# 2025 AERIAL MOOSE SURVEY

Amanda M. McGraw, MNDNR Forest Wildlife Research Group

## INTRODUCTION

Each year, we conduct an aerial survey in northeastern Minnesota to estimate moose (*Alces alces*) abundance and monitor and assess changes in the overall status of the state's largest deer species. The primary objective of this survey is to estimate moose abundance, percent calves, and calf:cow and bull:cow ratios. These demographic data help us to: 1) determine and understand the population's long-term trend (decreasing, stable, or increasing), sex-age composition, and spatial distribution; 2) set the harvest quota for the subsequent State hunting season (when applicable); 3) with research findings, improve our understanding of moose ecology; and 4) contribute to sound management strategies.

## METHODS

The survey area is approximately 5,945 $mi^2$ (~3.8 million acres; Lenarz 1998, Giudice et al. 2012) and includes the Boundary Waters Canoe Area Wilderness (Figure 1). We estimate moose numbers and age and sex ratios by flying transects within a stratified sample of plots randomly drawn from a sampling frame that covers most of the moose range in northeastern Minnesota (Figure 1). We used historic observations of moose, habitat information, and the extensive field experience of moose managers and researchers to stratify the sampling frame into low-, medium-, and high-density plots based on whether 0-2, 3–7, or 8 or more moose, respectively, would be expected (on average) to be observed in a specific plot. To keep the stratification current, we review the stratification scheme about every 5 years. We conducted the last stratification review in October 2018 and plan to conduct the next review later this year. Stratification helps to improve precision of the estimates (i.e., compared to a simple random sample). In 2012, we modified the stratification scheme by adding a 4th stratum (referred to as "long-term habitat plots") to better understand moose use of disturbed areas and evaluate the effect of forest disturbance on moose density over time. Initially, we selected 9 plots that have undergone or will undergo significant disturbance by wildfire, prescribed burning, or timber harvest. We survey the same habitat plots each year in order to better document temporal trends. In 2022, we added a 10th habitat plot (plot 208; part of the 2021 Greenwood Lake wildfire). In October 2024 a habitat plot (plot 403) was removed from the 2025 survey because a previously scheduled prescribed burn in that block is unlikely to take place in the foreseeable future. This resulted in 9 habitat plots surveyed in 2025, rather than the 10 habitat plots surveyed since 2022. Plot 403 will reenter the general plot pool for the 2026 survey. This year we surveyed 52 plots (43 randomly sampled and 9 habitat plots; see Figure 1).

The sampling frame (designed in 2005) contained 435 uniform rectangular plots (~5 mi x 2.7 mi; ~13.3 $mi^2$) oriented east to west (Figure 1). Sample plots were surveyed using helicopters (i.e., OH-58A until 2023, MD500E, and Bell-206B3 since 2024) flying 200-350 ft above-ground-level at 52-69 mph on east-west transects spaced ~0.3 mi apart, with search intensities that averaged 3.6 $min/mi^2$ (range: 1.9-5.6). Survey crews consisted of a MNDNR pilot and 2 observers (one seated behind the pilot). We determined the sex of moose using the presence of antlers or the presence of a vulva patch (Mitchell 1970), nose coloration, and bell size and shape. We identified calves by size and behavior. We used the program DNRSurvey on tablet-style computers (Toughbook®) to record survey data (Wright et al. 2015). DNRSurvey allowed

us to display transect lines superimposed on aerial photography, topographical maps, or other optional backgrounds to observe each aircraft's flight path over the selected background in real time, and to efficiently record data using a tablet pen with a menu-driven data-entry form. Two primary strengths of this aerial moose survey are the consistency and standardization of the methods since 2005, and the long-term consistency of field personnel.

We accounted for visibility bias using a sightability model (Giudice et al. 2012). The model was developed during 2004-2007 using adult moose that were radiocollared as part of a study of survival and its impact on dynamics of the population (Lenarz et al. 2009, 2010). Logistic regression indicated that "visual obstruction" (VO) was the most important covariate in determining whether radiocollared moose were observed. We estimated VO within a 30-ft radius (roughly 4 moose lengths) of observed moose. Estimated VO was the proportion of a circle where vegetation would prevent you from seeing a moose from an oblique angle when circling that spot in a helicopter. If we observed more than 1 moose (a group) at a location, VO was based on the first moose sighted.

