2018 Aerial Moose Survey

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Introduction

Each year we conduct an aerial survey in northeastern Minnesota to estimate the moose (*Alces americanus*) population and to monitor and assess changes in the overall status of the state's largest deer species. Specifically, the primary objectives of this annual survey are to estimate moose abundance, percent calves, and calf:cow and bull:cow ratios. These demographic data help us to 1) best determine and understand the population's long-term trend (decreasing, stable, or increasing), 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) otherwise contribute to sound future management strategies.

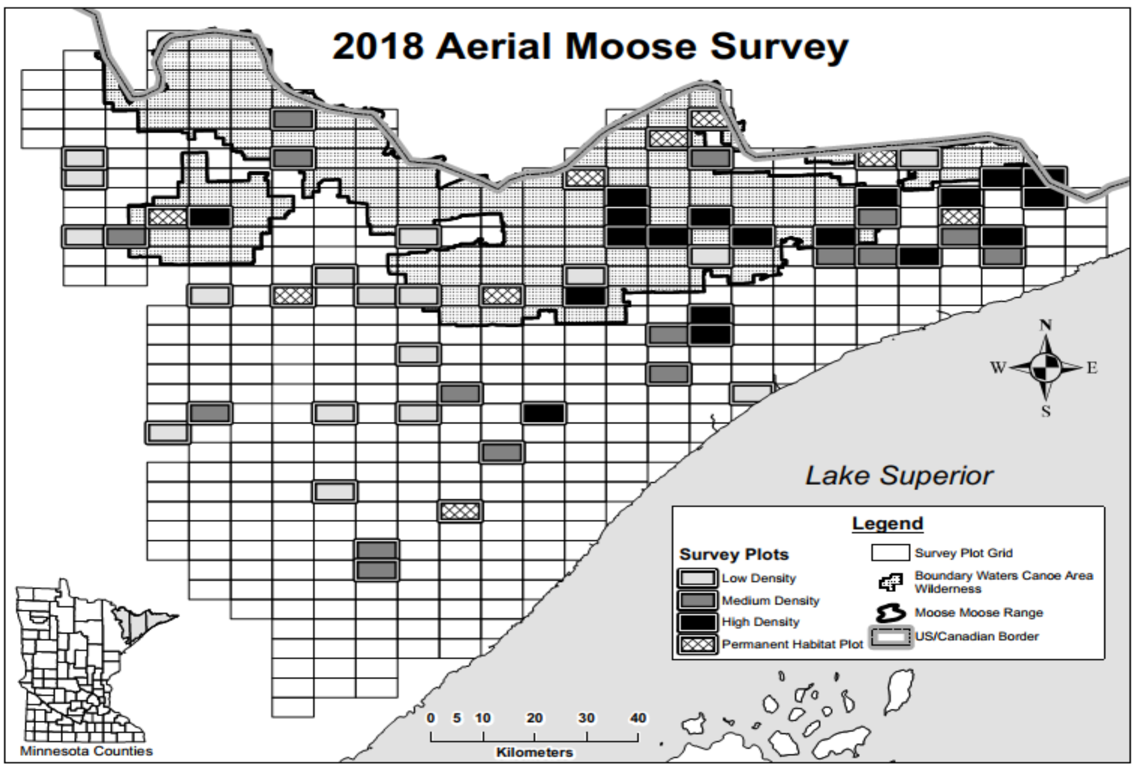
Methods

The survey area is approximately 5,985 mi^2 (almost 4 million acres, Lenarz 1998, Giudice et al. 2012). We estimate moose numbers and age and sex ratios by flying transects within a stratified random sample of the 436 total survey plots that cover the full extent of moose range in northeastern Minnesota (Figure 1). To keep the stratification current, all survey plots are reviewed and re-stratified as low, medium, or high moose density about every 5 years based on past survey observations of moose, locations of recently harvested moose, and extensive field experience of moose managers and researchers. Low, medium, or high density classes are based on whether ≤ 2, 3–7, or ≥8 moose, respectively, would be expected to be observed in a specific plot. The most recent re-stratification was conducted in November 2013 for the 2014 Survey, but additionally, individual plots are re-stratified after each annual survey as warranted by aerial observations. Stratification is most important to optimizing precision of our survey estimates. In 2012, we added a 4th stratum represented by a series of 9 plots (referred to as "habitat plots") which have already undergone, or will undergo, significant disturbance by wildfire, prescribed burning, or timber harvest. These same 9 plots are surveyed each year in an effort to better understand moose use of disturbed areas and evaluate the effect of forest disturbance on moose density over time. In total, we surveyed 52 (43 randomly sampled and the 9 habitat plots) of the 436 plots this year.

