. This database is being managed by the Species Conservation Database Analyst/Manager, a position that was newly filled in early 2025, and will continue to be developed into 2026 as new data are integrated.

Custom Applications

The Research and Species Conservation Database Analyst continues to develop 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 staff with tailored views into CPW research and species conservation data.

In 2025, with the help of the Governor's Office of Information Technology (OIT), the Terrestrial Section deployed CPW's own R Shiny Server: a platform that enables CPW's Data Analysts to develop and deploy internal web applications that tie into our back-end data systems. This new resource gives way to rapid application development: quickly developing complex, user-friendly web applications that empower staff with standardized analysis, reporting, and data visualization. A select few custom applications from the new R shiny server will be highlighted below along with other notable developments.

Elk Sightability Research Web Application

The elk sightability R Shiny web application is hosted on CPW's R Shiny Server and has been developed fully in-house in the Python and R programming languages. The application itself enables a daily data processing workflow for the elk sightability research project with functionality to extract and reconcile elk locations from both the Tracker database and the ElkSightability research database, obtain a random selection of elk last locations stratified spatially and by cover type, and to select targets for the day's helicopter sightability trials. The selected daily targets are also utilized by our aerial camera crew (flying in a fixed wing aircraft) to survey the same targets that the helicopter crew is flying for the sightability trials, enabling our Mammals Research staff to pair the two survey methodologies for comparison (i.e., visual sightability via helicopter and remote sensing via aerial photography collected by fixed wing aircraft). The app provides web maps that enable users to view data from their laptops or mobile phones, but it also provides customized KML files that can be exported and used in the field by the survey crew or pilots within mobile applications like Avenza Maps or Gaia GPS.

Northeast Cheatgrass Monitoring Web Application

The Northeast Cheatgrass Monitoring R Shiny web application is hosted on CPW's R Shiny Server and allows our Habitat Researcher and Habitat Biologists to access and analyze data stemming from cheatgrass monitoring surveys. Previously, relevant calculations for the cheatgrass monitoring project had been done by hand or in spreadsheets. With this new application, detailed summaries from monitoring efforts are automatically generated which describe overall species diversity, biomass, vegetation structure, and foliar cover at monitoring plots across CPW's Northeast Region. Detailed summary reports including maps, pictures, and vegetation summary information can be exported from the application and shared with relevant staff where appropriate. All in all, the Northeast Cheatgrass Monitoring app enables standardized reporting while empowering habitat staff with a centralized application for data analysis.

CPW MegaDetector App

Collectively, CPW Wildlife Biologists, Researchers, and Technicians spend hundreds of hours manually reviewing camera trap photos across the agency. Many of the photos that are reviewed in this process include empty photos (e.g., grass blowing in the wind and triggering the camera) or photos with only humans or vehicles in them. The CPW MegaDetector app was developed in-house to enable staff to identify and filter out camera trap images with animals from all other images (humans, vehicles, blank images) using MegaDetector (Beery et al. 2019), often vastly reducing the number of images that require human review and expediting the review process in general. A simple user interface is provided via a Python Streamlit web application where users can reference a source directory of camera trap images, set a confidence threshold for the MegaDetector model, then process the images through MegaDetector to identify whether the images contain animals, humans, vehicles, or nothing. The app itself is portable and can be installed on different computers, but depending on computer hardware, there are significant differences in processing speed. On a standard issued CPW laptop, the application will process photos through MegaDetector at the rate of approximately 0.5 photos per second. On a desktop computer with a high-end Graphics Processing Unit (GPU), photos are processed through MegaDetector at a rate of approximately 16 photos per second (Figure 1). The CPW MegaDetector application vastly reduces the amount of time that staff need to manually review images by filtering camera trap datasets down to just images that have animals in them, providing staff with more time to perform other tasks rather than review empty photos.

Figure 1. Summary information provided after running photos through CPW's MegaDetector App.

