



Moose (*Alces alces*) Population Survey in Yukon-Charley Rivers National Preserve, November 2025



Cow and calf moose in Yukon-Charley Rivers National Preserve, November 2025.
NPS / MATTHEW CAMERON

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Abstract

We conducted aerial surveys for moose (*Alces alces*) in Yukon-Charley Rivers National Preserve (YUCH) in November 2025. These surveys were conducted using GeoSpatial Population Estimator (GSPE) protocols that were adopted in 2003 and is the 8th such survey conducted in the Preserve. Survey units are approximately 5.6 mi² and are surveyed by a pilot/observer pair in a tandem fixed-wing aircraft. We surveyed 102 units covering 568 mi², representing 18% of the 3,096 mi² survey area, at an average pace of 6.4 minutes/mi². We observed 216 total moose, comprised of 113 cows, 32 calves, and 71 bulls. The GSPE population estimate was 729 moose (90% CI: 587–872), resulting in an estimated density of 0.24 moose/mi², which was similar to the long term 2003–2022 average of 0.27 moose/mi². The 90% confidence interval for the total moose estimate ($\pm 19\%$ of the mean) met our goal of 20% or better of the mean relative precision. Estimated sex ratios were 34 calves:100 cows, 6 yearling bulls:100 cows, and 57 bulls:100 cows. We recommend a continued conservative management of harvest to ensure that population stability continues and is able to absorb natural stochastic environmental fluctuations despite a baseline low density.

Acknowledgments

This survey was funded by the U.S. National Park Service and Yukon-Charley Rivers National Preserve, Alaska, and was made possible by funding from the Central Alaska Network. Many safe flight hours and aircraft support were provided during the survey by pilots Andy Greenblatt, Nick Thompson, Jessie Cummings, Leif Wilson, and Jake Combs. Mat Sorum, Matt Cameron, Isaac Hull, and James Cash served as observers in aircraft, and we thank all observers for their help and dedication to the survey. We thank thoughtful reviews from Jeff Wells and Jordan Pruszenski.

Executive Summary

- Overall survey dates: November 17–29, 2025 (8 days of surveys, 5 weather days)
- Total survey area: 3,096 mi² (8,018 km²), 555 survey units
- Area surveyed: 568 mi² (1,471 km²), 102 survey units
- Total moose observed: 216 (113 cows, 32 calves [2 set of twins], 71 bulls)
- Average search effort: 6.4 minutes/mi² (2.5 minutes/km²)
- Population estimate: 729 moose (90% CI: 587–872; $\pm 19\%$); long-term average 834 moose
- Estimated density: 0.24 moose/mi² (0.09 moose/km²); long-term average 0.27 moose/mi²
- Estimated age/sex ratios: 34 calves:100 cows, 6 yearling bulls:100 cows, 57 bulls:100 cows

Introduction

Moose (*Alces alces*) are an integral component of the boreal ecosystem in Yukon-Charley Rivers National Preserve (YUCH). Moose are considered good indicators of long-term habitat change within the Preserve ecosystem because they require large quantities of resources from their habitat year-round, and populations have the potential to respond to long-term changes in resource conditions. In addition, moose are an important subsistence and general hunting resource and are named specifically in the founding legislation for the Preserve (ANILCA 1980). The Central Alaska Network (CAKN) of the National Park Service (NPS) designated monitoring fauna distribution and abundance as 1 of the top 3 Vital Signs for the Network. Moose were identified as 1 such species to monitor as they are a common herbivore present in all 3 park units and indicate the health of lower elevational ecosystems (relative to the elevations within the Network). The CAKN is monitoring animal species across an elevational gradient as part of an effort to track long-term changes in ecosystems across 3 Alaskan park units (YUCH, Denali National Park and Preserve, and Wrangell-St. Elias National Park and Preserve). Moose surveys are scheduled for each park unit every 3 years.

YUCH conducted an aerial moose survey during November 17–29, 2025, in and around Yukon-Charley Rivers National Preserve, Alaska (Figure 1). Moose surveys have been conducted within YUCH for 38 years (Appendix A) and 10 surveys have been conducted within the current survey area over the last 28 years.

The objectives of the 2025 moose survey were to: 1) estimate numbers of total moose in a 3,096 mi² survey area of the Preserve and 2) estimate sex and age ratios.

