



Moose Distribution and Abundance in Rocky Mountain National Park

2025 Inventory Results





Bull moose in the Kawuneeche Valley of Rocky Mountain National Park.

NPS

Moose Distribution and Abundance in Rocky Mountain National Park: 2025 Inventory Results

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Abstract

We conducted a parkwide thermal infrared aerial survey in Rocky Mountain National Park (ROMO) in 2025 to inventory moose (*Alces alces shirasi*) distribution, estimate abundance, and characterize demographic composition to inform moose and wetlands management. The survey built on 2019–2020 pilot work and was designed to provide spatially comprehensive, defensible data for management and NEPA decision-making. Survey results showed that moose were widespread across ROMO but were concentrated in riparian and wetland habitats. Density estimates were higher in areas classified as more suitable habitat than in less suitable areas and demographic indices indicated a population mostly consisting of cow moose. Comparison with earlier surveys indicated moose density increased 49% from 2020 to 2025. Parkwide, we estimated a density of 0.259 moose/km² (HDI 0.207, 0.312) and a total population of 240 moose (HDI 190, 287). These findings suggest moose could have increasingly negative effects on willow and wetland health in ROMO, with potential to undermine ongoing restoration efforts. Because ROMO functions as a refuge from harvest and lacks the population regulation typically provided by large carnivores, the observed density and population data suggest timely management actions to curtail moose herbivory will be needed to restore wetland integrity.

Acknowledgments

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Introduction

Background

In 1978 and 1979, Colorado Division of Wildlife (now known as Colorado Parks and Wildlife, CPW) translocated 12 moose (*Alces alces shirasi*) from Utah and 24 from Wyoming into North Park, west of ROMO, to increase wildlife viewing and hunting opportunities (CPW 2013). Prior to the translocation of these animals from Wyoming and Utah, an occasional moose would disperse into Colorado, however there was no evidence of established breeding moose populations in the state of Colorado (CPW 2013, 2025a). In 1980, the first moose was observed on the west side of Rocky Mountain National Park (ROMO; “the park”) in the Kawuneeche Valley (Stevens 1988). This area, along with the rest of the park’s west side, is separated from the east side by the Continental Divide. Until 2011–2012, moose in the park were rarely seen outside the Kawuneeche Valley and the park’s west side. Today, moose are present in all watersheds within the park and are frequently observed on both the east and west sides. CPW’s statewide estimate of moose was 2,400 in 2014 and 3,600 in 2025, a 51% increase in 10 years (CPW 2025b). This increase was likely due to both continued population growth in areas near the original introduction site, additional translocations across Colorado, and the eruptive growth that follows moose establishment in a new location.

ROMO has prioritized the restoration of degraded wetlands for decades, with three large ongoing projects including the implementation of the Elk and Vegetation Management Plan (EVMP; NPS 2007), the Grand Ditch breach restoration (NPS 2013), and the new Kawuneeche Valley Restoration Collaborative (KVRC) project, which is focused on restoring wetlands on the west side of ROMO. Wetlands cover only 4% of the park’s area but contain 32% of the park’s plant species, 65% of the park’s rare plant communities, and 45% of bird species (Schweiger et al. 2016). The integrity of park wetlands has been impacted by several inter-related ecological changes over the last century, including the extirpation of beaver, loss of top predators, over-abundant elk populations, and declining aspen and willow vegetation communities. In the larger context, the park is an international biosphere reserve and serves as a core area to protect biodiversity and ecosystem function. ROMO has made some progress on east side vegetation restoration and elk population management. However, a growing moose population, with individuals that can consume 50–60 lbs. of willow per day and have a unique ability to impact wetland vegetation, is an emerging issue that already appears to be reducing the extent of park wetlands (Cooper et al. 2025) and has the potential to reverse decades of vegetation restoration (Zeigenfuss et al. 2025).

Problem

Moose populations are typically regulated by wolf and grizzly bear predation and hunter harvest (Schwartz et al. 2007). These top predators have been extirpated in ROMO for over 100 years and hunting is not allowed in the park. CPW began the process of releasing between 30 and 50 gray wolves in December 2023. Since then, wolves have passed through ROMO several times but have not remained (NPS, unpublished data). While the effect of wolves on moose populations in ROMO, or even if the wolves will occupy ROMO, is not known, data from Yellowstone National Park indicate wolves strongly prefer to predate on elk when they are present alongside moose (Metz et al.

2012). GPS collar data shows that moose which were collared inside the park spend a substantial amount of time in the park across seasons, which likely limits the opportunity for hunter harvest to affect the park population (NPS, unpublished data). Consequently, the park provides a refuge for large ungulates with a high potential for reducing willow abundance, and thus, exacerbating existing wetland degradation.

Currently, there are no approved management options for moose inside park boundaries. It would be possible for CPW to increase harvest outside of the park, which has the potential to reduce vegetation impacts inside the park. To assist with overabundant elk and resulting habitat degradation in ROMO in the past, CPW increased cow elk harvest outside of the park. But these changes to elk harvest rates were supported by population and demographic data that have been lacking for moose. More than 30 scientists and land managers gathered in November 2023 in Estes Park to discuss moose in ROMO. They agreed that without timely management action, wetlands, vegetation communities, biodiversity, and future moose populations are very likely to face negative impacts due to wetland degradation exacerbated by moose. They identified a lack of moose population and demographic information as the most critical information gap impeding development of a management plan (NPS 2023).

