A METHOD OF CORRECTING POPULATION AND SEX AND AGE ESTIMATES FROM AERIAL TRANSECT SURVEYS FOR MOOSE

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Abstract: It is generally accepted that most aerial censuses of moose underestimate the true population. This study involved recording locations of moose on 3,760 km of transect, 0.5 km in width. Estimators using the right-angled frequency distribution of sightings were applied to correct the original population estimate. Approximately 43 percent of all moose were missed with cows and calves being least visible, followed by lone animals. Aggregates of two or more were most readily seen. Moose were most visible in recently cut areas, less visible in older cuts and least visible in uncut stands of timber.

Aerial surveys of moose populations are a widely used method to determine density and age and sex composition (Timmerman 1974). However, it is generally recognized that these surveys tend to underestimate a given population (Caughley and Goddard 1972, Robinette et al. 1974; Leresche and Rausch 1974, Gasaway et al. 1978). Considerable work has been done to establish methods and formulae to make results of transect surveys more accurate. These have included both parametric (Eberhardt 1968; Gates et al. 1968) and non-parametric methods (Kelker 1945; Anderson and Pospahala 1970; Burnham and Anderson 1976). Robinette et al. (1974) and Eberhardt (1978) have presented summary papers of much of this work. In situations where detection depends upon the observer (rather than an animal flushing) Robinette et al. (1974) suggest accurate density may be calculated using King's method (Leopold 1933), Kelker's method (1945),

the method of Anderson and Pospahala (1970) or that of Gates et al. (1968). Eberhardt (1978) and Burnham and Anderson (1976) suggest the method of Anderson and Pospahala (1970), or other methods based on right-angled distances, should be used to improve estimates. It should be noted that any choice of estimator of the parametric or non-parametric type forces a choice between precision and unknown biases. Formulae for some of the estimators referred to above are summarized in Table 1.

It has been noted by many observers in Ontario that certain moose are more detectable than others. This is especially true of cows with calves which tend not to associate with large groups of moose and move about much less, creating few tracks. Alaskan data (Coady 1976; Gasaway et al. 1978) tend to support this observation.

The purpose of this study was to examine distributions of moose recorded on a line transect survey in order to improve age and sex and total population estimates. Some data are also presented to indicate variable visibility depending on age of cutover.

STUDY AREA

The study area is located in northeastern Ontario, south of Highway 11 between Kapuskasing and Hearst. Logging operations have extended southwards into the area since the early 1920's. About two thirds of the area has been cut over. The area is flat to gently rolling with no areas of major elevation.

Rowe (1972) describes the area as one of endless stretches of black spruce (Picea mariana) on both lowlands and uplands. Areas of improved drainage are characterized by stands of aspen (Populus tremuloides), balsam poplar (P. balsamifera), white birch (Betula papyrifera), balsam fir (Abies balsamea) and white spruce (Picea glauca). Sandy soils generally support stands of jack pine (Pinus banksiana). Bogs are common where black spruce predominates with tamarack (Larix laricina) and white cedar (Thuja occidentalis) sometimes common.

Lowlands areas which are cut over generally regenerate to speckled alder (Alnus rugosa) with some willow (Salix spp.). Upland areas and mesic sites such as poplar ridges regenerate to aspen, birch, balsam poplar and often balsam fir if left as a residual.

METHODS

Data were collected over two years during the winters of 1976/77 and 1977/78. The same transects were flown by the same observer and pilot in the same aircraft in both years. One of the major problems in moose aerial surveys has been that it is often difficult to tell if an animal is on or off the transect (Novak and Gardner 1975). This problem was eliminated by using photomosaics with the transects drawn on them to navigate and to plot locations of animals. The photographs were of scale 1:15,840 and were sufficiently clear to accurately plot the moose.

Surveys were flown 24 to 72 hours after snowfall, during bright or hazy-bright days between 10:00 and 14:00 hours. Temperature for both years averaged -18°C. The aircraft, a Super Cub (PA18), was flown down the center of the 500 m wide transect until tracks were seen. The area was then repeatedly circled to find the animals, mark their location on the photographs, count and identify the sex. Sexing was done using the vulva patch method (Mitchell 1970), except when antlers were present. Individual transect length varied from 20 km to 120 km. Total length of the 23 transects was 3,760 km, flown along the north-south mercator grid lines.