Since 2004, we have used the SightabilityModel package (Fieberg 2012) in the R programming language (R Core Team 2023) to compute annual population estimates for NE Minnesota. These estimates are adjusted for both sightability and sampling. We also annually compute composition ratios that include calf:cow, calf:total (proportion calves), and bull:cow ratios. We use these ratios as indices of annual productivity and breeding viability (given a polygamous mating system). For historic comparability, we compute composition ratios using the combined ratio estimator (Cochran 1977:165), which accounts for the sampling design but not sightability.

**RESULTS AND DISCUSSION**

We surveyed 52 sample plots consisting of 15 low-, 18 medium-, and 10 high-density plots, and 9 habitat plots (Figure 1). The survey required 9 survey days between 14 Jan and 30 Jan to complete, which is the average number of days typically required to complete the survey (annual mean = 9.2 days; range: 8 to 12). We also started 6 days later than usual due to marginal snow conditions. Generally, 8" of snow cover is our minimum threshold depth for conducting the survey. Most survey plots in 2025 had snow depths $\geq 8$" (63.5%), and overall survey conditions were rated as good for 96% of the plots. Furthermore, survey intensity, aircraft speed and height, etc. were very similar to values observed in previous surveys (see Verheijen 2025).

Crews this year observed 339 moose (174 bulls, 121 cows, 35 calves, 9 unclassified adults) on 45 (86%) plots, with an average of 7.5 moose per "occupied" plot. For comparison, apparent occupancy (ignoring detectability) in the previous 20 years ranged from 65% to 95% (mean = 80%), and the mean moose count in occupied plots ranged from 6.4 to 18.5 (mean = 10.9). Crews observed an average of 3.6 moose groups per occupied plot (range: 1-12) in 2025 compared to an average of 5.4 groups/plot (range: 3.0-9.3) in the previous 20 years. The average group size in 2025 was 2.1 moose (range: 1-10) compared to a mean of 2.0 (range: 1.8-2.4) in the previous 20 years. Visual obstruction estimates in 2025 averaged 41% (range: 0 to 90), and the average estimated detection probability was 0.57 (range: 0.20 to 0.85). The latter is similar to mean values observed in previous years (range: 0.52 to 0.66; see Verheijen 2025).

After adjusting for sampling and sightability, the estimated moose population in northeastern Minnesota was 4,040 moose (90% CI: 3,130 to 5,390) (Table 1, Figure 2). Bulls, cows, and calves accounted for about 55.6%, 32.6%, and 11.8% of the estimated population total, respectively. Estimated overall bull density was 0.37 bulls/mi$^2$ (90% CI: 0.27 to 0.53). However, it varied by stratum: 0.21 bulls/mi$^2$ (90% CI: 0.12 to 0.49) in the low stratum, 0.49 bulls/mi$^2$ (90% CI: 0.35 to 0.73) in the medium stratum, 0.80 bulls/mi$^2$ (90% CI: 0.60 to 1.14) in the high

stratum, and 0.58 bulls/mi$^2$ (90% CI: 0.46 to 0.88) in the habitat-plot stratum. This year's estimated calf:cow ratio was 0.41 (90% CI: 0.29 to 0.52) and the bull:cow ratio was 1.57 (90% CI: 1.14 to 2.00). This year's calf:cow ratio is down from the high point estimate from 2024 but remains on the high end compared to the long-term average (Figure 3). However, there are moderate-to-high levels of sampling uncertainty associated with our ratio estimates. Thus, it is difficult to separate true annual change from sampling variation when comparing ratio estimates among years (Figure 3). The calf:total ratio (proportion calves) closely mirrors the calf:cow ratio but with slightly less annual variability (Figure 3). The bull:cow ratio increased by 18% compared to last year, but precision of the bull:cow ratio is relatively poor (Figure 4). Furthermore, there is a lot of sampling variation in the bull:cow time series that likely reflects annual variation in the classification process and, possibly, how bulls and cows are distributed in space. The calf:cow ratio is better in this regard.