Population and demographic information has long been difficult to collect for moose in many parts of their continental range, including ROMO, because moose are more elusive than other ungulates, spending time isolated in dense vegetation where they are less visible to aerial or ground observers (Harris et al. 2015). Moreover, the low-flying aircraft typically used for such surveys can impact wilderness character, which must be preserved in parks according to the 1964 Wilderness Act. These challenges and limitations were addressed with a novel thermal infrared aerial survey method that was piloted in ROMO in 2019 and 2020. The method paired high-altitude aerial distance sampling transects (~2000 ft. above ground level) with a thermal infrared sensor feed viewed by independent double observers. The observation data was analyzed in a hierarchical Bayesian model which produced precise estimates of moose density across the survey area (Abouelezz and Hobbs 2025). In 2019 and 2020, about 65% of the park was surveyed (Figure 1). Some areas were excluded from the survey because of limited funding, including Wild Basin in the southeast corner of the park, Paradise Park in the southwest corner, and the North Fork of the Big Thompson River in the northeast corner. These regions encompass some of the remaining healthy wetlands and reportedly have dense moose populations. The sampling for the current project covered the entire park.

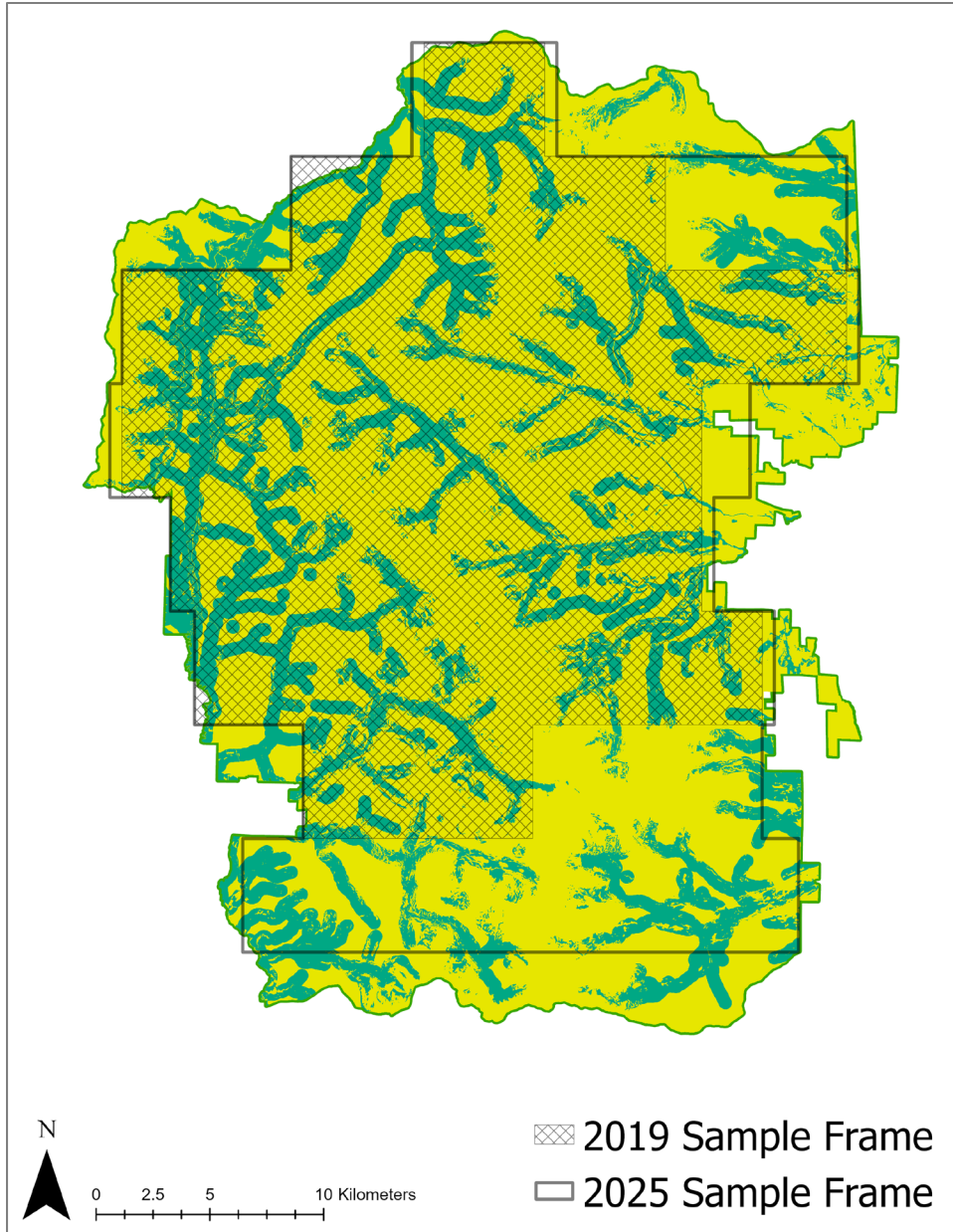


Figure 1. Aerial survey sample frames for 2019 (repeated in 2020) and 2025. Highly suitable moose habitat is displayed in green and less suitable moose habitat is displayed in yellow.

