THE VALUE OF AERIAL INVENTORIES IN MANAGING MOOSE POPULATIONS

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Abstract: Extensive moose (Alces alces) aerial inventories were conducted in northern Ontario from January to March, 1976. The study: (1) looked at the efficiency and accuracy of a Piper PA 12 aircraft, (2) compared results between plots and transects and among 9 periods of the winter, (3) tested a method of stratifying plots by recording tracks on transect surveys, and (4) tested aerial photographs for use in mapping of sightings. The Piper PA 12 crew found 94% of the moose and correctly sexed 98 and 87% of the adults and calves. All sightings were accurately mapped. The plot and transect methods gave similar inventory results except that: (1) an average of 25% more calves were estimated from plot surveys, (2) transects unlike plots provided a distribution pattern of moose, (3) transects eliminated the cost and time needed to stratify an area for plot surveys, and (4) generally tighter confidence limits were obtained from plot surveys. Inventory data collected during the 9 survey periods were similar. The method of pre-stratifying the plots by tracks was judged to be successful since the desired confidence limits were achieved. Foldable mosaics of aerial photographs proved easy to handle and useful in precisely mapping the locations of moose and tracks.

In this study, the general question I wished to answer was: can aerial inventories provide, at reasonable cost, data adequate for management of moose populations. More specifically, I examined: (1) the

use of plots or transects as the most appropriate sampling procedure, (2) the effects of time of winter on survey results, (3) the accuracy and efficiency of observers in a Piper PA 12 aircraft, (4) the value of plot stratification using track indices, and (5) the use of aerial photographs for mapping moose and tracks accurately.

The controversy over the value of moose aerial surveys is widespread. Stevens (1970) and LeResche and Rausch (1974) concluded that aerial counts did not provide valid estimates. Mantle (1972) stated that moose surveys were conservative. Edwards (1954) checked aerial counts against ground searches and reported that observers saw only 78% of the moose. Fowle and Lumsden (1958) surveyed plots with a Piston Beaver and helicopter and arrived at similar population estimates but transect population estimates were 54% lower than plot estimates. Evans et al (1966) reported that plot surveys gave results twice as large as total area counts and 4 times as large as transect surveys. Novak and Gardner (1975), using a helicopter, found that a Cessna 180 crew surveying plots located 94% of the moose, and that population estimates based on plot and transect surveys were similar when the aircraft circled during transect flights to check tracks and moose. Gasaway et al (1978) found that 9% of radio-collared moose were missed during intensive searches. Semyonoff (1956) concluded that the most reliable and the least expensive method for estimating moose numbers in the taiga-forest of Russia was to count tracks. Gawley and Dawson (1965) detected a poor correlation between track indices and numbers of moose, but they concluded that this system might be valid under optimum weather conditions. Evans et al (1966) also tried using tracks but found it difficult.

There have been few tests of observer ability to sex and age moose from the air. Novak and Gardner (1975), checking from a helicopter, found that a crew in a Cessna 180 sexed 50 adults correctly by the vulval patch but could not sex calves. Roussel (1975) reported that he sexed adult moose and male calves correctly from a helicopter by the vulval patch as verified by ground checks, but had difficulty sexing female calves.

I am not aware of any comparisons of inventories flown at different times of the same winter. In Ontario, moose were believed to be more difficult to inventory after January (Timmerman 1974).

An important observer error is the incorrect mapping of moose. Siniff and Skoog (1964) felt that observers might include animals along borders of survey plots as being inside, thus biasing the results. Bergerud (1963) and McNicol (1976) used aerial photographs to accurately map observations of caribou (Rangifer tarandus) and moose.

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STUDY AREA

The study area, Ontario Wildlife Management Unit 23 (9375 km^2) is representative of much of the moose range found in northern Ontario (49^o latitude, 84^o longitude). It is very flat with poorly drained clay soils. The lakes are small and shallow. Streams are narrow, often intermittent, and difficult to see from the air in the winter. Frequently they do not

appear on topographical maps (1:50,000). Beaver (Castor canadensis) ponds, although common, are infrequently shown on the maps as are logging roads, skid roads, trails and cut lines. The natural forest is composed of alder (Alnus rugosa) and black spruce (Picea mariana) on the wet sites and trembling aspen (Populus tremuloides), balsam poplar (Populus balsamifera) and white birch (Betula papyrifera), interspersed with white spruce (Picea glauca) and balsam fir (Abies balsamifera) on the drier sites. Some logged areas have been reforested with jack pine (Pinus banksiana) and white spruce. The flat nature of much of northern Ontario moose range makes plot and transect boundaries difficult to follow as there are few land features by which to orient.

MOOSE BEHAVIOUR

Adult moose travel a considerable distance each day, often along frozen streams or creeks, old logging roads and skidding trails. Generally, moose do not live under solid conifer cover, but select openings in the forest that provide some protection from the wind and at the same time allow them to sun themselves throughout the day. These habits mean that there is an abundance of tracks and that both tracks and moose are readily visible (Novak 1978).

In the winter, cow-calf groups tend to live in more isolated locations and often travel less than other social classes of moose (Houston 1971). This behaviour may aid in avoiding wolves (Canis lupus) and in reducing the energy drain on the calf (Peek et al 1974). Calves are always found with their dam since orphaned calves cannot survive long in the winter (Denniston 1956). Altmann (1958) stated that the cow-calf group joined the loose winter aggregations but I did not observe this. Usually about one third of the moose were observed as singles although they commonly formed groups of 2 to 4 individuals. The sex composition of these groups appeared to be random and the group loose knit (see also Peek et al 1974). Adults without calves, fed, rested in, and travelled across more open sites, such as the larger clear cuts, than cows with calves.

METHODS

Four crews (Table 1) surveyed the plots and transects (Fig. 1) in a Piper PA 12, Cessna 172, Cessna 180 and a DeHavilland Turbo-Beaver with estimated average searching speeds of 100, 120, 140 and 160 kph, respectively. In addition to the pilot, the PA 12 had 1 observer, the Cessna 172 had 2 and both the Cessna 180 and Turbo-Beaver, 3. An Alouette helicopter with 3 observers plus the pilot checked the results of the PA 12 crew.