Table 1. Estimators applicable to line transect data

Method	Formula	Definitions
King (Leopold 1933)	$N = nA/2Ld$	n = number of animals seen A = area censused L = length of transects d = mean sighting distance
Gates et al. (1968)	$N = (n-1)A/2L\bar{d}$	$\bar{d}$ = mean perpendicular distance
Kelker (1945)	$N = n^*A/2LD$	n* = number of animals within 2D D = maximum distance within which all animals are probably seen
Anderson and Pospahala (1970) - see text		

Data were summarized from the two surveys by measuring the distance of each animal or group of animals from the center of the transect. Moose were not bothered by the circling aircraft and did not move as it approached. A frequency distribution was plotted for moose in each of twelve 41.7 m divisions of the 500 m transect, six on each side of center (Figures 1 to 4). The data were then analyzed using the methods of Gates et al. (1968) and Anderson and Pospahala (1970).

Anderson and Pospahala (1970) used a quadratic equation to fit their data on duck nests. Curves examined for the present study included: quadratic, exponential, logarithmic and linear. Logarithmic curves did not fit the data. Quadratic, exponential and linear curves all fit the data with varying degrees of success.

The method is based on the observed fact that moose are less readily visible away from the center of the transect. Fitting a distribution to the data provides a maximum on the y-axis which should correspond to the point where close to 100 percent of the animals are seen. The area (A') of the rectangle formed by the line drawn through this point parallel to the x-axis and bounded by the lines at the edges of the transect is then calculated. The area (A) below the fitted curve is integrated. The ratio A'/A provides the correction factor for the survey.

It was noted during compilation of the data that the observer saw more moose on the right side of the aircraft, except in the case of lone animals. For this reason the data were not lumped. Also it can be seen that in all cases (Figures 1 to 3) except aggregates (Figure 4), more moose were seen in the 42 to 84 m segment than in the 0 to 42 m area