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In 2026, the park is expected to begin a formal planning process to develop a new parkwide wetland restoration and moose management plan. This project was created to estimate the first parkwide population estimate for moose to inform future management. Density data can be compared with existing estimates of moose carrying capacity (Cooper et al. 2025; Dungan et al. 2010) to determine the urgency of management action, and which management methods may be feasible.

Goals and Objectives

Our overall goal was to estimate moose abundance and distribution across ROMO. To estimate abundance, we expanded the spatial range of the aerial infrared method piloted in 2019/2020 to encompass the entire park (Figure 1).

The specific objectives of this project were to:

1. Estimate moose density and demographic indices (i.e., bull:cow and calf:cow ratios) in ROMO, using a double-observer infrared aerial survey method.
2. Inventory the distribution of moose throughout the park.
3. Compare 2025 moose density to past survey data (2019, 2020) to estimate moose population growth rates.

Methods

Methods Overview

We used the methods piloted in ROMO in 2019 and 2020 and described fully in a peer reviewed paper (Abouelezz and Hobbs 2025) to estimate moose densities, population sizes, and demographic ratios for ROMO. Here, we describe the methods in enough detail to understand the process and provide context for the results. Implementation of this method will require consulting Abouelezz and Hobbs (2025) and the R code used in this project.

The survey protocol uses thermal infrared (TIR) video collected by a fixed wing aircraft flying along transects distributed in a stratified random sampling design. The TIR video feed is viewed live by two onboard observers in a double-observer distance sampling strategy. TIR imagery is ideal for detecting moose in ROMO because moose often spend time in dense vegetation where their dark color makes them extremely difficult to detect. The TIR sensors allow warm moose, which exhibit relatively high thermal radiation, to stand out compared to the cooler early morning landscape, which exhibits relatively low thermal radiation (Figure 2). This thermal radiation difference ideally produces animals on the live feed as white heat signatures on a darker background, allowing observers to make detections where individuals might otherwise blend into their surroundings. TIR surveys have the additional benefit of allowing detection of moose from higher aircraft altitudes (~2000 ft above ground level, AGL), which reduces impacts to wilderness character, wildlife, and recreationists and improves aviator safety (Abouelezz and Hobbs 2025).



Figure 2. Thermal infrared images of a mature bull moose (A) and, later during the same survey, a cow and her calf (B), recorded during a survey flight conducted in Rocky Mountain National Park on July 25, 2019. Both groups are viewed within the context of riparian willow communities.

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Moose observations were analyzed using a hierarchical Bayesian mark recapture distance sampling model (Abouelezz and Hobbs 2025; Clement et al. 2017) to produce density, composition, and abundance estimates.

Study Area and Sampling Design

The study area for this project is ROMO. The study area was classified into binary habitat suitability bins of “more suitable” and “less suitable” moose habitat based on three metrics: slope, distance to water, and vegetation type. This classification served two purposes: it allowed a separate density estimate for the areas heavily used by moose (e.g., riparian wetlands) and it allowed a stratified sample that concentrated flights in areas with more moose. Any location (9 m × 9 m raster pixel)

with a slope greater than 45 degrees, farther than 285 m from water, or classified as unvegetated (including water, ice, and rock), uplands, or alpine was considered less suitable, while the remaining locations were considered “more suitable” (Figure 1). For more detail on the stratification, see Table 1 in Abouelezz and Hobbs (2025).

The 2019/2020 survey effort achieved good precision (<20 % Coefficient of Variation), so in 2025 we planned for a similar survey effort but expanded to the full area of the park (Figure 1). Sixty transects, each 5 km long by 0.536 km wide (split between 35 more and 25 less suitable), were flown in 2019/2020, for a total transect length of 300 km and surveyed area of 160.9 km². Because one of the objectives of this project was to estimate population growth rates, we retained the same 60 transects in the original survey area. To this, we added an additional 32 transects, each 5 km in length, with 54 total transects in the “more suitable” stratum and 38 in the “less suitable” stratum (Figure 3), for a total transect length of 460 km and surveyed area of 246.8 km².

