DEPARTMENT OF NATURAL RESOURCES

2020 Aerial Moose Survey

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Introduction

Each year we conduct an aerial survey in northeastern Minnesota to estimate the moose (*Alces alces*) 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.

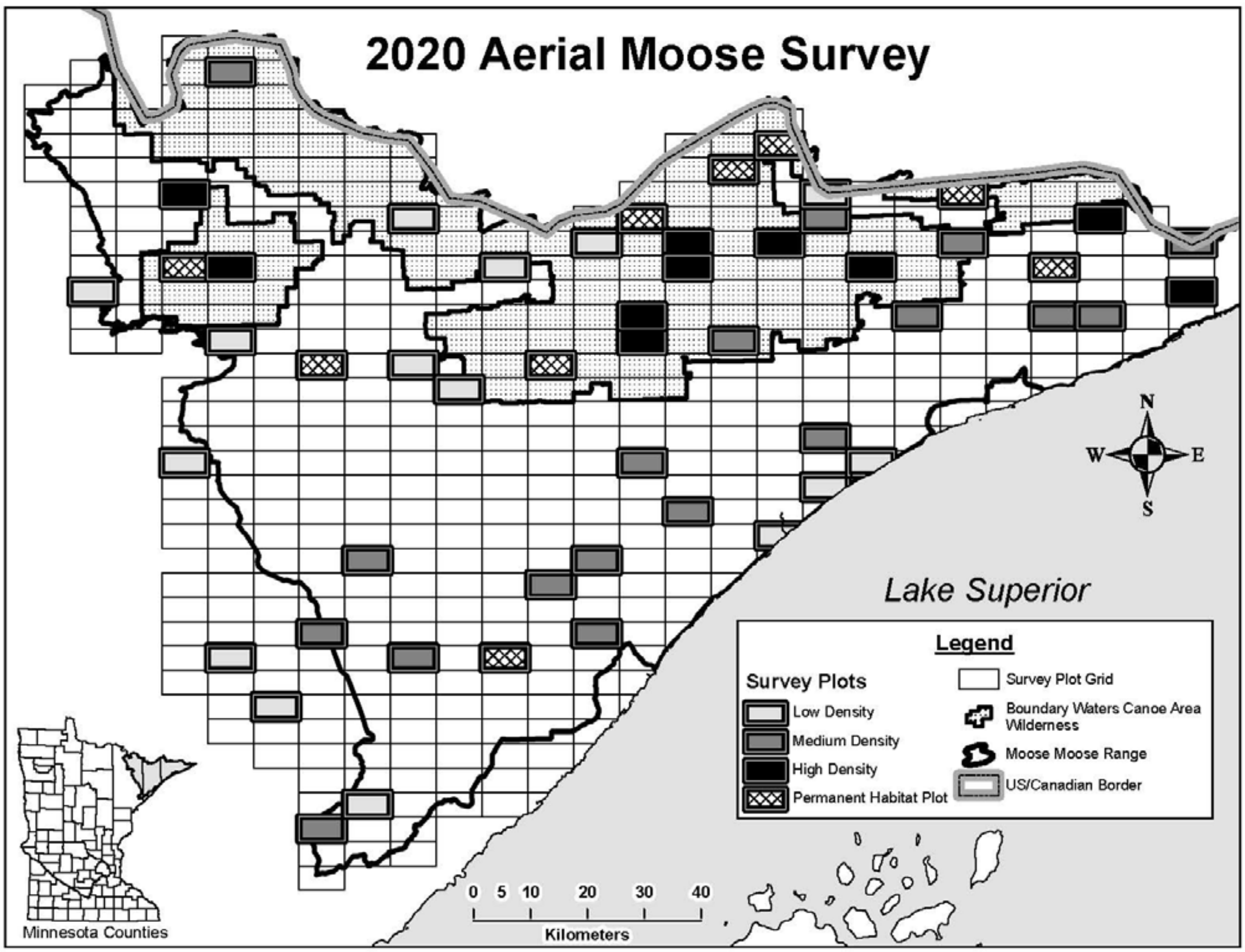
Methods

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 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, and high density classes are based on whether up to 2, 3–7, or 8 or more moose, respectively, would be expected to be observed in a specific plot. The most recent re-stratification review was conducted in October 2018. Additionally, individual plots may be 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 to the survey approach, 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 similarly oriented and 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 2020 aerial moose survey.