Although we know from field studies that fertility (pregnancy rates) of the population's adult females has been robust (Lenarz et al. 2010; DelGiudice, unpublished data), overall, survey results suggest that calf survival remains relatively low. Calf survival during the January−April interval can decline markedly (Schrage et al., unpublished data), and annual spring recruitment of calves (survival to 1 year old) can have a significant influence on the population's performance and dynamics. Findings of a recent field study documented similar low calf survival (0.44−0.49) to early winter in 2015−16 and 2016−17 (Obermoller 2017, Severud 2017, Severud et al. 2019). Calf survival by spring 2017 (recruitment) had declined to just 0.33. However, it is also important to note that adult moose survival has the greatest long-term impact on annual changes in the moose population (Lenarz et al. 2010). Consistent with the recent relative stability of the population trend, the annual survival rate of adult GPS-collared moose changed little (85–88%) during 2014−2017 (Carstensen et al. 2017) but was slightly higher than the previous long-term (2002−2008) average of 81% (Lenarz et al. 2009).

This year's population estimate is up 16% from last year's point estimate (Table 1, Figure 2). However, sampling uncertainty is moderately high in this survey (see 90% CIs) and, thus, it is often difficult to make statistically confident statements about the magnitude of annual population changes unless those changes are relatively large. This level of uncertainty is common in wildlife surveys, even when surveying large, dark, relatively conspicuous animals (such as moose) against a white background during winter. This is attributable to the varied 1) occurrence of dense vegetation, 2) habitat use by moose, 3) behavioral responses to aircraft, 4) effects of annual environmental conditions (e.g., snow depth, ambient temperature) on their movements, and 5) interaction of these and other factors. Thus, the best use of survey results is for monitoring population trends over several years rather than focusing on the magnitude of differences in annual estimates, including composition ratios.

Based on aerial surveys and research results (e.g., Lenarz et al. 2009, 2010; Severud 2017; Carstensen et al. 2017; Severud et al. 2019, 2020, 2022), we can say with reasonable confidence the moose population in NE Minnesota declined steeply between 2009 and 2013 and has since more-or-less stabilized at around 3,700 moose (Figure 2). The term "stabilized" as used here does not mean the population is constant, but rather true annual changes appear to be reasonably small (on average) and random (some years are up, and some are down). Furthermore, we caution there might be a small underlying population trend (a true mean rate of change that is either positive or negative), but it would be difficult to detect over the short term given the limitations of our survey. Finally, we caution that current population trends do not predict future population trends because underlying demographic factors affecting population abundance can change over time.

## ACKNOWLEDGMENTS

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Table 1.  Estimated moose abundance, 90% confidence intervals, calf:cow ratios, percent calves in the population, percent cows with twins, and bull:cow ratios from aerial surveys in northeastern Minnesota, 2005–2025.  Note: the survey was not conducted in 2021 due to the Covid-19 pandemic.