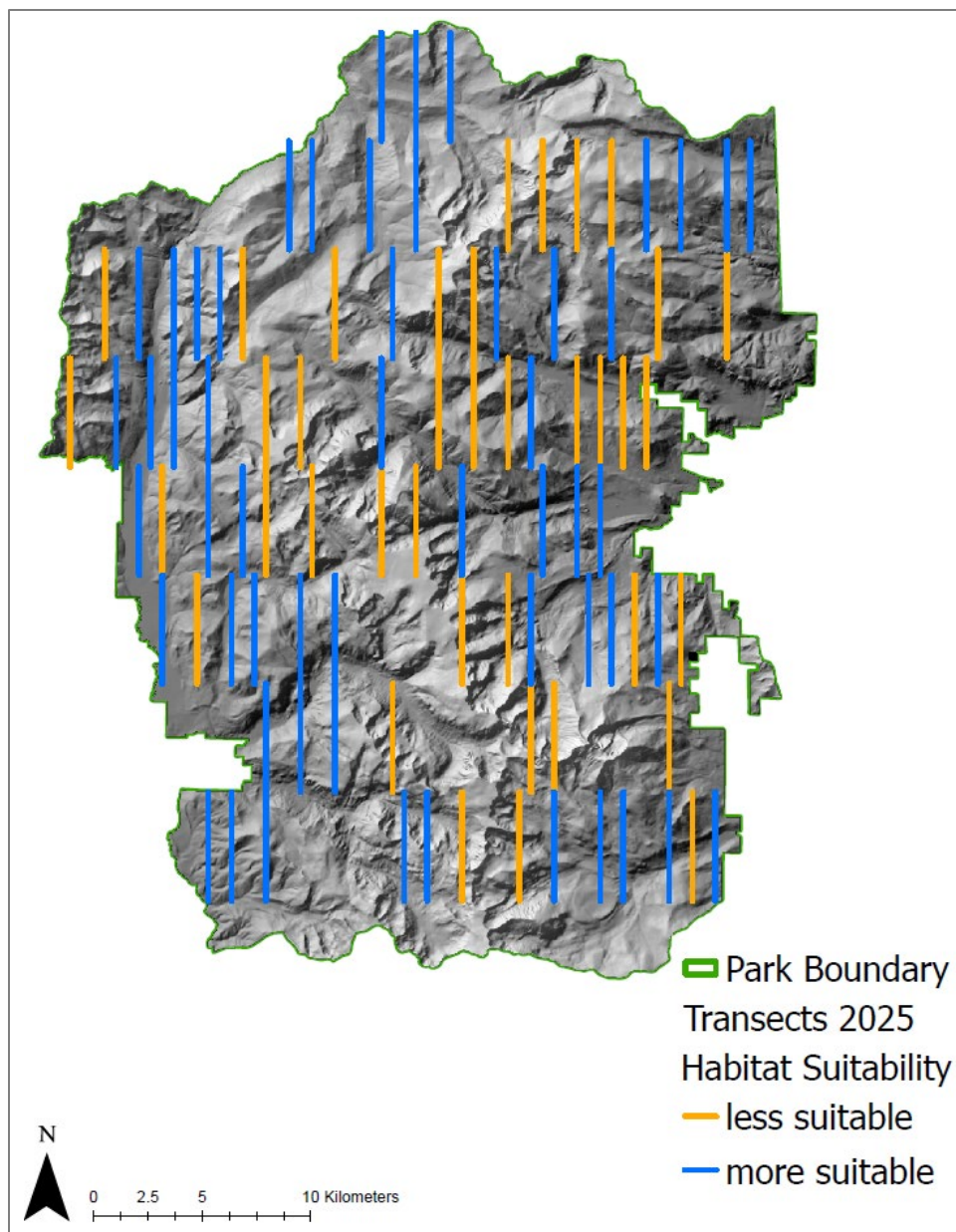


Figure 3. Flight transects flown in 2025 (colored by moose habitat suitability).
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Aerial Surveys

Flights were planned for the middle of July. We contracted the same air services company as was used in 2019 and 2020, Owyhee Air Research (Nampa, ID, USA). They used a fixed-wing, twin-engine aircraft (Vulcanair P-68C) with a 360° pan-tilt-zoom (PTZ) gimbal, multi-sensor, thermal infrared camera (TIR camera, 244 640 × 512 IR resolution, L3Harris MX-10, Melbourne, FL, USA). The flight team was directed to maintain a flight elevation of ~610 m AGL (~2000 ft), however actual flight elevations varied to maintain crew safety amid rapidly changing topography. Survey flights were conducted each morning and began approximately one hour before sunrise to

approximately two hours after sunrise, depending on weather and thermal conditions. Early morning flights provide optimal survey conditions when thermal contrast between the target animals and the surrounding landscape is greatest and thermal cluttering from warming rocks and trees is limited (Abouelezz and Hobbs 2025).

To implement the double observer design, onboard monitors were viewed by two trained, independent observers, situated in the aircraft such that observations were independent. When a potential detection occurred, observers waited until the target passed the $\frac{3}{4}$ point on their monitor screen before signaling a detection. The aircraft then reversed course and circled the potential target animal or group until both observers were able to independently record the species, sexes, count, and geographic location. Animals and groups were observed in both TIR and natural color video to confirm recorded observations. Each observer also recorded whether they had initially detected the animal, with 0 = not detected and 1 = detected. The aircraft then resumed the transect.