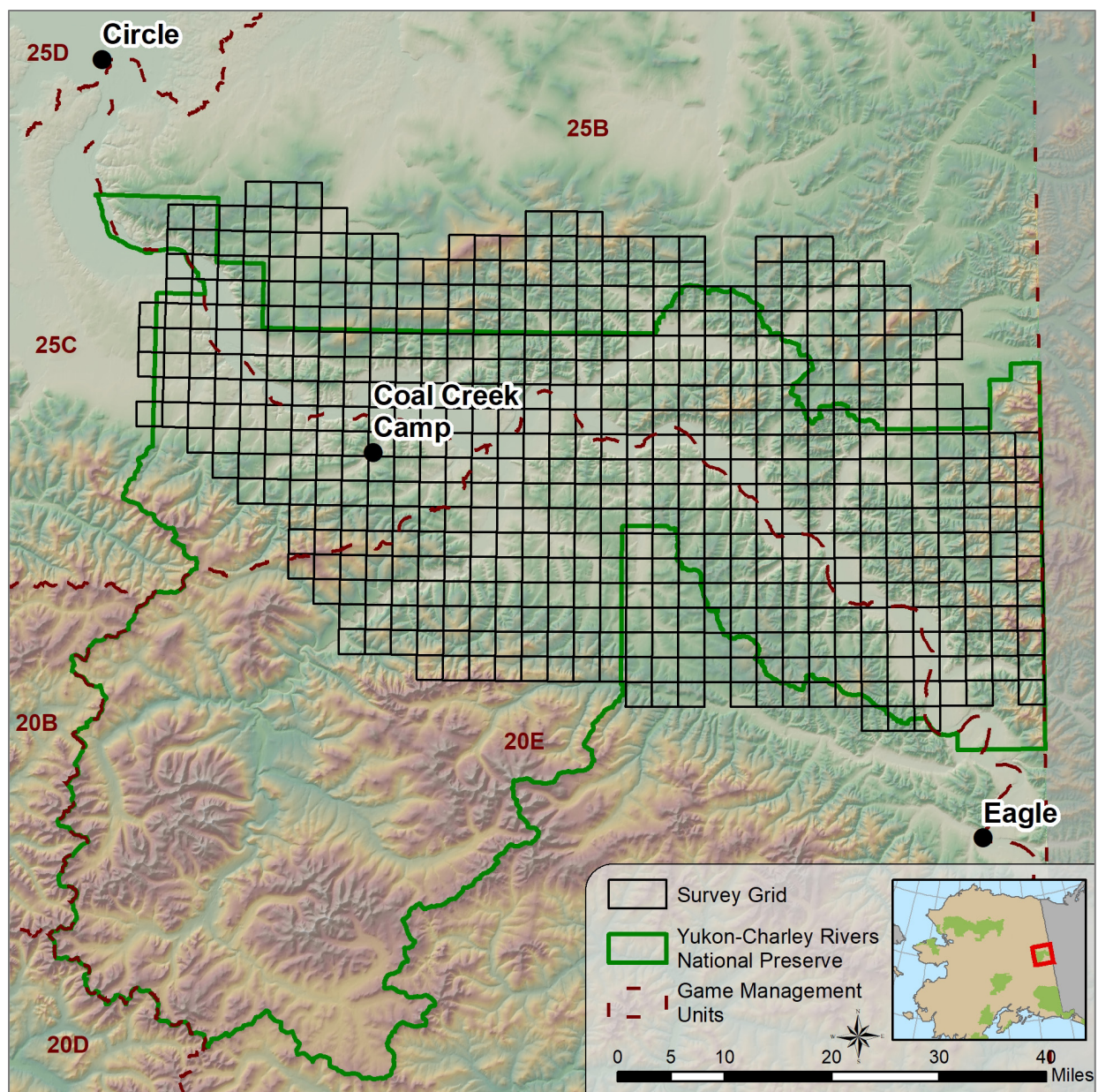


Figure 1. Location of moose survey units within and around Yukon-Charley Rivers National Preserve (YUCH), Alaska. State of Alaska Game Management Unit (GMU) boundaries are indicated in maroon (GMU 20E, 25B, and 25C).

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Study Area

The moose survey was conducted along a 30–40 mile- (48–64 km-) wide corridor of the Yukon River drainage within and around YUCH, between Eagle and Circle, Alaska (Figure 1). The topography of the area consists mainly of rolling hills and river bluffs (Figure 2). Isolated rugged terrain occurs on several eroded mountains, with peaks generally under 6000 feet (1800 meters). Vegetation is dominated by black spruce (*Picea mariana*) and several species of deciduous hardwoods including aspen (*Populus tremuloides*) and birch (*Betula papyrifera*). Ponds, sloughs, and large areas of

tussock tundra are common in the flats along the Yukon River and lower parts of large tributaries such as the Charley and Kandik rivers. Wildfire burns of varying sizes and ages are present throughout the study area, with approximately 7% of the study area burned in the past 1–10 years, 28% in the 11–30 year timeframe, and 30% 31+ years ago (AFS 2025; WFIGS 2025). Note that younger fires take priority over older fires in acreage calculation of overlap areas.



Figure 2. Typical topography and vegetation of the survey area. Foothills of the confluence of the Charley River and Yukon River.

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Methods

Moose population surveys were conducted using the GeoSpatial Population Estimator (GSPE) method (Ver Hoef 2008), a modification of a technique initially developed by Gasaway et al. (1986). The GSPE method is widely used in Alaska, which allows comparison between survey areas. The publications, “GeoSpatial Survey Operations Manual” (Kellie and DeLong 2006) and “GeoSpatial Population Estimator Software User’s Guide” (DeLong 2006) provide guidelines for sample unit design and selection, navigation, and data analysis.

A desktop stratification into high and low strata was conducted based on the expert opinions of 3 wildlife biologists, considering prior stratification decisions, prior moose counts, shrub and deciduous forest cover (Swanson 2023), *Salix* spp. cover (Nawrocki 2021), topography, fire history (AFS 2025), and landscape context. A correlation matrix was used to explore the strength of simple linear relationships among these variables and moose counts, but no formal predictive modeling was used. Units with 3 or more moose detected in a recent year (e.g., since 2009) were considered candidates for inclusion in the “high” strata, although this was not a hard rule, and other variables were always considered. The landcover types from Swanson (2023) that were targeted as moose habitat were TallShrubSeral, DeciduousForestShort, MixedForestShort, LowShrub&HerbBurned2015-2020, UplandLowWillow, UplandLowShrub, AlpineLowShrub, and SubalpineTallShrub, with particular attention paid to TallShrubSeral, UplandLowWillow, and SubalpineTallShrub. Mean *Salix* spp. cover of >20% was considered potential good habitat based on review of simple linear regressions with moose counts. Units that were significantly affected by fire (i.e., greater than ~1/3 coverage) in the range of 11–30 years ago were also considered potential candidates for good habitat (Maier et al. 2005). Based on prior survey experience in the area, very flat and very steep terrain were generally avoided, with most “high” strata placed in moderately rugged terrain. The arrangement of units in relation to one another was also considered, with small, isolated pockets of potentially decent habitat being less likely to be considered a “high” unit than marginal habitat located on the periphery of large expanses of good habitat. This was based on the assumption that small pockets of good habitat are unlikely to support high moose densities, but that marginal habitat may absorb overflow from high density, prime habitat. All these variables were considered in conjunction with one another to arrive at an informed decision on whether we would expect to see 3 or more moose in a given unit. The final stratification included 188 high units and 367 low units.