All 436 survey plots in the grid (designed in 2005) are 13.9-mi^2 rectangles (5 x 2.77 mi), oriented east to west, with 8 flight-transects evenly spaced 0.3 mi apart. Minnesota Department of Natural Resources (MNDNR) Enforcement pilots flew the 2 helicopters used to conduct the survey—1 Bell Jet Ranger (OH-58) and 1 MD500E. 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 the survey team's personnel, survey biometrician, and geographic information system (GIS) specialists.

We accounted for visibility bias using a sightability model (Giudice et al. 2012). This model was developed between 2004 and 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 the 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. We used uncorrected estimates (no sightability correction) of bulls, cows, and calves, adjusted for sampling, to calculate the bull:cow and calf:cow ratios at the population level (i.e., using the combined ratio estimator; Cochran 1977:165).

Figure 1. Moose survey area and 52 sample plots flown in the 2018 aerial moose survey.



Results and Discussion

The survey was conducted from 3 to 13 January 2018. It consisted of 9 actual survey days, and as in 2014, 2015, 2016, and 2017, it included a sample of 52 survey plots. This year, based on optimal allocation analyses, we surveyed 14 low-, 13 medium-, and 16 high-density plots, and the 9 permanent or habitat plots (Giudice 2018). Generally, 8" of snow cover is our minimum threshold depth for conducting the survey. Snow depths were 8–16" and >16" on 65% and 31% of the sample plots, respectively. Overall, survey conditions were rated as good for 98% and fair for 2% of the plots when surveyed. Average survey intensity was 48 minutes/plot (13.9 mi^2) and ranged from 40 to 60 minutes/plot (Giudice 2018).

This year a total of 415 moose were observed on 37 (71%) of the 52 plots surveyed (a total 723 mi^2), less than the 508 moose observed on 47 of 52 plots during the 2017 survey. An average of 11.2 moose (range = 1–31) were observed per "occupied" plot. Plot occupancy during the past 14 years averaged 82% (range = 65–95%) with a mean 11.8 moose observed per occupied plot. This year's 415 observed moose included 181 bulls, 170 cows, 63 calves, and 1 unclassified adult. Overall, estimated VO averaged 37% (range = 0−85%) and average estimated detection probability was 0.61 (range = 0.23−0.85); both were comparable to those of previous years.

After adjusting for sampling and sightability, we estimated the population in northeastern Minnesota at 3,030 (2,320–4,140, 90% confidence interval [CI]) moose (Table 1, Figure 2). As can be noted from the 90% confidence intervals associated with the population point estimates, statistical uncertainty inherent in aerial wildlife surveys can be quite large, 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. Consequently, year-to-year statistical comparisons of population estimates are *not* supported by these surveys. These data are best suited to establishing long-term trends; even short-term trends must be viewed cautiously.

Past aerial survey and research results have indicated that the long-term trend of the population in northeastern Minnesota has been declining since 2006 (Lenarz et al. 2010, DelGiudice 2017). The current population estimate is 65% less than the estimate in 2006 and the declining linear trend during the past decade remains statistically significant ($r^2 = 0.81$, $P < 0.001$, Figure 2). However, the leveling since 2012 persists, and a piecewise polynomial curve indicates that the trend from 2012 to 2018 is not declining (Figure 3). While this recent short-term trend (7-year) is noteworthy, it applies only to the existing survey estimates, and does not forecast the future trajectory of the population (Giudice 2018).

Table 1. Estimated moose abundance, 90% confidence intervals, calf:cow ratios, percent calves in the population, percent cows with twins, and bull:cow ratios estimated from aerial surveys in northeastern Minnesota, 2005–2018.

Survey	Estimate	90% Confidence Interval	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 – 9,100	0.29	13	3	0.89
2008	7,890	6,080 – 10,600	0.36	17	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	13	3	1.23
2014	4,350	3,220 – 6,210	0.44	15	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

The January 2018 calf:cow ratio of 0.37 is low but similar to the 13-year average since 2005 (0.35, Table 1, Figure 4). Calves were 15.1% of the total 415 moose actually observed and represented 15% of the estimated population (Table 1, Figure 4). Twin calves were observed with 6 of the 170 (4%) cow moose (Table 1). Although we know from recent field studies that fertility (pregnancy rates) of the population's adult females has been robust, overall, survey results indicate calf survival to January 2018 remains low, typical compared to most years since the population decline began following the 2006 survey (Table 1). 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 (0.442−0.485) to early winter in 2015−16 and 2016−17 (Obermoller 2017, Severud 2017). Calf survival by spring 2017 (recruitment) had declined to just 0.33. But 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 has changed little (85–88%) during 2014−2017 (Carstensen et al. 2017, unpublished data), but is slightly higher than the previous long-term (2002−2008) average of 81% (Lenarz et al. 2009).