2025 State Wildlife Action Plan

In 2025, Colorado's State Wildlife Action Plan (SWAP) was developed as a digital SWAP rather than a lengthy, written PDF document consisting of hundreds of pages. Information from the 2025 SWAP is consolidated and presented in an online dashboard named the SWAP Data Hub. The SWAP Data Hub aggregates information from the SWAP development process and enables staff and stakeholders to explore details regarding species ranked as Species of Greatest Conservation Need (SGCN), Colorado's Habitats, and the threats or conservation actions that impact SGCN and habitats. The SWAP Data Hub was developed in-house following a comprehensive species ranking process that began in 2024 (see separate SWAP Rankings Dashboard) to determine which Colorado species were SGCN, Not SGCN, or Species of Greatest Information Need (SGIN). Following the ranking process, it became apparent that CPW needed a comprehensive relational database to store data for Colorado's 2025 SWAP, and as such the SWAP_2025 database was developed and modeled around the required SWAP elements (Figure 2).

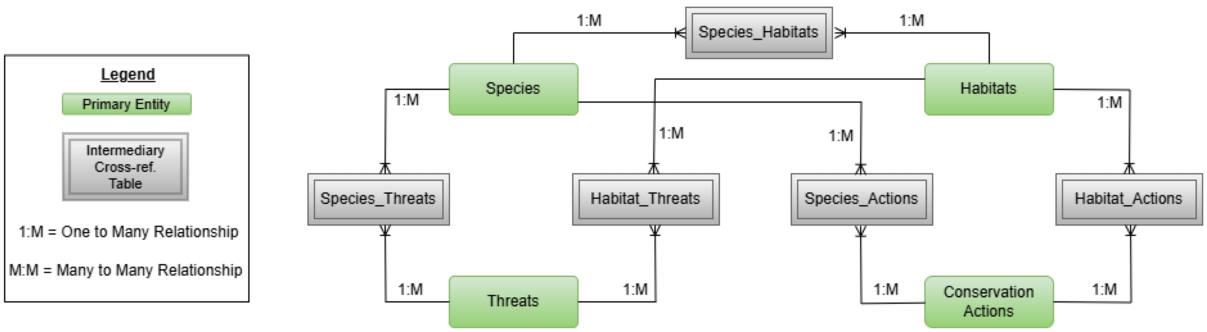


Figure 2. An entity relationship diagram from the SWAP database modeling process, describing the relationship between species, habitats, threats, and conservation actions in the SWAP_2025 database. Intermediary cross-referencing tables manage many to many relationships between primary entities.

The SWAP_2025 database enables CPW to store SWAP data in a standardized, consistent manner to ensure a high level of data integrity while providing a single data source to develop the SWAP Data Hub and other future SWAP data products. The database also allows for on-going conservation actions to be tracked in a centralized location, enabling CPW to align actionable on-the-ground measures with conservation actions and threats during the 2025 SWAP development process.

Colorado's 2025 SWAP was officially accepted by U.S. Fish and Wildlife Service (USFWS) in early 2026 and all relevant information has been centralized on CPW's SWAP Web Page. For more information, please visit the SWAP digital resources listed below.

- 2025 CPW SWAP Web Page: *https://cpw.state.co.us/state-wildlife-action-plan*
- 2025 Colorado SWAP Data Hub: *https://tableau.state.co.us/t/CPW_AquaticVisualization/views/2025SWAPDataHubProd/Colorado2025SWAPMenu?%3Aembed=y&%3AisGuestRedirectFromVizportal=y*
- 2025 SWAP Rankings Dashboard: *https://lookerstudio.google.com/embed/u/0/reporting/590a929e-cd66-4d95-9fc4-3bdac550f416/page/p_1iy9fto1nd*

Database Dictionaries

In order to better document research databases and to maximize their usability, the Research and Species Conservation Database Technician completed efforts to draft database dictionaries in 2025 for all primary Avian Research and Mammals Research databases on CPW's research SQL Server instance (Figure 3). These are living documents that detail specific information regarding the structure and functionality built into each database. 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 as new databases are developed.

CPW Animal Care and Use Committee Digital Forms

CPW's Animal Care and Use Committee (ACUC) has gone fully digital with all required forms. In 2025, development of ACUC digital forms was completed for new study applications, mortality reporting, study addenda, staff training records, and study renewal or completions. Previously these forms had been submitted and stored in hard copy format, requiring administrative staff to maintain hard copy versions while manually scanning, emailing, and storing digital versions of these documents. The new digital forms streamline ACUC data management, effectively eliminating multiple versions of documents and centralizing information. A new ACUC website has been created that provides links to the various new digital forms as well as a dashboard where staff can easily search and view current ACUC project documents submitted through the new digital forms as well as historic ACUC study information.