I calculated population estimates for the 5 transect and 4 plot surveys as well as for plots and transects for each of the 4 aircraft types by combining the moose counts on the 4 quadrats (Fig. 1 shows survey sequence). The best population estimate used the moose counts of the PA 12 crew and increased this by the proportion of moose missed (as checked by the helicopter).

There were variations among the crews during the transect surveys in the numbers of moose observed from the left and right sides of the aircraft. In addition, the crews were not recording a similar number of unseen aggregations on the plots and transects. I arrived at a

Table 1. Cost per hour, search time per 25 km^2 of transect and plot, and the number of crew members deployed during the aerial surveys of Ontario wildlife management unit 23, during the winter of 1976.

Aircraft	Cost/hr. ($)	Search Time (hr.)		Number of crew members deployed over survey period	
		Transects	Plots	Pilots	Observers
PA 12	40.00	0.8	1.0	1	1
Cessna 172	50.00	0.7	1.1	1	4
Cessna 180	75.00	0.7	0.8	1	7
Turbo-Beaver	120.00*	0.6	0.7	6	7

* Estimate probably minimal, no exact hourly rates available.

Table 2. The performance of the PA 12 crew in aging and sexing 22 bulls, 41 cows and 15 calves, on 9 plots flown within Ontario wildlife management unit 23, during the winter of 1976.

Class	Classified by PA 12 Crew	Moose aged and sexed correctly*	Those moose in error actually were			
			Bulls	Cows	Male Calf	Female Calf
Bulls	20	20				
Cows	43	39	1			3
Unknown Adult	2	0		2		
Male Calf	2	2				
Female Calf	5	3	1		1	
Unknown Calf	6	0			4	2

* Determined via helicopter checks.

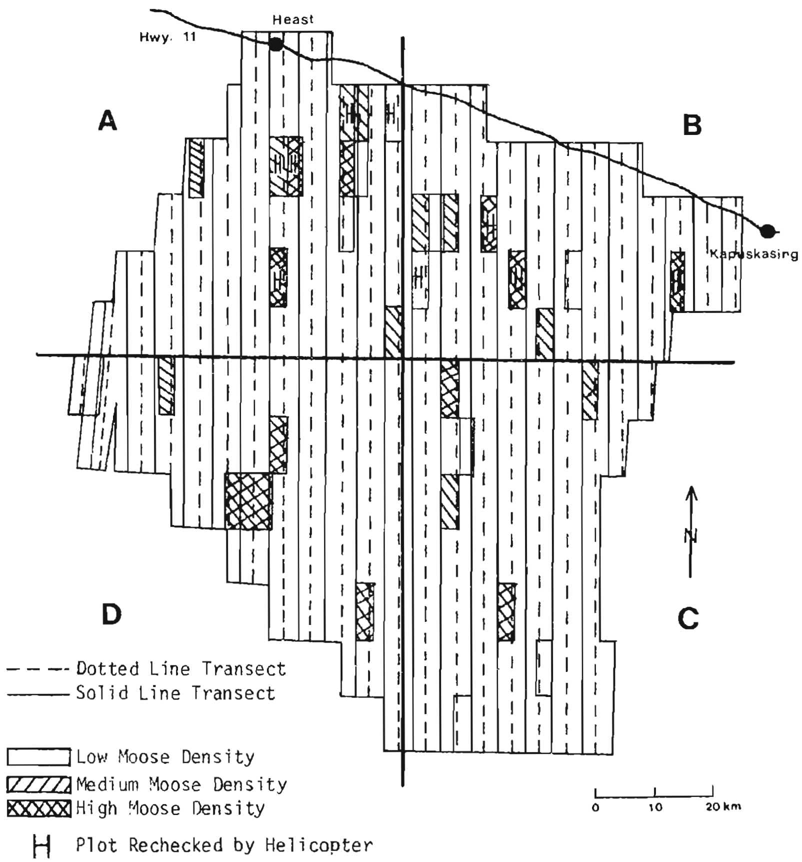


Fig. 1. The following survey sequence was followed by each aircraft crew (giving as an example the PA 12 crew's surveys): quadrat A 1st survey - dotted line transects, 2nd survey - solid line transects, 3rd survey - plots, then rotated to quadrat B and flew 4th survey - solid line transects, 5th survey - plots, then rotated to quadrat C and flew 6th survey - solid line transects, 7th survey - plots, then rotated to quadrat D and flew 8th survey - plots and 9th survey-solid line transects. The 4 aircraft flew at the same time, 1 in each quadrat.

separate population estimate by adjusting the data to compensate for these differences. This was done by increasing the moose count on the low side to equal the count on the high side of the transect and by increasing, per unit area, the observations of unseen aggregations on transects to equal the observations on the plots (see Thompson 1979, for additional methods for correcting population and sex and age estimates from aerial transect surveys for moose).

The following formula was used to estimate moose populations from fresh track counts recorded only during the 5 transect surveys:

$$\frac{\text{Number of Fresh Track Groups}}{\text{Number of Days since Snowfall}} \times \text{Average Group Size recorded by the 4 Crews per Quadrat}$$

If moose were seen on the transect then their number was recorded but the observation was treated as 1 fresh track group for these estimates. After the first 2 transect surveys, I calculated a relative moose density index for each plot. This was possible since a transect line passed through each of the 375 plots on the area. The formula was:

$$\text{Number of Moose} + \frac{\text{Number of Fresh Track Groups}}{\text{Number of Days since Snowfall}} \times \text{Average Group Size on the first 2 Transect Surveys}$$

The plots were stratified into 3 relative densities: 0.00 to 0.99, 1.00 to 3.99 and 4.00+ and selected to give 90% C.L. ($P \leq 0.10$).

A large number of antlerless adult males and cows without calves were not sexed. To determine whether this was due to the crew's inexperience, we had an experienced crew inventory the dotted line transects of quadrat A between 19 and 21 February in a Cessna 180. The efficiency of this crew had been previously confirmed (Novak and Gardner 1975).

