IMPORTANCE OF MOOSE IMMIGRATION INTO A HEAVILY HUNTED AREA FROM AN UNHUNTED AREA

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ABSTRACT: Collection of 4 years of data facilitated modelling the moose (*Alces alces*) population in a 269 km² study area adjacent to Algonquin Park, Ontario. Modelling indicated that a minimum immigration of 7 males and 6 females annually would be necessary to maintain population numbers in the study area while sustaining a controlled hunt. Immigrants would likely come from Algonquin Park.

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Moose (*Alces alces*) are known to emigrate from unhunted Algonquin Park, Ontario, to the heavily hunted areas adjacent to Algonquin Park (Wilton and Bisset 1988).

Ontario presently employs a selective harvest system; bull and cow permits are issued through a draw system to maintain moose numbers at desired levels. The importance of immigration into managed areas as well as the productivity of resident moose must be understood if the selective harvest system is to attain its goal. The objective of this study was to examine the importance of immigration into the study area.

STUDY AREA AND METHODS

Algonquin Provincial Park (45° 39'N, 78° 39'W) is located in south central Ontario between Georgian Bay (Lake Huron) and the Ottawa River and is approximately 7314 km² in area. The 269 km² study area is located between Kearney, Ontario, and the western boundary of Algonquin Park. Road access to and from the area is limited to the Rain Lake Road which runs between Kearney and the Rain Lake access point to Algonquin Park (Fig. 1).

Between 1985 and 1988 a check station was operated on the Rain Lake Road 1 km east of Kearney during the entire moose season (6 days/year). Data was gathered from all moose hunters exiting the study area, including hunter effort and success (Table 1). Incisors were extracted from all harvested moose, except calves, for cementum aging. Estimates of winter moose density were obtained following each hunt by flying randomly chosen permanent aerial plots which fell within the study area (Table 2). For purposes of analysis, the area was divided into two stratums (high and low) based on observed densities of moose. Statistical Analysis System (SAS Institute, 1985) computer software was used to investigate trends in moose density and harvest per unit hunter effort from 1985 to 1988 using the general linear model procedure's *t*-test for H_o: slope=0.

Moose recruitment into the study area is through reproduction and/or immigration. A deterministic demographic model was developed to estimate the contributions of reproduction and immigration to recruitment. Basic model assumptions were: 1) no emigration from the study area, 2) all reproductively active females bred successfully, 3) maximum reproduction in females began at age 2, 4) males first bred at age 2, 5) population was at stable age distribution and sex ratio, 6) 1:1 sex ratio at birth, 7) equal vulnerability of adults (non-calves) to harvest. Total harvest sample from 1985 to 1988 was used to calculate the age specific frequency distribution for age classes 1 to 10+ for both males and females. Age specific survival rates for age classes 1 to 10+ were calculated from the age specific frequency distribution using