This effort was two years in the making and employs data tools that are freely available in CPW's technology stack (Google Apps Script, Google Forms, Google Docs/Sheets) to bring the new digital ACUC process to life. When CPW staff submit information to the new digital forms, documents are automatically created which contain all relevant information provided by staff in the forms and an email alert is sent to relevant ACUC members. Those ACUC members can review the digital documents directly from their computer or work phone and request any changes or additional information as needed. Edits can be made directly in these digital documents, maintaining a single source of truth and streamlining administrative ACUC processes in a centralized manner.

Looking Forward to 2026

As we move into 2026, the primary focus will be the continued maintenance and maturity of existing database systems as seen in the 2025 end of year database summary (Figure 3). CPW's R Shiny Server and Tableau Server will continue to be utilized for deploying web-based front-end applications developed in house. Separately, an effort is underway to develop a comprehensive database for our Wildlife Health team. CPW Business Operations staff, Wildlife Health staff, and the Research and Species Conservation Database Analyst have developed a detailed-requirements document for such a database system, and CPW plans to scope costs in 2026. In general, we aim to expand upon all databasing capabilities in 2026, further automating data workflows and empowering CPW Researchers and other staff with data-driven insights.

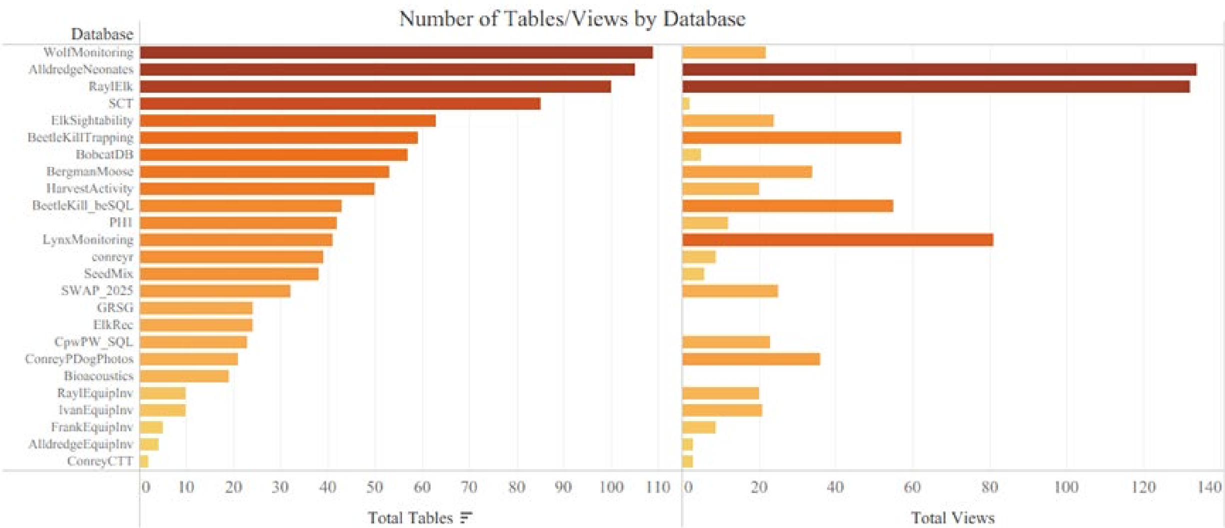
Literature Cited

Beery, S., D. Morris, and S. Yang. 2019. Efficient pipeline for camera trap image review. arXiv preprint arXiv:1907.06772.

CPW Mammals/Avian Research SQL Server Database Summary - January 2026

Total Databases	Total Tables	Total Views	Total Records
25 *+2 since last year*	1,058 *+176 since last year*	733 *+38 since last year*	187,425,280 +14.4M since last year

Views are virtual tables generated by querying data from one or more underlying database tables.
These summaries exclude system-related database tables.