The January 2018 estimated bull:cow ratio (1.25, Table 1; Figure 5) appears to be elevated compared to the long-term mean of 0.98 during 2005–2017, and compared to the mean ratio (0.87) of 2009−2012, when the population decline was steepest. Estimated bull:cow ratios have been this high previously (2013 and 2014) during the recent interval of apparent stability; however, due to the notable annual variability associated with the bull:cow ratios, there is no apparent upward or downward long-term trend (Figure 5).

Figure 2. Point estimates, 90% confidence intervals, and a linear trend line of estimated moose abundance in northeastern Minnesota, 2005–2018. (Note: The 2005 survey was the first to be flown with helicopters, and to include a sightability model and a uniform grid of east-west oriented rectangular 13.9-mi^2 plots).

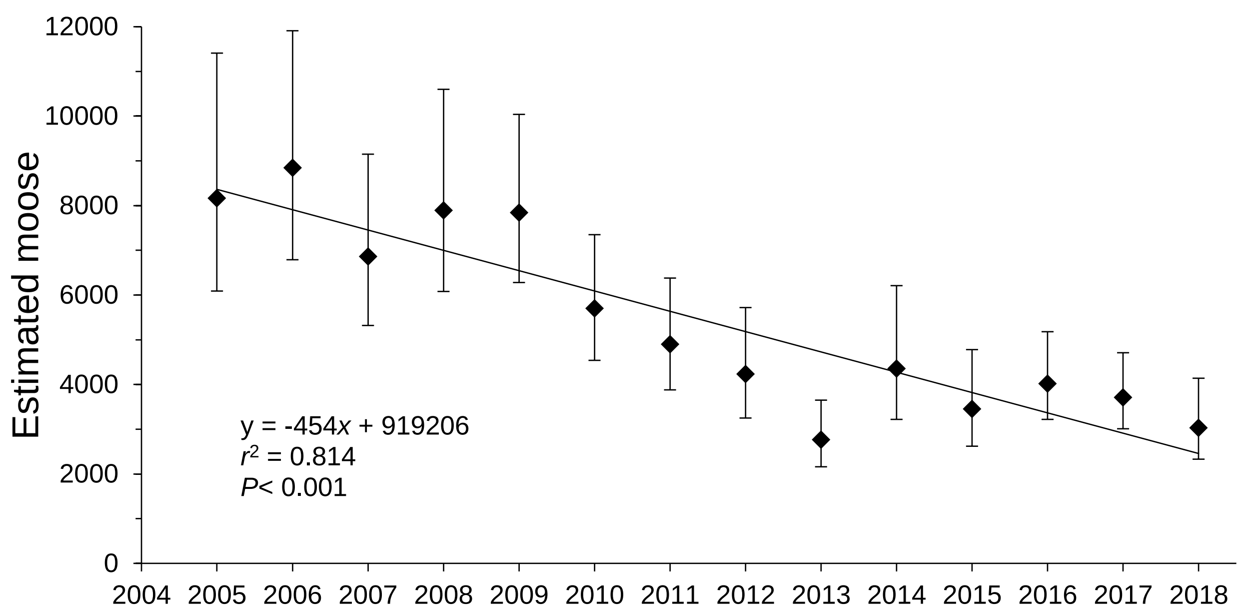


Figure 3. Point estimates, 90% confidence intervals, and a piecewise polynomial curve of moose abundance in northeastern Minnesota, 2005–2018. This curve shows a change in the short-term slope of the trend from 2012 to 2018 compared to 2009 to 2012.