Sample units to survey were randomly selected from each density strata following Kellie and DeLong (2006). Because observations are more variable in the high stratum than the low stratum, we allocated greater sample effort to the high-density units to reduce overall variance (Kellie and DeLong 2006). We selected 120 units to survey out of the 555 total units, with 80 units allocated to the high stratum and 40 units in the low stratum (Figure 3). We withheld 20% of the units from the random selection and subjectively used them to fill in-between blocks of units because the GSPE has a spatial component whose results are improved if there are no large gaps (>50 km) among surveyed units. Manual unit selection considered 3 factors: spatial coverage (eliminating gaps >8 units

between selected low stratum units and >4 units for selected high stratum units), maintenance of trend units (units that have been surveyed at least 6 out of 7 prior survey years), and survey efficiency (taking into consideration likely survey routes and aircraft fueling ranges).

For the survey, 5 tandem seat fixed-winged aircraft (Piper PA-18 and Top Cub CC-18) were used to survey ~ 5.6 mi² units that were delineated by 2 minutes of latitude by 5 minutes of longitude. Aircraft used Global Positioning System (GPS) to navigate to and within assigned units and search intensity varied with habitat. The survey protocol required high search intensity in forested habitats and lower intensity in open habitats or areas with significant water. Survey patterns varied according to terrain. Within lowland area, survey aircraft generally flew transects about 300 to 800 feet AGL at 70 knots. Within mountainous terrain, survey aircraft followed the contour of the mountains.

An observer was paired with each pilot, and the observer's job was to record data on an iPad using the NPS application, "Park Observer" (developed by the Alaska Regional GIS Team). iPads were loaded with base maps and the survey grid. Using the Park Observer "Fall Moose Comp" (v1.1) protocol, the observer recorded the track log as well as moose group location and composition which were detected during the survey. Two units were surveyed by a highly-experienced pilot without an observer present due to observer availability. Numbers of moose in each group were recorded and the sex and age classification of each moose was determined. Moose were classified as: cow, calf, yearling bull (spike or forked antlers), medium bull (antler spread > spike/fork, but < 50 inches [127 cm]), and large bull (antler spread ≥ 50 inches [127 cm]). By only classifying spike/fork bulls as yearlings there is a risk of missing some yearlings with palmated antlers, however we use this classification scheme for consistency with the long-term dataset. Total moose, moose density and sex/age ratios were calculated using the GeoSpatial Population Estimator software (DeLong 2006; Kellie and Delong 2006). A weighted least squares linear regression in Program R (R Core Team 2024) was then applied to the 2003–2025 density estimates, with estimate weights set to 1/SE².

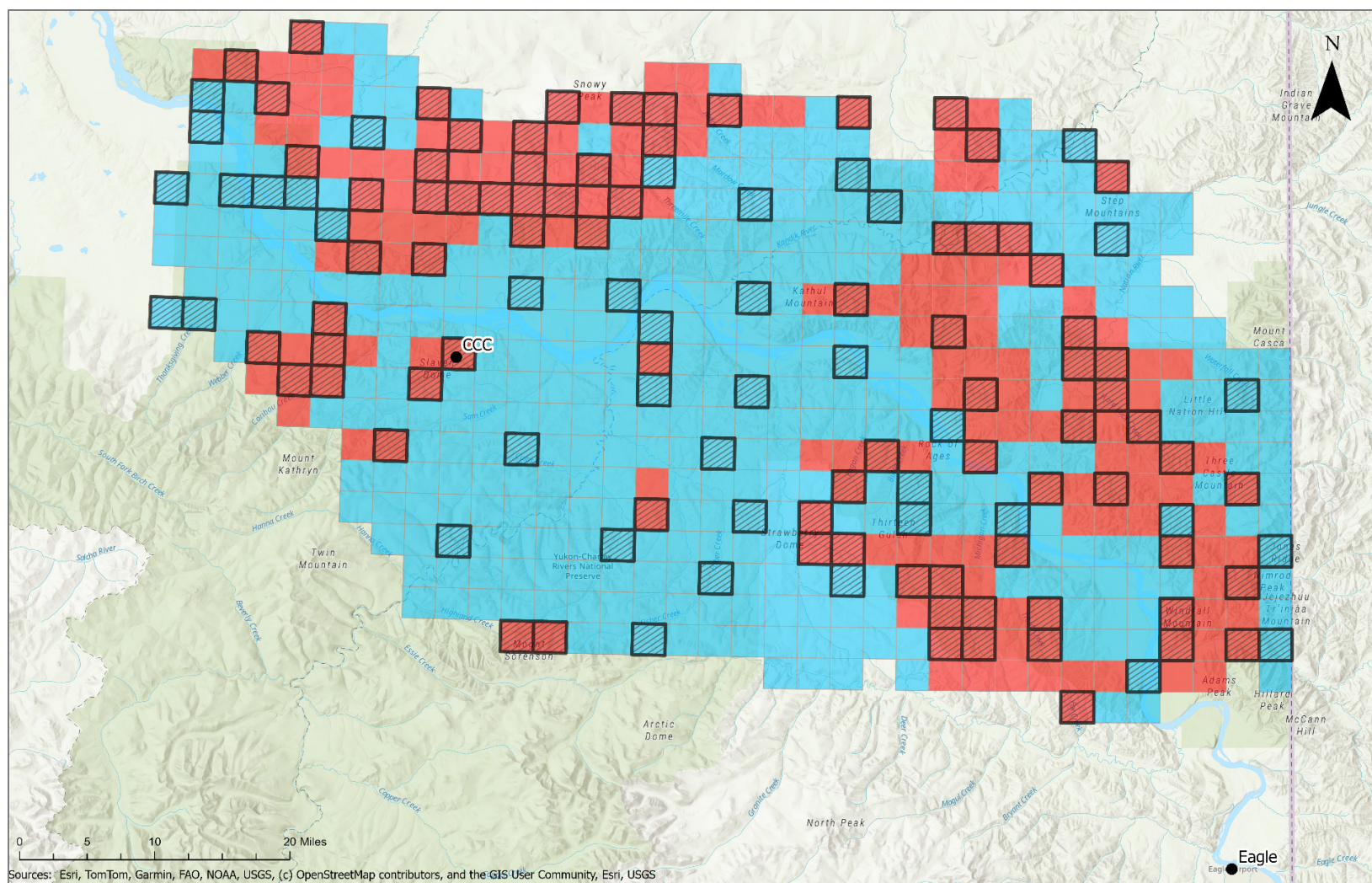


Figure 3. Map of stratification used during the fall moose survey in Yukon-Charley Rivers National Preserve, November 2025. High units are colored red, low units are colored blue, selected units have a black outline with diagonal hatching, and “CCC” indicates Coal Creek Camp.

