2014 Aerial Moose Survey

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Introduction

Each year, we conduct an aerial survey in northeastern Minnesota in an effort to monitor moose (*Alces alces*) numbers and fluctuations in the overall status of Minnesota's largest deer species. The primary objectives of this annual survey are to estimate moose numbers, calf:cow and bull:cow ratios. We use these data to determine and examine the population's trend and composition, to contribute to our understanding of moose ecology, and to set the harvest quota for the subsequent hunting season when applicable.

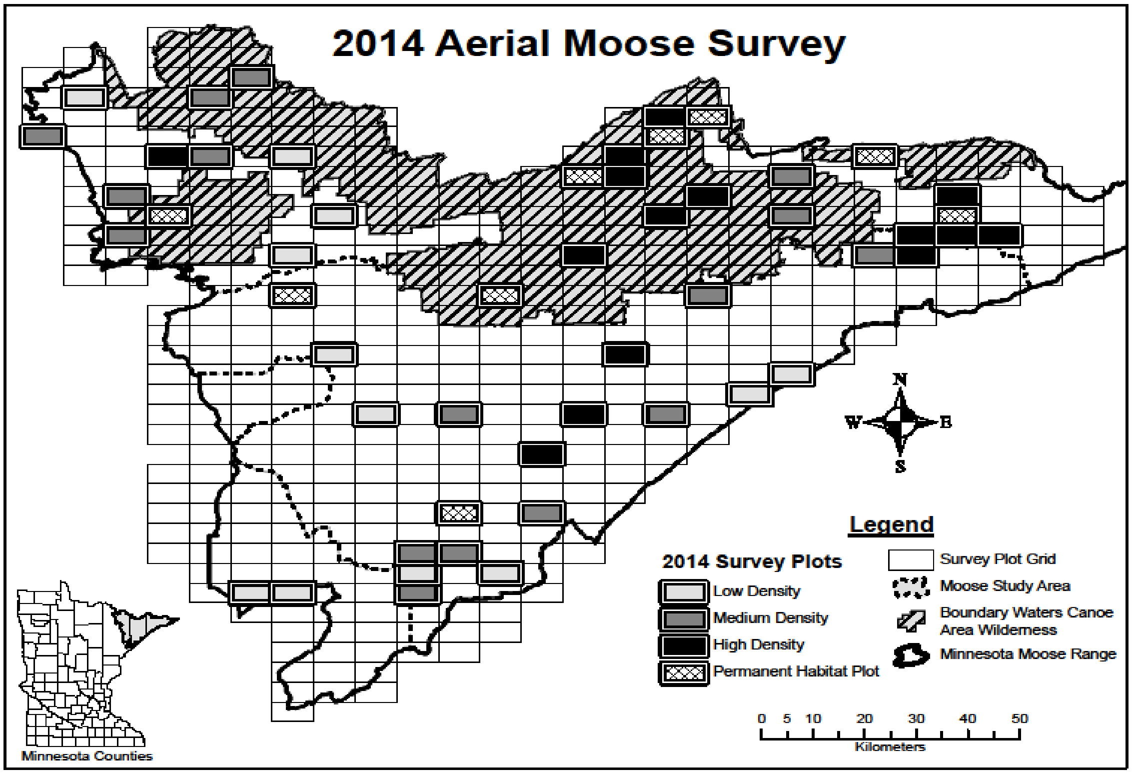
Methods

We estimated moose numbers, age and sex ratios by flying transects within a stratified random sample of survey plots (Figure 1). All survey plots are reviewed and re-stratified as low, medium, or high density about every 5 years based on past survey observations of moose, locations of harvested moose in past years, and extensive field experience of moose managers and researchers. For the most recent re-stratification (November 2013), survey plots were classified as low, medium, or high based on whether < 2, 3-7, or $\geq$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 to represent a series of 9 plots which have undergone disturbance by wild fire, prescribed burning, and 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.