Plots measured 2.5 x 10.0 km and the transect width was 0.5 km. These were the standard sizes used in Ontario. On the plots, the aircraft flew along lines 0.5 km apart and on the transects they flew up the centre of the 0.5 km strips. In both cases they searched for moose tracks and not the animals. Once fresh tracks or moose were spotted, the aircraft circled to find, sex and age the moose, and map the location of the group. The PA 12 crew recorded the presence of antlers. During the transect surveys the observers also mapped the track locations. If 1 or more moose in a group could not be sighted due to heavy conifer cover, this group was recorded as an unseen aggregation (Bergerud and Manuel 1969), although partial sightings were used in compiling sex and age data. Tracks made prior to a snowfall were recorded as old tracks. The records of unseen aggregations and unsexed moose were converted to bulls, cows and calves using the ratios of bull:cow:calf that were observed and recorded by each crew on transects and plots. The confidence intervals on transects were calculated by dividing the transects into 10 km sections and using these as sample units.

Unantlered adults were sexed by the vulval patch (Ellström 1965, Mitchell 1970). The sexing of calves by this method was discontinued shortly after the surveys began since most observers found it too difficult. The helicopter crew looked for antler buttons on calves and antler scars on adults when checking the sexing accuracy of the PA 12 crew. The observers did not try to find the vulval patch on adults accompanied by calves (unless there were two adults in the vicinity) since calves are usually found only with adult cows. Calves were aged by their size in relation to the female.

The helicopter crew checked the results of the PA 12 crew by systematically searching for moose and tracks along 11 flight lines per plot and by referring to the topographical maps (scale 1:50,000) used by

the crew and on which were marked their observations. Moose that had moved since being recorded were relocated by tracking. Each crew was told that their records would be checked randomly by the helicopter in order to equalize search effort.

The helicopter crew also used black and white aerial photographs to check the mapping precision of the PA 12 crew. These photographs measured 20 x 20 cm with a scale of 1:17,000. They were taken in the summer from an average height of 2400 m with an 86 mm lens. I also used 19 x 12 cm winter photographs taken from a height of 300 m (scale 1:18,800) on 35 mm film. Photographs were joined along the back to make a foldable mosaic of either a plot or a transect. Special flights were done on 23 April, 1976 by the PA 12 crew to test the usefulness of these photographs for locating plot boundaries and recording observations.

The inventories began when there was 35 cm of snow on the ground. Flying height varied between 50 and 180 m to fit light conditions, topography and forest cover. The surveys were flown only under good visibility and generally within 6 to 72 hours following a snowfall heavy enough to cover tracks made prior to that period. Flying was generally restricted to the period between 1000 and 1530 hours with about 1 hour off in order to optimize tracking and minimize fatigue. Snow depth in the bush was recorded at the Ministry of Natural Resources' snow stations near Hearst and Kapuskasing, and temperature and snow depth records were obtained from the Kapuskasing airport.

RESULTS

Survey Period and Weather

The surveys extended from 7 January to 11 March, 1976 under good snow conditions (Fig. 2). Throughout the surveys, the snow was soft and the moose were not hindered by crust. The maximum temperature never reached $0^{o}C$.

Area Surveyed

Each of the 4 aircraft crews flew plot surveys over 9% of the area and transect surveys over 12% of the area. The transects were 1880 km long in the dotted line survey and 1870 km long in each of the subsequent solid line surveys. The experienced crew surveyed 470 km of the dotted line transects. The helicopter crew checked 7 plots the same day as the PA 12 flew them and 2 plots the following morning. They also checked the track records of the PA 12 crew on 210 km of transects. The times needed to search 25 km^2 on transects and plots are recorded in Table 1.

Performance of the PA 12 Crew as Rated by Helicopter

The PA 12 crew found and correctly aged 10 fresh track groups crossing the transects but missed 5 of 43 old track groups. On the 9 plots checked, the PA 12 crew missed 4 moose (6%). They correctly sexed 98% of the adults and 87% of the calves (Table 2). All of the 44 groups seen were mapped correctly.

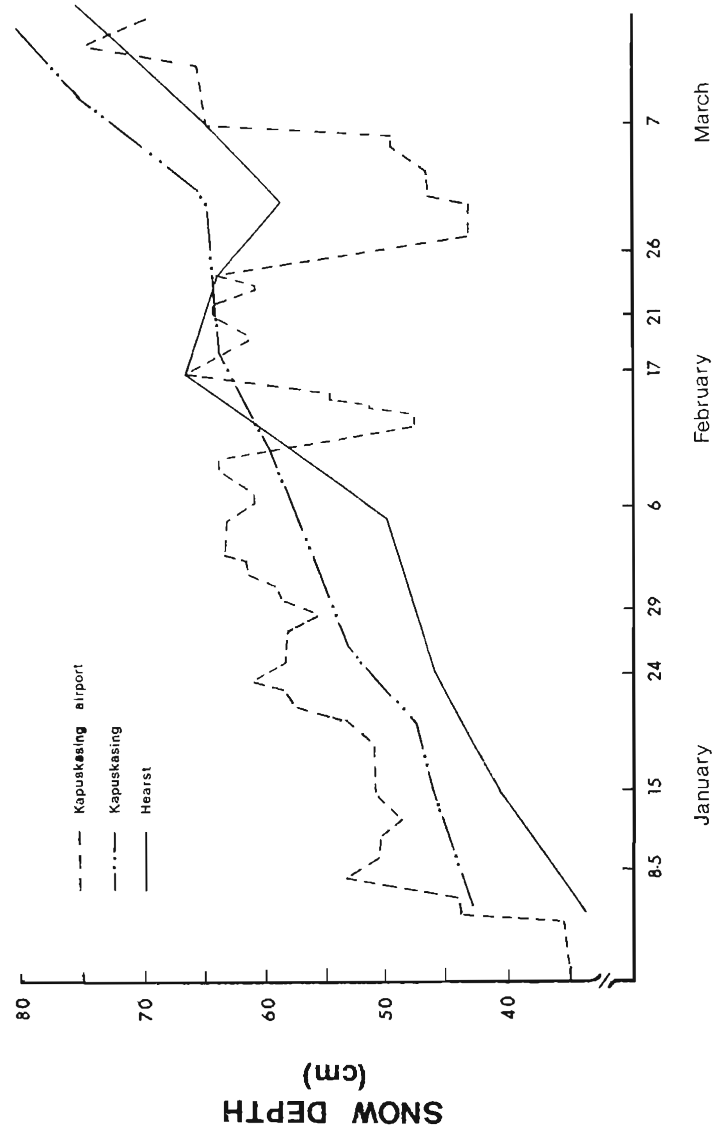


Fig. 2. Snow records for Ontario wildlife management unit 23, 1976. Note the irregular snow depth records encountered at the exposed wind swept airport site as compared to the other two sites which were located in the forest.

