2016 Aerial Moose Survey

Glenn D. DelGiudice, Forest Wildlife Populations and Research Group

Introduction

Each year, we conduct an aerial survey in northeastern Minnesota to monitor moose (*Alces americanus*) numbers and fluctuations in the overall status of the state's largest deer species. The primary objectives of this annual survey are to estimate moose numbers, 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) and composition, 2) set the harvest quota for the subsequent hunting season (when applicable), 3) improve our understanding of moose ecology, and 4) otherwise contribute to sound future management strategies.

Methods

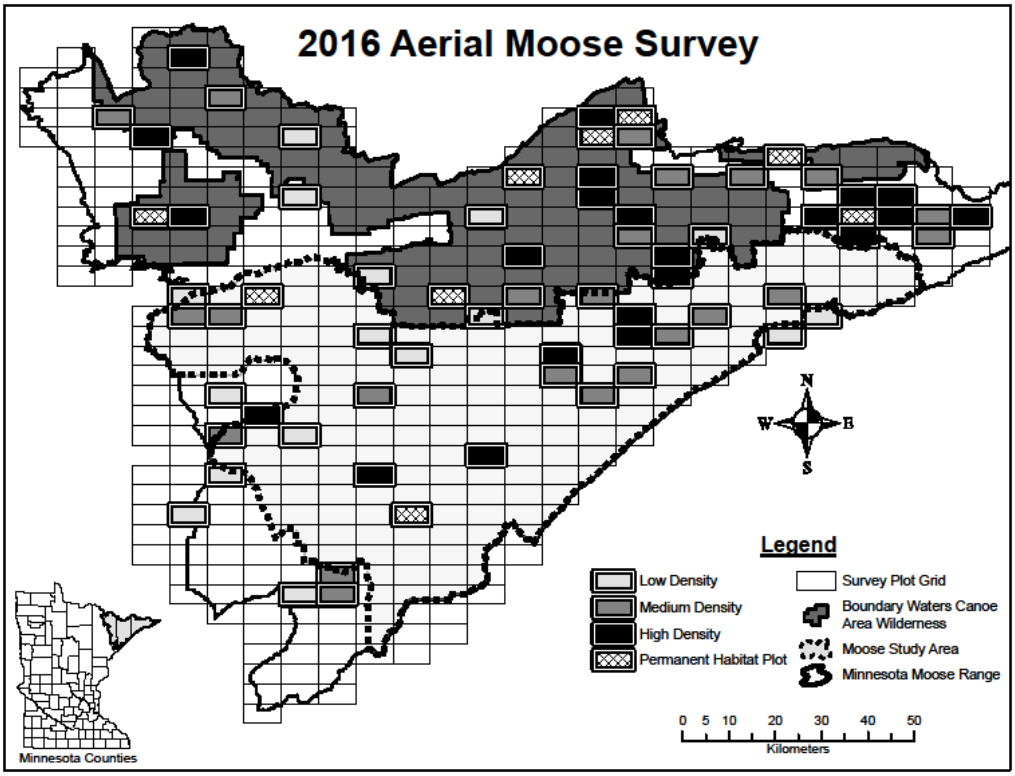
The survey area is approximately 5,985 mi^2 (almost 4 million acres, Lenarz 1998, Giudice et al. 2012). We estimate moose numbers, and age and sex ratios by flying transects within a stratified random sample of the 436 total survey plots that cover the full extent of moose range in northeastern Minnesota (Figure 1). 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. The most recent re-stratification was conducted in November 2013 for the 2014 Survey. Survey plots were classified as low, medium, or high based on whether ≤ 2, 3–7, or ≥8 moose, respectively, would be expected to occur in a specific plot. 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. Each year since, these same 9 plots are surveyed in an effort to evaluate the effect of disturbance on moose density over time. In total, we surveyed 52 of the 436 plots this year.

