ABSTRACT: The Shabotik area was shown to have sustained high moose (Alces alces) harvests since the area was opened to the public in 1966. Aerial census data and a productivity index taken from the harvest data indicated a stable age distribution justifying the use of life table analysis of harvest data. Net productivity was initially calculated for the years 1966 to 1969 by following the yearly cohorts. The average net productivity was 25.5%. Yearling vulnerability was calculated which in turn allowed a calculation of the average net productivity for those years of 1966 to 1974. The average net productivity value was 25.7%. A transformation of life table data into natural logarithms allowed the calculation of the average mortality rate for those years of 1967 to 1974, this value was 24.8%. It was concluded that the annual net productivity rate equalled the annual mortality rate (\( r_m = q_x \)). With knowledge of the size of the annual harvest and some knowledge of the probable extent of wolf predation on moose it was possible to calculate a minimum pre-hunt population size. Adjusting this population estimate to a mid-winter estimate indicated that this minimum estimate was 273% higher than the
average January aerial census figures.

INTRODUCTION

In 1966 a half dozen moose management areas were established in Northern Ontario. Their purpose was to collect detailed moose harvest and hunter data on which to base management decisions.

The Shabotik was one such area chosen. It is located on the Trans-Canada Highway (#17) north of Lake Superior halfway between Thunder Bay (368 km. to the west) and Sault Ste. Marie and the Michigan, U.S. border (352 km. to the southeast).

The 804 km$^2$ Shabotik unit was logged for pulpwood from 1942 to 1964 and 39% of the area was cut during that time. Skidding was done by horses and cutovers were relatively small. Areas left were principally aspen Populus tremuloides, birch Betula papyrifera ridges and black spruce Picea mariana swamps. A fire in 1954 consumed 10% of the Shabotik area.

The Shabotik's 180 kilometers of roads were opened to the public in 1966. Prior to this time the only hunting was done by Abitibi employees and fly-in hunters, the total seasons harvests were thought to be less than 50 moose (R. Jerrard pers. comm.).

A check station was set up in 1966 to monitor the first two weeks of the harvest; an average of 69% of the total seasons harvest occurs during this time period. The check station has operated in the Shabotik each year since 1966.
The sustained heavy harvests that have occurred in the Shabotik since 1966 has given it the reputation of being one of the highest quality moose habitats in north central Ontario.

The continuous operation of a check station in the Shabotik, intensive aerial censuses since 1969 and a thorough knowledge of the area by district wildlife staff has allowed a calculation of:

1. harvest size
2. age structure
3. net productivity
4. annual mortality
5. a minimum population size

The harvest sample is taken to represent the living population and a life table constructed from the harvest data is consequently considered to reflect the living population structure.

To justify the use of life table data the following assumptions have to be tested. First the sample collected must come from a stable age distribution (Caughley, 1966; Wilson et al., 1971, 127) and secondly the sampling method must be free of sampling bias. The Shabotik moose population will be thought to be stable if it can be shown that the population size has remained constant, that recruitment has remained constant and there has been no significant ingress or egress in the study area over the time period of the study. Hunter sampling bias of moose is known to occur in the two youngest age classes with calves being under represented, yearlings over represented. There is also a sex bias with bulls being over represented (Pimlott, 1959; Simkin 1965). Caughley (1966) recognized that most game populations are over sampled in the younger age classes and concluded that the mortality rate curve ($q_x$) is the least
influenced by bias and therefore the most efficient life table series for comparing the pattern of mortality with age in different populations.

METHODS

The early season harvests were monitored by a check station located at the entrance of the Shabotik's road system. Each vehicle entering the Shabotik was stopped, a check-in form completed and a numbered tag attached to the hunter's windshield. Upon leaving a check-out form was completed allowing a calculation of hunting pressure and success rates. A harvest data form was completed for each successful hunter. Hunters were encouraged to return the lower moose jaw; "Successful Hunter" crests were an extra incentive given in return for the lower jaw. Moose were aged by the wear class method (Passmore et al., 1955) in 1966 and by cementum annulations of the first incisors (Sergeant et al., 1959) for each year after 1966. Calves and yearlings for 1966 were included in cohort net productivity calculations.

Total season harvests were measured in 1966, 1973 and 1974 from a combination of check station data, export permits and contact with resident hunters when they returned the lower moose jaws at various government offices in the province. Total season harvests were calculated for 1966, 1967 and 1968 using temporal kill data obtained from district mailed game surveys for those three years and applying the percent district kill during the time of the check station operation to the check station harvests. Unfortunately district mailed game surveys were not conducted after 1968, however, the average harvest rate obtained from mailed game
surveys conducted in the White River District from 1957 to 1968 were applied to the average check station harvest from 1966 to 1972 to enable a calculation of total season harvest for those years.