Figure 1. Distribution of all moose recorded on transect

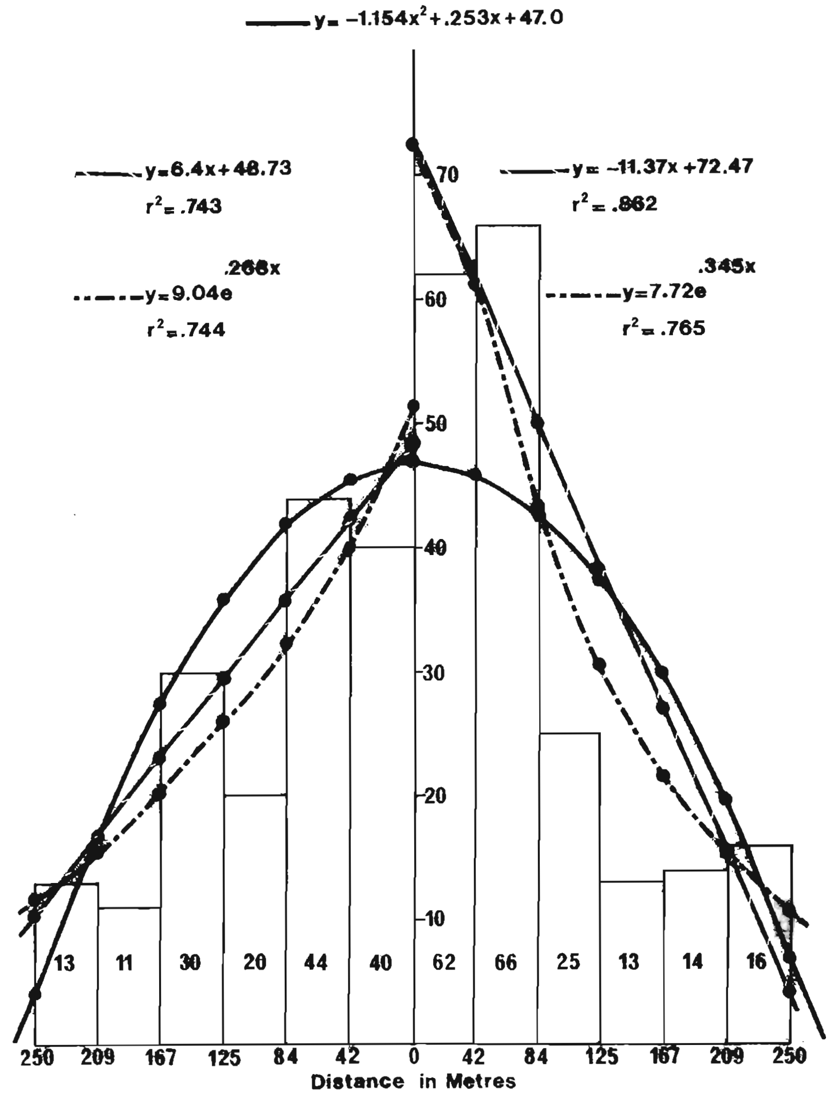


Figure 2. Distribution of lone moose (bulls and cows) recorded on transect