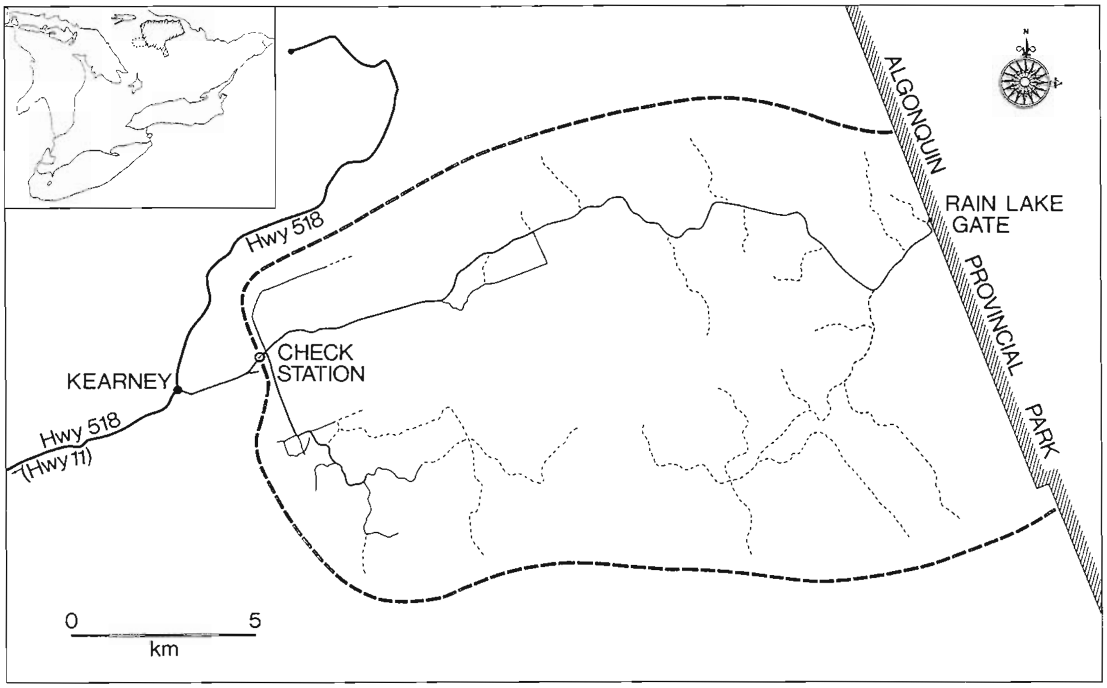

Fig. 1. Study area in Algonquin Region, Ontario, Canada showing location of Kearney check station.

Chapman-Robson (1960) method (Table 3). Calves (age class 0) were truncated due to probable harvest bias (Boer 1990a). Calf survival was estimated to be 0.50 (Garner, unpubl. data). Since K carrying capacity (KCC) on the study area is unknown, estimates of age specific fecundity rates below, near, and above KCC from Boer (1990b) were used (Table 4). Finite rate of increase (λ) for males and females was calculated from estimated survival and fecundity rates using Leslie projection matrices (Getz and Haight 1989). The stable sex ratio was estimated using the method of Caughley (1977).

Immigration of males and females was calculated by multiplying their λ by their mean number in the study area population, then subtracting that figure from the mean number of males or females, the result being equal to the immigration required to maintain numerical stability for the next year. In addition to calculations based on observed densities in the study area, the required immigration to maintain a desired density of 0.4 moose/km^2 was also calculated.

All calculations of immigration are based on estimates of the mean number of moose in the study area from 1985 to 1988 (both high and low strata). The specific population parameter(s) accounting for annual fluctuations in population size remains unknown. Mean density values were used to provide more representative results of perceived population conditions because of the annual changes in the population density estimates. Therefore, values derived are representative of the average moose population levels for the study period.

RESULTS

Summarization of harvest data gathered during the 4 year period from 1985 to 1988 suggests no significant trend ($P = 0.3728$) in population numbers within the study area based on harvest per unit effort (Table 1, hunter effort). The estimated total population in the study area (Table 2) from 1985 to 1988 also suggests no significant trend over time (*P*

Table 1. Summary of data gathered from the Kearney Check Station, 1985 to 1988, Algonquin Region, Ontario, Canada.

	1985	1986	1987	1988
Total Hunters	564	543	556	426
Total Moose Harvested	60	58	42	40
Overall Success (%)	10.6	10.7	7.6	9.4
Bull Permits	87	103	122	89
Cow Permits	31	18	24	21
Total Permits	118	121	146	110
Bulls Harvested	31	36	27	20
Bull AVT* Filling Rate (%)	34.6	35.0	22.1	22.5
Cows Harvested	21	15	8	11
Cow AVT Filling Rate (%)	67.7	83.3	33.3	52.4
Overall Filling Rate (%)	44.1	42.1	24.0	28.2
Calves Harvested	8	7	7	9
Percent Calves in Harvest	13.3	12.1	16.7	22.5
Total Non AVT Holders	446	422	410	316
Non AVT Holders Success Rate	1.8	1.7	1.7	2.8
Hunter Effort**	33.6	33.6	48.1	39.9
Hunters/km²	2.1	2.0	2.1	1.6
Harvest/km²	0.22	0.22	0.16	0.15

* Adult Validation Tag.
** Hunter Days/Moose Harvested.

Table 2. Post-hunt moose density and population estimates for Kearney study area, 1985 to 1988, Algonquin Region, Ontario, Canada.