A standardized aerial moose inventory was developed for the Shabotik and conducted each January from 1969 to 1975. This inventory was conducted with a turbo Beaver and a three man observing crew. Transects were flown at \( \frac{1}{2} \) mile (0.8 km.) wide intervals; when moose were spotted or were indicated by the amount of fresh track activity the area was circled. Circling was continued until the navigator was confident that no more moose remained to be counted.

The number of wolves inhabiting the Shabotik during the winter was estimated from two sources of information; personal knowledge of the area by district wildlife staff and extrapolation of the findings of an intensive wolf inventory (Bergerud 1975) in the proposed Pukaskwa National Park located 48 km. south of the Shabotik.

It is preferable in population analysis to deal with the male and female segments of the population separately, however the sample sizes of aged moose in this study were too small to warrant separation into two segments.

RESULTS AND DISCUSSION

A requirement that must be met before the use of life table data is justified is that there has not been a significant ingress or egress of animals in the study area. Moose are known not to be a strongly territorial species (Peterson, 1955, 113) therefore the removal of moose should not in itself trigger the movement of moose from surrounding areas into areas formerly occupied. Moose in mountainous
areas and in tundra areas commonly follow yearly migration routes (Houston, 1968; Edwards and Ritcey, 1956); no significant migrations have been noted in Ontario's taiga habitat (Peterson, 1955, 110; Goddard, 1970; Saunders, et al., 1972).

Goddard (1970) concluded from tagging programs conducted in the vicinity of the town of Geraldton, located approximately 320 km. northwest of the Shabotik, that there was no evidence of a directional tendency of moose to move from unhunted areas to heavily hunted areas. Saunders et al. (1972) reported on a similar tagging experiment in the Red Lake Road area of Northwestern Ontario; they could find no significant differences in the dispersal of male and female moose, between young and old moose of the same sex, between the distance moved and the number of years between tagging and recovery nor did they find any preference in direction of movement from tagging to recovery site. It is concluded from this evidence that there probably has been no significant ingress or egress of moose in the Shabotik.

Standardized aerial censuses were conducted each January from 1969 to 1975 (Graph 1). It is realized that these censuses do not account for all the moose present (LeResche et al., 1974), rather these censuses are collectively regarded as a population index. The best line of fit for the census data gives a flat slope which indicates no major population change in the last seven years.

Net productivity in this paper has the same meaning as it did for Pimlott (1959) and Sinkin (1965) i.e. the percentage that can be removed yearly without diminishing the population; in this definition it is realized that the proportion that can be removed implies natural mortality as well as hunter harvest. This study has not considered
Graph 1

AERIAL MOOSE CENSUS RESULTS 1969 - 1975

<table>
<thead>
<tr>
<th>YEAR</th>
<th>CODED YEAR (X)</th>
<th>MOOSE SIGHTED (Y)</th>
</tr>
</thead>
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<tr>
<td>1969</td>
<td>1</td>
<td>140</td>
</tr>
<tr>
<td>1970</td>
<td>2</td>
<td>175</td>
</tr>
<tr>
<td>1971</td>
<td>3</td>
<td>187</td>
</tr>
<tr>
<td>1972</td>
<td>4</td>
<td>198</td>
</tr>
<tr>
<td>1973</td>
<td>5</td>
<td>138</td>
</tr>
<tr>
<td>1974</td>
<td>6</td>
<td>150</td>
</tr>
<tr>
<td>1975</td>
<td>7</td>
<td>167</td>
</tr>
</tbody>
</table>

$Y = 0.64X - 167$
gross productivity but only net productivity, that is the proportion of the population being recruited into the pre-hunt population.

An index to net productivity was initially used to determine whether there had been population structural changes due to fluctuating productivity. The net productivity index used was yearlings in the harvest divided by yearlings plus adults. This would be an actual measurement of net productivity except for the commonly found positive hunter bias to yearlings (Pimlott 1959; Simkin 1965). Yearlings are used rather than calves because although over represented they are still a better representation than calves are (Pimlott 1959; Simkin 1965).

The best line of fit for this data (Graph 2) has a slope that is nearly flat, as well, no individual year is drastically different from the mean of 31.8%, the standard deviation of the mean was 5.6. This is interpreted as indicating that no major population structure changes have occurred as a result of changes in the productivity between 1966 and 1974.

The net productivity was calculated for individual years of 1966, 1967, 1968 and 1969 by following individual cohorts through the years in the life table (Table 1). Cohorts were followed and the number of moose in each cohort was divided by the number of moose on the cohort line and under the cohort line.