As in previous years, all survey plots were rectangular (5 x 2.67 mi.) and oriented east to west with 8 transects. Minnesota Department of Natural Resources (MNDNR) Enforcement pilots flew the Bell Jet Ranger (OH-58) helicopters used to conduct the survey. We sexed moose using the presence of antlers or the presence of a vulval patch (Mitchell 1970), nose coloration, bell size and shape, and identified calves on the basis of size and behavior. We used the program DNRSurvey on Toughbook® tablet style computers to record survey data. DNRSurvey allowed us to display transect lines superimposed on a background of aerial photography, observe the aircraft's flight path over this background in real time, and record data using a tablet pen with a menu-driven data entry form. Two of the primary strengths of this survey are the consistency and standardization of the methods since 2005 and the long-term consistency of the survey team personnel.

We accounted for visibility bias by using a sightability model (Giudice et al. 2012). We developed this model between 2004 and 2007 using moose that were radiocollared as part of research on the dynamics of the northeastern moose population (Lenarz et al. 2009). Logistic regression indicated that the covariate "visual obstruction" (VO) was the most important covariate in determining whether radiocollared moose were observed. We defined VO as the proportion of vegetation within a circle (30-ft. radius or roughly 4 moose lengths) that would prevent you from seeing a moose when circling that spot from an oblique angle. If we observed more than 1 moose 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 sample plots flown in the 2014 aerial moose survey. The study area for ongoing MNDNR moose research also is shown.



Results and Discussion

The survey was conducted from 7 to 18 January 2014. It consisted of 9 actual survey days and included 52 survey plots. Snow depths were consistently greater than the minimum 8" desired for the survey (92% of plots had >16", 8% had 8-16"), with 96% of the plot surveys conducted under good survey conditions and 2% under fair conditions. Overall, survey conditions were notably better than during the past several years. During the survey flights, 419 moose were observed on 41 (79%) of the 52 plots flown (694 mi^2), including 176 bulls, 174 cows, 65 calves, and 4 unclassified moose. This apparent occupancy of plots compares to a 10-year average of 82%. An average of 10.2 moose were observed per "occupied" plot (range = 1-51 moose) compared to a 10-year average of 12.2 moose. Estimates of the calf:cow and bull:cow ratios were 0.44 and 1.24, respectively, both among the highest ratios since 2005 (Table 1).

After adjusting for sampling and sightability, we estimated the population in northeastern Minnesota at 4,350 (3,220–6,210) moose (Table 1). Based on the log rate of change (0.456; 90% CI: 0.086, 0.827), the 2014 population estimate was significantly higher (58%; 90% CI: 9-128%) than the 2013 estimate of 2760 moose, but similar to the 2012 and 2011 estimates of 4,230 and 4,900 moose, respectively. As can be noted from the 90% confidence limits associated with the population point estimates (3,220-6,210; Table 1, Figure 2), statistical uncertainty inherent in aerial wildlife surveys, even of large, relatively conspicuous animals such as moose during the winter, can be quite large due 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) on their movements, and (5) the interaction of these factors. Past aerial survey and research results have indicated that the trend of the population of northeastern Minnesota has been declining since 2006 (Lenarz et al. 2010, DelGiudice 2013). Despite this year's higher point estimate, the downward trend persists (r^2 = 0.82, P = 0.0003, Figure 2). Lenarz et al. (2010) used simulation modeling to integrate survival and reproductive rates measured between 2002 and 2008 and found that the population was decreasing approximately 15% per year over the long-term. The 2013 estimate (2,760 moose) indicated a 35% decrease from 2012 and a 52% decrease in the population since 2010, not inconsistent with the declining trend, but exceeding the projected rate of change (Table 1). It is likely that the population was underestimated in 2013 and that with almost optimum snow and survey conditions this year, more moose were observed and the estimate is more reflective of actual moose numbers, although the variability associated with the estimate is large due to atypically high numbers of moose being observed in low and medium density plots.

Table 1. Estimated moose numbers, 90% confidence intervals, and calf:cow ratios, percent calves, percent cows with twins, and bull:cow ratios estimated from aerial surveys in northeastern Minnesota, 2005-2014.