	Low Stratum (94.15 km²)		High Stratum (174.85 km²)		
Year	Density[1]	Estimated Population	Density[1]	Estimated Population	Total Estimated Population
1985	0.16	15	0.27	47	62
1986	0.04	4	0.42	73	77
1987	0.20	19	0.35	61	80
1988	0.04	4	0.24	42	46

[1] From aerial surveys (moose/km²).

Table 3. Estimated survival rates of Kearney study area moose population based on age specific frequency distribution of harvest.

Males							Females					
Age Class	1985	1986	1987	1988	Total	Survival Estimate	1985	1986	1987	1988	Total	Survival Estimate
0	3	4	4	3	14	0.50[1]	5	3	3	6	17	0.50[1]
1	7	10	12	9	38	0.62[2]±.06	7	3	2	3	15	0.67[2]±.08
2	5	8	5	3	21	0.62	1	3	3	3	10	0.67
3	11	10	4	4	29	0.62	7	3	0	1	11	0.67
4	1	3	1	3	8	0.62	0	1	0	1	2	0.67
5	1	3	2	1	7	0.62	3	2	2	0	7	0.67
6	0	2	1	0	3	0.62	0	1	0	0	1	0.67
7	0	0	1	0	1	0.62	0	0	0	0	0	0.67
8	0	0	0	0	0	0.62	0	0	0	1	1	0.67
9	1	0	0	0	1	0.62	0	0	0	0	0	0.67
10+	1	0	1	0	2	0.00	1	1	0	0	2	0.00

[1] Estimated from D.L. Garner, Algonquin Provincial Park, 1990, unpubl. data.

[2] Estimated from Chapman and Robson (1960).

Table 4. Age specific moose fecundity rates for populations below, near, and above K carrying capacity (KCC).

	Fecundity Rate[1]		
	Age 0	Age 1	Ages 2-10+
<KCC	0.000	0.325	0.620
~KCC	0.000	0.205	0.530
>KCC	0.000	0.090	0.440

[1]Fecundity (females per female) after Boer (1990a).

= 0.6283). Harvest has averaged 78% of the previous post-hunt population over the 4 year period, suggesting that considerable recruitment is occurring to maintain population numbers. Reproduction could account for some, but probably not all of the necessary recruitment.

Using mean population estimates from 1985 to 1988 and assumed survival and fecundity levels, results of the modelling show that varying levels of immigration are needed to maintain population numbers (Table 5). In the low stratum area, assuming the population is below KCC, net required immigration to maintain mean population numbers is 1.14 males and 1.01 females annually. In the same area, assuming the population is near KCC, the annual net immigration required is 1.29 males and 1.12 females. An annual net immigration of 1.45 males and 1.28 females is needed in the low stratum area to maintain population numbers assuming the current population is above KCC. In the high stratum area, assuming the population is below KCC, net annual immigration required is 6.04 males and 5.38 females. Assuming the population is near KCC for the high stratum area, the annual net immigration required is 6.86 males and 5.94 females. The required net annual immigration in the high stratum area, assuming the population is above KCC, is 7.69 males and 6.79 females to maintain population numbers.

Table 5. Calculations of net annual immigration required to maintain population numbers under various K carrying capacities (KCC) on 269 km² study area.

	Low Stratum (94.15 km²)					High Stratum (174.85 km²)					Entire Area (269 km²)		
		Mean No.		Net Immigration			Mean No.		Net Immigration		Net Immigration		
	Mean N	Male	Female	Male	Female	Mean N	Male	Female	Male	Female	Male	Female	Total
<KCC[1]	10.50	5.17	5.33	1.14	1.01	55.75	27.45	28.30	6.04	5.38	7.18	6.39	13.57
~KCC[2]	10.50	5.17	5.33	1.29	1.12	55.75	27.45	28.30	6.86	5.94	8.15	7.06	15.21
>KCC[3]	10.50	5.17	5.33	1.45	1.28	55.75	27.45	28.30	7.69	6.79	9.14	8.07	17.21

[1]Male λ=0.78, female λ=0.81, stable sex ratio=0.97:1.00 (male:female).
[2]Male λ=0.75, female λ=0.79, stable sex ratio=0.97:1.00 (male:female).
[3]Male λ=0.72, female λ=0.76, stable sex ratio=0.97:1.00 (male:female).