Plots vs. Transects

Moose counts - The crews recorded 606 and 676 moose on plots and transects (Table 3). Per unit area, 50% more moose were seen on plots than transects. In addition, there were, per unit area, 6.6 unseen aggregations on transects and 30.0 on plots.

Population estimates - The best population estimate was 1556 moose. The average population estimates for the plot and transect surveys were 1325 and 1292 if the crews' results were used and 1325 and 1360 if the results from the time periods were used (Table 3). The average estimates of bulls, cows and calves were similar, but individual estimates from each aircraft and each time period varied considerably (Table 3). Adjustments for unseen aggregations and for variations in counts on the left and right sides of the aircraft raised the average transect population estimates to 1559 moose.

Moose groups - During the surveys the 4 crews saw 326 groups of moose on the transects and 321 groups on the plots (Table 4). It was not possible to make direct comparisons of the mean group sizes or the frequencies of the different group sizes by aircraft crew since group size was found to change with time (see Inventory Results vs. Time of Winter). However, I compared the rate of decrease of mean group size between plot and transect surveys using regression analysis of: (1) all the data, (2) exluding cow-calf groups, and (3) excluding the last transect survey, and only the regression equation based on those data excluding cow-calf groups and the last transect survey showed a declining

Table 3. Moose population estimates, based on the number of moose counted for Ontario wildlife management unti 23, during the winter of 1976.

Aircraft Type or Survey Sequence	Transects				Plots			
	Bulls	Cows	Calves	Totals	Bulls	Cows	Calves	Totals
PA 12	493 ± 158* (63)**	653 ± 160 (89)	201 ± 66 (24)	1346 ± 294 (176)	526 ± 105 (67)	664 ± 50 (87)	278 ± 27 (32)	1468 ± 274 (186)
Cessna 172	326 ± 101 (42)	480 ± 128 (64)	195 ± 80 (27)	1001 ± 233 (133)	371 ± 60 (42)	630 ± 51 (74)	299 ± 14 (30)	1300 ± 231 (146)
Cessna 180	359 ± 112 (46)	887 ± 235 (106)	185 ± 71 (23)	1430 ± 333 (175)	411 ± 86 (47)	850 ± 199 (92)	257 ± 16 (32)	1518 ± 411 (171)
Turbo-Beaver	594 ± 142 (86)	585 ± 137 (78)	210 ± 73 (28)	1389 ± 272 (192)	266 ± 22 (30)	542 ± 34 (51)	207 ± 19 (22)	1015 ± 118 (103)
First	677 ± 189 (65)	669 ± 198 (70)	219 ± 91 (22)	1566 ± 361 (157)	356 ± 62 (45)	570 ± 51 (77)	211 ± 21 (27)	1137 ± 247 (149)
Second	565 ± 160 (57)	827 ± 198 (81)	224 ± 85 (22)	1616 ± 375 (160)	338 ± 42 (41)	759 ± 123 (74)	272 ± 17 (28)	1369 ± 299 (143)
Third	390 ± 110 (39)	739 ± 230 (74)	156 ± 64 (15)	1286 ± 309 (128)	296 ± 60 (34)	722 ± 42 (84)	259 ± 15 (29)	1277 ± 143 (147)
Fourth	300 ± 119 (28)	599 ± 155 (60)	228 ± 84 (23)	1126 ± 276 (111)	584 ± 102 (65)	634 ± 60 (69)	300 ± 18 (33)	1518 ± 354 (167)
Fifth	473 ± 161 (48)	541 ± 151 (53)	190 ± 77 (19)	1204 ± 299 (120)				

* 90% confidence limits

** Number of moose counted, including unseen groups converted to equal number of moose.

Table 4. Number of moose groups recorded by aircraft types on plots and transects and by time during the winter of 1976, for Ontario wildlife management unit 23.

Aircraft Type or Midpoint of Survey period	Survey Type	Group Size 1	2	3	4	5	6	7	Total
PA 12	Plot	32(34)*	45(27)	13(9)	5(4)	1(0)	0(0)	0(0)	96(74)
	Transect	33(33)	41(22)	7(6)	6(5)	2(2)	0(0)	0(0)	89(68)
Cessna 172	Plot	24(27)	43(26)	8(3)	3(3)	1(1)	0(0)	0(0)	79(60)
	Transect	26(27)	26(14)	7(3)	5(2)	0(0)	1(0)	1(1)	66(47)
Cessna 180	Plot	23(25)	52(31)	11(7)	0(0)	1(1)	1(1)	0(0)	88(65)
	Transect	22(23)	32(18)	18(15)	4(3)	0(0)	1(1)	1(1)	78(61)
Turbo-Beaver	Plot	21(21)	32(16)	4(1)	0(0)	0(0)	0(0)	1(1)	58(39)
	Transect	34(39)	36(21)	13(6)	5(5)	4(4)	1(0)	0(0)	93(75)
January 8.5	Dotted line Transect	20(23)	24(18)	16(9)	7(5)	0(0)	1(1)	1(1)	69(57)
January 15	Solid Line Transect	27(31)	22(14)	12(8)	6(4)	3(3)	2(0)	0(0)	72(60)
January 24	Plot	24(26)	30(17)	12(6)	4(3)	1(1)	0(0)	0(0)	71(53)
January 29	Solid Line Transect	24(24)	31(18)	8(7)	2(2)	0(0)	0(0)	1(1)	66(52)
February 6	Plot	22(23)	43(22)	8(5)	1(0)	2(1)	0(2)	0(0)	76(53)
February 17	Solid Line Transect	22(22)	28(11)	6(4)	3(2)	0(0)	0(0)	0(0)	59(39)
February 21	Plot	31(31)	38(22)	7(2)	2(2)	0(0)	0(0)	0(0)	78(57)
February 26	Plot	32(35)	55(38)	6(1)	1(0)	1(0)	0(0)	1(1)	96(75)
March 7	Solid Line Transect	22(22)	30(14)	3(2)	2(2)	3(3)	0(0)	0(0)	60(43)

* Excluding cow-calf groups. Note: removal of these groups sometimes resulted in a greater occurrence of lone moose since occasionally cow-calf groups were found in close proximity to another adult.

mean group size over the winter ($P<0.05$).