All 436 survey plots in the grid (designed in 2005) are 13.4-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 and Forestry pilots flew the 2 Bell Jet Ranger (OH-58) helicopters used to conduct the survey. We determined the sex of moose using the presence of antlers or the presence of a vulval patch (Mitchell 1970), nose coloration, and bell size and shape. We identified calves on the basis of 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 this background in *real time*, and to efficiently record data using a tablet pen with a menu-driven data entry form. Two of the 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 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 the covariate "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. VO was the proportion of

vegetation that 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 visibility bias correction) of bulls, cows, and calves, adjusted for sampling, to calculate the bull:cow and calf:cow ratios (i.e., using the combined ratio estimator; Cochran 1977:165).

Figure 1. Moose survey area and 52 sample plots flown in the 2016 aerial moose survey. The study area for ongoing MNDNR moose research also is shown.



Results and Discussion

The survey was conducted from 4 to 15 January 2016. It consisted of 9 actual survey days, and as in 2014 and 2015, it included a sample of 52 survey plots. This year, based on optimal allocation analyses, we surveyed 10 low-, 17 medium-, and 16 high-density plots, and the 9 permanent or habitat plots (Giudice 2016). Generally, 8" of snow cover is our minimum threshold depth for conducting the survey. Snow depths were marginal (less than 8") on 10% of the survey plots, but 8–16" and >16" on 62% and 29% of the sample plots, respectively. Overall, survey conditions were good for 79% and fair for 21% of the plots when surveyed. Average survey intensity was 49 minutes/plot (13.4 mi^2) and ranged from 40 to 65 minutes/plot (Giudice 2016).

This year a total of 506 moose were observed on 47 (90%) of the 52 plots surveyed (a total 697 mi^2). An average of 10.8 moose (range = 1–38) were observed per occupied plot. This is a notable difference from the 392 moose observed on 34 of 52 plots (65%) in the 2015 survey. Plot occupancy during the past 12 years averaged 81% (range = 65–95%) with a mean 11.9

moose per occupied plot. This year's 506 observed moose included 208 bulls, 206 cows, 87 calves, and 5 unclassified.

After adjusting for sampling and sightability, we estimated the population in northeastern Minnesota at 4,020 (3,230–5,180, 90% confidence interval) 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. Rather, these data are best suited to establishing long-term trends.

Past aerial survey and research results have indicated that the trend of the population in northeastern Minnesota has been declining since 2006 (Lenarz et al. 2010, DelGiudice 2015). The current population estimate is 55% less than the estimate in 2006 and the declining linear trend during the past decade is still significant ($r^2 = 0.79$, $P < 0.001$, Figure 2). However, there appears to be a leveling since 2012, and a piecewise polynomial curve indicates that the trend from 2012 to 2016 is not declining (Figure 3). While this recent short-term trend is noteworthy, it applies only to the existing survey estimates, not the future trajectory of the population (Giudice 2016).

Table 1. Estimated moose numbers, 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, 2005–2016.

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

The January 2016 calf:cow ratio of 0.42 is 24% higher than the 11-year average since 2005 (0.34, Table 1, Figure 4), and is the third highest since 2005. Calves were 17% of the total 506 moose actually observed and represented 17% of the estimated population (Table 1, Figure 4). Twin calves were observed with 5% of the 206 cow moose, which is elevated slightly relative to most years since 2005 (Table 1). Overall, survey results indicate calf survival to January 2016 is higher than in most years since the population decline began following the 2006 survey. This

is consistent with results of a separate helicopter survey which documented the number of adult GPS-collared cows that had calved in spring 2015 that were still accompanied by calves in early November–early December 2015 (Severud and DelGiudice, unpublished data). Annual recruitment of calves can have a significant influence on the population performance of moose, but it is not actually determined until the next spring's calving season when calves observed during winter become yearlings. Little is known about survival of moose calves during the period between the annual winter survey and subsequent spring calving. It also is important to note that adult moose survival has the greatest long-term impact on annual changes in the moose population (Lenarz et al. 2010). Somewhat consistent with the recent (2012–2016) apparent relative stability of the population trend, the annual survival rate of adult GPS-collared moose has been 85–88% during the past 2 years, slightly higher than in 2013 (81%, Carstensen et al., unpublished data) and the previous long-term average of 81% (Lenarz et al. 2009).

