TWENTY-PLUS YEARS OF AERIAL MOOSE CENSUS IN MINNESOTA

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ABSTRACT: Aerial moose censuses have been conducted on two major areas in Minnesota using plot samples from 1959 to 1981. Stratification and optimal allocation of plots has increased the census precision. Accuracy was improved in the northeast by using a crew of four in the aircraft and conducting the census in early December through January with a ground cover of 20-80 cm of uncrusted snow. Moose populations in northwestern Minnesota increased at the rate of 4% per annum from 1960 through 1972, and at 1% from 1973 through 1981. The true population changes in this area may have been masked by the addition of an adjacent, but ecologically dissimilar, unit to this census area in 1972. From 1977 to 1981 this population has increased at the rate of 8% per year. In northeastern Minnesota the moose population increased from 1959 through 1966, decreased from 1966 through 1974, and increased from 1974 to 1981 at the rates of +3, -5 and +12% per annum, respectively. The data obtained from the census has played an important role in the management of Minnesota's moose populations.

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Aerial censusing of moose is frought with many difficulties, but remains as the basic tool used to measure moose (Alces alces) populations across the continent (Timmermann 1974, Karns and Gasaway 1982). Aerial moose censuses have been used in Minnesota since 1959 to obtain estimates of the population and monitor population trends. This paper reviews and comments on these aerial census results.

Moose populations in Minnesota occur in two distinct areas of northern Minnesota (Fig. 1) (Karns et al. 1974). Major types of vegetation in the northwest area (NWA) (Kuchler 1964), consist of

conifer bog (Larix-Picea-Thuja), maple-basswood (Acer-Tilia), oak savanna (Quercus-Andropogon), and bluestem prairie (Andropogon-Panicum-Sorghastrum), and the northeastern area (NEA) moose range lies in the Great Lakes spruce-fir (Picea-Abies) and Great Lakes pine (Pinus) forest types.

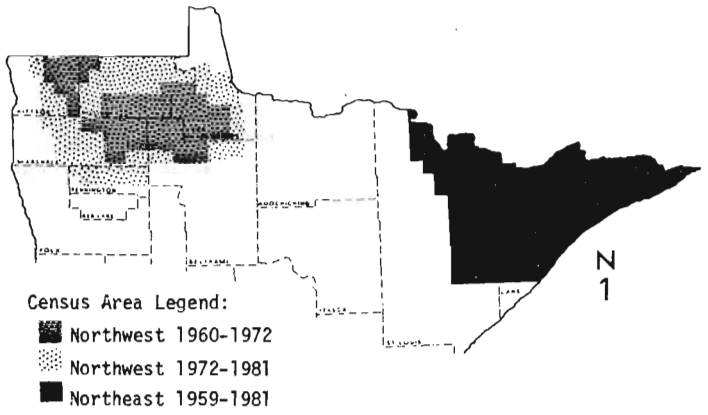

Figure 1. Aerial moose census areas in Minnesota. 1959-1981.

METHODS

Methods used to census moose in northern Minnesota have been patterned after Trotter (1958), and evolved with our experience and increasing knowledge of moose distribution. From 1959 to 1961 censuses were conducted on 64 km^2 (8 x 8 km) plots selected at random for each area, with no stratification. Beginning with the 1962 census, and going through 1971, the areas were subdivided into high and low moose density strata and plots were reduced in area to 38.4 km^2 (4.8 x 8 km).

Starting with the 1972 census, and continuing through the 1981 census, a stratified random plot design with optimum allocation of plots (Snedecor and Cochran 1967) with three to six strata and the 4.8 x 8 km plots has been used. The census areas have been restratified several times during this period in keeping with our knowledge of moose distribution. Plot boundaries were straight-line, corresponding to the legal Range and Township subdivision of the state. Plots were oriented on both east-west and north-south axes in the NWA and only east-west in the NEA.

Aircraft used were Cessna 172, 180, 185 and deHaviland Beaver (piston). Flights were made with crews of three or four individuals, including the pilot and all served as observers during the census. Flight altitude ranged from 120 to 240 meters over the terrain, and flying speed ranged from 130 to 180 km/hr. Pilots flew at an altitude and speed in keeping with safe operation of the aircraft under prevailing conditions of weather and terrain. Most flights were conducted between mid-December and late January, although in some years flights were made in February and March.