Unsexed adults - The crews were unable to sex 36 and 39% of the adults without antlers or accompanied by calves on plots and transects (Table 5). The proportion of unsexed moose was dependent on the aircraft type used, on both transects ($P<0.005$) and plots ($P<0.005$). There was no difference in the proportion between plots and transects for each aircraft taken separately.

The experienced crew was able to correctly sex all 14 adult moose seen on the transects. Even though the number of moose checked by this crew was quite small, they seemed to be more accurate in sexing adult moose than the crews in this study.

Sex-age ratio - The ratio of bull:cow:calf was dependent on the type of aircraft performing the transect survey ($P<0.005$); however, no relationship was found between ratios and aircraft type for plot surveys. In a comparison of plots vs. transects for each aircraft, only the results of the Turbo-Beaver gave evidence that the bull:cow:calf ratios were different ($P<0.025$) although, the ratios were similar using the combined observations of the 4 crews.

In every case, (inspite of there being no statistical difference between the data), fewer calves were estimated for transects than plots, an average of 16 vs. 20%, (an increase of 25%, Table 3). This difference may have been due to: (1) variations in the crews' abilities to sex and age moose, or (2) the random selection of the plots. To test the latter hypothesis, I compared the sex and age data on the 34 plots with the data on those transect sections passing through the same plots. I found

Table 5. Percent of adult moose not sexed by the vulval patch on Ontario wildlife management unit 23 (winter of 1976). Antlered moose and cow-calf groups excluded.

Aircraft Type or Survey Sequence	% Not Sexed		
	Transects	Plots	Total
PA 12	25 (106)*	32 (93)	28 (199)
Cessna 172	45 (70)	40 (65)	43 (135)
Cessna 180	24 (108)	21 (76)	23 (184)
Turbo-Beaver	63 (118)	56 (59)	60 (177)
Experienced Crew (Cessna 180)	0 (14)	--	0 (14)
First	44 (106)	21 (71)	
Second	57 (91)	32 (66)	
Third	26 (73)	41 (84)	
Fourth	33 (55)	47 (72)	
Fifth	29 (77)		

* Adult moose seen.

Table 6. Number of plots needed to be flown in the low (A), medium (B) and high (C) strata on Ontario wildlife management unit 23, 1976, for various probabilities and confidence levels. The percentage values refer to amount of study area that would have to have been surveyed.

Desired Probability Occurrence	Desired Confidence Limits ±20%				±15%				±10%			
	A	B	C	Total(%)	A	B	C	Total(%)	A	B	C	Total(%)
80%	6	8	8	22 (6)	10	13	13	36(10)	18	25	24	67(18)
90%	9	13	12	34 (9)	15	20	19	54(14)	25	35	33	93(25)
95%	12	17	16	45(12)	19	26	25	69(18)	31	43	41	115(31)

that the bull:cow:calf ratios on the plots (N=606) and corresponding transect sections (N=79) were similar: 31:50:19 and 30:51:19.

Antler records - The PA 12 crew recorded similar proportions ($P>0.5$) of antlered bull moose on transects (N=105) and plots (N=83): 32% vs. 36%.

Inventory Results vs. Time of Winter

Track counts - There was no trend with time in either old or fresh track counts (Fig. 3). The sum of old and fresh tracks over 10 km sections gave mean counts of old tracks that varied greatly ($P<0.10$) among the 5 transect surveys (1.02 $\pm$ 0.17, 1.27 $\pm$ 0.21, 3.01 $\pm$ 0.43, 2.80 $\pm$ 0.42, 2.93 $\pm$ 0.37). While the mean counts of fresh tracks were similar for the last 4 transect surveys, they were quite different ($P<0.10$) from the mean count for the first survey (0.31 $\pm$ 0.07, 0.53 $\pm$ 0.11, 0.67 $\pm$ 0.13, 0.52 $\pm$ 0.10, 0.63 $\pm$ 0.13).

Population estimates - Analyses comparing the population estimates of bulls, cows, cows with calves, calves and all moose combined vs. time of winter showed no trends. Estimates of the number of moose based on fresh track group counts from the first to the fifth transect surveys were: 1325 $\pm$ 302, 2129 $\pm$ 492, 2413 $\pm$ 446, 1762 $\pm$ 388, 2267 $\pm$ 538 (average of 1979 $\pm$ 438 or 127% of the best estimate). The track counts used to calculate these estimates showed no trend over the winter (Fig. 3).

The confidence intervals ranged from 12 to 27% of the plot population estimates of the 4 aircraft and from 20 to 23% of the transect population

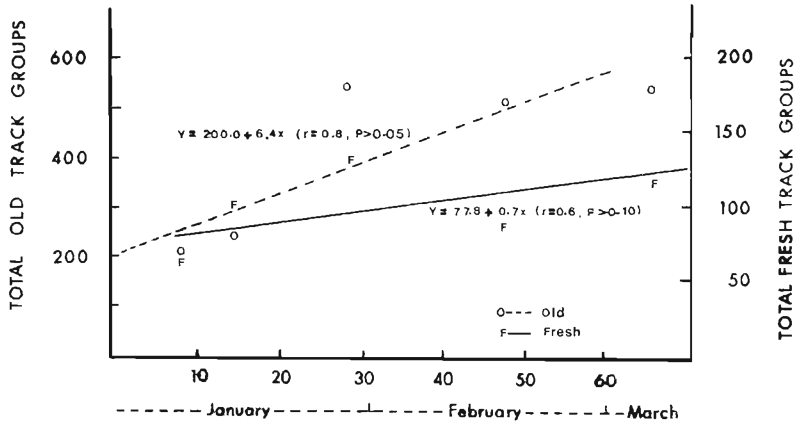
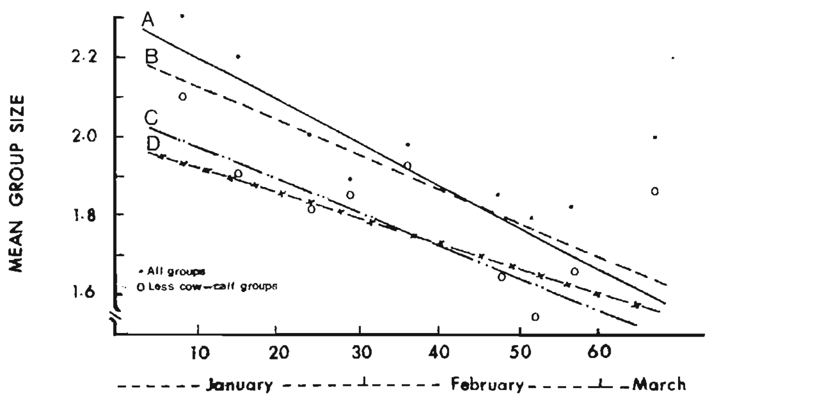


Fig. 3. Variation in the total number of fresh (F) and old (o) track groups counted over the winter of 1976 on Ontario wildlife management unit 23.