Survey	Estimate	90% Confidence Interval	Calf: Cow	% Calves	% Cows w/ twins	Bull: Cow
2005	8,160	5,960 – 11,170	0.52	19	9	1.04
2006	8,840	6,670 – 11,710	0.34	13	5	1.09
2007	6,860	5,230 – 9,000	0.29	13	3	0.89
2008	7,890	5,970 – 10,420	0.36	17	2	0.77
2009	7,840	6,190 – 9,910	0.32	14	2	0.94
2010	5,700	4,480 – 7,250	0.28	13	3	0.83
2011	4,900	3,810 – 6,290	0.24	13	1	0.64
2012	4,230	3,190 – 5,600	0.36	15	6	1.08
2013	2,760	2,120 – 3,580	0.33	13	3	1.23
2014	4,350	3,220 – 6,210	0.44	15	3	1.24

Estimated calf recruitment from this year's survey remained *relatively* high and similar to last year's estimate (Table 1). The calf:cow ratio in mid-January 2014 was 0.44, up slightly from last year's survey (0.33), and calves represented 15% of the total moose observed, also slightly elevated from last year's estimate (Table 1). Like last year, only 3% of the cow moose were accompanied by twins (Table 1). Based on survey results calf survival through to mid-January 2014 appears relatively high. However, an ongoing study of GPS-collared moose calves indicates that calf survival is low (Severud and DelGiudice, unpublished data), and *annual* recruitment of the calves is not actually determined until the next spring calving season when winter survey-observed calves become yearlings. At this point, little is known about the survival rates 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 most significant impact on annual changes in the moose population (Lenarz et al. 2010), and elevated annual mortality of adult moose has continued during the past year (~21%, Carstensen et al., unpublished data).

The estimated bull:cow ratio (Table 1; Figure 4) was similar to last year's estimate and is the highest since 2005. Further, the past two year's estimated bull:cow ratios indicate that adult bulls may outnumber adult females, although there is a great deal of variability associated with

Figure 2. Point estimates, 90% confidence intervals, and trend line of estimated moose numbers in northeastern Minnesota, 2005-2014. (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 5 x 2.67 mi plots).