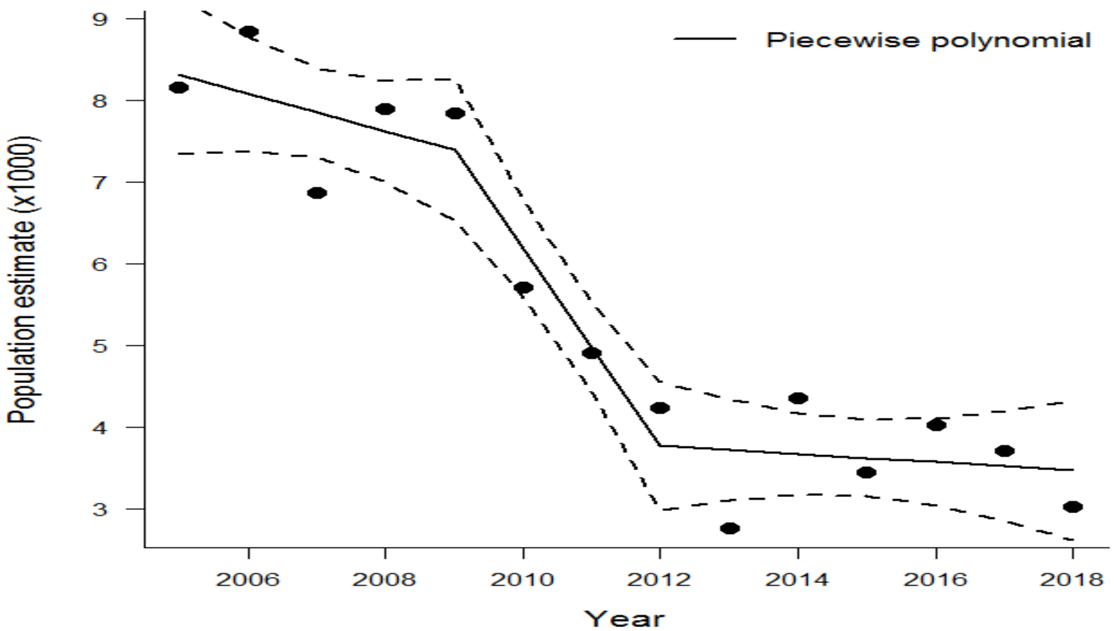


Figure 4. Estimated calf:cow ratios (solid diamonds, dashed trend line) and percent calves (open squares, solid trend line) of the population from aerial moose surveys in northeastern Minnesota, 2005–2018.