Flying was done on the long axis of the plots until moose were sighted, at which time the areas were circled at a lower altitude to ascertain the sex and age of the moose, and to locate other animals in the proximity that may have been missed in the original observation. Attempts were made to obtain 100% coverage of the plot and distances between flight lines were adjusted according to the type and amount of vegetative cover. All data were recorded on a standard form that

remained essentially unchanged throughout the period. Estimates were made of moose missed on the plot in the first few years, but were too subjective and are not included in this analysis.

Changes in flight crews were kept at a minimum to reduce this source of variability. Crews received preliminary instructions in conducting the census, but no formal training sessions were conducted.

RESULTS

Moose population size on the two areas was estimated from the aerial census data and 95% confidence limits applied (Table 1). Because the moose population is generally underestimated by the census these are not true confidence intervals, as they do not include the true population size the specified percent of the time. However, confidence intervals do reflect some of the sampling error associated with the population estimates, and therefore, changes in sampling design can be evaluated by changes in the confidence interval. Stratification of the census areas and optimum allocation improved precision of the estimates as reflected by the reduced confidence interval (Table 1). Moose densities, as observed on the plots, ranged from 0 to 3 moose/km^2.

Applying least squares regression analysis to population estimates for the NWA showed a steadily increasing trend from 1960 through 1971. The rate of increase for this period was 4% per year. The NWA census area was enlarged in 1972 from 6760 km^2 to 14040 km^2. The cover type on the original census area, as described by Kuchler (1964) is largely conifer bog, whereas the added area was comprised of the maple-basswood,

Table 1. Estimates of moose populations in northern Minnesota from aerial censuses with ± 95% confidence limits as a percent.

Year	Area			
	Northwest		Northeast	
	Number plots completed	Population estimate	Number plots completed	Population estimate
Unstratified, 64 km^2 plots:				
1959-60	No census		17	687±55%[3]
1960-61	16	1392	16	2774±57%
1961-62	16	1409±39%[1]	17	4478±53%
Two strata, 38 km^2 plots:				
1962-63	25	1450	29	3022±41%
1963-64	26	1236±41%	54	2970±26%
1964-65	26	1959±40%		No census
1965-66	26	1864±25%		No census
1966-67	23	2054±33%	40	3357±42%
1967-68	26	1835		No census
1968-69	25	1652±21%	32	1872±39%
1969-70		No census		No census
1970-71	25	1993±31%	40	2631±38%
1971-72	26	2367±27%	40	2993±33%
Stratified, optimum allocation, 38 km^2 plots:				
1972-73	40	3144±17%[2]	40	1663±27%
1973-74	40	2671±20%	50	2207±35%
1974-75	40	3539±29%	50	2179±21%
1975-76	45	2396±21%	50	2399±27%
1976-77	45	3538±34%	50	3469±40%
1977-78	45	2515±25%	52	1385±27%
1978-79	45	2158±21%	52	4450±24%
1979-80	47	2808±21%	49	4492±22%
1980±81	50	3294±19%	50	4742±24%
1981-82	51	3402±17%	50	4986±22%

1) Census area of approximately 6760 square kilometers used from 1959 to 1971

2) Census area changed to 14,040 square kilometers beginning with 1972-73 census.

3) Census area between 13,000 and 15,600 square kilometers.

oak savannah and bluestem prairie types. Primary land-use on the pre-1972 census area was wildlife management, forestry, and some marginal agriculture. The area added in 1972 was primarily in agriculture and brushlands. Since 1972 the estimated moose populations have fluctuated widely between alternate years, with a slight overall increasing trend through 1981 (Table 1). The low points occur in years of a moose hunting season, generally in the previous October. Adding the number of moose taken during these seasons can account for roughly half of the observed differences from 1972 through 1977. (Table 2). General observations by field personnel indicate that moose were actually declining on the pre-1972 census area during this period, and increasing and expanding in the area added in 1972. The rate of change for this population from 1972 to 1981 is about 1% per year. During the period from 1977 to 1981, a period not fraught with the large population changes, the rate of increase is 8% per year.