| Year | Population estimate | 90% CI | Calf:Cow | % Calves | % Cows w/ twins | Bull:Cow |
|------|------|------|------|------|------|------|
| 2005 | 8,160 | 6,090 – 11,410 | 0.52 | 19 | 9 | 1.04 |
| 2006 | 8,840 | 6,790 – 11,910 | 0.34 | 13 | 5 | 1.09 |
| 2007 | 6,860 | 5,320 – 9,150 | 0.29 | 13 | 3 | 0.89 |
| 2008 | 7,890 | 6,080 – 10,600 | 0.36 | 16 | 2 | 0.77 |
| 2009 | 7,840 | 6,270 – 10,040 | 0.32 | 14 | 2 | 0.94 |
| 2010 | 5,700 | 4,540 – 7,350 | 0.28 | 13 | 3 | 0.83 |
| 2011 | 4,900 | 3,870 – 6,380 | 0.24 | 13 | 1 | 0.64 |
| 2012 | 4,230 | 3,250 – 5,710 | 0.36 | 15 | 6 | 1.08 |
| 2013 | 2,760 | 2,160 – 3,650 | 0.33 | 12 | 3 | 1.23 |
| 2014 | 4,350 | 3,220 – 6,210 | 0.44 | 17 | 3 | 1.24 |
| 2015 | 3,450 | 2,610 – 4,770 | 0.29 | 13 | 3 | 0.99 |