Results and Discussion

The survey was conducted from 6 to 17 January 2020. It consisted of 9 actual survey days, and as from 2014 to 2019, it included a sample of 52 survey plots. This year, based on optimal allocation analyses, we surveyed 15 low-, 18 medium-, and 10 high-density plots, and the 9 permanent or habitat plots (Giudice 2020). Generally, 8" of snow cover is our minimum threshold depth for conducting the survey. Snow depths were greater than 16" on 100% of the sample plots. Overall, survey conditions were rated as good for 88%, fair for 12%, and poor for 0% of the plots when surveyed. Average survey intensity was 48 minutes/plot (13.9 mi^2) and ranged from 25 to 60 minutes/plot (Giudice 2020).

This year 308 moose were observed on 39 (75%) of the 52 plots surveyed (a total 723 mi^2), less than the 429 moose observed on 43 of 52 plots during the 2019 survey. An average of 7.9 moose (range = 1–28) were observed per "occupied" plot. Plot occupancy during the past 16 years averaged 81% (range = 65–95%) with a mean 11.6 moose observed per occupied plot. The average group size was 2.1 moose, similar to the previous 16 years (2 moose), and ranged from 1 to 8 moose per group. This year's 308 observed moose included 131 bulls, 138 cows, 37 calves, and 2 unclassified adults. Overall, estimated VO averaged 44% (range = 0−85%) and average estimated detection probability was 0.55 (range = 0.23−0.85). Both VO and detection probability have remained relatively constant since 2005.

After adjusting for sampling and sightability, we estimated the population in northeastern Minnesota at 3,150 (2,400–4,320, 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.

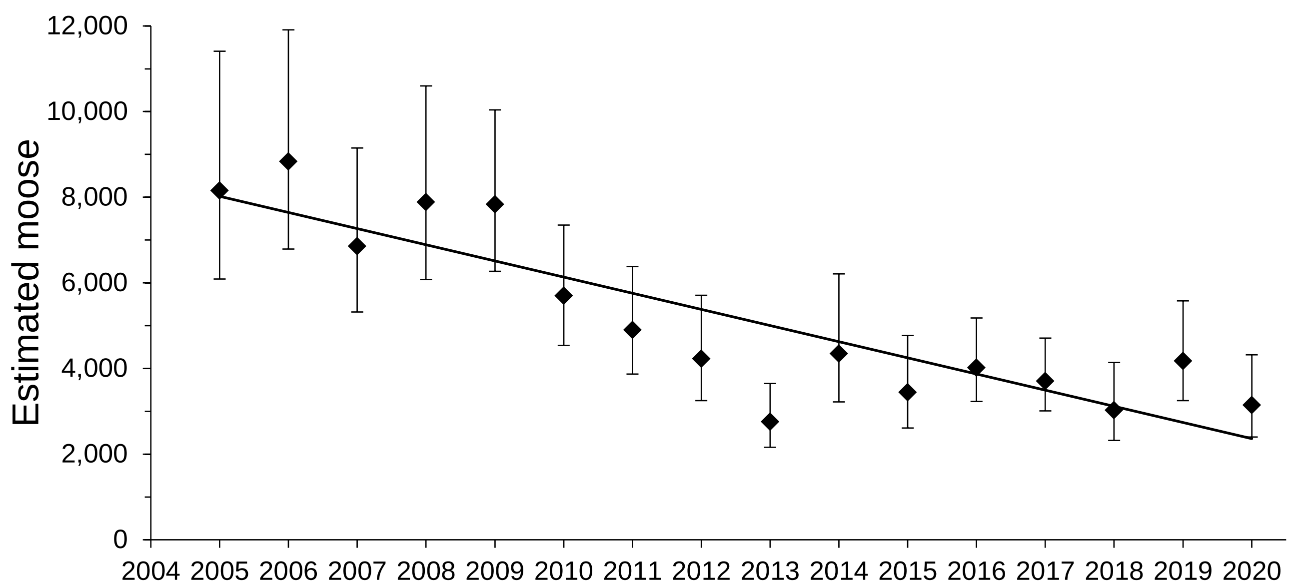
Past aerial survey and research results have indicated that the long-term trend of the population in northeastern Minnesota has been declining since 2006 (Lenarz et al. 2010, DelGiudice 2019). The current population estimate is 64% less than the estimate in 2006 and the declining linear trend during the past decade remains statistically significant ($r^2 = 0.762$, $P < 0.001$, Figure 2). However, the leveling since 2012 persists, and a piecewise polynomial curve indicates that the trend from 2012 to 2020 is not declining (Figure 3). While this recent short-term trend (9 years) is noteworthy, it applies only to the existing survey estimates, and does not forecast the future trajectory of the population (Giudice 2020).