Using this method the net productivity for 1966 was 28.2%, 1967 was 24.1%, 1968 was 24.1% and 1969 was 23.3%. The 4 year mean average was 25.0%. Net productivity for years after 1969 was not calculated because of the limited number of years through which these cohorts could be followed.
Graph 2  
Productivity Index 1966 - 1974

<table>
<thead>
<tr>
<th>YEAR (X)</th>
<th>CODED YEAR</th>
<th>PRODUCTIVITY INDEX (Y)</th>
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<td>1966</td>
<td>1</td>
<td>33.3</td>
</tr>
<tr>
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<td>2</td>
<td>32.4</td>
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<td>33.3</td>
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<td>8</td>
<td>36.5</td>
</tr>
<tr>
<td>1974</td>
<td>9</td>
<td>38.6</td>
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</table>

\[ Y = 31.8 \]

\[ Y = 0.47X + 29.3 \]
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<tbody>
<tr>
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<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>12+</td>
<td>-</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<td>0</td>
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<td>1</td>
</tr>
<tr>
<td>13+</td>
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<td>0</td>
<td>0</td>
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<td>2</td>
<td>1</td>
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</tr>
<tr>
<td>N</td>
<td>49</td>
<td>39</td>
<td>41</td>
<td>47</td>
<td>33</td>
<td>53</td>
<td>49</td>
<td>66</td>
<td>55</td>
</tr>
</tbody>
</table>

Calculation of Net Productivity

$\text{cohort line} \div (\text{cohort line} + \text{everything under cohort line})$
The average net productivity from 1967 to 1974 was calculated by first adding the individual yearly harvest age structures (Table 1) together to produce the life table shown in Table 2. The 1966 data was not included because these moose were aged by the wear class method and Addison et al. (1974) could find no acceptable way to transfer wear class ages of older animals to actual yearly ages. It has already been stated that yearlings are over-represented in hunter harvests, the vulnerability of yearlings was computed by dividing the uncorrected percent yearlings in the adult harvest (Graph 2) by net productivity of that year from 1966 to 1969 (taken from Table 1).

1966 vulnerability $\frac{31.3}{28.2} = 1.18$

1967 vulnerability $\frac{32.4}{24.2} = 1.34$

1968 vulnerability $\frac{23.0}{24.1} = 0.95$

1969 vulnerability $\frac{34.8}{23.3} = 1.49$

The 4 year mean average yearling vulnerability was 1.24. The 1966 to 1969 mean average yearling vulnerability was taken to represent the average yearling vulnerability from 1967 to 1974.

The average net productivity was calculated similar to Pinlott (1959) and Simkin (1965).

$$P = \frac{Y \times 1}{Y + A \times \frac{1}{\text{vulnerability}}} \times 100$$

$$= \frac{118 \times 1}{370 \times 1.24} \times 100$$

$$= 25.7\%$$
Where $P$ represents net productivity

$Y$ is equal to the number of yearlings (Table 2)

$A$ is equal to the number of adults (Table 2)

The net productivity has been calculated independent of mortality rates other than, of course, the proportion of yearlings in the harvest and the magnitude of the cohort lines.

Net productivity of 25.0% or 25.7% is similar to what Pinlott (1959) found in Newfoundland (20 - 25%) and Simkin (1965) found in Northwestern Ontario (24%).

The annual mortality rate was obtained by first transferring age class abundance of harvested moose into their natural logarithms (Table 2) and plotting the natural logarithms of age class abundance against their age classes (Graph 3). The antilog of the slope of the best line of fit of these plotted points is equal to the annual survival rate (Ricker, 1958; Laws, 1974) and consequently one minus the antilog of the slope is equal to the annual mortality rate. Annual mortality is seldom constant throughout the entire lifespan of most animals. Most long lived animals have initial high mortality followed by a relatively constant mortality rate through the adult years with increased mortality in old age, for this reason different portions of life table data were taken and the best lines of fit determined for each. The following are four equations for different age intervals:

1. $\ln Y = -284.9X + 4.51, r = .968$ Age 1 to age 13
2. $\ln Y = -302.1X + 4.75, r = .841$ Age 1 to age 14
3. $\ln Y = -269.0X + 4.60, r = .960$ Age 2 to age 13
4. $\ln Y = -293.1X + 4.61, r = .964$ Age 2 to age 14
<table>
<thead>
<tr>
<th>Incisor Age</th>
<th>Coded Age</th>
<th>Number of Moose</th>
<th>Ln. of Number of Moose</th>
</tr>
</thead>
<tbody>
<tr>
<td>½</td>
<td>0</td>
<td>52</td>
<td>3.95</td>
</tr>
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<td>1</td>
<td>105</td>
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</tr>
<tr>
<td>20½</td>
<td>20</td>
<td>0</td>
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</tr>
</tbody>
</table>
GRAPH 3  NATURAL LOGARITHMS OF AGE CLASS ABUNDANCE VERSUS AGE CLASS

\[ Y = -28.9X + 4.61, r = .968 \]
Equation number one has the best correlation coefficient \( r = .968 \) and therefore the slope of this equation was used in the calculation of the annual mortality rate (Graph 3).