Analysis Methods

Moose observations were analyzed using a hierarchical Bayesian mark recapture distance sampling model (Abouelezz and Hobbs 2025; Clement et al. 2017) which was modified to relax some of the key assumptions of basic distance sampling models. A standard distance sampling assumption is that detection is 100% on the transect line. The independent observations from two observers allow the estimation of moose detection probability on the flight line using mark-recapture principles. Away from the line, we used standard distance sampling principles where detection was modelled as a decaying function which decreases with distance from the flight line out to the maximum distance of 268 m (1/2 the 536 m strip width).

After data quality assurance and quality control steps, the Bayesian mark recapture distance sampling model was run in Program R (R Core Team 2025). The model details, including a detailed explanation of how assumptions were addressed, is discussed in Abouelezz and Hobbs (2025).

Results

Aerial Survey Description

Infrared aerial surveys occurred daily from 7/18/2025 to 7/23/2025. The aircraft was based out of Loveland, CO at the Northern Colorado Regional Airport (FNL). A flight was attempted on 7/17/25, but low fog prevented the aircraft from taking off from FNL. The average take off time was 4:40 AM and the average landing time back at FNL was 7:51 AM. Excluding the time to ferry to and from the park, the average survey time per day was 2 hours and 16 minutes.

The survey team flew all 92 of the 5 km transects planned for this year’s survey in 23 hours. Total flight hours included an additional 7.8 hours to ferry to and from Boise, for a total of 30.8 hours of flight time to complete the project.

Observation, Detections, and Group Size

Across the 92 transects flown (Figure 3), the survey team observed 73 moose in 42 groups (Figure 4). Of these, the team observed 54 moose in 30 groups in the 2019/2020 survey area. The majority of moose were observed within “more suitable” transects (61 of 73 moose). Most of the groups had few members (Figure 4A) and more than half of the observed moose were females (Figure 4B). There was a notable concentration of moose observed in the Poudre Headwaters at the north end of the park.

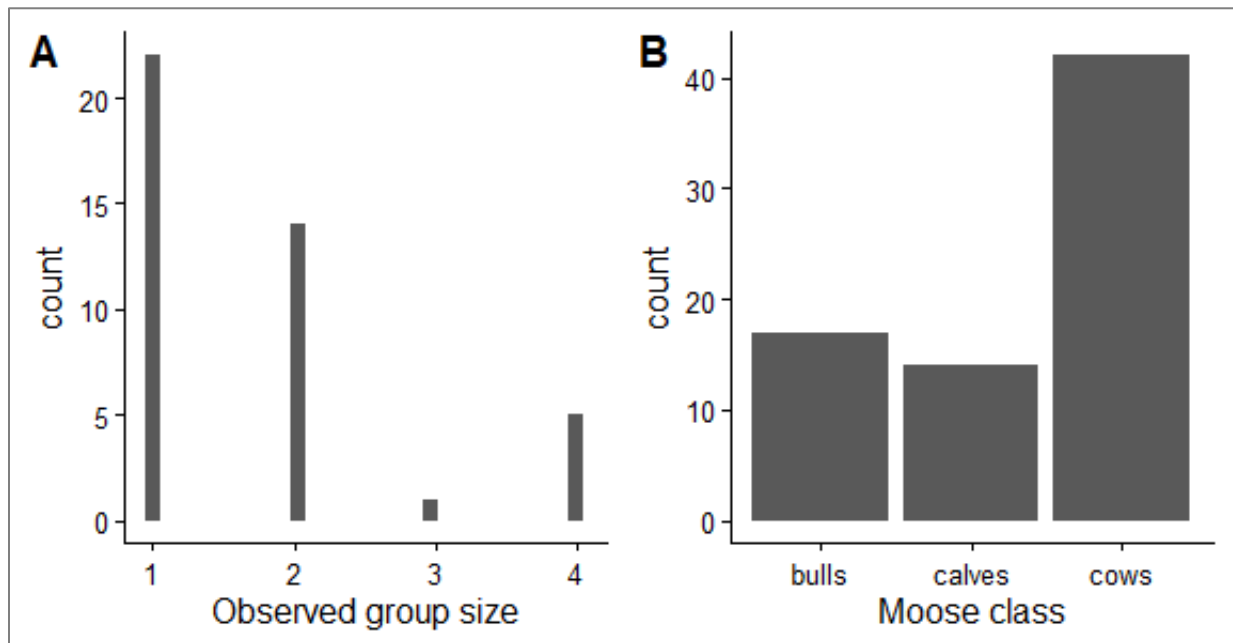


Figure 4. Characteristics of moose observed in Rocky Mountain National Park during infrared aerial surveys. A) Histogram of observed moose group size. B) Histogram of observed moose demographics. NPS / DEACY

The probability of detecting moose along the transect line was near one, with detection probability and precision decreasing slightly further from the line (see Appendix). This is very similar to the results in past surveys (Abouelezz and Hobbs 2025). The accumulation of data across surveys appears to be improving the precision of the detection parameter, as expected.

The average modelled group size was 1.76 (HDI [95% High Density Interval] 1.49, 2.05), lower than the average group sizes in 2019 (2.1) and 2020 (2.19).

