TESTING THE SENSITIVITY OF MOOSE HARVEST DATA TO CHANGES IN AERIAL POPULATION ESTIMATES IN ONTARIO

H. R. Timmermann,[1] H. A. Whitlaw[1] and A. R. Rodgers[2]
[1]Ontario Ministry of Natural Resources, N.W. Region Science and Technology Section, R.R. #1, 25th Side Road, Thunder Bay, Ontario P7C 4T9; [2]Centre for Northern Forest Ecosystem Research, Lakehead University, 955 Oliver Road, Thunder Bay, Ontario, P7B 5E1.

ABSTRACT: A model for predicting moose winter density in northcentral Ontario was computed using a stepwise linear regression relating 29 aerial census estimates to 4 harvest variables: percent hunter success, percent calves in the fall harvest, days hunted per kill and moose seen per hunter. The final model was: Moose density ($/km^2$) = -0.065 + 1.073 (arcsine percent hunter success) + 0.554 (arcsine percent calves) ($F=14.25$, $df=27$, $R^2=0.528$, $p<0.05$). It was validated by comparing predicted and observed density estimates for 33 aerial censuses carried out in the same region between 1975 and 1991. Approximately half (15/33) of the predicted density values using the harvest equation fell within the 95 percent confidence interval of the aerial census estimate. Insufficient sample sizes in mail survey harvest data are believed to have contributed to variations between actual and predicted values in 8 of the 33 data sets. In future, we believe quality harvest data, especially hunter success and percent calves in the harvest, can help identify changes in population densities.

ALCES VOL. 29 (1993) pp.47-53

Effective management of moose (*Alces alces*) populations requires ongoing assessment of parameters which indicate or enumerate herd size, composition, growth rate and productivity. Rate of population change over time can be determined from a comparison of population estimates separated by one or more years. Counting moose from aircraft while they are on their winter range is considered the most practical method of estimating moose numbers over large areas on most North American ranges (Timmermann 1974). The technique is costly, especially for large areas, because it relies on aircraft and may only yield crude estimates of abundance in areas of dense forest cover.

Ontario has employed aerial surveys to estimate moose densities and population trends since the late 1950's (Trotter 1958, Lumsden 1959). Intensive searching of stratified randomly selected, standard size plots has been a key component of the province's selective harvest strategy since 1983 (Bisset 1991). In addition, Ontario collects hunter harvest data on an annual basis to help evaluate harvest in each of nearly 70 Wildlife Management Units (WMU's) with moose seasons. These WMU's were established in 1975 to allow managers to organize population data in separate geographic areas on the basis of land form, forest types, and habitat potential (Smith 1990). Selective bull and cow harvest quotas are set annually by using the most reliable moose population estimate for each WMU and are calculated on the basis of a percentage of adult cows in the herd or a percentage of the total population. However, recent reductions and restructuring of wildlife budgets are limiting the ability of managers to measure population changes and adjust harvests in a timely manner. These considerations raise the possibility that expensive aerial surveys might be supplemented by less expensive hunter surveys. The objective of this paper is to test the utility of using selected harvest parameters to help monitor changes in population densities.

METHODS

Moose populations in northcentral Ontario were estimated from sample counts of representative portions of the population by standardized aerial census (Bisset 1991). Estimated densities were derived from observed animals plus those not sighted but believed to have been missed, based on the track aggregate method (Bergerud and Manuel 1969). Surveys were conducted periodically (once every 3-4 years) between 1975 and 1991 in each of 14 WMU's of northcentral Ontario to measure population trends and estimate densities for a selective moose harvest strategy (Timmermann and Whitlaw 1992). Harvest statistics were derived from annually conducted, random post-hunt provincial mail surveys (Barbowski 1972) and voluntarily submitted jaw samples (Timmermann and Whitlaw 1992). Four selected harvest statistics were related to aerial census data using a stepwise linear regression to test their sensitivity to documented changes in population densities. Percent hunter success, average number of days hunted per moose shot and average number of live moose seen per hunter were calculated for all licensed hunters. Estimates of percent calves in the fall harvest were obtained from Big Game Harvest Cards voluntarily submitted by hunters.

The entire dataset contains 62 complete pairs of harvest and aerial survey data for analysis (Table 1). Twenty nine pairs were used to generate the regression equation, and the remaining 33 to cross-validate the model. Data were randomized by selecting every second data set (Table 1). Both harvest variables expressed as percentages (calves in the fall harvest and hunter success) were transformed using an arcsine transformation (Zar 1984). All four harvest parameters result from the autumn (October - December) harvest, 9 to 11 months after completion of the corresponding aerial survey. No attempts were made to estimate recruitment or mortality during this period. Pairwise correlation coefficients between the independent variables used to generate the equation were calculated in a correlation matrix. Similarity of the distributions of estimated (predicted from the regression equation) and observed (actual density estimates from aerial surveys) values was tested using a Kolmogorov-Smirnov goodness of fit test for continuous data. Significance was determined at α=0.05.