The January 2020 calf:cow ratio of 0.36 is similar to the 15-year average since 2005 (0.35, Table 1, Figure 4). Calves were 12% of the total 308 moose actually observed and represented 18% of the estimated population (Table 1, Figure 4). Twin calves were observed with 3 of the 138 (2%) 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 2020 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).

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, 2005–2020.

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 – 9,150	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

Figure 2. Point estimates, 90% confidence intervals, and a linear trend line of estimated moose abundance in northeastern Minnesota, 2005–2020 ($y = -377x + 764585$, $r^2 = 0.762$, $P < 0.001$). 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.



The January 2020 estimated bull:cow ratio (0.90, Table 1; Figure 5) is similar to the long-term average of 1.00 during 2005–2019, and compared to the mean ratio of 2009−2012 (0.87), when the population decline was steepest. However this ratio has been as low as 0.64 (2011) during the steep decline. During the recent 9-year trend of stability, the average bull:cow ratio has been 1.12. However, due to the notable annual variability associated with the bull:cow ratios, the apparent upward trend line is not statistically meaningful (Figure 5).

Figure 3. Point estimates, 95% confidence intervals (dashed lines), and a piecewise polynomial curve of moose abundance in northeastern Minnesota, 2005–2020 (Giudice 2020). This curve shows a change in the short-term slope of the trend from 2012 to 2020 compared to 2009 to 2012.