Population Size and Density

In the larger “parkwide” sample frame used in 2025, we estimated a density of 0.259 moose/km² (HDI 0.207, 0.312) and a total population of 240 moose (HDI 190, 287) (Table 1). In the sub-area initially surveyed in 2019, moose density increased 49% from 2020 to 2025 (Table 2, Figure 5). This increase corresponds to an average annual population growth rate of 6.3% (from 2019–2025).

Table 1. Parkwide 2025 population size, density, and group size results. SD is the standard deviation. CV is the Coefficient of Variation, a measure of precision. HPD lower and HPD upper refer to the lower and upper bounds of the 95% High Probability Density area.

Metric	Stratum	Mean	SD	CV	HPD lower	HPD upper
Population size	More Suitable	191	21.3	11.2%	150	232
	Less Suitable	49	10.5	21.4%	28	68
	Combined	240	25.1	10.5%	190	287
Population density	More Suitable	0.422	0.0473	11.2%	0.332	0.514
	Less Suitable	0.103	0.0221	21.5%	0.0652	0.149
	Combined	0.259	0.0271	10.5%	0.207	0.312
Group size	Combined	1.76	0.144	8.2%	1.49	2.05

Table 2. Population size, density, and group size in 2019, 2020, and 2025, in the sub-area initially surveyed in 2019. All estimates are for combinations of more and less suitable habitat strata. SD is the standard deviation. CV is the Coefficient of Variation, a measure of precision. HPD lower and HPD upper refer to the lower and upper bounds of the 95% High Probability Density area. Source for 2019 and 2020 data: Abouelezz and Hobbs (2025).

Metric	Year	Mean	SD	CV	HPD lower	HPD upper
Population size	2019	149	25.7	17.2%	100	198
	2020	143	23.9	16.7%	97	189
	2025	215	26.4	12.3%	163	265
Population density	2019	0.215	0.037	17.2%	0.145	0.286
	2020	0.207	0.0345	16.7%	0.144	0.276
	2025	0.309	0.0381	12.3%	0.235	0.382

Table 2 (continued). Population size, density, and group size in 2019, 2020, and 2025, in the sub-area initially surveyed 2019. All estimates are for combinations of more and less suitable habitat strata. SD is the standard deviation. CV is the Coefficient of Variation, a measure of precision. HPD lower and HPD upper refer to the lower and upper bounds of the 95% High Probability Density area. Source: Abouelezz and Hobbs (2025).

Metric	Year	Mean	SD	CV	HPD lower	HPD upper
Group size	2019	2.1	0.293	14.0%	1.58	2.69
	2020	2.19	0.297	13.6%	1.64	2.78
	2025	1.83	0.179	9.8%	1.5	2.19

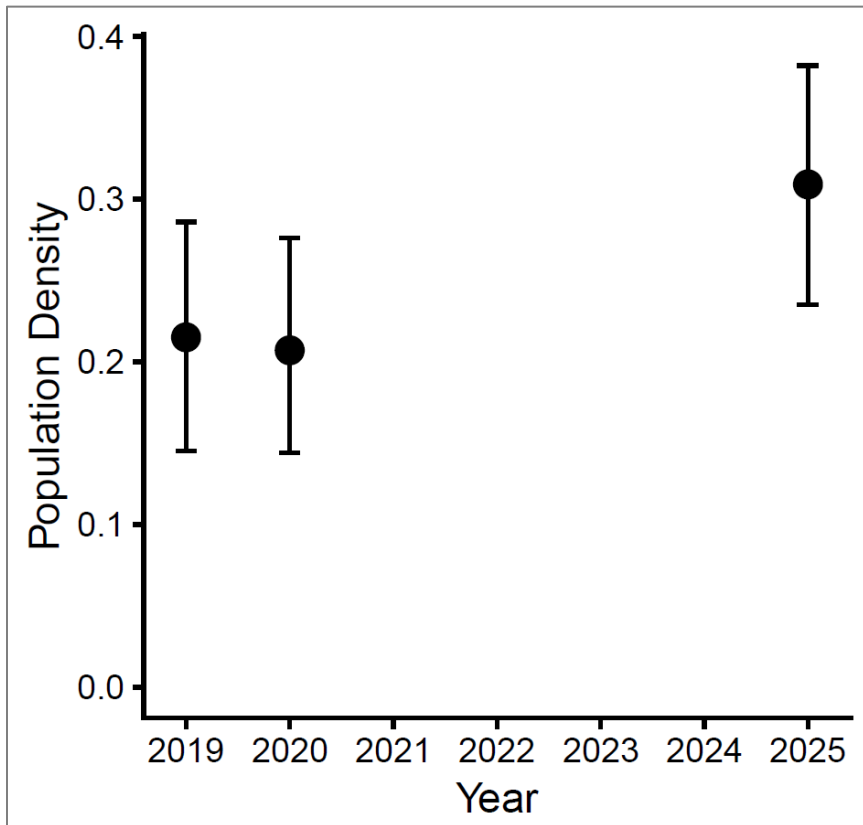


Figure 5. Moose density (moose/km²) in the 2019 sample frame across three years. The points show the median of the Bayesian posterior distribution and the error bars show the 95% High Probability Density range of the posterior distribution.