RESULTS

Stepwise regression analysis of the four harvest variables generated the following significant predictive equation: Moose density (/km^2) = [-0.065 + 1.073 (arcsine percent hunter success) + 0.554 (arcsine percent calves)], (F=14.25, df=27, R^2=0.528, p<0.05). Once the first 2 most significant variables (percent hunter success and percent calves in the fall harvest) were entered into the regression model, the remaining ones did not bring any improvement (Table 2). Significant correlations exist between percent hunter success and the two remaining variables, mean number of days hunted per moose (r=-0.755) and mean number of live moose seen per day hunted (r = 0.427) ($r_{0.05(2)(29)}$=0.355). Results testing the validity of the predictive equation indicate that the two sample distributions (estimated moose density from aerial survey and predicted moose density from the regression model) were not significantly different (Z=0.739, p=0.4602, n=33). The greatest variations between predicted and actual estimates occurred in 8 of 33 datasets in 5 of 14 WMUs, with two (WMU's 14 and 12A) contributing the most variation (Fig. 1).

DISCUSSION

Information on relative population changes of moose can be obtained by using an index or relative measure of population trend like hunter harvest data (Timmermann and Buss 1994). The general assumption is that as populations increase or decrease so do hunter success rates and the proportion of calves in an any sex/age harvest strategy. Since the majority of jurisdictions monitor sport har-

Table 1. A comparison of 4 selected harvest indices (% success, mean number of days hunted/moose shot, mean number of live moose seen/hunter, and % calves harvested in the fall) with moose density estimates (obtained from aerial census), for 14 WMU's in northcental Ontario, 1975-1991.

WMU	Year	(N)[1]	% success	Mean number of days hunted per moose shot	Mean number of live moose seen per hunter	%calves harvested in the fall (n)	Actual aerial census density (/km²) (± 95% CI)	Predicted density from the regression model (/km²)*
11A	1976	(76)	18.9	45.0	1.0	9.3 (55)	0.228 ± 0.06	0.190
	1980	(56)	20.3	14.0	1.4	3.6 (59)	0.134 ± 0.09	
	1984	(8)	11.5	64.1	1.0	21.4 (28)	0.168 ± 0.07	0.178
	1986	(11)	25.5	42.3	3.9	17.9 (39)	0.243 ± 0.11	
	1991	(14)	20.2	43.7	2.0	3.0 (35)	0.424 ± 0.17	0.169
11B	1984	(65)	17.5	49.7	2.9	17.4 (50)	0.270 ± 0.05	
	1989	(46)	18.6	39.5	2.0	27.0 (63)	0.290 ± 0.06	0.289
12A	1975	(223)	25.6	39.0	1.3	13.9 (204)	0.316 ± 0.18	0.290
	1979	(160)	23.0	30.6	1.6	22.7 (173)	0.268 ± 0.08	
	1982	(42)	18.8	60.9	1.4	9.6 (83)	0.342 ± 0.08	0.191
	1984	(60)	31.7	27.6	2.2	18.5 (80)	0.351 ± 0.07	
	1990	(55)	17.1	49.8	3.0	13.1 (56)	0.311 ± 0.08	0.192
12B	1975	(223)	26.6	39.0	1.3	13.9 (204)	0.402 ± 0.08	
	1979	(160)	23.0	30.6	1.6	22.7 (173)	0.395 ± 0.12	0.311
	1982	(143)	22.3	45.8	1.4	9.6 (208)	0.359 ± 0.09	
	1984	(115)	27.6	26.5	1.9	20.2 (201)	0.381 ± 0.08	0.348
	1986	(136)	18.2	49.0	2.5	24.5 (196)	0.333 ± 0.06	
	1989	(125)	22.1	33.1	2.1	26.7 (187)	0.409 ± 0.07	0.324
13	1975	(673)	23.7	39.0	1.2	15.9 (350)	0.275 ± 0.05	0.280
	1977	(505)	17.7	38.6	1.1	9.1 (291)	0.213 ± 0.05	
	1980	(429)	14.4	20.1	1.1	13.0 (227)	0.191 ± 0.03	0.163
	1981	(365)	14.8	42.7	1.4	16.2 (221)	0.255 ± 0.05	
	1983	(456)	21.3	39.3	1.8	16.3 (442)	0.260 ± 0.06	0.257
	1985	(322)	15.2	60.3	1.8	21.9 (465)	0.256 ± 0.05	
	1988	(396)	21.3	39.2	2.3	22.5 (595)	0.464 ± 0.08	0.291
14	1976	(75)	26.5	23.9	1.4	20.0 (38)	0.155 ± 0.02	0.334
	1977	(22)	39.2	13.3	2.0	16.6 (54)	0.395 ± 0.05	
	1980	(56)	32.0	6.0	2.2	14.6 (52)	0.202 ± 0.05	0.366
	1981	(26)	33.2	15.9	1.8	7.1 (47)	0.470 ± 0.09	
	1986	(34)	21.7	32.3	2.0	18.8 (48)	0.608 ± 0.18	0.275
15B	1978	(512)	17.9	35.8	1.1	17.2 (555)	0.170 ± 0.04	0.224
	1979	(464)	22.3	36.8	1.3	17.0 (693)	0.250 ± 0.06	
	1982	(231)	20.0	56.0	1.9	15.4 (455)	0.230 ± 0.06	0.237