| 2016 | 4,020 | 3,230 – 5,180 | 0.42 | 17 | 5 | 1.03 |
| 2017 | 3,710 | 3,010 − 4,710 | 0.36 | 15 | 4 | 0.91 |
| 2018 | 3,030 | 2,320 – 4,140 | 0.37 | 15 | 4 | 1.25 |
| 2019 | 4,180 | 3,250 – 5,580 | 0.32 | 13 | 3 | 1.24 |
| 2020 | 3,150 | 2,400 – 4,320 | 0.36 | 18 | 2 | 0.90 |
| 2021 | - | - | - | - | - | - |
| 2022 | 4,700 | 3,440 – 6,780 | 0.45 | 19 | 3 | 0.94 |
| 2023 | 3,290 | 2,480 – 4,560 | 0.38 | 16 | 6 | 1.26 |
| 2024 | 3,470 | 2,570 – 4,940 | 0.51 | 17 | 6 | 1.33 |
| 2025 | 4,040 | 3,130 – 5,390 | 0.41 | 12 | 3 | 1.57 |
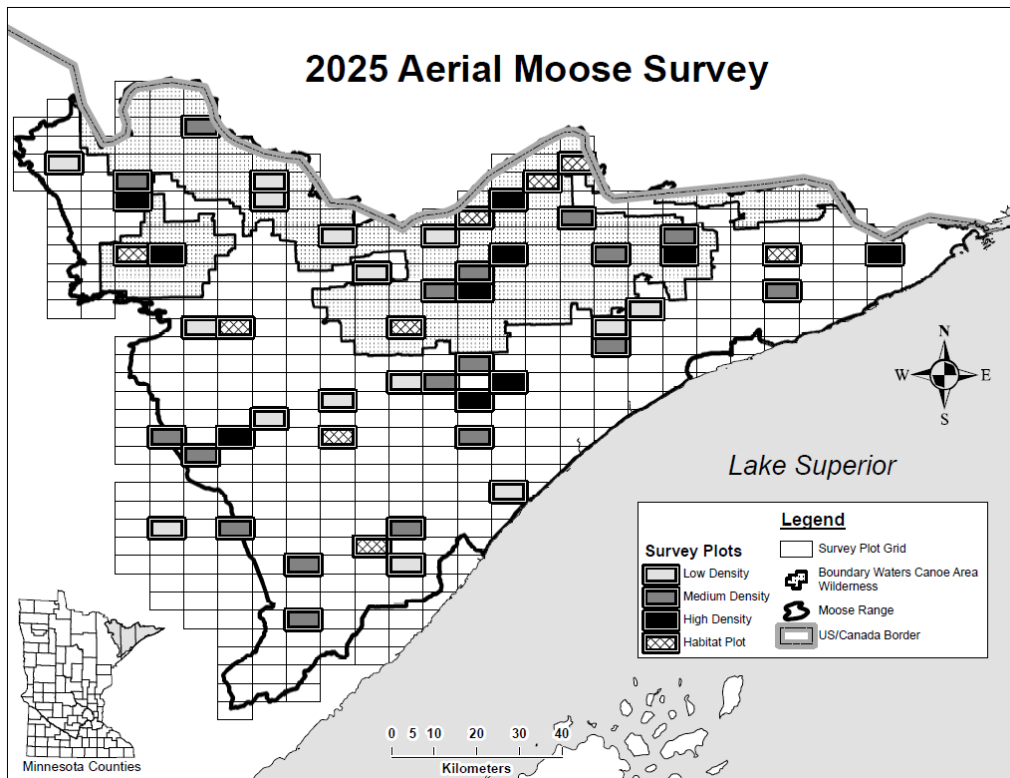
Figure 1.  Moose survey area, sampling frame, and the 52 sample plots flown in the 2025 aerial moose survey.
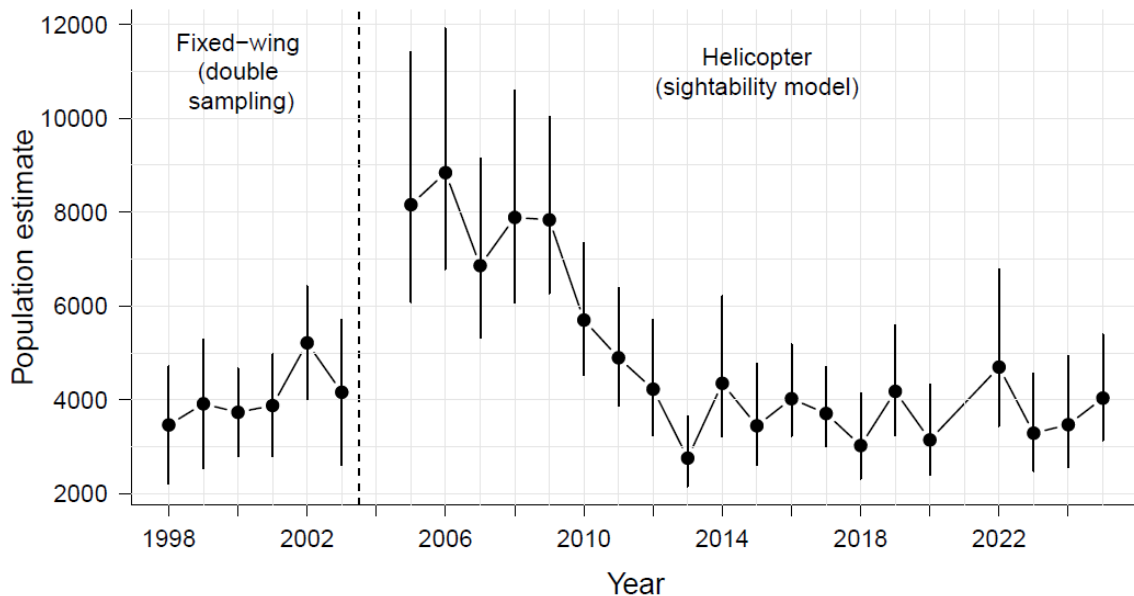