NPS / DEACY

Demographic Composition

Independent determinations of group composition by the two observers were in complete agreement. Parkwide estimates of the ratio of bulls to cows was 0.55 (HDI 0.11, 1.12), while the ratio of calves to cows was 0.36 (HDI 0.05, 0.80; Table 3). The precision of demographic variables was poorer than population size and density, however, precision in 2025 was better than in 2019/2020. Overall, 2025 demographic parameters were more similar to estimates from 2019 than 2020 (Table 4).

Table 3. Composition of moose in 2025 by sampling area, where “old” is constrained to the area sampled in 2019/2020 and resampled in 2025 and “new” is the 2025 parkwide sampling frame. All estimates are for combinations of more and less suitable habitat strata. SD is the standard deviation. CV is the Coefficient of Variation, a measure of precision. HPD lower and HPD upper refer to the lower and upper bounds of the 95% High Probability Density area.

Metric	Area	Mean	SD	CV	HPD low	HPD high
Bulls per cow	Old	0.42	0.142	33.8%	0.168	0.691
	New	0.545	0.288	52.8%	0.112	1.12
Calves per cow	Old	0.386	0.132	34.2%	0.159	0.648
	New	0.362	0.218	60.2%	0.0482	0.798
Proportion cows	Old	0.561	0.0648	11.6%	0.435	0.689
	New	0.546	0.104	19.0%	0.343	0.743
Proportion calves	Old	0.21	0.0529	25.2%	0.115	0.32
	New	0.182	0.0802	44.1%	0.0388	0.34
Proportion bulls	Old	0.228	0.0554	24.3%	0.122	0.335
	New	0.273	0.0934	34.2%	0.0997	0.455

Table 4. Composition in 2019/2020/2025 in the sub-area surveyed in Abouelezz and Hobbs (2025). All estimates are for combinations of more and less suitable habitat strata. SD is the standard deviation. CV is the Coefficient of Variation, a measure of precision. HPD lower and HPD upper refer to the lower and upper bounds of the 95% High Probability Density area.

Metric	Year	Mean	SD	CV	HPD lower	HPD upper
Bulls per cow	2019	0.39	0.179	45.9%	0.093	0.737
	2020	0.928	0.372	40.1%	0.329	1.66
	2025	0.42	0.142	33.8%	0.168	0.691
Calves per cow	2019	0.386	0.178	46.1%	0.11	0.749
	2020	0.645	0.287	44.5%	0.182	1.21
	2025	0.386	0.132	34.2%	0.159	0.648
Proportion cows	2019	0.577	0.0851	14.7%	0.415	0.746
	2020	0.405	0.0797	19.7%	0.255	0.564
	2025	0.561	0.0648	11.6%	0.435	0.689
Proportion calves	2019	0.21	0.0698	33.2%	0.0869	0.354
	2020	0.244	0.0702	28.8%	0.117	0.384
	2025	0.21	0.0529	25.2%	0.115	0.32
Proportion bulls	2019	0.213	0.0697	32.7%	0.0856	0.352
	2020	0.351	0.0774	22.1%	0.207	0.507
	2025	0.228	0.0554	24.3%	0.122	0.335

Discussion

Moose Abundance and Demographic Estimates

We used an innovative infrared aerial survey method paired with a hierarchical Bayesian analysis to estimate moose population size, density, and demographic parameters in ROMO. Our primary finding is that the population has grown 49% from 2020 to 2025 in the sub-area originally sampled, and the estimated parkwide population is 240 moose. Comparing these data to 2010 densities across North America shows that densities in the park are at or above many values reported across the continent and are high relative to the majority of western U.S. and many Canadian boreal populations (Jensen et al. 2018).

Impacts from moose herbivory have been implicated as a primary cause of a 98% decline in tall willow from 1999 to 2019 in the Kawuneeche Valley on the west side of the park, where moose have been established the longest (Cooper et al. 2025). The results from this survey raise the concern that the increasing moose population could lead to the loss of tall willow in other parts of the park, which would precipitate loss of the underlying riparian wetlands.

Demographic parameters varied among survey years with consistency between 2025 and 2019 surveys. The 2025 estimate of the number of calves per cow was 0.386, lower than the average of 0.67 calves per cow estimated by Bergman et al. (2025) in other areas of Colorado during 2014–2020. A decline in birth rate is often seen when large herbivore populations reach or exceed the nutritional carrying capacity of a landscape (Gaillard et al. 1998). However, the demographic estimates in this study are somewhat imprecise, so the low calf to cow ratio should be interpreted with caution. Bull per cow ratios also varied among years. The estimate was 0.39 (95% HPD: 0.09–0.74) in 2019, which increased to 0.93 (95% HPD: 0.33–1.66) in 2020, and declined to 0.42 (95% HPD: 0.17–0.69) in 2025. The elevated 2020 estimate suggests greater relative representation of bulls that year; however, as with calf to cow ratios, credible intervals were wide and overlapped with other years, indicating that true differences among years are uncertain.