Table 1 (cont'd)

WMU	Year	(N)[1]	% success	Mean number of days hunted per moose shot	Mean number of live moose seen per hunter	%calves harvested in the fall (n)	Actual aerial census density (/km²) (± 95% CI)	Predicted density from the regression model (/km²)*
15B	1985	(274)	18.6	44.8	1.6	15.2 (341)	0.212 ± 0.05	
	1989	(277)	16.6	45.3	1.5	15.9 (333)	0.255 ± 0.06	0.203
	1991	(149)	16.5	43.2	1.7	18.7 (284)	0.364 ± 0.06	
16C	1981	(93)	19.6	28.6	2.2	6.5	0.05 ± 0.01	0.182
	1984	(158)	17.7	47.1	1.4	21.4 (51)	0.13 ± 0.03	
	1990	(64)	15.1	59.2	1.4	4.5 (67)	0.10 ± 0.02	0.171
17	1984	(148)	14.2	48.1	0.8	14.8 (52)	0.05 ± 0.01	
18A	1978	(72)	10.6	37.4	0.9	9.1 (48)	0.128 ± 0.02	0.099
	1981	(44)	13.9	37.4	1.3	15.4 (27)	0.062 ± 0.01	
	1983	(102)	14.5	45.4	1.0	9.1 (33)	0.141 ± 0.04	0.142
	1985	(84)	10.0	73.5	1.7	14.3 (42)	0.103 ± 0.02	
	1989	(59)	6.8	116.8	1.3	7.7 (39)	0.079 ± 0.02	0.051
18B	1978	(72)	10.6	37.4	0.9	9.1 (48)	0.07 ± 0.01	0.099
	1985	(15)	28.2	26.6	2.8	0.0 (7)	0.10 ± 0.02	
19	1978	(181)	18.9	14.6	1.0	17.3 (175)	0.105 ± 0.02	0.235
	1980	(356)	7.7	40.4	0.8	23.4 (141)	0.105 ± 0.02	
	1982	(175)	11.7	121.5	1.1	12.4 (186)	0.163 ± 0.05	0.129
	1984	(179)	10.7	84.8	1.0	15.3 (118)	0.156 ± 0.07	
	1987	(138)	10.8	75.6	1.6	15.9 (88)	0.133 ± 0.03	0.139
	1990	(63)	12.1	78.1	2.1	19.0 (63)	0.130 ± 0.03	
21A	1979	(759)	14.1	52.9	1.0	13.0 (652)	0.170 ± 0.04	
	1983	(472)	14.7	55.3	1.2	10.9 (330)	0.220 ± 0.05	0.154
	1986	(357)	13.2	62.2	1.3	16.9 (284)	0.180 ± 0.04	
	1990	(130)	12.1	66.0	1.4	13.2 (280)	0.180 ± 0.04	0.138
21B	1979	(759)	14.1	52.9	1.0	13.0 (652)	0.190 ± 0.05	
	1982	(328)	11.2	112.4	1.0	11.7 (324)	0.170 ± 0.04	0.120
	1985	(382)	13.9	62.7	1.2	15.1 (311)	0.170 ± 0.03	
	1988	(428)	12.8	63.9	1.2	15.9 (315)	0.190 ± 0.05	0.161
	1991	(119)	12.0	75.4	1.8	16.3 (123)	0.170 ± 0.12	

[1] Source: Provincial Mail Survey

* Density predicted in 33 data sets derived from the regression equation correlating 29 of 62 pairs of harvest and aerial survey data

Table 2. Dependence of moose density on arcsine percent hunter success and arcsine percent calves, as determined by stepwise multiple regression.