The estimated bull:cow ratio (1.03, Table 1; Figure 5) is similar to the long-term mean of 0.98 during 2005–2015. However, there has been a great deal of annual variability associated with the bull:cow ratios, consequently, they exhibit no clear upward or downward long-term trend.

Figure 2. Point estimates, 90% confidence intervals, and a linear trend line of estimated moose numbers in northeastern Minnesota, 2005–2016. (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 13.4-mi^2 plots).

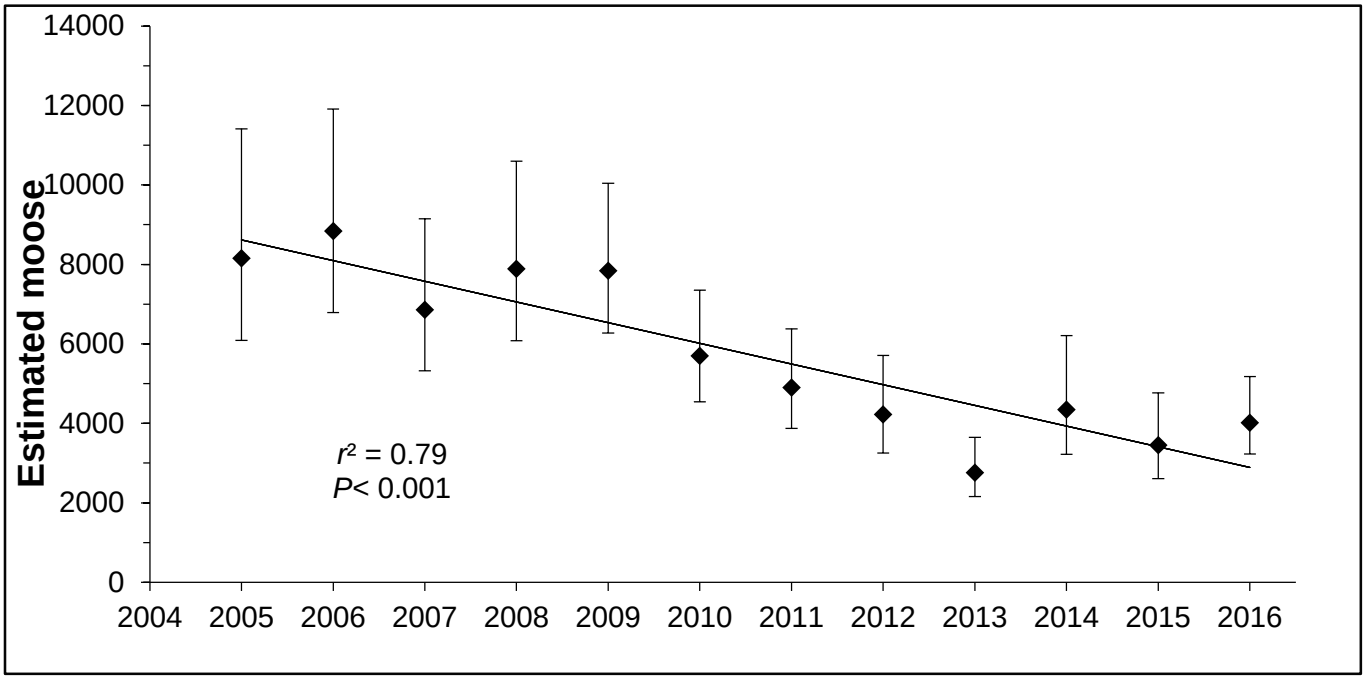


Figure 3. Point estimates of moose, 90% confidence intervals, and a piecewise polynomial curve of moose numbers in northeastern Minnesota, 2005–2016. This curve shows a change in the short-term slope of the trend from 2012 to 2016 compared to 2009 to 2012.