A All groups excluding last survey Y = 2.3 - 0.010x, (r = -0.9, P<0.01)
B All groups Y = 2.2 - 0.008x, (r = -0.8, P<0.01)
C Excluding cow-calf groups and last survey Y = 2.1 - 0.009x, (r = -0.9, P<0.01)
D Excluding cow-calf groups Y = 2.0 - 0.006x, (r = -0.8, P < 0.05)

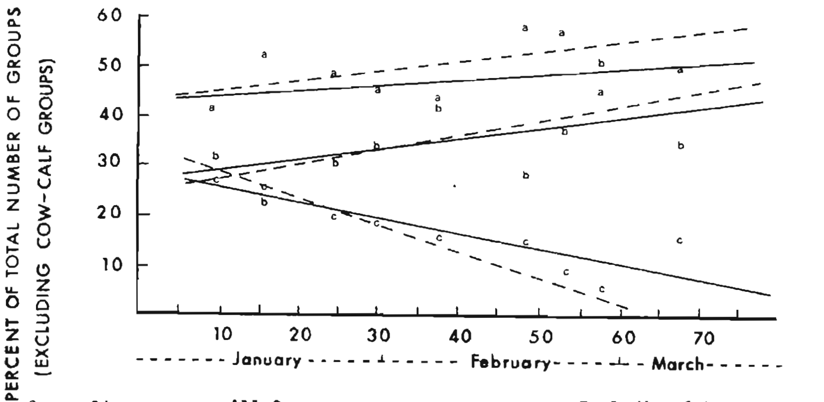
Fig. 4. Variation in mean moose group size over the winter of 1976 on Ontario wildlife management unit 23. Data from plots and transects were combined.

estimates. When the estimates were made by time periods, the confidence intervals ranged from 11 to 23% for the plots, and 23 to 25% for the transects (Table 3).

Moose groups - Group size declined throughout the winter until the last survey when it increased (Fig. 4). The proportion of single moose did not change throughout the winter, groups of 2 increased only when cow-calf groups were included ($Y=32.8 + 0.4x$; $r=0.8$, $P<0.025$) and groups of 3 or more decreased ($P<0.01$, Fig. 5).

Unsexed adults - The percent of unsexed adults showed no trends over the 9 survey periods (Table 5). However, tests on transect and plot surveys separately showed a dependence of the proportion of unsexed moose on time of winter (Plots - $P<0.01$, Transects - $P<0.005$).

Period of antler shedding - Only the records of the PA 12 crew were used to relate antler drop to time of winter. The percent of antlered bulls showed a distinct decreasing trend over the winter (Fig. 6). Extrapolation of this line showed that all the moose would have been antlered on 19 December (± 18 days or 1 SD) and all antlers shed by 14 March (± 15 days). The earliest recorded antler drop on the study area, as determined from hunter reports, was from a yearling shot 26 November, 1975. Moose check station records collected between 1 and 15 December from 1970 to 1975 showed that 3 of 20 bulls (15%) during this period had shed both antlers. During these surveys, the last antlered bull was seen on 8 March.



Group Size		All Surveys ———	Excluding 9th------
1	a	$Y=43.7 + 0.1x$ ($r=0.5, P>0.10$)	$Y=43.2 + 0.2x$ ($r=0.5, P>0.20$)
2	b	$Y=27.7 + 0.2x$ ($r=0.5, P>0.10$)	$Y=24.5 + 0.3x$ ($r=0.6, P>0.05$)
3	c	$Y=28.6 - 0.3x$ ($r=-0.8, P<0.01$)	$Y=32.3 - 0.5x$ ($r=-0.9, P<0.01$)

Fig. 5. Frequency of occurrence of group size 1, 2 and 3+. Data collected during the winter of 1976 on Ontario wildlife management unit 23.

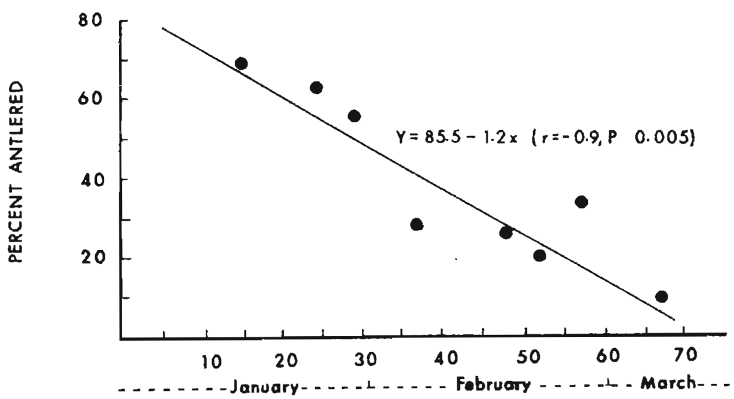


Fig. 6. The percent of bull moose found antlered on Ontario wildlife management unit 23 during 8 survey periods by the PA 12 crew in 1976.

Result of Stratification

Plot selection - The 375 plots were divided into 224 low (60%), 110 medium (29%) and 41 high (11%) density areas (Fig. 7). For the plot surveys, I selected the number of plots expected to give us results within 20% of the mean population estimate ($P \leq 0.10$, Table 6). This required flying 34 plots. Nine low, 13 medium and 12 high density plots should have been flown, but due to a clerical error, 10 low, 11 medium and 13 high density plots were actually flown, resulting in 5, 10 and 32% of the low, medium and high density plots being surveyed.