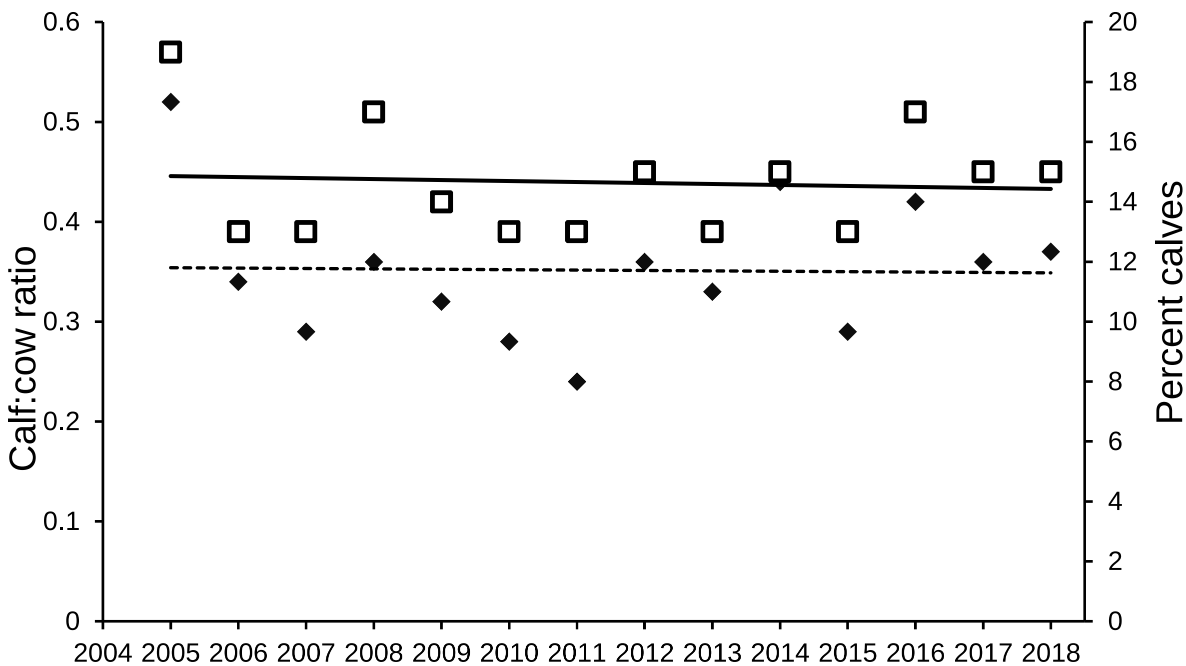
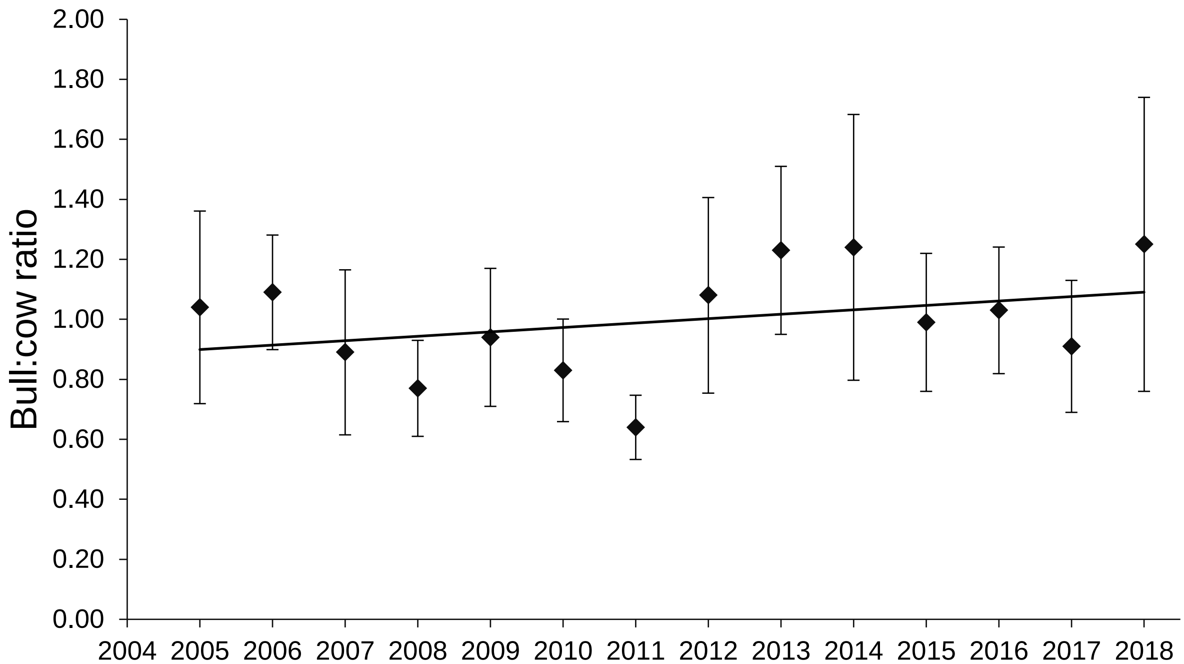


Figure 5. Estimated bull:cow ratios, 90% confidence intervals, and trend line from aerial moose surveys in northeastern Minnesota, 2005–2018.



Acknowledgments

This survey is an excellent partnership between the Divisions of Enforcement and of Fish and Wildlife, the Fond du Lac Band of Lake Superior Chippewa, and the 1854 Treaty Authority. Specifically, thank you to Thomas Buker, Chief Pilot, for coordinating all of the aircraft and pilots; Tom Rusch for coordinating flights, survey crews, and other important parts of this effort; and Mike Schrage (Fond du Lac Band of Lake Superior Chippewa) and Andy Edwards (1854 Treaty Authority) for securing supplemental survey funding from their respective groups. Enforcement pilots, Brad Maas and John Heineman, and Luke Ettl (MIFC) skillfully piloted the aircraft during the surveys; Tom Rusch, Andy Edwards, Mike Schrage, and Nancy Hansen flew as our seasoned observers. Thank you to John Giudice who continues to provide critical statistical consultation and analyses, and to Barry Sampson for creating the process to generate the GIS survey maps and GPS coordinates for the transect lines, and for his work on re-stratification of the survey plots. We gratefully acknowledge Bob Wright, Brian Haroldson, and Chris Pouliot for creating the program, DNRSurvey. Bob also modifies the software as needed, updates specific maps, and provided refresher training for survey observers using DNRSurvey. The efforts of all of these people contribute to survey improvements, ensure the survey's rigor and the comparability of long-term results. This report has been reviewed by Paul Telander, Lou Cornicelli, Mike Larson, John Giudice, Mike Schrage, and Andy Edwards.

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