Annual mortality \( (q_x) = 1 - \text{antilog} (-.2849) \)

\[ = .2478 \]

or 24.8%

It has therefore been determined that net productivity is equal to annual mortality \( (mx = qx) \) indicating that a stationary population structure exists.

I have decided that the mortality rate which I have calculated to be 24.8% per year can be assigned to three categories, A, B and C.

- **A** is the average annual hunter harvest (Graph 4) that has occurred from 1966 to 1974.
- **B** is the average winter predation of moose by wolves.
- **C** is mortality from all other causes such as summer predation of moose by wolves, accidental drownings, disease etc.

It is considered that mortality C cannot be determined at this time. Mortality A has been measured as an average of 88 moose harvested per year. Mortality B has been calculated by estimating the number of wolves in the Shabotik at 13 or one wolf per 64 km².

R. Jerrard, (pers. comm. 1975) the Fish and Wildlife Supervisor of the White River District estimates from his close association with the Shabotik that 3 or 4 packs of 3 or 4 wolves each occupies the Shabotik.

A wolf census conducted by helicopter in the proposed Pukaskwa National Park (located 48 km south of the Shabotik) found one wolf per 64 km².

Mech (1970) found on Isle Royale that wolves predated moose during the winter months at a rate of .67 moose per month per wolf. The winter period (length of freeze up) is just over six months, therefore 13 wolves will be expected to predate \( (13 \times 6 \times .67 = 52) \) 52 moose.
GRAPH A  
MOOSE HARVEST IN THE SHACOTIK 1966 - 1974

Harvest through check station x-x
Calculated total harvest from o---o
district reports

YEAR  CHECK STATION  CALCULATED HARVEST  SEASON HARVEST
1966   62           128
1967   57           70
1968   44           83
1969   58           82
1970   42           82
1971   59           82
1972   52           82
1973   71           102
1974   61           87
Total annual mortality = \( q \times P = A + B + C \)

\[
0.248 \times P = 88 + 52 + C
\]

\[
P = \frac{140 + C}{0.248}
\]

\[
= 565 + 4.0 C
\]

Where \( q \times \) is the mortality rate and \( P \) is the population size.

To compare this population estimate of 565 moose to the winter aerial census results, the mortalities from hunting must be removed and since the aerial census occurs in January it can be estimated that half the winter predation from wolves has occurred and therefore the expected minimum January population would be

\[
(565 - 88 - 52 \div 2 = 451)\ 451 \text{ moose.}
\]

This population is a minimum of 273% higher than the average aerial winter census count of 165 moose. This discrepancy is due to the inefficiency of aerial census techniques for big game in general (Goddard, 1967; Caughley, 1974) and winter moose census in particular (LeResche, 1974).

**CONCLUSIONS**

The calculation of mortality rates from life table data can only be justified if:

1. a stable age structure exists
2. there has been no significant ingress or egress of animals in the study area
3. the data itself has not come from a biased source or else these biases have been determined and compensated for (Caughley, 1966).
Requirement # 1 was met by the use of aerial census data and a preliminary calculation of an annual productivity index. Tagging studies conducted in the Geraldton area (Goddard 1970) and the Red Lake area (Saunders, 1972) of Ontario indicated a lack of egress from the tagging areas and also a lack of differential movement of age classes. This evidence was used to conclude that there was probably no significant ingress or egress of moose in the Shabotik thus satisfying requirement # 2. Moose harvests are known to include biases in the calf and yearling classes (Pimlott 1959; Sinkin 1965). Calves were not used in the calculation of average annual mortality rate and yearling vulnerability was calculated and compensated for in the calculation of annual net productivity thus satisfying the third requirement for the use of life table data.

It was shown that the average annual net productivity ($mx$) was equal to the average annual mortality ($qx$). In a stationary age structure it is necessary that $mx = qx$ and this supports the premise that the life table data was taken from a stable age structure.

Knowing that $mx = qx$ and that their value is approximately 25% per annum and having some knowledge of the mortalities occurring from hunters and wolves allowed a calculation of a minimum population size. The minimum population size was estimated to be 273% higher than the actual average aerial census count, pointing out the well known weaknesses of aerial censusing for moose (LeResche et al., 1974).
ACKNOWLEDGMENTS

I wish to thank Robert Jerrard, Fish & Wildlife Supervisor and Tom Harrison, former District Biologist for their thoroughness in collection of the data presented here and their emphasis on maintaining continuity over the past ten years.

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