PRELIMINARY REPORT ON ACCURACY OF AERIAL MOOSE SURVEYS

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Abstract. Sample quadrats were established around radiocollared moose and each quadrat was surveyed with a search intensity of approximately 4 to 5 min/mi^2 using transect/contour searches similar to standard Alaska Department of Fish and Game surveys. A second, more intensive search of 10 to 13 min/mi^2 was then made of each quadrat. Substantially more moose were seen during the intensive search than during transect/contour surveys in all three physiographic areas. Habitat selected by moose was the most critical environmental factor affecting sightability of 45 radiotagged moose. During early and late winter, 84 and 61 percent, respectively, of the radiocollared moose selected habitat types with low canopies (herbaceous, low shrub, and tall shrub). Moose utilizing these open habitats were easier to see regardless of search intensity. Moose using forest habitats were often missed during the initial transect/contour survey but were usually seen later during the intensive search. Spruce-dominated quadrats were the only areas in which uniformly high sightability could not be achieved with intensive search effort. Activity of moose also affected sightability. Lying moose were missed more frequently than standing moose during transect/contour surveys and intensive searches. Snow condition was identified as having considerable influence upon sightability, but the adverse effects of poor snow condition were largely overcome by intensive search effort. The application of these data to moose trend surveys and censuses is discussed.

Moose management in much of North America today requires reliable estimates of moose population size. To provide these estimates a census method is needed which provides a high degree of precision (narrow confidence limits about the mean estimate) and incorporates sightability correction factors that provide accuracy. Moose survey methods employed by the Alaska Department of Fish and Game (ADF&G) currently provide

little basis for estimating population size or density and provide no means for evaluating precision and accuracy. Studies to improve methods began with the evaluation of accuracy.

Aerial surveys and censuses of large mammals generally underestimate the number of animals present (Caughley and Goddard 1972). Therefore, sightability estimates are needed to develop estimates of actual animal numbers. "Sightability may be defined as the probability that an animal within an observer's field of search will be seen by the observer. The probability is determined by the distance between the animal and the observer; by such characteristics of location as thickness of cover, background, and lighting; by such characteristics of the animals as color, size, and movement; and by the observer's eyesight, speed of travel, and level of fatigue" (Caughley 1974).

Few sightability estimates exist for moose or other large animals. LeResche and Rausch (1974) reported that experienced, current observers saw an average of 68 percent of the moose in four, one-square-mile pens on the Kenai Peninsula, Alaska. Novak and Gardner (1975) estimated 90 percent sightability of moose during aerial transect surveys over 25 km^2 plots in a forested portion of Ontario. As a basis for calculating sightability Novak and Gardner assumed that all moose present during the aerial surveys were later found by intensively searching plots in a helicopter. Several other studies have demonstrated that increasing search intensity increased the sightability of moose and improved the accuracy of population estimates (Fowle and Lumsden 1958, Evans et al. 1966, Lynch 1971, Mantle 1972). However, an unknown proportion of the moose present was not seen during the most intensive searches which precluded calculation of 100 percent reliable sightability values.

Assuming that less than 100 percent sightability of moose will be achieved under most circumstances, regardless of the methods employed, we sought to define aerial search patterns and intensities that would provide relatively high and predictable sightability values under a variety of conditions. These search patterns and sightability values would then be used in the development of census procedures. The sampling design for the census methods under consideration in Alaska utilizes small sample areas and is a modification of the random-stratified procedures reported by Siniff and Skoog (1964) and Evans et al. (1966). The more popular linear transect sample unit was rejected because of the problems of adapting the long, narrow sample units to the specific terrain and estimating the sightability of moose along transects with highly variable habitat types found in Alaska.

The present paper addresses methods for obtaining sightability values for aerial surveys and reports preliminary findings from interior Alaska. These findings will assist in correcting population estimates based upon sampling designs now being tested. Eventually we hope to have an accurate and precise population estimator.

METHODS

The basic requirement for calculating sightability error is the determination of moose missed during an aerial survey. To fulfill this requirement 44 moose were instrumented with radiocollars to allow positive location and identification. The radiocollars were brown in color to prevent bias associated with collar visibility. A representative cross section of the population was collared, including 13 bulls, 18

cows with calves, and 14 cows without calves. Surveys were conducted on the Tanana Flats, Tanana Hills, and foothills of the Alaska Range. Survey aircraft were Piper Super Cubs and a Bellanca Scout, both high performance two-place airplanes.