Potential Improvements for Future Surveys

The method detailed in Abouelezz and Hobbs (2025) and used in this project continues to prove effective. Despite dense vegetation and rough topography, it has reliably produced population estimates and densities that can be used to support park wetland and moose management needs.

Several possible improvements could increase the precision of estimates while decreasing the flight time, and associated costs, needed to meet precision goals. One key potential improvement is implementing a spatially explicit model-based approach that uses covariate information to produce unbiased estimates of moose density from an unbalanced survey design. These improvements have been previously deployed for distance sampling aerial surveys for Dall's sheep in national parks in Alaska (Schmidt and Deacy 2021). Spatial distance sampling allows survey effort to be concentrated in areas with more moose without introducing bias. Rather than treating transects as the sampling unit upon which inference is based, this alternative method can use pixels at the scale of the spatial covariates for inference. This better leverages the spatial information gained during aerial surveys.

This is a result of the characteristics of the exact location where moose are observed which can be used to model pixel-based moose density continuously across the survey area.

Another complementary approach that would reduce the resources needed to monitor moose populations in the park would be pairing less frequent surveys (e.g., every other or every third year) with predictive population models to estimate moose populations in years without a survey. This is similar to the elk population predictions previously used to predict future elk populations on their winter range in ROMO based on different management scenarios (Ketz et al. 2016). This approach could greatly reduce the resources needed to monitor moose populations while still producing the annual estimates that are needed to guide adaptive management.

In addition to improving abundance estimation, there are opportunities to increase the precision of demographic parameters. Estimating composition for relatively low-density and cryptic species using aerial surveys presents inherent challenges, which can often disproportionately impact calf detection and classification, particularly in smaller group sizes associated with park moose (Gasaway et al. 1986; Johnson et al. 2010; Nichols et al. 2011). Integrating complementary data sources may strengthen inference regarding recruitment and sex structure. Potential approaches include camera trap-based composition surveys and use of classification data of individuals obtained during collaring operations. Combining infrared-based estimation with independent composition data could improve the precision of calf to cow and bull to cow ratios and enhance the park's ability to detect demographic shifts and inform population dynamics.

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Appendix

The probability of detecting moose along the survey transect line in Rocky Mountain National Park is shown in Figure 6.

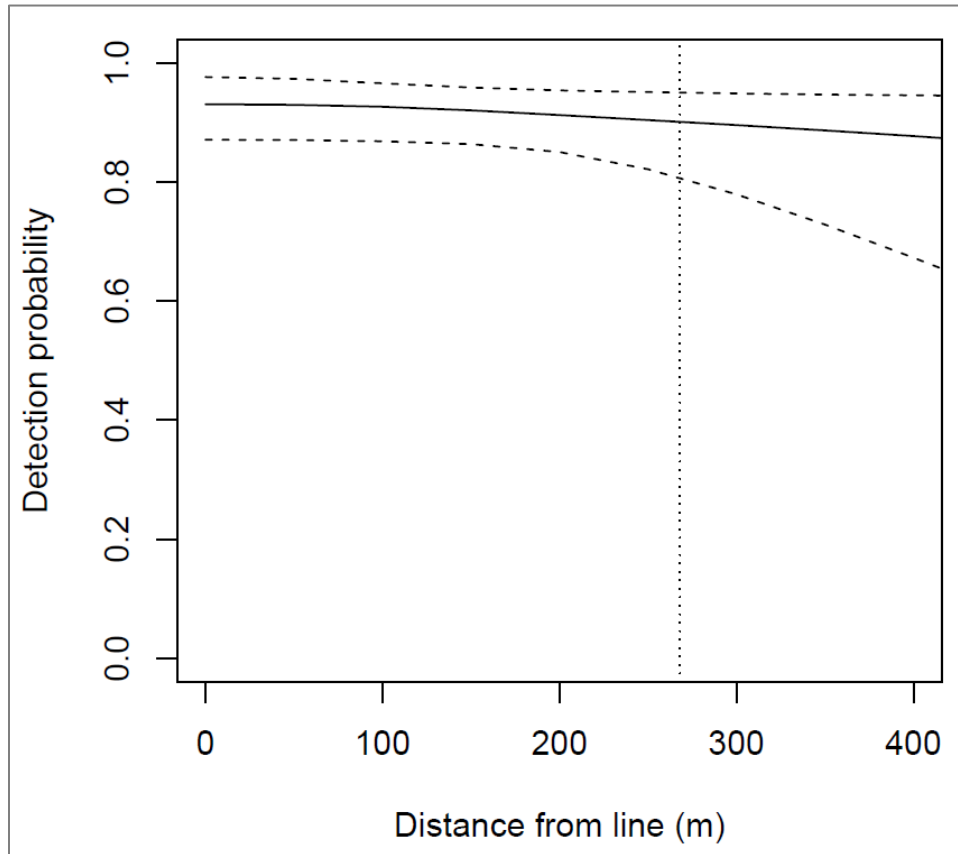


Figure 6. The detection function for the distance sampling survey of moose in Rocky Mountain National Park. The vertical dotted line is marked at 268 meters to indicate the width of the survey strip used in the analysis.

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