Database	# Records (Tables)	# Records (Views)	Total Record Count
RaylElk	23,308,179	60,897,773	84,205,952
ConreyPDogPhotos	10,506,216	22,843,589	33,349,805
AlldredgeNeonates	3,786,172	21,222,607	25,008,779
LynxMonitoring	8,518,532	14,091,116	22,609,648
ElkSightability	5,718,728	5,749,233	11,467,961
PH1	653,829	1,732,273	2,386,102
BergmanMoose	499,247	1,742,886	2,242,133
BeetleKill_beSQL	848,302	1,240,986	2,089,288
ElkRec	1,211,849	0	1,211,849
HarvestActivity	660,031	262,205	922,236
WolfMonitoring	209,767	476,949	686,716
SeedMix	197,265	139,478	336,743
CpwPW_SQL	58,291	123,815	182,106
ConreyCTT	44,118	132,288	176,406
conreyr	167,134	1,301	168,435
BobcatDB	57,745	48,922	106,667
BeetleKillTrapping	56,307	32,877	89,184
SCT	71,851	6,610	78,461
IvanEquipInv	8,858	27,664	36,522
SWAP_2025	12,687	19,413	32,100
GRSG	24,747	0	24,747
RaylEquipInv	2,167	7,835	10,002
Bioacoustics	1,707	0	1,707
FrankEquipInv	337	1,324	1,661
AlldredgeEquipInv	67	3	70
Grand Total	*56,624,133*	*130,801,147*	*187,425,280*

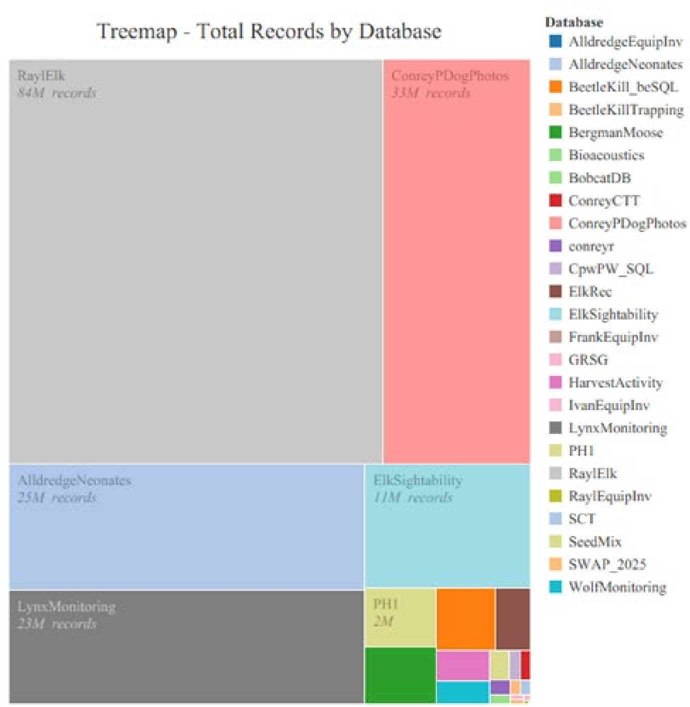


Figure 3. The 2025 end of year summary containing total counts of tables, views, and records from all SQL Server databases managed by the Research and Species Conservation Database Analyst.

APPENDIX A. CPW mammal research abstracts accepted for publication January – December 2025.

When the wild things are: defining mammalian diel activity and plasticity

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Citation: Devarajan, K. [numerous authors], J. S. Ivan, [numerous authors]. 2025. When the wild things are: defining mammalian diel activity and plasticity. Science Advances 11:eado3843. DOI: 10.1126/sciadv.ado3843

ABSTRACT Circadian rhythms are a mechanism by which species adapt to environmental variability and fundamental to understanding species behavior. However, we lack data and a standardized framework to accurately assess and compare temporal activity for species during rapid ecological change. Through a global network representing 38 countries, we leveraged 8.9 million mammalian observations to create a library of 14,587 standardized diel activity estimates for 445 species. We found that less than half the species' estimates were in agreement with diel classifications from the reference literature and that species commonly used more than one diel classification. Species diel activity was highly plastic when exposed to anthropogenic change. Furthermore, body size and distributional extent were strongly associated with whether a species is diurnal or nocturnal. Our findings provide essential knowledge of species behavior in an era of rapid global change and suggest the need for a new, quantitative framework that defines diel activity logically and consistently while capturing species plasticity. Published Feb. 2025