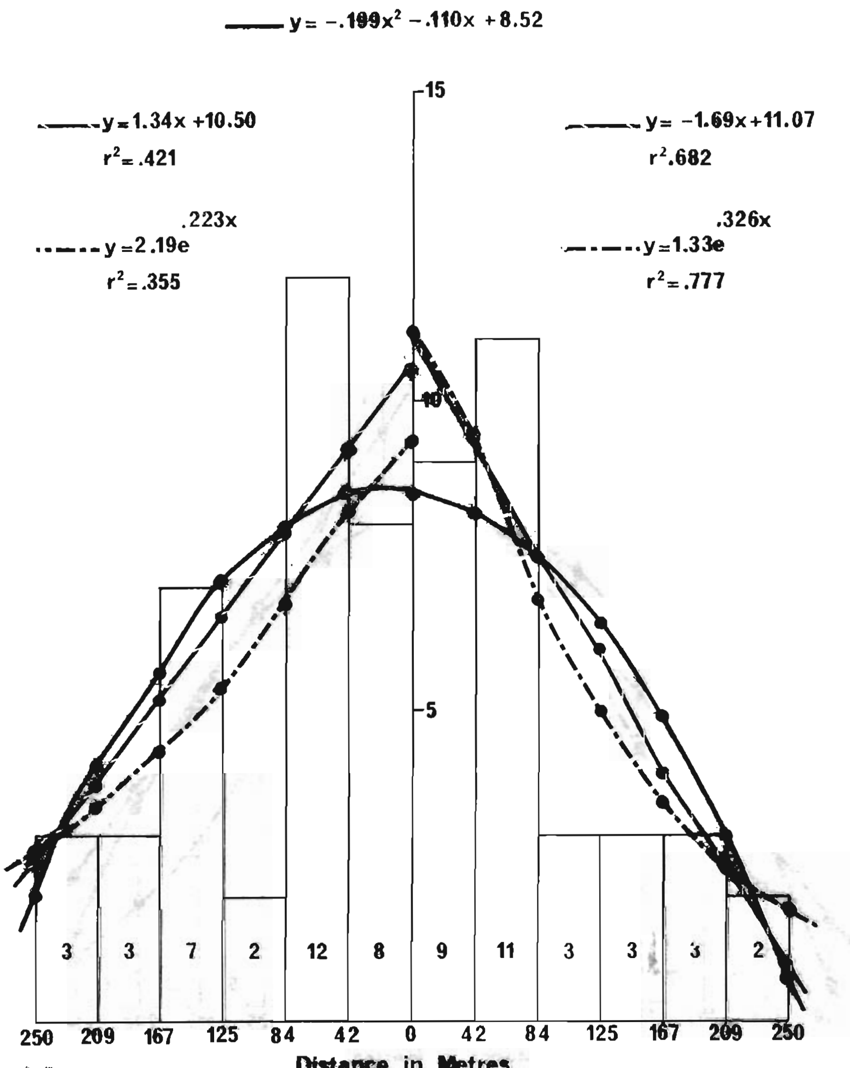


Figure 3. Distribution of cows with calves recorded on transect

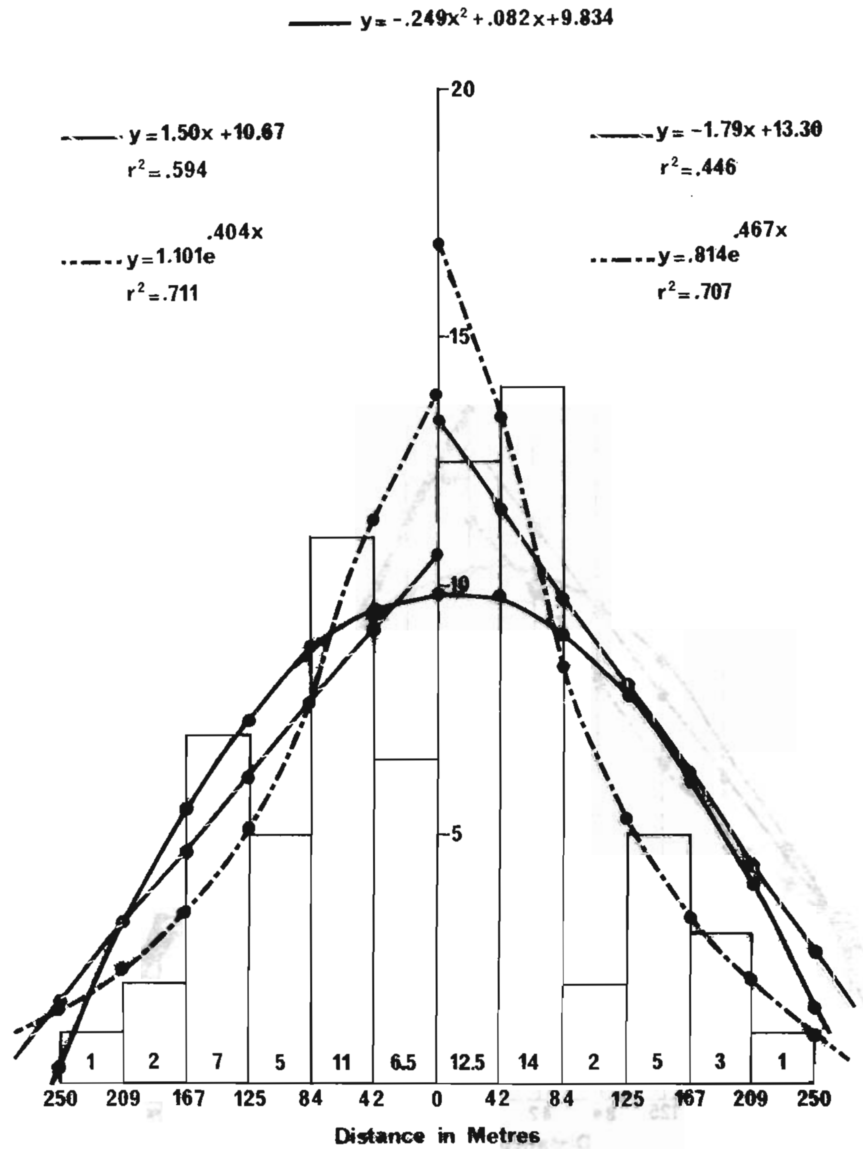
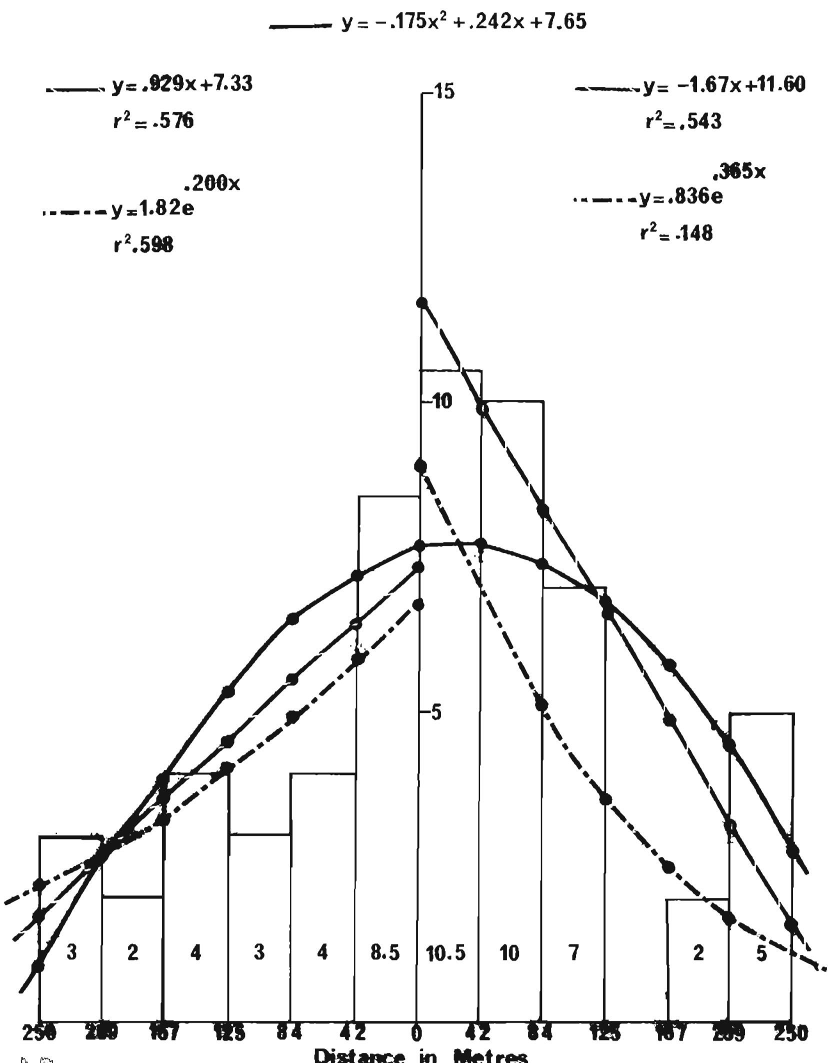