Sightability of radioequipped moose was determined as follows: 1) a very general location (within 0.75-1 mile) of an instrumented moose was found from an altitude greater than 1000 feet above ground level by the pilot only; 2) a quadrat was laid out which generally encompassed the radiocollared moose (at no time was the specific location identified); 3) the quadrat was surveyed by the pilot and observer and simulated standard ADF&G methods which theoretically give complete coverage using parallel transects flown at 0.5-mile intervals in flat terrain and a contour flight path in hills or mountains; and 4) following the first survey, the quadrat was searched intensively with a continuous circling pattern on the flats and close contour flights in the hills. In a few cases, a circling pattern was substituted for close transects during intensive searches in the hills.

On flat terrain with few map references, physiographic features were used to describe sample quadrat units from the air. These quadrats were usually in the shape of an irregular polygon with objects such as recognizable clumps of trees serving as corner markers. Before the quadrat was searched, boundaries were flown and measured by airspeed, time, and heading. Figure 1 depicts how a quadrat established in this manner would look from the air. The sample units were later drawn to scale and the area determined with a compensating polar planimeter.

Transect surveys over flat terrain were conducted from an altitude of 300 feet at approximately 70 mph indicated airspeed (IAS) with

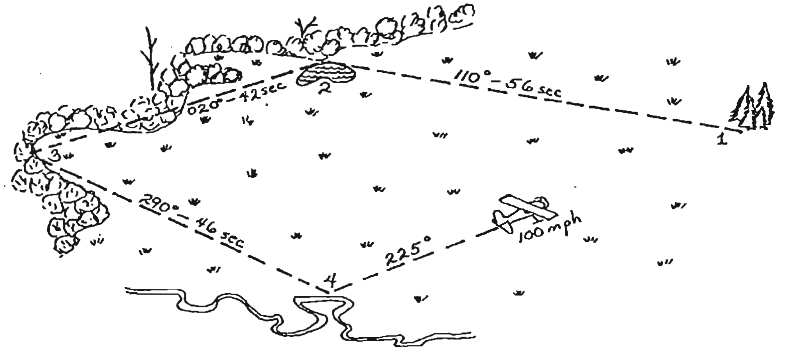

Figure 1. Laying out a quadrat in flat terrain using: 1) a clump of spruce, 2) a pond, 3) an irregular border of herbaceous bog, and 4) an oxbow in a creek as quadrat corners. Heading, airspeed and time are used to determine length of each boundary, and allow calculation of quadrat area.

approximately 0.5-mile transect intervals. The observer and pilot searched an area approximately 0.25 miles wide on each side of the flight line. All flight lines were extended at least 0.5 miles beyond the quadrat boundaries so moose could not be seen during turns to establish the subsequent flight line. Search time during transect patterns was not recorded because that time was regulated by the flight speed and pattern. The theoretical search time using the above values was 1.6 min/mi^2 if no moose were seen; however, the actual time was usually greater and varied with the number of moose seen because at least one low pass was made over each aggregation of moose to determine the sex and age of individuals.

The intensive search pattern consisted of a series of overlapping, irregular circles, 0.1 to 0.25 miles in radius and flown at 70 mph IAS (Fig. 2). Hence, search intensity was regulated by the radius of the circles. Smaller circles were flown and greater search intensity was applied to forest-dominated habitat types than to shrub-dominated habitat.

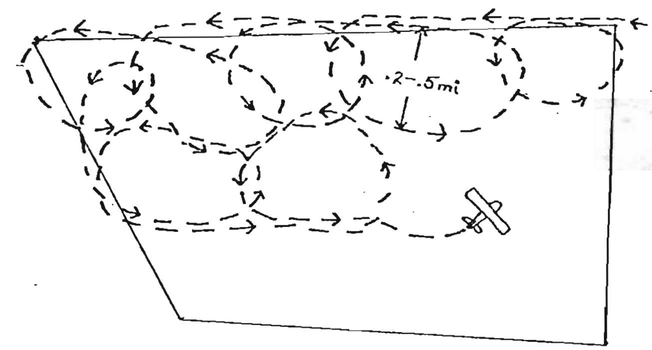

Figure 2. Flight pattern (top view) used during intensive search of flat terrain illustrating the elongated, overlapping parallel circling pattern to ensure complete coverage of a quadrat.