UNGULATE ECOLOGY AND MANAGEMENT

Hierarchy in structuring of resource relection: understanding elk eelection across space, time, and movement strategies

Storm Crews[1, 2], Nathaniel D. Rayl[3], Mathew W. Alldredge[4], Eric J. Bergman[4], Chuck R. Anderson Jr.[4], Eric H. VanNatta[5, 6, 7], Joseph D. Holbrook[6, 7], Guillaume Bastille-Rousseau[1, 2]
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Citation: Crews, S., N. D. Rayl, M. W. Alldredge, E. J. Bergman, C. R. Anderson Jr., E. H. VanNatta, J. D. Holbrook, and G. Bastille-Rousseau. 2025. Hierarchy in structuring of resource selection: understanding elk selection across space, time, and movement strategies. Ecology and Evolution 15:e71097.
https://doi.org/10.1002%2Fece3.71097

ABSTRACT Movement is a fundamental aspect of animal ecology that varies across space, time, and among individuals or groups within apopulation. Broad-scale patterns of animal movement are often classified into different movement strategies, such as resident, nomadic, or migratory. While landscape-level environmental patterns can predict the presence of different movement strategies in an area, elucidating how these patterns downscale to fine-scale resource selection behaviors remains a challenge. Partially migratory systems, where both migrants and residents coexist, offer a unique opportunity to address these questions. Using tracking data from four Rocky Mountain elk (*Cervus canadensis*) herds situated primarily within Colorado, USA, we assessed between-herd, seasonal, and within-herd variation in resource selection behavior. We modeled fine-scale seasonal resource selection and compared strategy-specific behaviors using resource selection functions. Additionally, we used a consistency score to quantify the extent of differentiation in resource selection behavior across strategies, seasons, herds, and groups of covariates. We found variation in strategy frequency within each herd and in selection behavior, highlighting the complexity and context-dependence of strategy-specific selection. Despite herd-specific differences, some consistent trends emerged, with elk avoiding human development and roads at fine scales while selecting areas with higher productivity during summer. Our consistency analysis identified where elk most diverged in their selection behavior, revealing the greatest differences among herds, followed by variation between seasons, and lastly between movement strategies. Elk exhibited more uniform responses to productivity, contrasting with greater differentiation in responses to anthropogenic-related covariates. Overall, our study improves our under-standing of elk behavior across space, time, and movement strategies and sheds light on the hierarchical influences of space and time in constraining behavior. Published March 2025.

Drivers of spring migration phenology in Rocky Mountain elk

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Citation: Crews, S., N. D. Rayl, M. W. Alldredge, E. J. Bergman, C. R. Anderson Jr., and G. Bastille-Rousseau. 2025. Drivers of spring migration phenology in Rocky Mountain elk. Scientific Reports 15:7807.
https://doi.org/10.1038/s41598-025-91947-4

ABSTRACT By migrating, ungulates take advantage of cyclical fluctuations in resources, which allows them to persist at greater population numbers than they would in the absence of these seasonal movements. We sought to identify the drivers of spring elk (*Cervus canadensis*) migration and evaluate how well individuals were able to

optimize access to forage prior to departure, while migrating, and upon arrival on summer range. Specifically, we investigated the timing and duration of spring migration in four Colorado elk herds to test how forage quality and snow dynamics pre-, during, and post-migration influenced elk departure from winter range and the length of time spent migrating. Our analyses revealed significant heterogeneity among and within herds. Overall, spatiotemporal dynamics in forage and snow emerged as critical drivers influencing migratory phenology, but the discrete covariates associated with forage and snow were herd-specific. We did not find marked sub-strategies wherein some herds or individuals optimized a specific component of migration, but rather found that elk varied in their ability to optimize access to forage at all times analyzed. Our findings suggest that elk exhibit a flexible response to environmental cues, adjusting migration timing and duration in accordance with local conditions. These results contribute to a deeper understanding of the mechanisms driving ungulate migration and emphasize the importance of considering dynamic environmental factors in studies of migration phenology. Further, they emphasize the importance of forage conditions not just on the migratory route, but also on winter and summer range. Additionally, they provide baseline knowledge of elk migrations in Colorado, useful information for ensuring the conservation and persistence of these migratory routes and the productivity they facilitate. Published March 2025