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Results

Weather and Snow Conditions

The Coal Creek weather station recorded approximately 6" of snow depth at the beginning of the survey and 13" by the end, with temperatures ranging from a low of -18°F to a high of 26°F (WX Weather Module 2025). Temperatures during active survey periods were generally mild, with an average flight-level air temperature of 21°F . The Yukon River was partially frozen-over during the survey, with the consolidated ice initially beginning near the western edge of the study area and building upstream throughout the survey. Snow cover throughout the study area was complete with some vegetation showing, however snow/frost coverage on trees was dependent on elevation and aspect, with some areas having complete coverage and others with no snow on trees. Lighting conditions were variable, with slightly more flat-light days than bright. High wind speeds throughout the survey period made surveying the units north of Eagle particularly challenging, which combined with a few other minor logistical issues resulted in us missing our target survey unit number.

Survey Details

The survey was conducted between 17–29 November, completing 102 of 555 survey units which covered 18% of the survey area (Table 1). Most units (91) were completed between the 17th and 20th, and then we paused until the 25th due to an incoming snowstorm. Observers felt sightability was comparable between pre-storm and post-storm units due to wind-scouring of the fresh snow in steep terrain. Sixty-six (35%) of the high-density units and 36 (10%) of the low-density units were surveyed (Table 1). A total of 60.2 hours of flight time was spent searching for moose for an average of 35.4 minutes per survey unit. Search intensity averaged 6.4 minutes per mi^2 (2.5 minutes/ km^2), slightly higher than the long-term average of 6.0 minutes per mi^2 (Table 2). Fourteen high strata units and 4 low units were not completed, primarily due to high winds north of Eagle.

Aviation and project costs for the 2025 YUCH fall moose survey are found in Appendix B. Complete survey results for the entire 2025 survey are archived in, and can be retrieved from, the ADFG WINFONET database under the survey name “YUKON-CHARLEY, Fall, 2025” (<http://winfonet.alaska.gov/>; accessed 09 December 2025).

Table 1. Summary of stratification and sampled units from GSPE moose population surveys in Yukon-Charley Rivers National Preserve, 2003 to 2025. Areas are presented as square miles and number of survey units are in parentheses.

Survey Year	Survey Area	Sample Area	% Sampled	Stratification		Survey	
				High	Low	High	Low
2003	3157 (566)	591 (106)	18.7	1049 (188)	2108 (378)	340 (61)	251 (45)
2006	3096 (555)	841 (151)	27.2	899 (161)	2197 (394)	540 (97)	301 (54)
2009	3096 (555)	618 (111)	20.0	899 (161)	2197 (394)	329 (59)	289 (52)
2012	3096 (555)	664 (119)	21.4	899 (161)	2197 (394)	362 (65)	301 (54)
2015	3096 (555)	714 (128)	23.0	949 (170)	2147 (385)	458 (82)	256 (46)
2019	3096 (555)	670 (120)	21.6	1127 (202)	1969 (353)	447 (80)	223 (40)
2022	3096 (555)	614 (110)	19.8	1160 (208)	1936 (347)	419 (75)	195 (35)
2025	3096 (555)	568 (102)	18.3	1048 (188)	2048 (367)	367 (66)	201 (36)

Table 2. Summary of GSPE survey statistics and density estimates for moose population surveys in Yukon-Charley Rivers National Preserve, 2003 to 2025. Averages in bottom row include all surveys presented.

Survey Year	Method	Survey Area mi ² (# units)	Sampled Area mi ² (# units)	Search Intensity (min/mi ²)	Population Estimate	Relative Precision	Density (moose/mi ²)
2003	GSPE	3157 (566)	591 (106)	6.6	696	0.24	0.22
2006	GSPE	3096 (555)	841 (151)	5.4	605	0.19	0.20
2009	GSPE	3096 (555)	618 (111)	6.7	1109	0.19	0.36
2012	GSPE	3096 (555)	664 (119)	6.0	780	0.21	0.25
2015	GSPE	3096 (555)	714 (128)	5.0	1138	0.18	0.37
2019	GSPE	3096 (555)	670 (120)	5.7	873	0.16	0.28
2022	GSPE	3096 (555)	614 (110)	5.9	738	0.26	0.24
2025	GSPE	3096 (555)	568 (102)	6.4	729	0.19	0.24
Average	–	–	660 (118)	6.0	834	0.20	0.27

Population Estimate

The GSPE population estimate for observable moose in YUCH was 729 moose (90% confidence interval [CI] = 587–872 [19% relative precision]) which yielded a density of 0.24 moose/mi² (0.09 moose/km²; Figure 4; Table 2). A weighted least squares linear regression of the estimated density from 2003–2025 showed no significant population change ($p = 0.55$).