Figure 4. Distribution of aggregates (excluding cow-calf groups) recorded on transect



directly under the aircraft on both sides. This results from the "blind spot" beneath the airplane. Aggregates of several animals could be expected to make more tracks than single moose or cows with calves, and as a result, would not be as subject to this bias.

RESULTS

Density is often estimated as the number of animals recorded on the transects divided by the total area of the strips. This value is then extrapolated to the entire study area. This straight-forward method provided remarkably similar estimates of 1,388 ± 291 and 1,397 ± 309 moose in 1977 and 1978 respectively. An F-test indicated the data are from the same populations. The average age and sex breakdown and number of aggregates combined for the two surveys is summarized in Table 2.

Table 2. Breakdown of moose recorded on transect during the two surveys.

Total moose	354
Lone bulls or cows	66
Cows with calves	70
Aggregates (excluding cows with calves)	59
Average aggregate size	2.545

Using this method the ratio of bulls to cows to calves was 35.0:45.2:19.8.

Gates Method

The formula $N = \frac{(n-1)A}{2L\bar{d}}$ (Table 1)

was used to calculate a total population. When applied to the total number of animals, the revised estimate becomes 2,019 moose. The sex ratio would be the same as mentioned above. Results from applying the Gates estimator to the various categories is shown in Table 3. The sex and age ratio from this method was 30.8:48.5:20.7. The change (vs the 1,388 estimate above) in the number of males was significant using a chi-square analysis, $0.05 < P < 0.10$. Cow-calf groups did not change significantly. Confidence interval (90%) for this estimate from Gates et al. (1968) is ± 349.

Anderson and Pospahala Method

Quadratic Distribution

An example of the calculations for a quadratic distribution for all moose together is as follows (Figure 1).

$$y = 47.0 + 0.253x - 1.154x^2 \text{ (all moose)}$$

$$A = \int_{-6}^{6} dy/dx = 47.0x + \frac{0.253x^2}{2} - \frac{1.154x^3}{3}$$

$$= (282 + 4.554 - 83.088) - (-282 + 4.554 + 83.088)$$

$$= 397.824$$

The y-intercept of this distribution is y=47.00. The area (A') bounded by this line and the edges of the transect (ideal distribution of moose across the transects) is:

$$A' = 47.00 \times 12$$

$$= 564.00$$

Then A' is larger than A by a factor of 0.4177. This is an amount by which the original estimate for all moose should be increased. A new estimate of moose on the area is 1,957.

When this method, using a quadratic distribution, is applied to the three categories (Figures 2, 3 and 4), the estimates increase lone animals by 38.9 percent, cows with calves by 43.7 percent and aggregates by 37.8 percent (Table 3). The sex and age ratio in this population is 31.3:48.5:20.1, bulls to cows to calves respectively. Again, this represents fewer males and more females and calves than in the 1,388 estimate. The change in males was nearly significant $0.1 < P < 0.2$. There was no significant difference in age and sex ratios using this method compared to that of Gates et al. (1968).

Linear and exponential curves were also fitted to the data. Since it was decided not to lump the data due to left and right-side biases, these distributions necessitated a different curve for each side of the transect (Figures 1 to 4).

Linear Distribution

As noted, this method required a calculation for each side of the transect. These were averaged to provide the factor used to increase the original estimate of 1,388 moose. For all animals together the factor for increase was 76.5 percent resulting in an estimated population of 2,450. Applying the derived equations and y-intercepts to the three categories provided an increase of 73.2 percent for lone animals, an increase of 53.5 percent for cow-calf groups and an increase of 68.6 percent for aggregates (Table 3). The sex and age ratio in this population is 30.9:50.6:18.4 bulls to cows to calves respectively. Both males and females were significantly different from the original sex ratio in the 1,388 population, $0.05 < P < 0.1$. No difference was seen in calves.