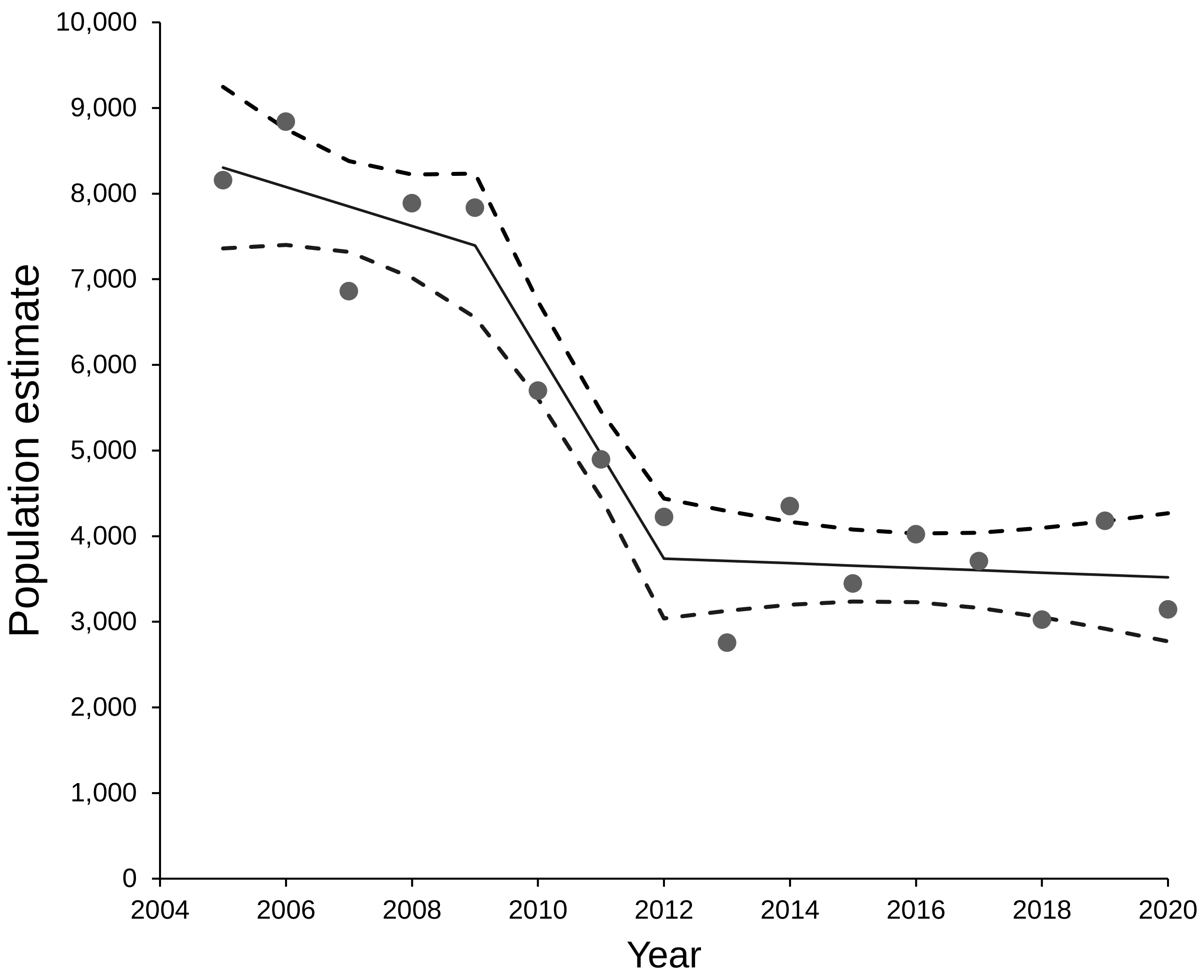


Figure 4. Estimated calf:cow ratios (solid diamonds, dashed trend line) and percent calves (open squares, solid trend line) of the population from aerial moose surveys in northeastern Minnesota, 2005–2020.