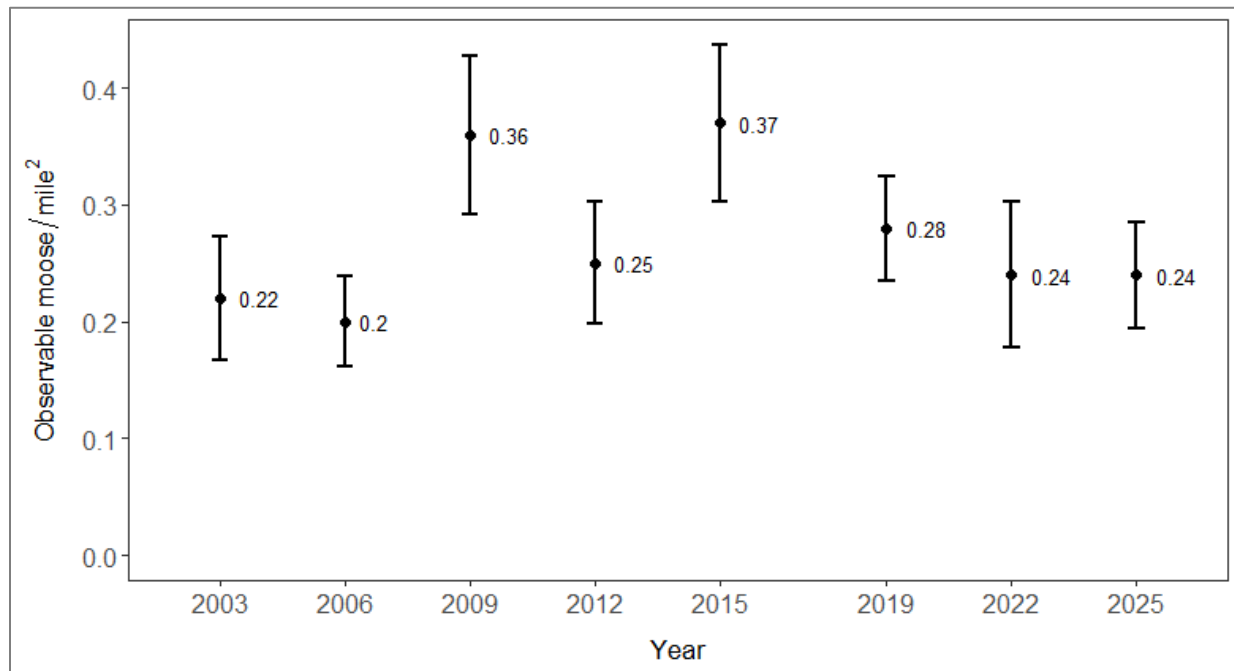


Figure 4. Moose densities (moose/mi²) with 90% confidence intervals for Yukon-Charley Rivers National Preserve from GSPE surveys from 2003–2025, Alaska.

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Sex and Age Composition

The sex and age composition of the 216 observed moose was as follows: 113 cows, 71 bulls, and 32 calves (Table 3). Composition of the observed bulls included 4 yearling bulls (spiked or forked antlers), 30 medium bulls, and 37 large bulls. The estimated sex and age ratios of the population were 34 calves:100 cows (90% CI = 22–45), 6 yearling bulls (spike/fork):100 cows (90% CI = 3–10), and 57 bulls:100 cows (90% CI = 40–73; Table 3). Two sets of twins were observed in the survey (Table 3).

Table 3. Summary of observed moose during the surveys in Yukon-Charley Rivers National Preserve, 2003 to 2025. Sex and age ratios were calculated in WinfoNet for GSPE surveys and 90% confidence intervals for these are reported in parentheses. Averages in bottom row include all surveys presented.

Survey Year	Area (mi ²)	Total Bulls	Total Cows	Total Calves	Total Moose	Bulls/100 Cows	Yearling Bulls/ 100 Cows	Calves/ 100 Cows	% Bulls	% Cows	% Calves	Sets of Twins
2003	591	55	87	17	159	60 (38–82)	6 (2–11)	25 (13–37)	35	55	11	1
2006	841	63	89	28	180	73 (53–94)	7 (2–11)	33 (21–46)	35	49	16	5
2009	618	102	164	42	308	60 (40–79)	13 (8–18)	27 (17–37)	33	53	14	4
2012	664	80	118	25	223	68 (46–89)	11 (5–17)	24 (15–33)	36	53	11	0
2015	718	105	165	44	314	72 (50–94)	4 (2–6)	25 (17–32)	33	53	14	4
2019	670	70	142	37	249	49 (34–65)	2 (0–3)	28 (19–36)	28	57	15	1
2022	648	61	101	21	183	60 (35–85)	7 (3–11)	19 (12–26)	33	55	12	2
2025	568	71	113	32	216	57 (40–73)	6 (3–10)	34 (22–45)	33	52	15	2
Average	660	76	122	31	229	62	7	27	33	53	13	2

Discussion

The results of the 2025 YUCH moose survey were similar to the long-term averages for GSPE surveys in the preserve, with regards to both moose density and sex/age ratios (Table 2 and Table 3). The estimated density of 0.24 moose/mi² was the same as the 2022 survey. This density is 11% below the long-term 2003–2022 average of 0.27 moose/mi², but regression analysis showed no significant trend across the 2003–2025 monitoring period. These numbers are indicative of a relatively stable but low-density population. For comparison, adjacent moose populations occur at densities averaging 0.28 (1999–2023), 0.49 (2000–2022), and 1.14 (2014–2023) moose/mi² in the Yukon Flats National Wildlife Refuge, Tetlin National Wildlife Refuge, and the Taylor Corridor Survey Area in the southern portion of GMU 20E, respectively (Carmello and Jamison 2023; Hunter 2024; Lake and Guldager 2023). The calf to cow ratio was the highest recorded to date, with 34 calves:100 cows (90% CI = 22–45), which is 31% higher than the 2003–2022 average of 26 calves:100 cows (Table 3). This higher recruitment suggests the potential for a moderate population increase in the near-term future. The bull to cow ratio (57 bulls:100 cows (90% CI = 40–73) is consistent with the long-term 2003–2022 average of 63 bulls:100 cows (Table 3) and is high relative to some other hunted areas. For example, GMUs 20B and 20A tend to have ratios of less than 40 bulls:100 cows (Hollis and Wells 2024; Wells 2025).