Table 3. Summary of derived population estimates

Method	Lone Moose	Aggregates	Cow/Calf	Total* Population	All** Moose
Gates	360	318	413	1,995	2,019
Quadratic	359	319	394	1,959	1,957
Linear	448	390	421	2,283	2,450
Exponential	-	-	-	-	2,174

* sum of lone moose, aggregates and cow/calf

** derived from extrapolation based on distribution of all moose observed

Exponential Distribution

This distribution was discarded because of a poor fit to the data for aggregates (r^2 = 0.148 right side) and for lone bulls and lone cows (r^2 = 0.355 left side).

A good fit was indicated for all moose (Figure 1). Applying the integration and y-intercept method resulted in a population estimate of 2,174 moose (Table 3).

Visibility by Age of Cutover

The study area was grossly categorized into uncut areas, areas cut more than 15 years ago and areas cut less than 15 years ago (Figures 4, 5 and 6). Unfortunately, the sample size was too small to examine sex and age differential visibilities in this manner, or to divide the areas cut into habitat types.

As was suspected, moose were most visible in recently cut areas (43.2% missed) and least visible in uncut forest (62.1% missed). Visibility in old cuts was intermediate between these two (50.7% missed). These factors were derived as above using the quadratic distribution y-intercept method.

DISCUSSION

Harvest data from the area surveyed indicated a legal kill of 246 moose each year for the last four years. During the same period, winter aerial surveys showed a stable herd, estimated at 1,388 ± 291 moose. The number of calves estimated in this herd in February averaged about 270. Wolves are present in the area, but estimates of loss to predators are not known. Mortality of moose calves during the late winter period is probably extensive as shown by studies on Isle Royale (Mech 1970; Peterson and Allen 1974) and in Alaska (Bishop and Rausch 1974).

Figure 5. Distribution of all moose recorded on transect in uncut forest

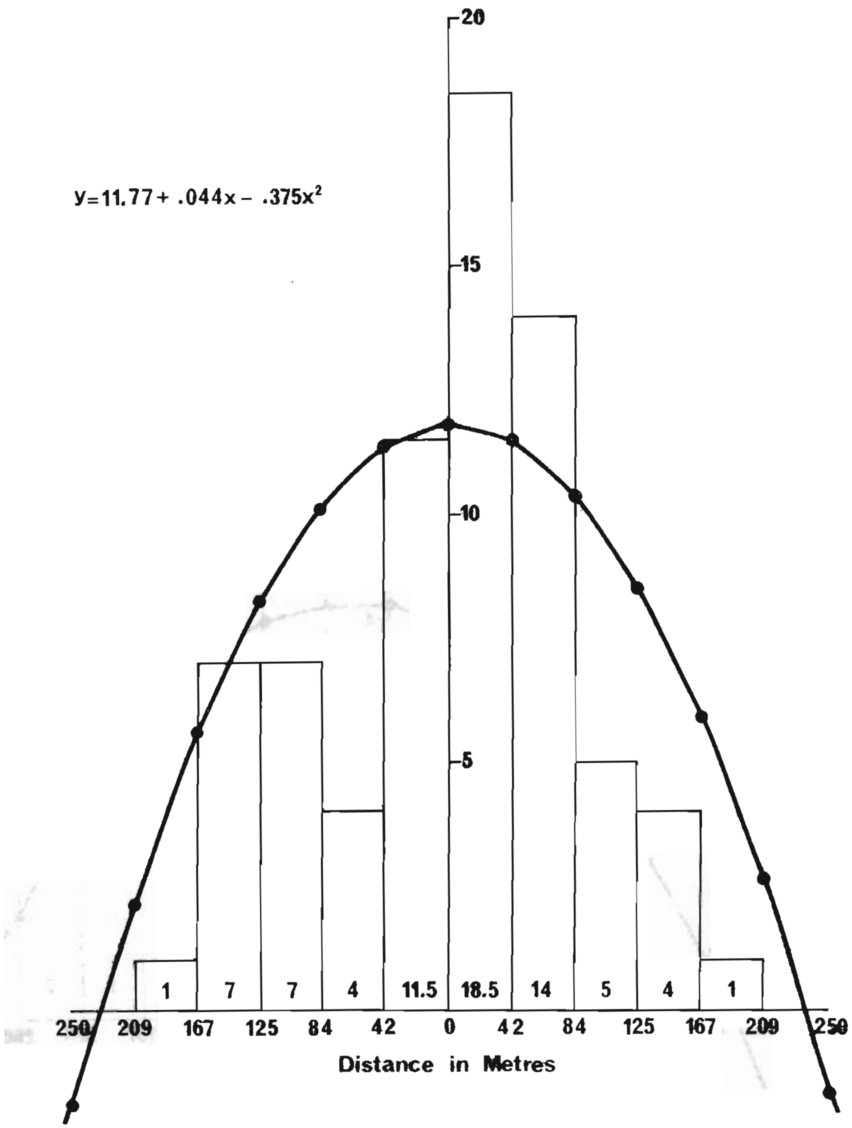


Figure 6. Distribution of all moose recorded on transect in areas cut over at least 15 years ago