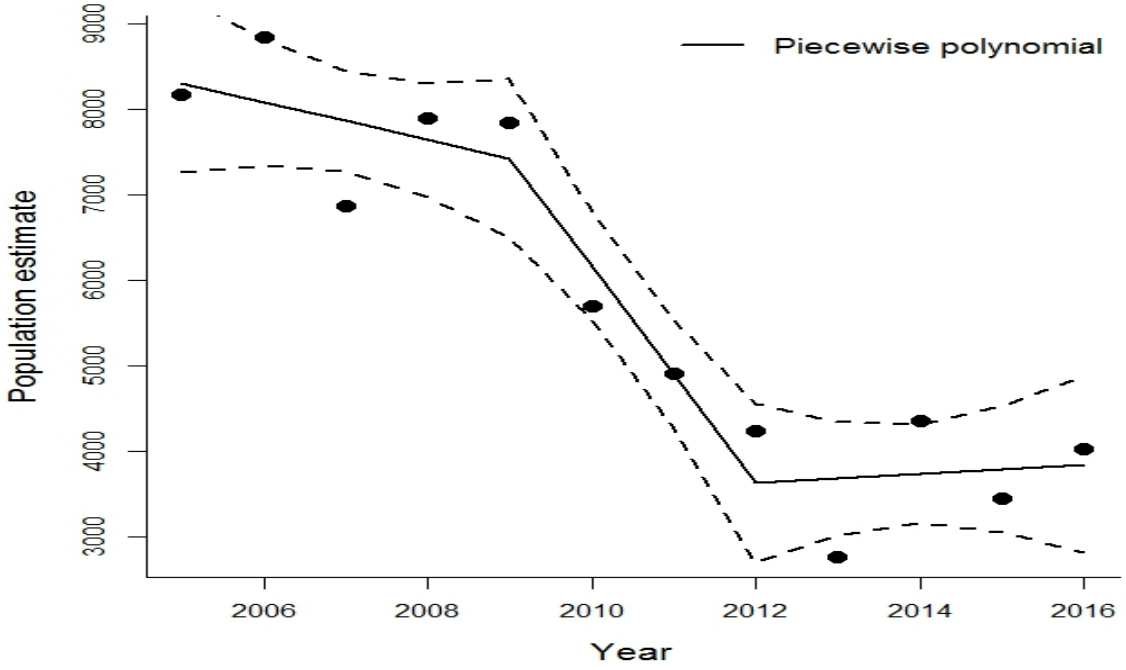


Figure 4. Estimated calf:cow ratios (solid diamonds, dashed trend line) and percent calves (open squares, solid trend line) of the population from aerial moose surveys in northeastern Minnesota, 2005–2016.