Counts by strata - Due to moose movements there was considerable variation in successive counts of moose on the same plots by the 4 crews. For example, counts on 1 plot by the 4 crews gave results of 3, 9, 11 and 3 moose while on another plot they recorded 6, 3, 9 and 2 moose. The count was the same, 0 moose, for all 4 crews on only 1 of the 34 plots. The average number of moose counted on the low, medium and high strata plots for all aircraft crews were 2.78 ± 2.95, 4.16 ± 3.22 and 5.97 ± 5.36 ($\pm$ 1 SD). Only the number of moose counted by the PA 12 crew showed a slight dependence on the plot density index values (Table 7; $Y=2.9 + 0.9x$; $r=0.5$, $P<0.005$). Moose counts for the first plot survey showed a similar dependence on the plot density values ($Y=1.8 + 0.9x$; $r=0.6$, $P<0.001$).

Group sizes - The mean group sizes on the plots differed among the three strata ($P<0.05$, Table 8). However, there were no apparent differences among the strata in the frequency of single moose or groups

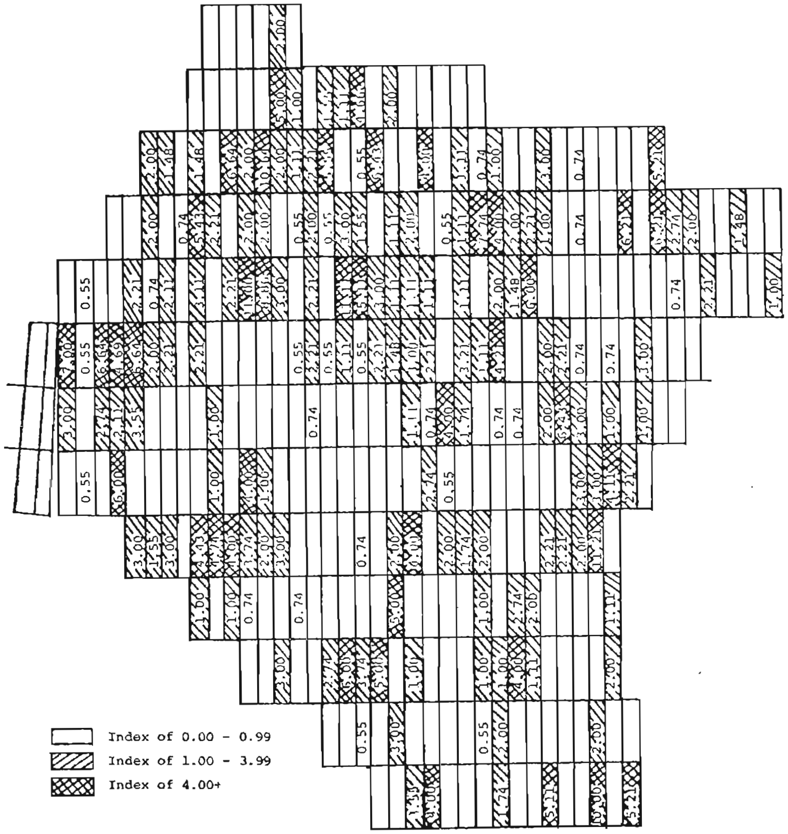


Fig. 7. Index values for each of the 375, 2.5 x 10.0 km plots making up Ontario wildlife management unit 23 for the winter of 1976.

Table 7. Mean moose counts on the 3 strata recorded for aerial surveys conducted on Ontario wildlife management unit 23, during the winter of 1976.

Aircraft or Plot Survey	Low	Medium	High
PA 12	2.7 ± 2.9*	5.0 ± 4.0	8.0 ± 5.9
Cessna 172	2.8 ± 3.0	4.0 ± 2.5	5.7 ± 5.8
Cessna 180	3.5 ± 4.1	4.2 ± 3.1	6.7 ± 5.0
Turbo-Beaver	2.8 ± 3.0	4.0 ± 2.5	5.7 ± 5.8
First	2.2 ± 2.7	3.3 ± 4.1	6.9 ± 5.8
Second	3.0 ± 3.5	4.6 ± 2.7	4.9 ± 4.1
Third	2.7 ± 2.1	4.0 ± 2.9	5.9 ± 5.8
Fourth	3.3 ± 3.7	4.8 ± 3.2	6.1 ± 6.0

* ± 1 SD

Table 8. Average group size by the 3 strata levels as recorded for aerial surveys conducted on Ontario wildlife management unit 23, during the winter of 1976.

Aircraft	All Data			Less Cow-Calf Groups		
	Low	Medium	High	Low	Medium	High
PA 12	1.8	2.1	1.9	1.7	1.8	1.8
Cessna 172	1.8	2.1	1.9	1.5	1.9	1.8
Cessna 180	1.8	2.0	1.9	1.7	1.9	2.0
Turbo-Beaver	1.7	1.9	1.8	1.4	1.9	1.5
Average	1.8	2.0	1.9	1.6	1.9	1.8

of 3 or more moose.

DISCUSSION

Performance of the PA 12 Crew

The PA 12 crew found 94% of the moose on 9 plots as verified by the helicopter. This finding was similar to those of Novak and Gardner (1975) and Gasaway et al (1978). I do not support the conclusion of LeResche and Rausch (1974) that moose surveys, at best, can only be used to indicate trends in the population since during their study: (1) the ground was not completely covered by snow, and (2) the moose paddocks contained between 7 and 43 moose or an equivalent of 68 to 415 moose per 25 km^2. Our experience even in the helicopter flying under optimum snow conditions was that densities as low as 10 moose per 25 km^2 plots sometimes caused confusion since tracks criss-crossed.

It would appear that although the vulval patch method can be used reliably to sex adults from fixed-wing aircraft it is unreliable in sexing calves unless a helicopter is used. W. Gasaway (personal communication) found that 11 month old females did not always have vulval patches.

In addition, the PA 12 crew: (1) correctly mapped the location of 44 moose groups, (2) aged all old and fresh tracks correctly, and (3) found all fresh tracks but missed 12% of the old tracks.

Plots vs. Transects

Comparison between plot and transect survey techniques demonstrated

important similarities (Table 3). The average population estimate from the transect surveys, 1292, matched closely the estimate found by averaging the plot surveys, 1325 and compared favourably with the best estimate of 1556 moose. The average estimates of bulls, cows and calves from the plot and transect surveys were also similar although individual estimates varied somewhat. There was no difference in the average size of moose groups or in the proportion of unsexed adult moose on the plots and transects. The two methods differed in the total number of moose seen, in the number of unseen aggregations recorded and in the sex-age ratios.