Preferred moose forage and snow depth have the potential to influence moose population dynamics (McRoberts et al. 1995; Seaton et al. 2011). Here, we describe general patterns of these factors observed in Yukon-Charley to help understand the patterns of moose population dynamics estimated from the survey results. Trends in high quality moose habitat (namely wildfire) have been documented to influence the moose population of this area (Schmidt et al. 2022). The percentage of survey area that is considered prime moose habitat (in the 11–30 years since-last-burn successional stage; Maier et al. 2005) has been relatively stable over the last 6 years (27–28%, Appendix C). This is substantially higher than the 2000s (~4% of the survey area was in the 11–30 year post-burn stage in 2003–2009). This suggests potential food resources remain relatively high within the preserve. Severe winters conditions, such as deep snow, have the potential to affect moose population dynamics (McRoberts et al. 1995). Since the 2022 survey, Yukon-Charley experienced 1 winter with deeper-than-normal snowpack followed by two winters with shallower-than-normal snowpack (Appendix C). Average daily low temperature was normal or warmer than average over the past 3 years (Appendix C). The more favorable winter conditions experienced over the last two winters could have contributed to the higher-than-normal calf recruitment this year.

The 90% confidence interval for the total moose estimate ($\pm 19\%$ of the mean) met our goal of 20% or better of the mean relative precision (Sorum et al. 2018). This contrasts with the 2022 survey, which had a poor relative precision of $\pm 26\%$ (note that the greater the $\pm$ percentage is, the lower the relative precision is). In 2022, the poor relative precision was attributed to a high proportion of zero-moose units in the high strata (50%). The authors of that report recommended critically reviewing the survey stratification to improve future estimates (Sorum et al. 2023). The desktop stratification for this survey changed 59 units from high to low and 39 units from low to high. During this survey the

number of high units with 0 moose was reduced by half from 51% to 24%, while the number of low units with 0 moose increased from 65% to 72%. These improvements, likely attributable to the updated desktop stratification, helped improve the relative precision of the estimate by 7% despite 8 fewer units being sampled.

Our survey results reflect a continued trend of a relatively low-but-stable population density and high bull-to-cow ratio. This suggests that moose in YUCH remain at our management objective of natural and healthy levels. We recommend a continued conservative management of harvest to ensure that population stability continues and is able to absorb natural stochastic environmental fluctuations despite a baseline low density.

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Appendix A. Pre-GSPE Survey Details

Tables 4 and 5 show summaries of moose population monitoring in YUCH done before 2000.

Table 4. Summary of area and results during early moose population surveys in Yukon-Charley Rivers National Preserve, 1987 to 1999. Methodology followed variations of those described in Gasaway et al. (1986). Areas are presented as square miles and number of survey units are in parentheses. Results presented here because they are not directly comparable to the GSPE.

Survey Year	Method	Survey Area	Sample Area	% Sampled	Search Intensity (min/mi²)	Population Estimate	Relative Precision	Density (moose/mi²)	Sightability Correction Factor
1987	Gasaway	3556	240	6.7	4.4	1116	–	0.31	–
1994	Gasaway	2790	1844	66.1	1.0	551	0.23	0.20	1.34
1997	Stratified Random	2758 (201)	1358 (98)	49.2	3.9	602	0.20	0.22	1.22
1999	Stratified Random	2745 (200)	1389 (100)	50.6	4.0	830	0.19	0.30	1.18

Table 5. Summary of observed moose during early surveys in Yukon-Charley Rivers National Preserve, 1987 to 1999. Results presented here because they are not directly comparable to the GSPE.

Survey Year	Area (mi²)	Total Bulls	Total Cows	Total Calves	Total Moose	Bulls/100 Cows	Yearling Bulls/ 100 Cows	Calves/100 Cows	% Bulls	% Cows	% Calves	Sets of Twins
1987	3556	88	73	7	169	121	14	10	52	43	4	0
1994	2790	147	176	37	364	84	7	21	40	48	10	1
1997	1358	136	197	51	384	60	8	28	35	51	13	3
1999	1389	169	266	77	513	51	5	36	33	52	15	6

Appendix B. Survey Logistics

Tables 6 and 7 show the aviation usage and overall costs associated with sampling moose at YUCH during the 2025 field season. Figure 5 shows the flight paths used.

Table 6. Aviation usage and cost during the 2025 fall moose survey.

Planes	Pilots	Description	Hours	Total
C-185	Nick Thompson	Shuttle	6	\$1,400
PA-18, Top Cub	Andy Greenblatt, Nick Thompson, Jessie Cummings, Leif Wilson, Jake Combs	Survey & Ferry	104	\$50,655
Total	N/A	N/A	110	\$52,055

Table 7. Overall project cost during 2025 fall moose survey.

Category	Description	Quantity	Cost/Unit	Total
Food	–	–	–	\$1,910
Fuel	CCC/Eagle 100LL	950 gal	\$12	\$11,400
	FAI Ferry 100LL	130 gal	\$7	\$910
Aviation	Detailed in Table 6	–	–	\$52,055
Total Costs	N/A	N/A	N/A	\$66,275