Thus estimates of required immigration into the entire study area (Table 5) range from 7.18 to 9.14 males per year and 6.39 to 8.07 females per year (13.57 to 17.21 total), depending on recruitment due to reproduction (i.e., estimated fecundity).

Modelling for a desired moose population density within the combined study area (Table 6) revealed that a minimum net annual immigration of 11.70 males and 10.42 females would be required to maintain population numbers, assuming the population was below KCC. A desired population near KCC would require a net annual immigration of 13.30 males and 11.51 females. The net annual immigration required to maintain population numbers, assuming the population was above KCC, would be 14.89 males and 13.16 females.

DISCUSSION

Modelling estimates the number of immigrating moose required to maintain the moose population at its average level from 1985 to 1988. Substantial year-to-year variations in moose density have been observed on both the high and low stratum areas. Possible reasons for the variations in moose densities may be the result of: 1) annual variation in immigration in any given year (i.e., immigration may have been substantially higher or lower than the average requirement), 2) survival rates in any given year may have been higher or lower than the calculated average,

Table 6. Calculations of net annual immigration required to maintain population numbers for desired population density (0.4 moose/km²) under various K carrying capacities (KCC) on 269 km² study area.

		Mean No.		Net Immigration		
	Mean N	Male	Female	Male	Female	Total
<KCC[1]	108.00	53.18	54.82	11.70	10.42	22.12
~KCC[2]	108.00	53.18	54.82	13.30	11.51	24.81
>KCC[3]	108.00	53.18	54.82	14.89	13.16	28.05

[1] Male λ=0.78, female λ=0.81, stable sex ratio=0.97:1.00 (male:female).

[2] Male λ=0.75, female λ=0.79, stable sex ratio=0.97:1.00 (male:female).

[3] Male λ=0.72, female λ=0.76, stable sex ratio=0.97:1.00 (male:female).

3) fecundity may have deviated in any given year from the values used for below, near, and above KCC. In addition, errors in aerial inventory and estimated harvest may decrease or increase respectively, the amount of immigration needed to sustain population numbers.

The efficacy of any modelling exercise is best evaluated with respect to the underlying assumptions concerning vital rates. The assumption that no emigration from the study area is occurring is tenuous. If emigration is occurring, then immigration must increase in order to maintain population numbers. Any assumptions regarding "average conditions" is also questionable. The stochasticity of natural systems makes predictions based on the model of dubious value. However, assuming reasonable accuracy in the model parameters, it does suggest that recruitment through reproduction does not account for relative constancy of moose numbers on the study area and that immigration must be occurring. Further, if a desired moose population density is to be achieved, a decrease in harvest or natural mortalities and/or an increase in immigration or reproduction is required.

Calculated results of immigration indicate that the Algonquin Park moose population may play an important role in maintaining population numbers within the study area. Possible management implications of immigration into the heavily hunted Wildlife Management Units (WMU'S) adjacent to Algonquin Park may be calculated as follows. A square equivalent in area to Algonquin Park (7314 km^2) possesses a perimeter of 342.0 km. The study area includes 17.7 km of Algonquin Park boundary (Fig. 1). Assuming that the calculated rates of immigration into the study area are representative, then total immigration into the WMU'S adjacent to Algonquin Park may equal 19.3 ($342 \div 17.7$) times the magnitude of immigration into the study area, or 290 (19.3 X 15) moose annually (assuming near KCC fecundity). The estimated 1989 harvest in the four WMU'S (48, 50, 54, 55 a and b) adjacent to Algonquin Park was 401 moose. Therefore, it is possible that immigrants could replace 72% ($290 \div 401$ X 100) of the estimated harvest.

The results presented indicate the potential importance that immigration may play in sustaining population numbers within a given area. The modelling is presented as an aid to thinking and interpreting field data. Further information on specific population demographic parameters is needed to fine tune the model for predicting the rate of immigration. Model results of required immigration rates allude to the importance of careful monitoring of the Algonquin Park moose population. Failure to do so could result in improper harvest levels in the WMU'S adjacent to Algonquin Park in the event of an unrecorded significant increase or decrease in the Algonquin Park moose population.

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