The NEA population trend consisted of 3 legs: the first ascending from 1960 through 1966, then descending from 1966 to 1974, and ascending from 1974 to 1981. The average annual rate of change for these periods was +3, -5, and +12% respectively.

Time spent searching plots for moose was correlated with the number of animals observed on the plot. As an example, for the 1981-82 census period the time spent searching a plot was 33 +0.5X and 27 + 0.4X minutes (where X is number of moose observed on the plot) in the NEA and NWA, respectively.

Interpretation of moose population estimates derived from aerial census must take into account many factors influencing the census. Census results for NEA in winters 1959-60, 1961-62, 1968-69, 1972-73, and 1977-78

Table 2. Moose populations for northwestern Minnesota and registered harvests.

Year	Estimated Population	Registered Harvest[1]	Estimated Population Plus Harvest
1972	3144		3144
1973	2671	306	2977
1974	3539		3539
1975	2396	449	2845
1976	3538		3538
1977	2515	598	3113
1978	No Census		
1979	2808	303	3111
1980	3294		3294
1981	3402	432	3834

[1] Biennial moose seasons with mandatory registration of all moose taken by hunters.

do not provide estimates consistent with the population trends (Table 1). The confounding factors (Table 3) were used to establish the following criteria for conducting aerial moose censuses: 1) acceptable census period is between mid-December and late January, 2) snow depth must be 20 to 80 cm and uncrusted, and 3) use a crew of 4 capable people in the aircraft. Similarly, low estimates were observed in the NWA during the winter of 1963-64, 1968-69, and 1978-79, but the underlying cause or causes were not determined.

DISCUSSION

Censuses in the NWA following the biennial moose hunts are generally lower than the preceeding no-hunt census, suggesting the technique was sensitive to population changes. In contrast, these pronounced changes corresponding to the hunt are not evident in the NEA data. I assume that the census for the NEA lacks the sensitivity displayed in the NWA due in part to the general lack of a conifer canopy making the moose very visible during the census. Dissimilarities are not limited to vegetative types and land use, but to predators and harvests with timber wolves (Canis lupus), black bear (Ursus americanus), and subsistence hunting by Native Americans being prevalent on the pre-1972 area and rare in the area added in 1972. Thus, true population changes in NWA from 1972 through 1981 were probably masked by combining two adjacent, yet very dissimilar, units into one census area.

The aerial moose census, as conducted in Minnesota, was a series of compromises tailored to fit time and budgetary restraints. Accuracy

Table 3. Moose population changes attributable to problems with census technique.

Census	Cause	Effect
Northeast		
1959-60	Crew inexperience, census in February and March	Moose in conifers
1961-62	4 people in crew reduced to 3 until 1977	Reduced number of observers, thus number of moose observations declined
1968-69	Snow depth >80 cm in mid-January	Early moose movement into conifer cover.
1972-73	Snow depth <15 cm.	Insufficient snow cover to eliminate background rock outcrops, stumps, etc., or to register tracks readily visible to census crew
1977-78	Heavy crust on snow	Restricted moose movements, thus the probability of observing moose was reduced.
Northwest		
1963-64	Unknown	Reduced estimated population
1968-69	Unknown	Reduced estimated population
1978-79	Unknown	Reduced estimated population

of the survey and size of the population can be increased by increasing search effort on plots surveyed, but increased cost/plot would reduce the number of plots surveyed. Fewer plots, in turn, may have an adverse affect on the statistical precision. In effect, precision is traded off for accuracy. Resurvey of plots or subplots (Gasaway et al. 1981) may provide an economical means of correcting for unobserved moose. Using a differential count technique (i.e. Cook and Jacobson 1979) estimates the unobserved moose but the method is expensive when used on plots, requires strata of uniform cover-type and is untested on moose.

Recognizing these limitations, the census data has been very useful in our moose management program, including alternate year moose seasons, and monitoring populations and trends from 1959 to 1981. Increases in accuracy would allow us to monitor more closely the effects of moose hunts and other factors affecting these populations and to develop a more comprehensive moose management plan.

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