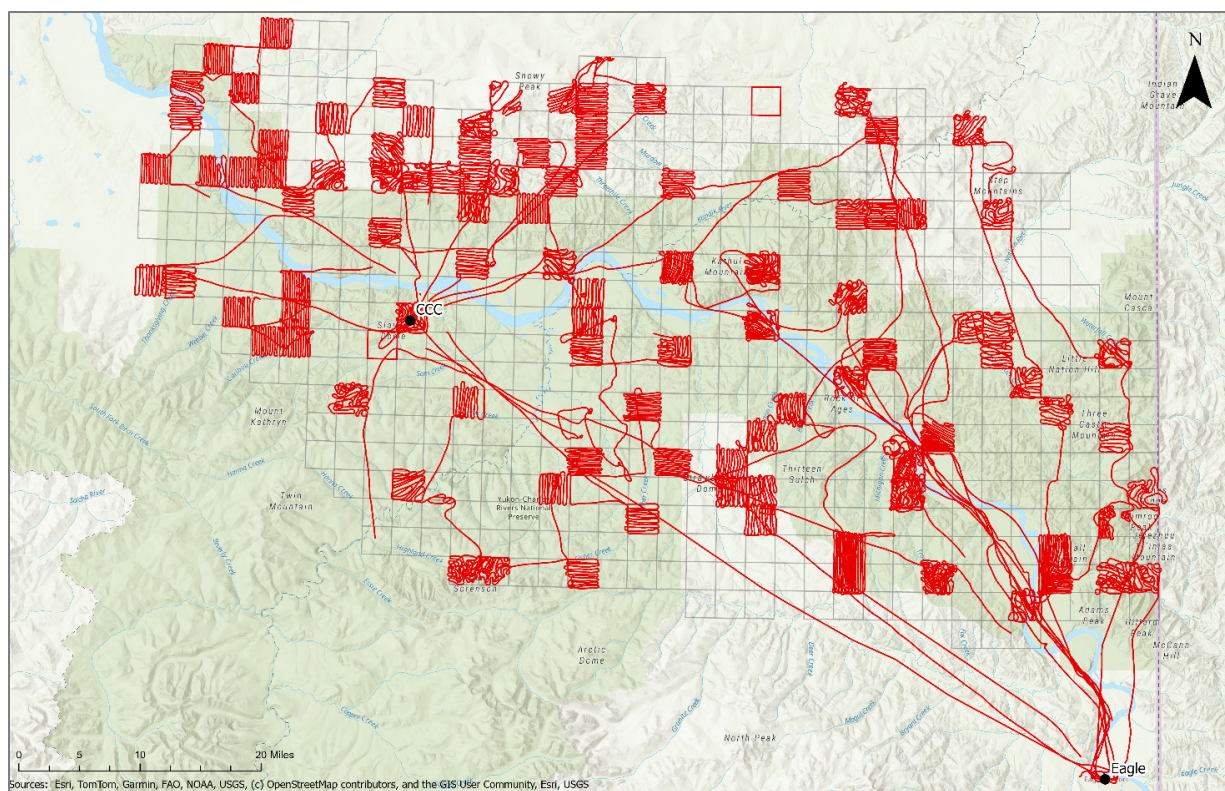


Figure 5. Flight paths of the five planes that conducted the 2025 moose survey. Note that flight tracklogs for units 39 and 295 are missing. Those units show an artificial track line border in this map to mark them as surveyed.

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Appendix C. Weather and Fire Data

Figures 6–8 show relevant fire history, snow depth, and daily temperature information observed since the early 2000s.

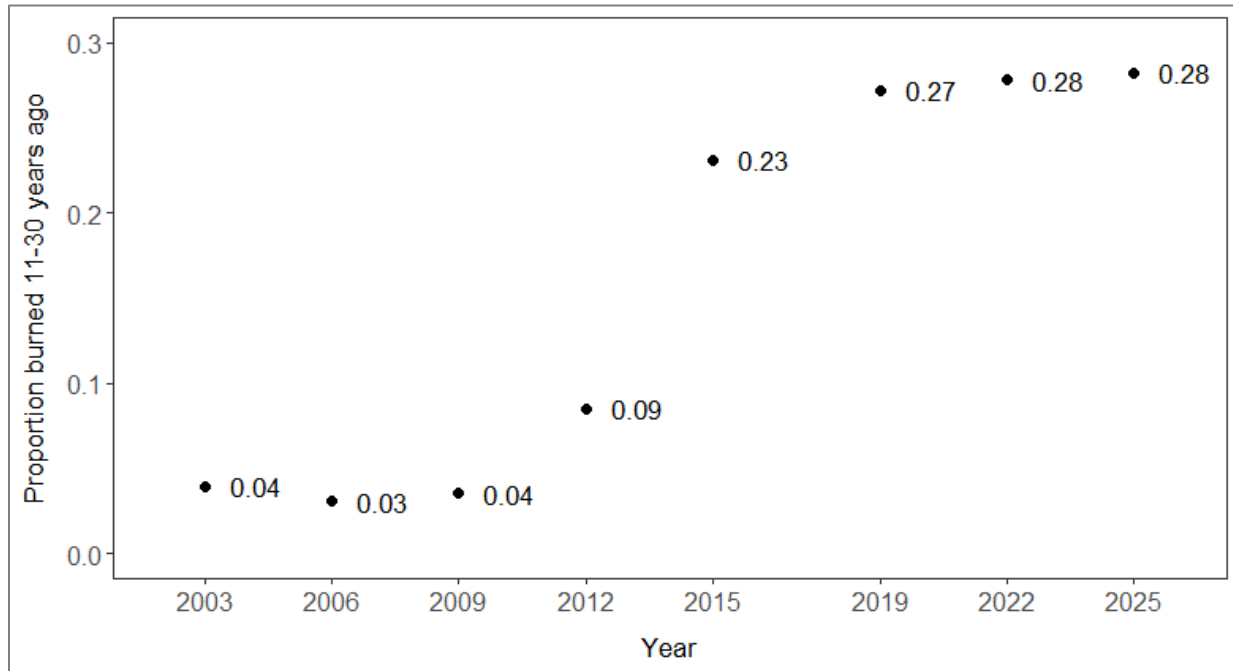


Figure 6. Proportion of the study area burned by fire 11–30 years ago. In areas of overlap, more recent burns take precedence over older burns. Based on data from AFS (2025).