Figure 2.  Aerial-survey estimates (with 90% CIs) of moose abundance in NE Minnesota, 1998–2025. Note: the 1998-2003 survey period is not directly comparable to 2005-2025 estimates. It is shown here for documentation only. Additionally, the survey was not conducted in 2021 due to the Covid-19 pandemic.
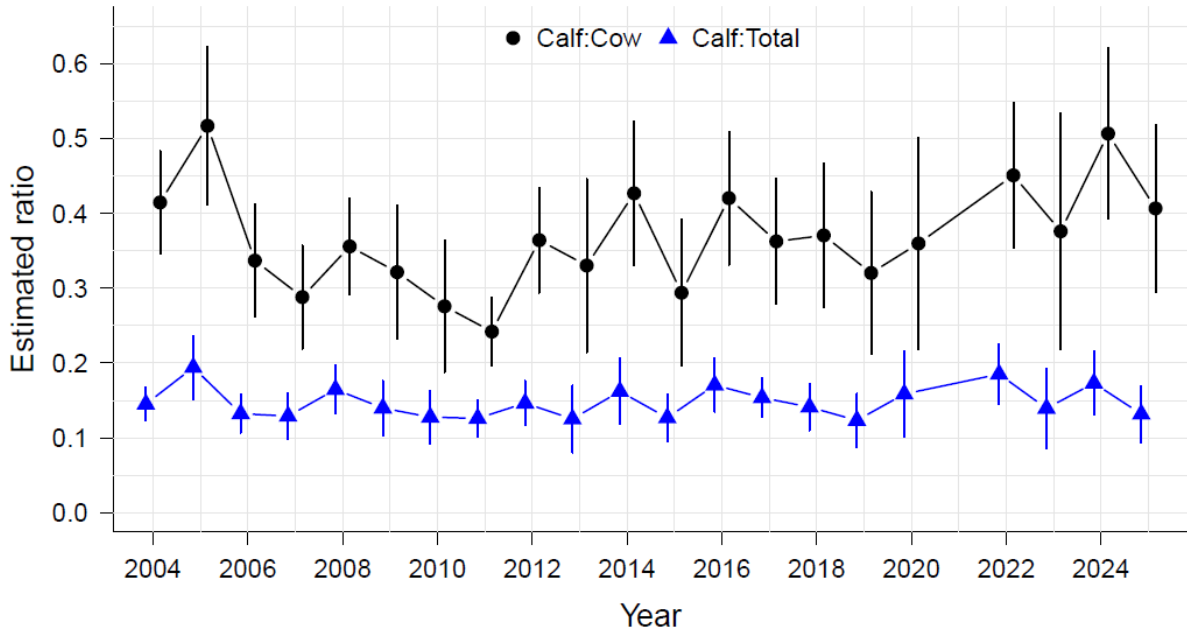
Figure 3. Estimated calf:cow ratios (black circles, with 90% CI) and proportion calves (blue triangles, with 90% CI) from aerial moose surveys in northeastern Minnesota, 2004–2025. Note: the survey was not conducted in 2021 due to the Covid-19 pandemic.
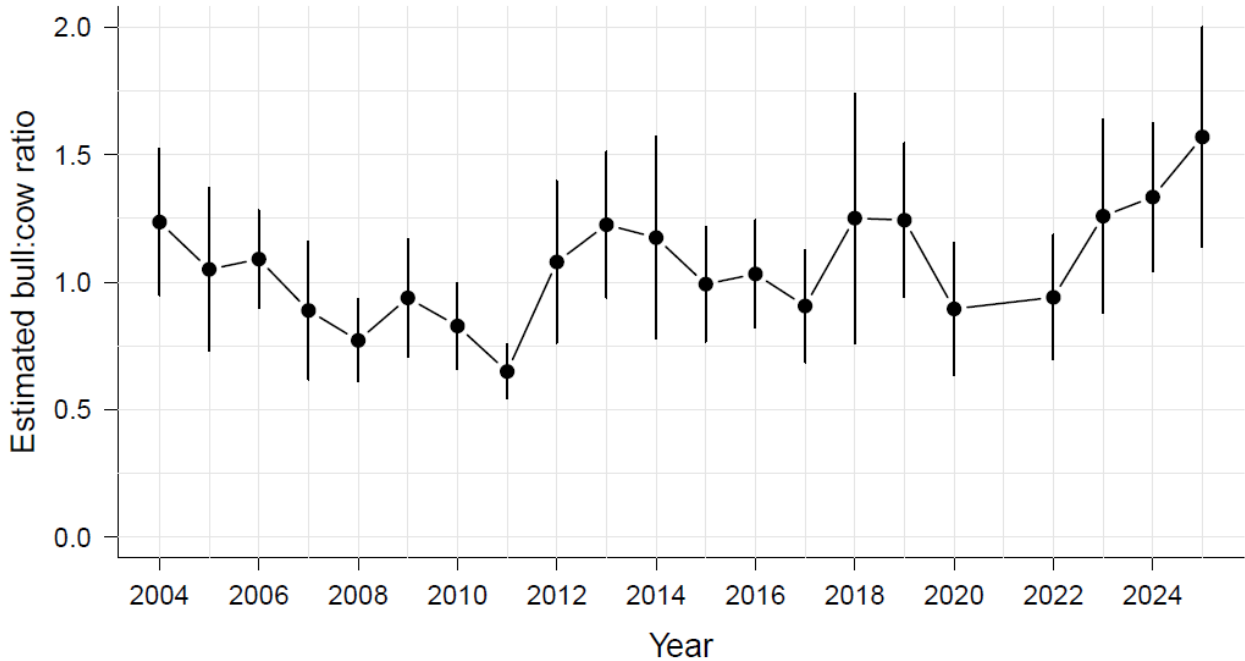


Figure 4. Estimated bull:cow ratios (with 90% CI) from aerial moose surveys in northeastern Minnesota, 2004–2025. Note: the survey was not conducted in 2021 due to the Covid-19 pandemic.