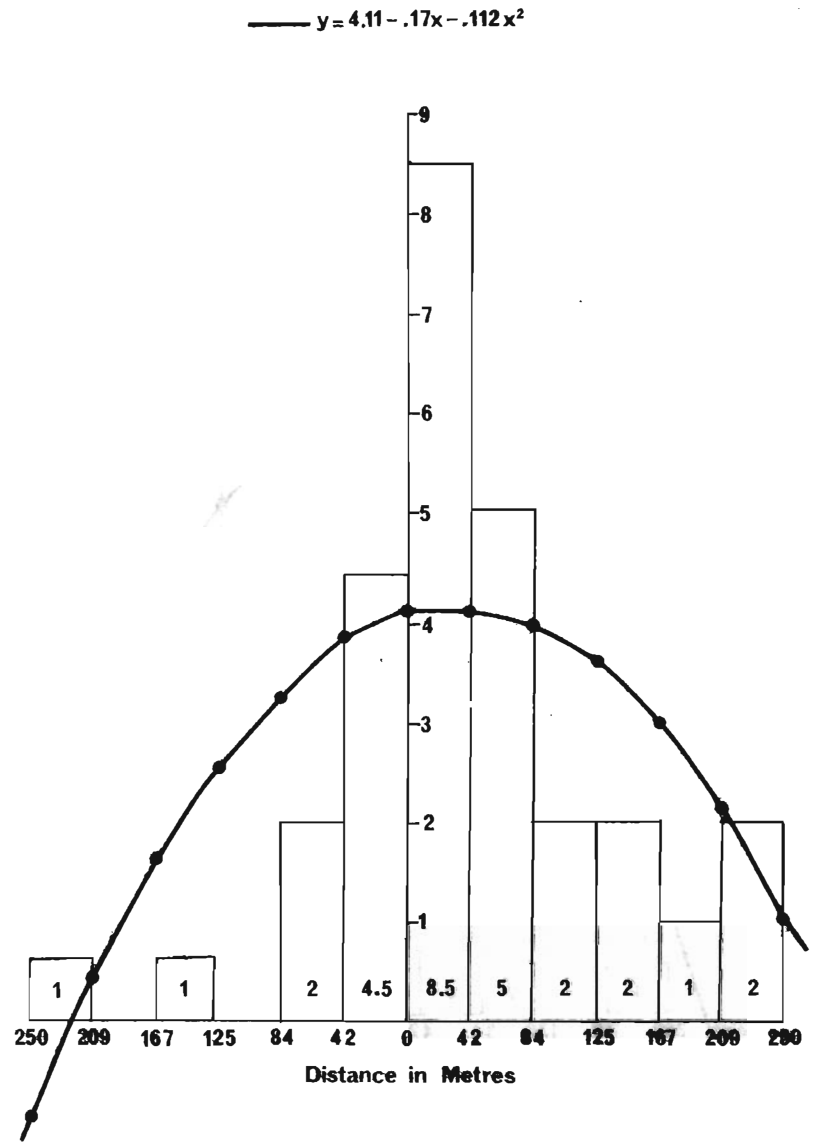
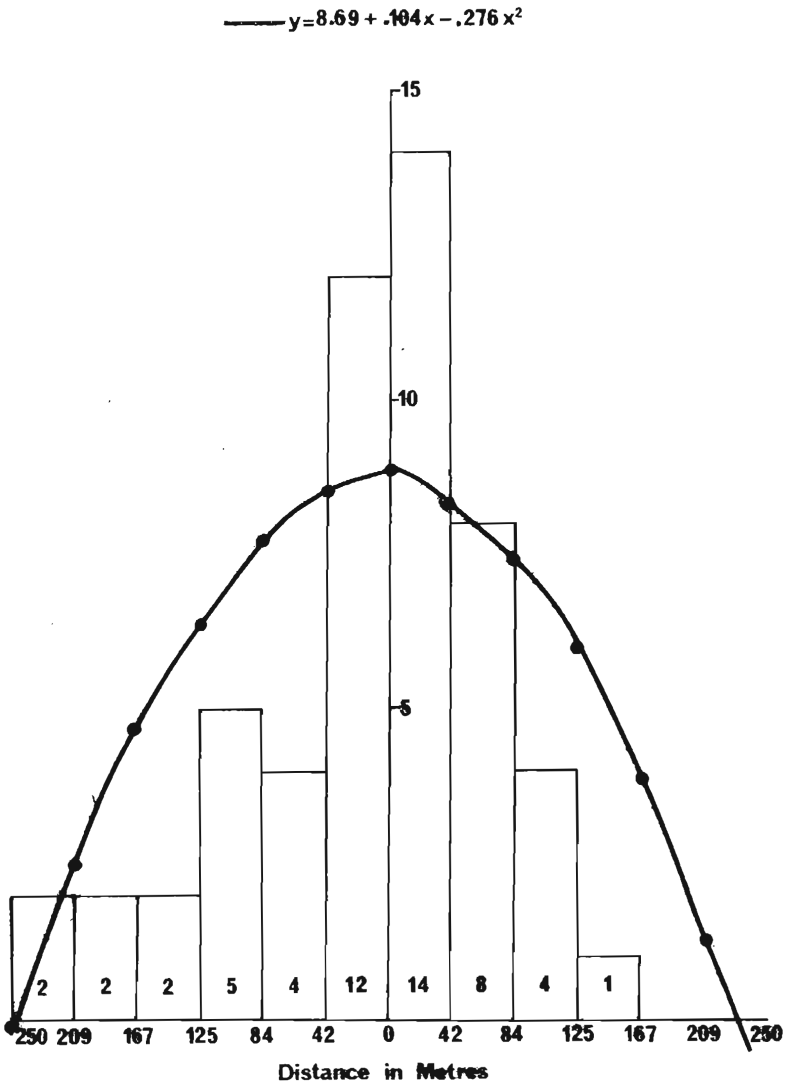