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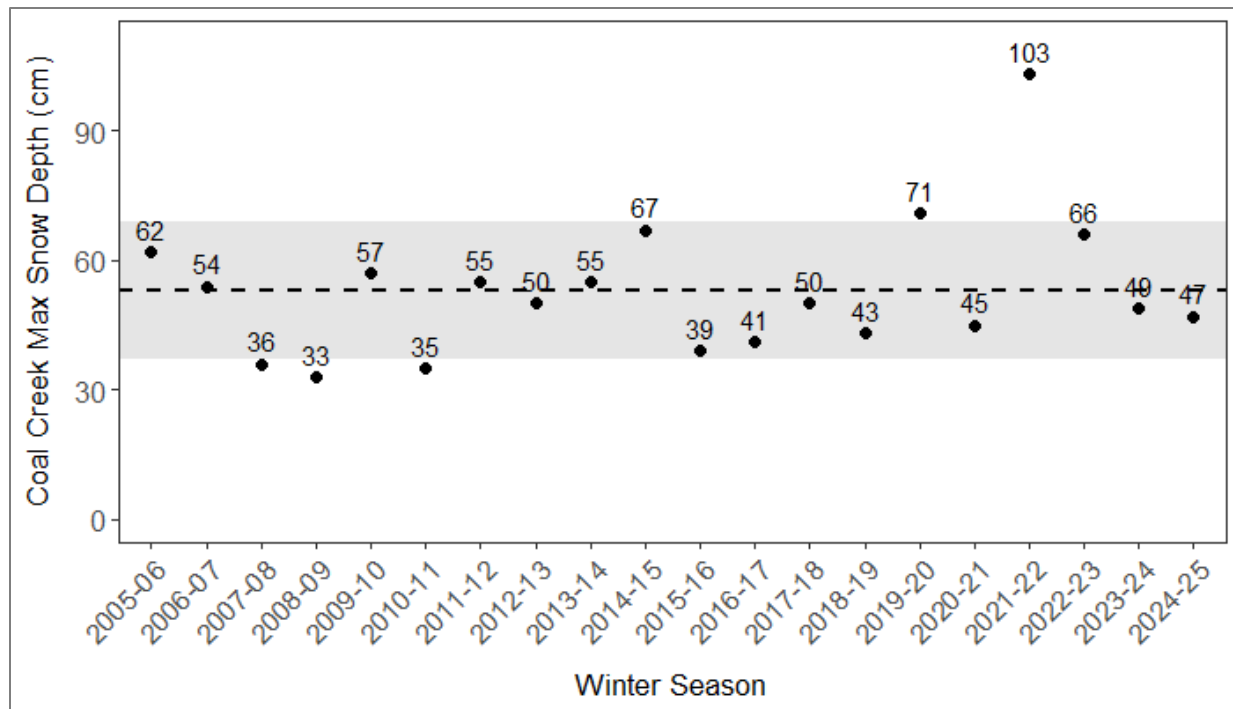


Figure 7. Max snow depth (cm) recorded at Coal Creek Camp for each winter season from the 2005–2006 season till the 2024–2025 season. The dashed line represents the mean maximum snow depth across winter seasons, and the shaded area represents ± 1 SD. Data from Sousanes et al. (2025).

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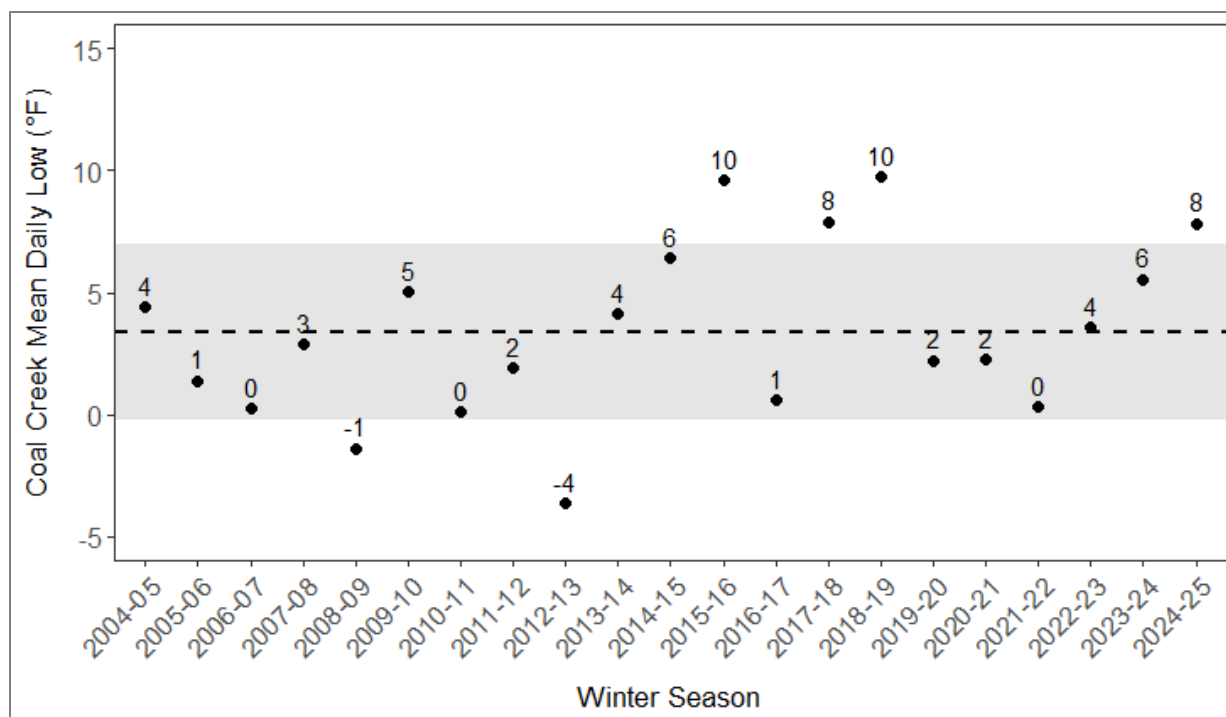


Figure 8. Mean daily low temperatures (°F) recorded at Coal Creek Camp for each winter season (October–April) from the 2005–2006 season till the 2024–2025 season. The horizontal dashed line represents the mean-of-means across all winter seasons, and the shaded area is ± 1 SD from that mean. Note that data prior to 2007 were limited by sensors that bottomed out at -40°F , which affected records from 15 days. Data from Sousanes et al. (2025).

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