Doe diligence: a regional analysis of antlerless deer harvest regulations in the Midwestern United States of America

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Citation: Draper, J. P., E. E. Brandell, J. Isabelle, C. Jacques, C. McCoy, E. Michel, D. J. Storm, C. Ott-Conn, B. Wojcik, W. C. Turner, and D. P. Walsh. 2025. Doe diligence: a regional analysis of antlerless deer harvest regulations in the Midwestern United States of America. PLoS One, 20(6): p.e0324708. https://doi.org/10.1371/journal.pone.0324708

ABSTRACT Wildlife management in the United States of America (US) is primarily delegated to the individual states wherein state wildlife agencies manage wildlife populations to achieve multiple and sometimes conflicting objectives. White-tailed deer (*Odocoileus virginianus*) are an important species in the Midwestern US whose populations are primarily managed through recreational hunting. Managers aim to adjust populations by altering the harvest of antlerless (usually female) animals by changing the number of harvest permits available, hunting season lengths, or applying incentive programs like earn-a-buck, where a hunter must harvest an antlerless deer before they may harvest an antlered deer. We estimated the effect on antlerless deer harvest from changes in these regulations and changes in the number of licensed hunters across eight states in the Midwest. We used a Bayesian hierarchical model to estimate individual state and regional (i.e., across all states) effects. We found that increasing antlerless harvest permits increased antlerless harvest; however, this effect plateaued as the number of available permits increased. Providing unlimited harvest permits increased harvest, but the same increases were achieved by minimally increasing the number of limited harvest permits. Increasing the length of hunting season had a generally positive effect on antlerless harvest but the effect was non-linear and state dependent. The earn-a-buck incentive program resulted in the largest estimated increase in harvest. Finally, the number of licensed deer hunters in a state had a strong positive effect on the number of antlerless deer harvested. Our findings show that commonly applied

changes in harvest regulations have a weak effect on the number of antlerless deer harvested, highlighting the challenges facing deer managers in the Midwestern US. Published June 2025.

AccelerometerBehavior: R package for classifying ungulate behaviors into three states

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Citation: Smiley, R. A., S. T. Rankins, J. N. Gavin, L. Millward, D. P. Thompson, J. A. Crouse, P. Van Wick, K. Anderson, C. W. Epps, A. E. Jolles, B. R. Beechler, R. L. Levine, T. N. LaSharr, B. L. Wagler, R. T. Rafferty, A. B. Courtemanch, T. W. Mong, and K. L. Monteith. 2025. AccelerometerBehavior: R package for classifying ungulate behaviors into three states. Ecology and Evolution 15:e72722. https://doi.org/10.1002/ece3.72722

ABSTRACT Advances in technology provide new opportunities to study animal behavior at increasingly fine scales. GPS collars for wildlife are commonly equipped with accelerometers, which record fine-scale movements with relatively little energy demand, yet the data remain underutilized. We paired activity data with behavioral states from direct observations and developed random forest models to classify behaviors into 'stationary', 'foraging', and 'travelling' states for 3 ungulate species (bighorn sheep, *Ovis canadens*is; moose, *Alces alces*, and mule deer, *Odocoileus hemionus*). Our algorithm had an overall classification accuracy ≥87% and area under the receiver operating curve ≥0.93 for all species. The mean class error rate was 15.65% (range 4.4-26.8%). We also developed a general 'ungulate' model (classification accuracy of 90% and area under the receiver operating curve of 0.95) to be applied to species lacking observation data. We developed an R package, AccelerometerBehavior, that allows users to classify ungulate behavior using our models that were validated with observation data. Unlike existing packages, AccelerometerBehavior allows users to apply existing models to new activity datasets without needing their own direct observations, which can be difficult to obtain. AccelerometerBehavior, thereby, facilitates the use of activity data and expands its potential for understanding ungulate behavior. Additionally, for each species, we compared activity budgets developed using AccelerometerBehavior (5-minute resolution) with those developed from Hidden-Markov models using GPS data (1-hour resolution). Activity budgets developed using AccelerometerBehavior estimated that animals spent substantially more time stationary and less time foraging than those developed from Hidden-Markov models and GPS data, emphasizing the need to consider the method and resolution of data when remotely assessing animal behavior. AccelerometerBehavior, which is hosted on GitHub, is simple and allows for the expanded use of activity data that are continuously collected on GPS collars yet are underutilized to study ungulate behavior. Published December 2025.