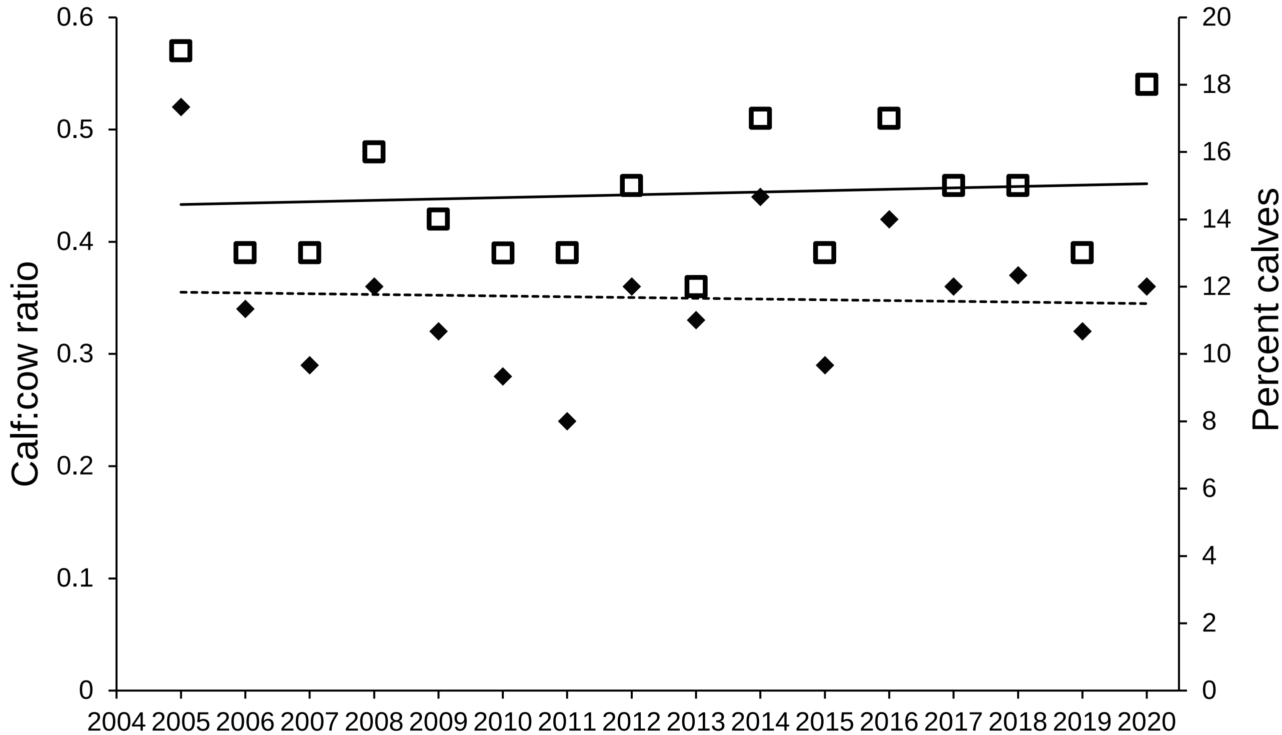
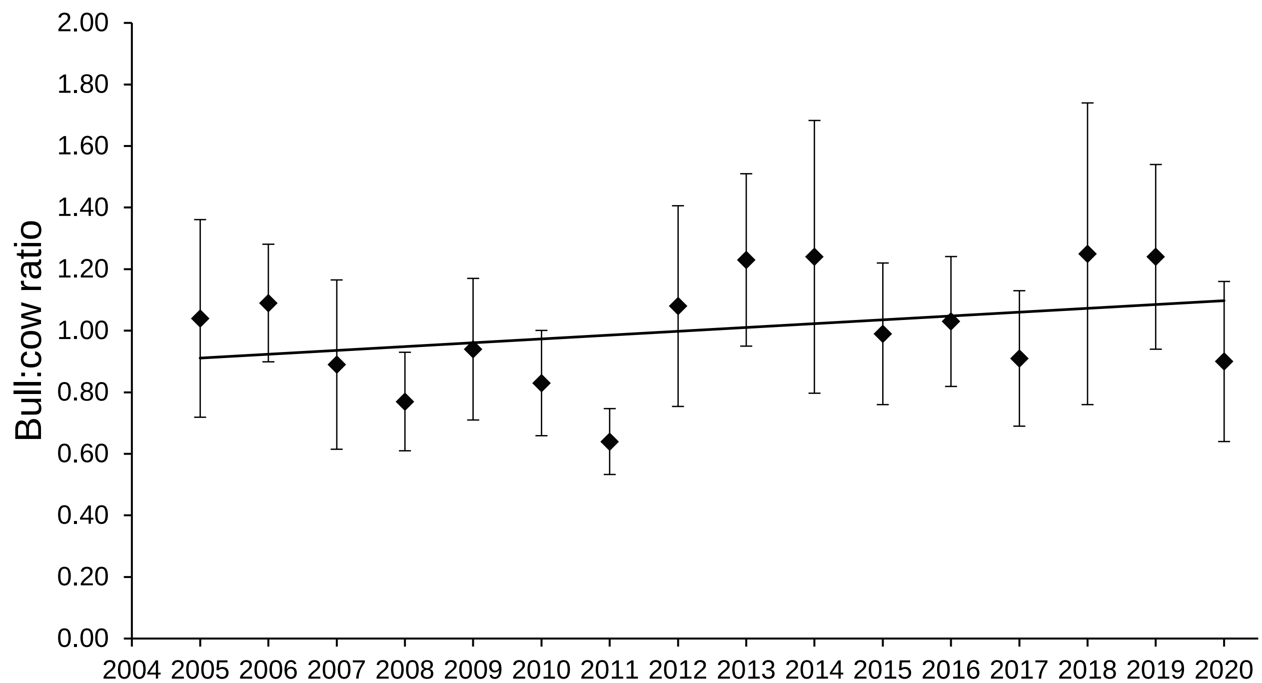


Figure 5. Estimated bull:cow ratios, 90% confidence intervals, and trend line from aerial moose surveys in northeastern Minnesota, 2005–2020.



Acknowledgments

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