Independent variables	Increment in R^2	F	df	P
Arcsine percent success	0.454	22.43	28	$p<0.05$
Arcsine percent calves	0.074	14.52	28	$p<0.05$
Mean number of live moose seen per day hunted	0.0			
Mean number of days hunted per adult moose shot	0.0			
	Overall F-test			
R^2	0.528			
Adjusted R^2	0.491			
$F_{2,27}$	14.28			

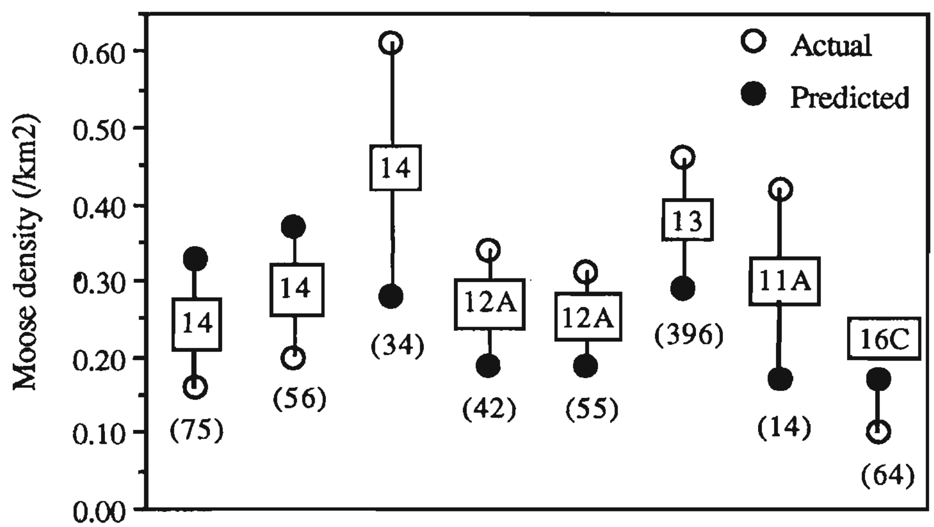

Fig. 1. Variation between actual and predicted density estimates for 8 of 33 datasets showing the greatest variation, out of 33 datasets used. (WMU number in each box).

vests closely, harvest magnitude and composition could conceivably help managers determine population trends. Harvest quotas for Montana, for example, are routinely determined in part by range conditions, age structure of the harvest, and past hunting success (Stevens 1971). In Newfoundland, Mercer and Manuel (1974:662) reported that hunter success and the number of moose seen per day provided "perhaps the best data to indicate population changes". Daily success declined 52% and moose seen per day decreased 53% between 1960 and 1972. A population decline was also indicated by quadrat aerial census after 1965 and decreases of 76, 60, and 33% occurred between 1964 and 1972 in three management areas. In Quebec, Crête *et al.* (1981) and Crête and Dussault (1987) reported an inverse relationship between hunting effort (hunter days per moose killed) and moose density (R^2=0.99), suggesting that declining success was caused by declining moose populations. Additionally, densities were positively related to moose harvest per 10km^2. However, several authors caution that total kill may only be broadly indicative of population levels and may not necessarily reflect fluctuations in effort to achieve success (Peterson 1955, Pimlott 1961, Lykke and Cowan 1968). Further, Crête and Dussault (1987) caution that although assessment of moose density, recruitment and harvest rate through hunting statistics is possible, confidence intervals of single predictions are wide.

Hunting season length, licence fee increases, transportation costs, weather, and changing harvest strategies can all affect harvest statistics (Crichton 1993). Ontario, for example, employed three distinct moose harvest strategies over the past three decades (Timmermann and Whitlaw 1992). Our data span a portion of this period and are therefore influenced by such changes. In Alberta, hunter days statistics were biased because hunters often reported the length of their hunting trip (ie. 5 days) even when they killed a moose the first day and really only hunted 1 day (Lynch pers. comm. 1993).

Recently Courtois and Crête (1993) in Quebec reported that the best independent variables in their regression model for predicting moose density were: harvest per 10 km^2, longitude, number of calves per female, latitude and group of hunting zones ($R^2 = 0.76$, $n = 49$, $p = 0.0001$). In our analysis, percent hunter success and percent calves in the fall harvest appeared to correlate well with aerial census density estimates. The magnitude of variation occurring in 8 of 33 sets of data representing 5 of 14 WMU's might be attributed in part to low sample sizes (Table 1). Our harvest statistics were obtained from the provincial mail survey dataset that randomly samples 10% or less of the total number of licensed hunters annually. These results are believed to provide reasonably accurate information on a regional and provincial basis. At the WMU level however, a low sample is frequently obtained particularly for less popular WMUs. These harvest estimates are less precise and in many cases inaccurate (Gollat and Timmermann 1987). The parallel district post card survey introduced in 1984 is considered to yield more accurate results because of its timing and higher sampling rate (ie. 50-100%). Unfortunately, this dataset only spans the period 1984-1992, and thus we employed the less accurate provincial mail survey statistics in our analysis.