CARNIVORE ECOLOGY AND MANAGEMENT

Flexibility in female spatiotemporal behavioral tactics to counter infanticide risk during the mating season

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Citation: Heeres, R. W., M. Leclerc, S. Frank, A. Kopatz, F. Pelletier, andA. Zedrosser. 2025. Flexibility in female spatiotemporal behavioral tactics to counter infanticide risk during the mating season. Movent Ecology 13(1):35.
https://doi.org/10.1186/s40462-025-00561-6

Background Parental care is exclusively provided by females in most mammals, and mothers use several spatiotemporal behavioral tactics to minimize risks to offspring and to enhance fitness of both the mother and offspring. In species with infanticide and varying maternal care duration, dependent offspring remain vulnerable to male infanticide until separation from the mother. However, extending maternal care likely results in parent–offspring conflicts. We investigated the spatiotemporal behavioral tactics of lone female brown bears and mothers accompanied by offspring of varying ages in relation to infanticide risk and offspring separation during the mating season.
Methods We used data from 144 individuals (92 females and 52 males, 2003–2022) to characterize female spatiotemporal behavioral responses to males during the mating season by contrasting home range and encounter area sizes, proximity to males, and dyadic associations in relation to female reproductive status. We investigated the spatiotemporal behavioral responses of mothers from a socio-spatial perspective by connecting large-scale movement behavior (home range and overlap) and small-scale social behavior (proximity and associations) of adult females and males.
Results We found that females with dependent offspring of any age avoided males during the mating season. In comparison, lone females or mothers that lost or separated from their offspring during the mating season used larger areas and moved in closer proximity to males. The home range of mothers that remained with their offspring still largely overlapped with male home ranges, however, they did not associate (< 100 m) with males. Additionally, mothers with yearlings had similar sized home ranges as solitary females, but larger home ranges in comparison to mothers with cubs-of-the-year. This suggests that mothers with yearlings are more conspicuous on the landscape which may result in a higher detectability by males.
Conclusion Our results suggest that mothers with offspring of any age perceive adult males as potential source of infanticide and use spatiotemporal avoidance tactics. Generally, family groups had high home range overlap with adult males, but family groups that remained together throughout the mating season did not associate with any adult male. Mothers with yearlings used larger areas in comparison to mothers with cubs, potentially indicating their increasing energetic needs. The use of spatiotemporal behavioral tactics to avoid infanticide by females with dependent offspring irrespective of age likely disrupts movement, mating, and social dynamics and on the long-term potentially increases the risk of infanticide to older offspring. Published May 2025.

Bears avoid residential neighborhoods in response to the experimental reduction of anthropogenic attractants

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Citation: Venumière-Lefebvre, C. C., H. E. Johnson, S. W. Breck, M. W. Alldredge, and K. R. Crooks. 2025. Bears avoid residential neighborhoods in response to the experimental reduction of anthropogenic attractants. Frontiers in Ecology and Evolution 13:1657106. doi: 10.3389/fevo.2025.1657106