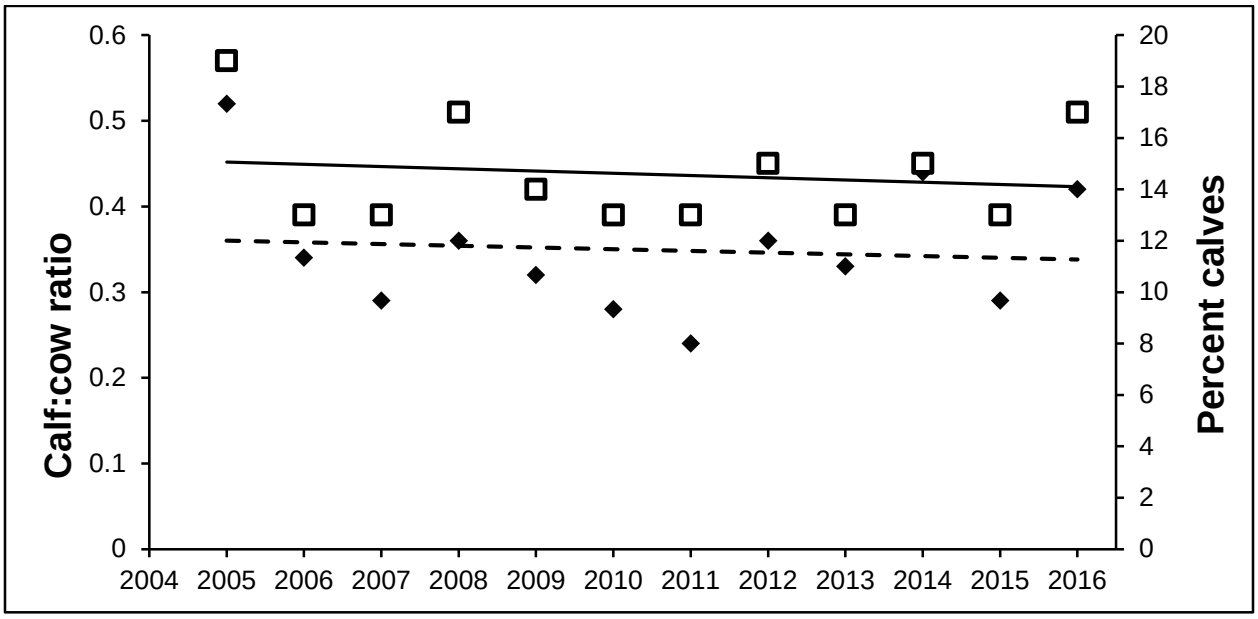
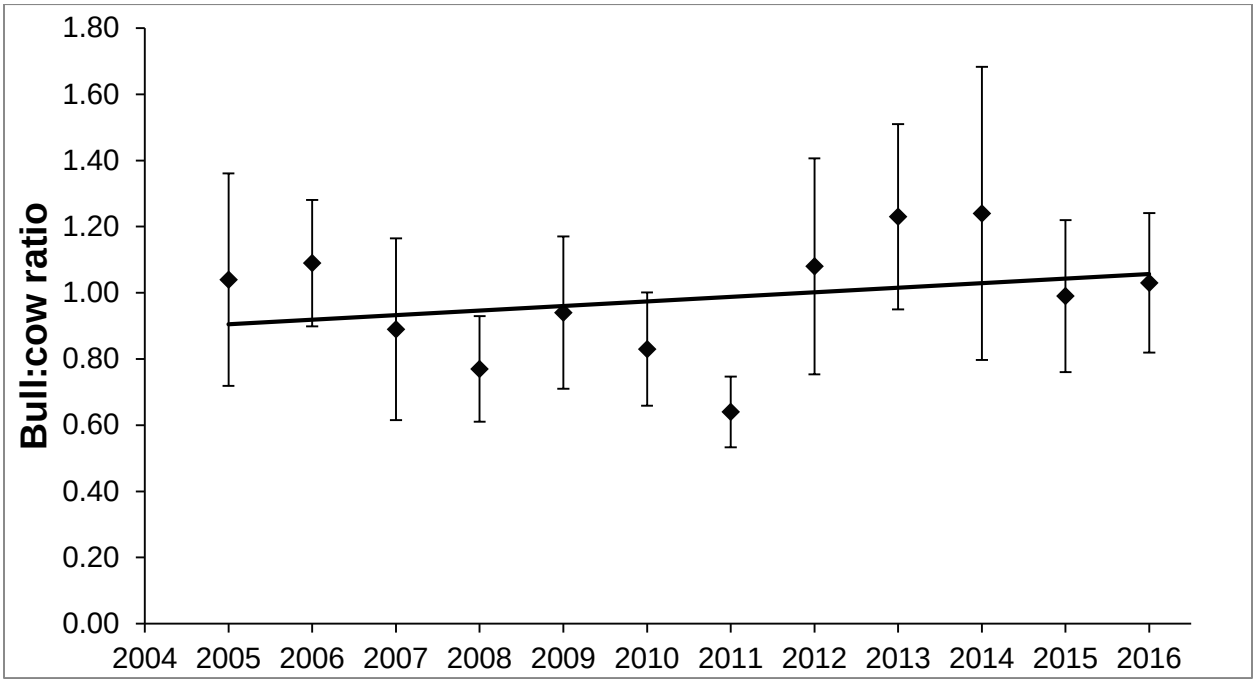


Figure 5. Estimated bull:cow ratios, 90% confidence intervals, and trend line from aerial moose surveys in northeastern Minnesota, 2005–2016.



Acknowledgments

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