Our regression model was generated from a long-term (16 year) dataset using standardized aerial census and harvest data evaluations. We caution readers attempting a similar analysis to meet these criteria. Although aerial surveys provide more accurate population estimates, we believe quality harvest data can be a useful tool in helping to identify changes in WMU population densities. We recommend higher quality district mail survey data should be phased in to replace provincial harvest statistics.

ACKNOWLEDGEMENTS

Our appreciation is extended to all hunters who submitted data, staff of districts who recorded the information and to the pilots and crew of survey aircraft. We thank H. Cumming, School of Forestry, Lakehead University, Thunder Bay, Ontario and comments by 2 anonymous referees for their critiques of the manuscript and suggestions for improvement. Travel costs to attend the 29th Conference and Workshop were shared among the Ontario Federation of Anglers and Hunters, the Ontario Ministry of Natural Resources and the senior author in a partnership agreement.

REFERENCES

BARBOWSKI, J. 1972. Mail surveys of moose hunters in Ontario. Proc. N. Am. Moose Conf. Workshop 8: 326-339.

BERGERUD, A. T., and F. MANUEL. 1969. Aerial census of moose in central Newfoundland. J. Wildl. Manage. 32: 729-

746.

BISSET, A. R. 1991. Standards and guidelines for moose population inventory in Ontario. Ont. Min. Nat. Resour., Wildl. Br., Toronto. 37pp.

COURTOIS, R., and M. CRÊTE. 1993. Predicting moose population parameters from hunting statistics. Alces 29:75-90.

CRÊTE, M., R. J. TAYLOR, and P. A. JORDAN. 1981. Optimization of moose harvest in southwestern Quebec. J. Wildl. Manage. 45: 598-611.

_______, and C. DUSSAULT. 1987. Using hunting statistics to estimate density, cow-calf ratio and harvest rate of moose in Quebec. Alces 23: 227-242.

CRICHTON, V. F. J. 1993. Hunter effort and observations- the potential for monitoring trends of moose populations - a review. Alces 29:181-185.

GOLLAT, R., and H. R. TIMMERMANN. 1987. Evaluating Ontario moose harvests using a postcard questionnaire. Alces 23: 157-180.

LUMSDEN, H. G. 1959. Ontario moose inventory winter, 1958-59. Ont. Dep. Lands and For. Rep., Toronto. 11pp.

LYKKE, J., and I. M. COWAN. 1968. Moose management and population dynamics on the Scandinavian Peninsula, with special reference to Norway. Proc. N. Am. Moose Conf. Workshop 5: 1-18.

MERCER, W. E., and F. MANUEL. 1974. Some aspects of moose management in Newfoundland. Naturaliste can. 101: 657-671.

PETERSON, R. L. 1955. North American Moose. Univ. of Toronto Press. 280pp.

PIMLOTT, D. H. 1961. The ecology and management of moose in North America. Terre et Vie 2: 246-265.

SMITH, H. 1990. Managing a moose population. Pages 25-29 *in* M.Buss and R. Truman, eds., The Moose in Ontario, Book 1. Ont. Min. Nat. Resour., Wildl. Branch., Toronto. 78pp.

STEVENS, D. 1971. Shiras moose. Pages 89-95 *in* T.W.Mussehl and F.W. Howell eds. Game management in Montana. Dep. Fish. Wildl. and Parks, Fed. Aid Wild. Restor. Proj. Rep. Helena.

TIMMERMANN, H. R. 1974. Moose inventory methods: a review. Naturaliste can. 101: 615-629.

_______, and H. WHITLAW. 1992. Selective moose harvest in North Central Ontario - a progress report. Alces 28: 137-163.

_______, and M. E. BUSS. 1994. Population and harvest management. *in* A.W. Franzmann and C.C. Schwartz, eds. Ecology and management of moose in North America. Wildl. Manage. Instit., Stackpole Books: (in prep).

TROTTER, R. H. 1958. An aerial census technique for moose. NE. Sect. Wildl. Soc. Mimeogr. 10pp.

ZAR, J. H. 1984. Biostatistical Analysis: Second Edition. Prentice Hall, New Jersey. pp 162-205.