Figure 7. Distribution of all moose recorded on transect in newly cut (up to 14 years ago) forest



The above estimate of calves in the population is prior to the deep snow period in March when predation is heaviest. Clearly, a stable population is not possible if only 24 calves (270 calves minus 246 total kill) were available to balance losses to predators, accidents, starvation and old age before the next calf crop in May. The estimate of 1,388 moose is too low. Population estimates derived here are summarized in Table 3. These values range from 41 to 64.5 percent greater than the figure originally calculated.

In deciding which estimate to use, two factors should be considered: 1) how well the calculated curves fit the observed distribution and, 2) how well the calculated curves approximate the known or suspected differential visibility biases of age and sex groups in aerial surveys. That is, in general, aggregates should be more visible (and therefore increased proportionately less) than other groups especially cows with calves. This is in fact seen in comparing the observed distribution of aggregates compared to the two other categories (Figures 2, 3 and 4). 3) An accurate estimator should account for the reduced visibility beneath the aircraft, but not substantially overestimate the y-intercept.

The parametric method of Gates et al. (1968) assumes no extraneous visibility bias towards the center of the transect. As a result, it will produce a low estimate of population from these data due to the blind spot beneath the aircraft. Further reducing the estimate is the "right-handed bias" in these data, where more animals were seen on the right half of the transect.

Of the curves fitted to the data, the quadratic curve consistently underestimated the y-intercept; the linear plots indicated a greater percentage of aggregates were missed than lone animals or cows with calves; and the exponential curves poorly described the observed distribution of aggregates and lone moose. Neither the linear nor the exponential distributions accounted for the "right-handed bias" because a separate curve had to be developed for both sides of the transect. Therefore, in spite of the underestimate of the y-intercept and resultant low population figure, it appears that quadratic distribution permits the best estimate of all three categories, (Figures 2, 3 and 4) (aggregates, lone moose and cows with calves). However, if the manager is interested in total moose on the study area (from Figure 1), the linear equations provide the best fit to the observed data. This indicated we missed 43.3 percent of the moose present.

Further work is required to determine visibility biases by habitat type.

Any aerial survey and analysis procedures are subject to biases. Ones which were possibly not met in this study were: 1) animals were likely not uniformly and independently distributed, 2) while most sightings were independent events, some animals were found while circling to sex other groups, and 3) there was visibility bias towards the center of the transect. The first bias can never be overcome in a natural setting, but is reduced with the size of the area sampled. The second bias did not occur often enough to significantly alter the results. Visibility bias towards the center of the transect would reduce the population esimate achieved.

In summary, it is shown that transect surveys for moose can produce more accurate estimates than are presently attained in Ontario.

Recognition of the fact that differential visibilities occur among types of aggregates of moose can produce more accurate sex and age data than straight-forward extrapolation of recorded data.

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