Per unit area, 50% more moose were seen on the plots than on the transects. The difference was due to stratification and the greater sampling intensity of high density plots. However, this increase in sightings meant that per unit area, it took 29% longer to survey an average plot as compared to the transects (Table 1).

The sex-age data was similar for plots and transects for 3 of the aircraft crews but quite different for the Turbo-Beaver crew. However, in every survey, the percent of calves estimated on the plots (average of 20%) was greater than that estimated on the transects (average of 16%). The observed variation was due, I believe, to stratification which segregated the plots according to total numbers and not the different social groups. Transect surveys should sample the different density areas in the same proportion as they occur.

There was quite a difference in the number of unseen aggregations recorded on transects and plots: 6.6 vs. 30.0. This may be explained by the narrow nature of the transects on the topographical maps and the apparant reluctance of observers to mark such groups as being on the transects. This difficulty can be resolved by using large scale aerial photographs.

It should be stressed that in this study, the transect surveys were flown by searching for tracks and then circling to find the animals. The traditional method of flying transects is to fly in a straight line without turning to check on tracks and animals. If the transects in this study had been flown in this manner, our counts would probably have been as unsatisfactory as the results of Fowle and Lumsden (1958) and Evans et al (1966).

Inventory Results vs. Time of Winter

Inventory data was compared for 9 survey periods of the winter to see if: (1) there were noticeable trends in the number of moose observed, and (2) observers became more proficient at spotting moose and tracks and in sexing and aging the animals as the surveys progressed.

There was no trend in either old or fresh track counts. Summing tracks over 10 km sections initially gave a mean track count that was quite low in comparison to subsequent surveys. From this I concluded that the crews had problems in observing old and fresh tracks at the beginning of the transect surveys.

Population estimates based on the counts of fresh tracks per day were generally higher than the best estimate of 1556 moose. These estimates may have been inflated due to crossing of moose groups over 2 or more transects or recrossing the same transect. I do not see any value in the use of track counts to estimate moose populations although they may provide the distribution of the moose over large areas.

Population estimates derived from the plot and transect surveys did not differ, nor were there any differences among estimates of bulls, cows and calves on transects or plots. From this, I concluded that there was no discernible trend in moose counts with time of winter. Results from some surveys were so close that it is possible that the ability of observers to find moose did not improve with experience. There was no apparent trend in the ability of observers to sex adults using the vulval patch.

Mean group size declined uniformaly from early January to late February and then increased slightly for the last survey. During the last survey we saw the effect which a rapid accumulation of snow had on reversing the trend of decreasing group size. Rounds (1978) found that mean annual group size in Riding Mountain National Park, Manitoba, remained constant.

My observations of moose suggest that the cow-calf group is a stable unit during the whole winter and should be excluded from calculations of mean group size.

This study suggests that information on moose can be obtained throughout the winter if surveys are flown under ideal tracking conditions. However, since moose groups are larger at the beginning of the winter, and more bulls are antlered (reducing the amount of circling necessary to check on the vulval patch), we recommend that moose inventories be conducted as early in the year as snow conditions allow. Phillips et al (1973) and Des Meules (1964) also recommended this.

Time to Complete Surveys

Searching times on transects ranged from 0.6 to 0.8 hours and on plots from 0.7 to 1.1 hours per 25 km^2. The crews recorded 50% more moose per equal area on plots than on transects which could account for the longer searching times on plots. In 1974, 11 randomly selected plots (46 km^2) on the study area were flown by an experienced Turbo-Beaver crew and it took 0.3 hours to survey 25 km^2 then as compared to 0.7 hours in this study. The population estimate in 1974 was only 750 moose. I believe controlled survey techniques and the increased effort by the observers resulted in increased searching times and an increased estimate.

Results of Stratification

The commonly employed technique of dividing a survey area into 3 or 4 broad,contiguous strata would probably have resulted in wider confidence limits because considerable variability in moose densities was found between adjoining plots (Fig. 7).

The stratification method on the plots was judged successful since 3 of the 4 population estimates were within the required interval. The calculated confidence intervals on the estimates from the transect surveys gave more uniform results but were higher than those for plots. Initial stratification attempts on the plots stratified the bulls, cows and calves more accurately (as judged by the tighter C.L.'s) than when all the moose were combined. I also tested the 3 strata for differences in group size frequencies. The results supported my belief that different social classes used different habitats.

In conclusion, with regard to plot stratification, I felt that although the method proved successful in obtaining the desired confidence limits, it was too costly and time consuming to be of practical value under normal survey conditions. Before the first plot survey could be flown, 2 transect surveys had to be flown and then several days were needed to analyze the data.

Aerial Photographs

The use of foldable photo-mosaics proved successful. The consensus of the PA 12 crew and our experience in the helicopter was that: (1) the problem of determining whether moose were "on" or "off" transects or plots was eliminated, and (2) the aircraft did not have to circle repeatedly and gain altitude to accurately map the moose.

The observers preferred the larger scale photographs. The use of photographs could also assist in studies of moose habitat and behaviour by typing the habitat directly from the photographs or from follow-up ground checks.

Seber (1973) observed that with smaller plots there was a greater chance of error per unit area in determining whether individuals on the edges are inside or outside the boundary. Concerning size he observed that a density estimate from a large number of small quadrats will usually have smaller variance than that from a few large quadrats of the same area, but as a general rule there should not be more empty quadrats than quadrats with just 1 individual. Use of the appropriate aerial photographs would eliminate the edge problem and permit managers to pick more smaller plots.

MANAGEMENT RECOMMENDATIONS

Plot and transect survey techniques showed important similarities. However, I recommend flying transect surveys to avoid the costly and time consuming procedures necessary to properly stratify an area for plot surveys. Transect surveys, unlike plot surveys, provide a distribution pattern of the animals.

I recommend that inventories be flown as early in the winter as snow conditions allow since group sizes are larger and most bulls antlered. This makes tracking and sexing of animals easier. Surveys should be flown with a set of large scale aerial photographs to accurately map moose and tracks.

In conclusion, moose aerial inventories conducted under ideal tracking conditions by trained crews can provide the necessary data for a modern moose management program.

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