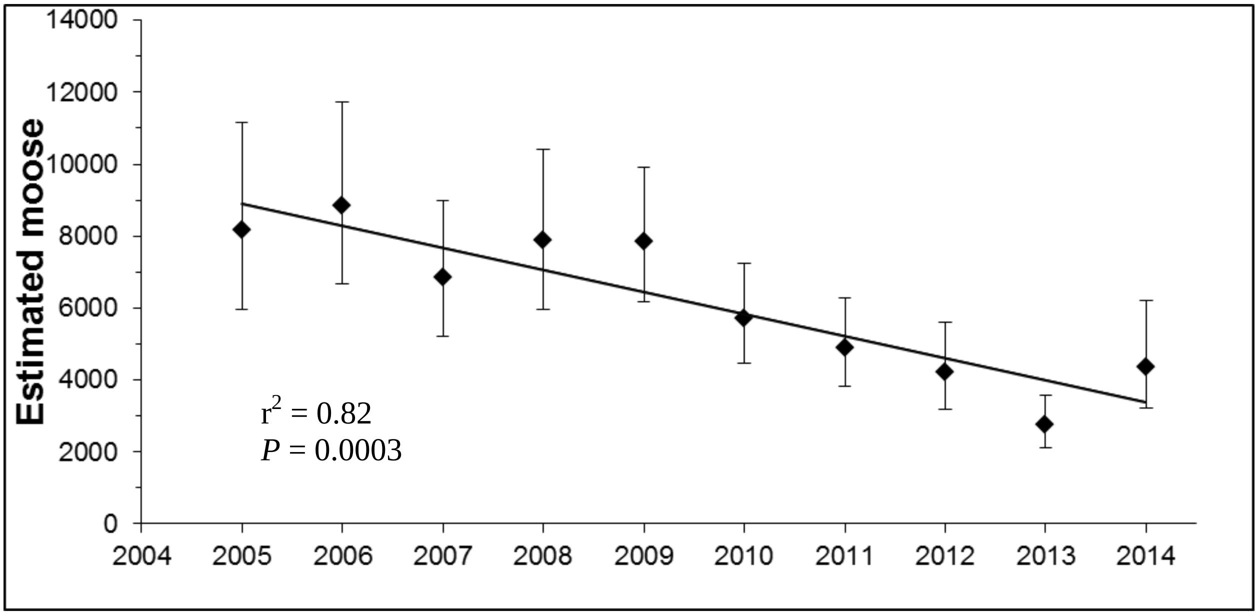
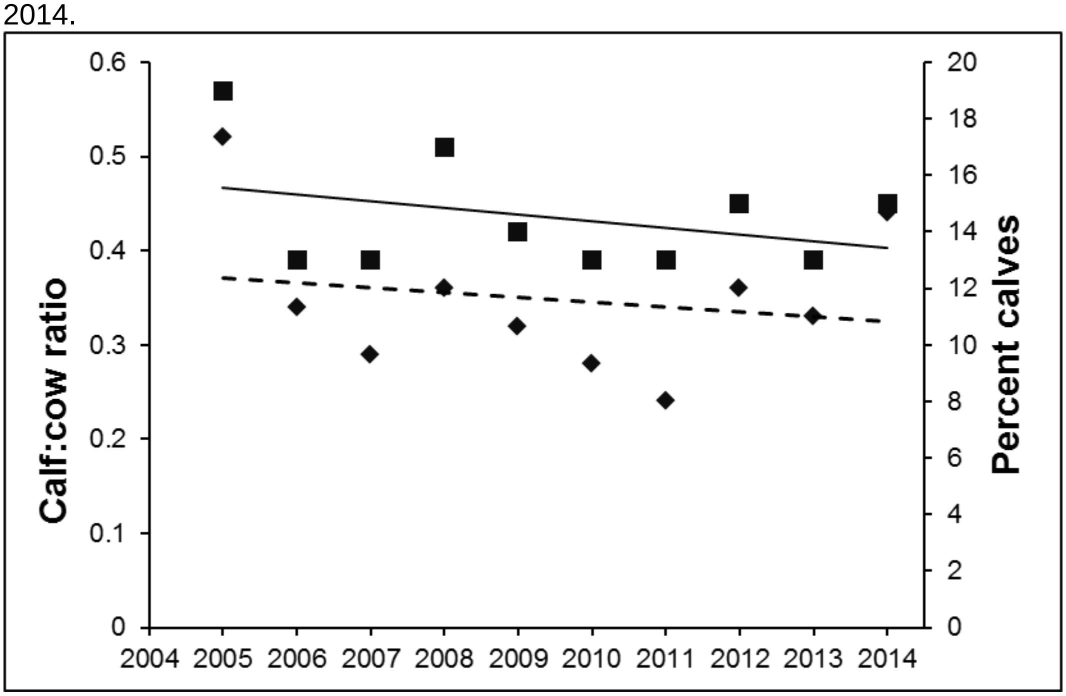
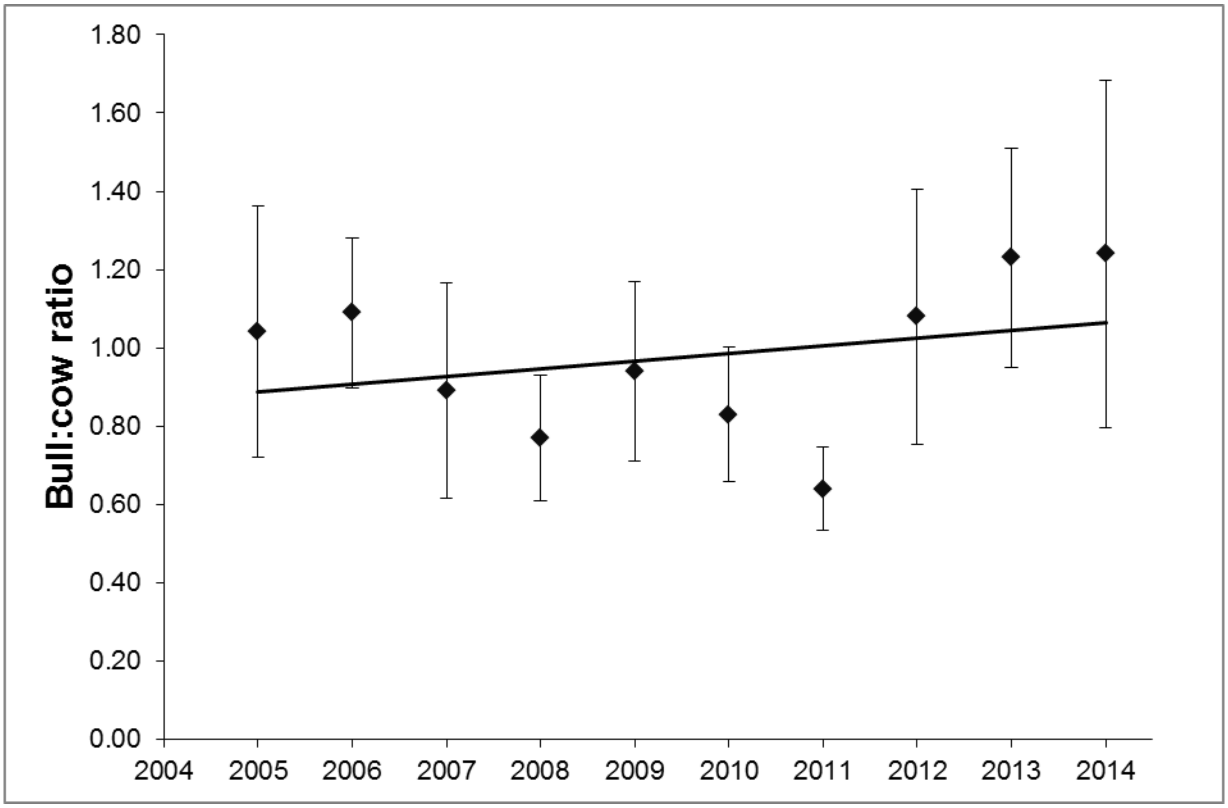