Introduction: Urbanization is an extreme form of land use alteration, with human development driving changes in the distribution of resources available to wildlife. Some large carnivores have learned to exploit anthropogenic food resources in urban development, resulting in human-carnivore conflict that can have detrimental impacts to people and carnivores, as exemplified by American black bears. Management agencies commonly promote the use of bear-resistant garbage containers for reducing conflicts, but little is known about the actual behavioral responses of bears to this intervention.
Methods: To understand whether black bears alter their behavior in response to changes in residential waste management, we investigated patterns of bear behavior in Durango, Colorado, where anthropogenic attractants were experimentally manipulated. Using location data from collared black bears, we modeled resource selection and movement in response to areas that had received bear-resistant garbage containers compared to those that did not.
Results: Bears avoided residential areas where garbage availability had been reduced, and this avoidance response increased over subsequent years, potentially suggesting that bears were learning from the management intervention. Bear movement rates, however, were not notably affected by the garbage reduction.
Discussion: Our findings highlight the importance of reducing the availability of anthropogenic attractants for changing bear behavior and reducing risk of urban human-bear conflict, and that these responses can strengthen overtime as bears learn from the management intervention. Published September 2025.

“The landscape of love”: sex-specific habitat-use during the mating season in a solitary large carnivore

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Citation: Zarzo-Arias, A., R. W. Heeres, A. G. Hertel, M. Leclerc, S. Frank, S. Steyaert, J. Kindberg, J. E. Swenson, V. Penteriani, F. Pelletier, and A. Zedrosser. 2025. "The landscape of love": sex-specific habitat-use during the mating season in a solitary large carnivore. Landscape Ecology 40(12):222. https://doi.org/10.1007/s10980-025-02250-6

Context
In mammals, reproductive strategies and movement behavior can differ between sexes, influenced by biological and environmental factors. Whereas males typically adopt a “roam-to-mate” strategy, increasing movement to locate

females, females may also adjust their behavior to enhance mating opportunities. Habitat and human disturbance can further shape the spatial structure of mating encounters.
Objectives
This study investigates sex-specific habitat use during mating in brown bears. We test (1) which habitats facilitate initial male–female encounters, and (2) how habitat use differs between solitary and consorting individuals, focusing on sex-based differences and responses to anthropogenic features.
Methods
We used GPS data from 70 unique adult brown bears (44 females, 26 males) during the mating season in Sweden (2006–2016). We contrasted initial encounter areas of male–female pairs with surrounding available habitat to assess encounter site preferences, accounting for natural and anthropogenic landscape features. Additionally, we compared habitat use for each sex when solitary versus consorting.
Results
Bears most often encountered the opposite sex in clearcuts and young forests. When consorting, males moved farther away from anthropogenic areas than when solitary and increased their use of clearcuts, whereas females reduced their use of young and old forests, in contrast to males. Both sexes approached roads more when consorting.
Conclusion
This study revealed distinct sex-specific habitat preferences during brown bear consorting behavior, supporting the evidence of female "roam-to-mate" behavior by adjusting to males' habitat use. Our findings emphasize the importance of managing anthropogenic landscapes for conservation efforts, especially if they disrupt mating behaviors. Published November 2025.

WILDLIFE DISEASE RESEARCH

Rabbit Hemorrhagic Disease Virus 2 experimental infection in snowshoe hares (*Lepus americanus*)

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ABSTRACT Rabbit hemorrhagic disease virus 2 (RHDV2) is an emerging virus of lagomorphs, with an extremely high mortality rate. Outbreaks of RHDV2 have been reported in domestic and wild European rabbits (*Oryctolagus cuniculus*) and wild lagomorphs globally, with the recent emergence and establishment of RHDV2 in the USA in 2018 and 2020, respectively. Here, we describe experimental infections in snowshoe hares (*Lepus americanus*), a species of conservation interest in the US. In this pilot study that took place January-April 2022, six hares were orally exposed to infectious virus and monitored for clinical signs and viral shedding for 2 wk. Snowshoe hares were relatively resistant to disease, with no hares succumbing to lethal infection during the experimental time frame (14 d) and animals showing histopathologic evidence of recovery from hepatic injury. Liver samples collected postmortem and pooled fecal samples collected daily were PCR positive for RHDV2, indicating that the hares were indeed infected and shedding viral particles. The majority of hares (5/6) seroconverted by the end of the study. These findings suggest that snowshoe hares are susceptible to RHDV2 and can potentially shed virus onto the landscape, but are less likely to be affected clinically than certain other species of lagomorph. Published July 2025.

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