Figure 3. Estimated calf:cow ratios (solid diamonds, dashed trend line) and percent calves (solid squares, solid trend line) from aerial moose surveys in northeastern Minnesota, 2005-2014.



these annual ratio estimates. Consequently, there is no clear upward or downward long-term trend (2005-2014) in bull:cow ratios.

Figure 4. Estimated bull:cow ratios, 90% confidence intervals, and trend line from aerial moose surveys in northeastern Minnesota, 2005-2014.



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Literature Cited
Cochran, W. G. 1977. Sampling techniques. Third edition. Wiley and Sons, New York, USA.

DelGiudice, G. D. 2013. 2013 Aerial moose survey. Minnesota Department of Natural

Resources, Section of Wildlife, unpublished report. St. Paul, Minnesota. 6pp.

Fieberg, J. 2012. Estimating population abundance using sightability models: R sightability model package. Journal of Statistical Software 51:1-20.

Gasaway, W. C., and S. D. DuBois. 1987. Estimating moose population parameters. Swedish Wildlife Research (Supplement) 1:603–617.

Giudice, J. H., J. R. Fieberg, M. S. Lenarz. 2012. Spending degrees of freedom in a poor economy: a case study of building a sightability model for moose in northeastern Minnesota. Journal of Wildlife Management 76:75-87.

Lenarz, M. S., M. E. Nelson, M. W. Schrage, and A. J. Edwards. 2009. Temperature mediated moose survival in northeastern Minnesota. Journal of Wildlife Management 73:503-510.

Lenarz, M. S., J. Fieberg, M. W. Schrage, and A. J. Edwards. 2010. Living on the edge: viability of moose in northeastern Minnesota. Journal of Wildlife Management. 74:1013-1023.

Mitchell, H.B. 1970. Rapid aerial sexing of antlerless moose in British Columbia. Journal Wildlife Management. 34: 645-646.

R Development Core Team. 2011, R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Version 2.13.1, ISBN 3-900051-07-0 http://www.r-project.org/.