Sample units in the hills and mountains were easily identified and laid out using topographic features such as creek bottoms and ridgetops. Initial contour surveys in hilly terrain were flown between 70 and 80 mph IAS from an altitude of 200 to 500 feet. Flight lines were generally 0.3 to 0.5 miles apart. Observations were commonly downhill and made from only one side of the aircraft. In an effort to duplicate traditional ADF&G survey methods, only the sites where moose were easily seen or likely to be seen were searched during the initial contour survey. Search time was defined as the time actually spent observing within the quadrat.

The flight pattern for intensive searches in hills and mountains was similar to that flown for the initial contour survey except that flight line intervals were less than 0.3 miles apart, dense habitat types generally received greater search intensity than open habitat types, and, whenever possible, turns at the end of contour flight paths were made over the sample area to increase the chance of sighting moose.

In the latter stages of the study, a circling pattern was occasionally substituted for intensive close contour flights in hills.

The habitat type at the exact site where all moose were initially observed was recorded as either herbaceous, low shrub, tall shrub, deciduous forest, spruce forest, sparse spruce forest, or larch. Alternate habitat types available to but not selected by the moose were assessed by recording habitat types which existed within an estimated 200-yard radius of a single moose or from the center of an aggregation of moose. The percent coverage of these available habitat types was visually estimated at the time of siting for collared moose only.

Snow conditions were divided into several components. The age and appearance of snow were categorized as fresh, moderate, or old. Snow cover was then categorized as 1) complete ground cover, 2) fresh snow cling on limbs of trees and shrubs, 3) some low vegetation showing, and 4) distracting amounts of bare ground showing. During analyses of the effects of snow on sightability, snow condition was rated as good (complete snow cover or complete cover plus fresh snow on trees and shrubs), moderate (some low vegetation showing), or poor (distracting amounts of bare ground showing).

If a radiocollared moose was not sighted during the intensive search, it was located electronically.

RESULTS

Search Time and Sightability Values

Search Time

The search patterns chosen resulted in variable search times per unit of area, and since search time is closely related to sightability of moose it is useful to compare relative search intensities used in this study with other surveys where sightability is unknown.

Mean search time spent on low intensity counts during the present study was 4 to 5 min/mi^2 (Table 1). Search time during the comparable ADF&G moose composition surveys ranged from 0.8 to 3.0 min/mi^2 over large areas. This disparity in search time was attributed to differences in the flight patterns. ADF&G composition surveys traditionally high-grade an area by searching only areas of relatively high moose density or areas where moose are easily seen, thereby neglecting large, densely timbered tracts of the survey area. The effect was to reduce mean time spent per unit of area to relatively low values that could not be duplicated with the small quadrats sampled during the study. Time spent during intensive searches was substantially greater than that spent during transect/contour searches, averaging 10 and 13 min/mi^2 in hills and flats, respectively (Table 1).

Sightability Values

Sightability values were summarized according to major topographic features (flats, hills, and mountains) and dominant vegetation types. Disregarding the influence of other variables, sightability was greater

Table 1. Time Searched per Square Mile During Surveys Conducted Between 1974 and 1978 in Interior Alaska.

Type of Survey	Mean min per mi sq (Range) Flats	Hills	Mtn. Foothills
Composition Counts[a]			
in Game Management Units			
20A	1.4(1-1.9)	-	1.9(1.5-2.2)
20B	-	2.1(1.5-3.0)[c]	-
13	0.8	-	1.2
Present Study			
Transect/Contour	-[b]	5.0(2.1-14.8)	4.1(1.5-8.9)
Intensive	13.2(5.3-21.5)	10.0(4.5-26.2)	10.9(2.9-22.6)

[a] These are examples of typical surveys conducted by the Alaska Department of Fish and Game. Transects were used over flat terrain while contour flights were flown in irregular terrain.

[b] The actual time spent searching was not recorded, however the time per mi^2 was theoretically 1.6 min per mi^2 plus the time spent circling moose to identify sex and age.

[c] Values are mean min/mi^2 for 10 surveys during November and December of 1974-1975.

and more consistent during intensive searches than during transect/contour surveys in all three major topographic areas (Table 2). Relatively high sightability was achieved under a wide variety of environmental conditions during intensive searches in mountains, hilly, and flat terrain. Lower and more variable proportions of moose were generally seen during transect/contour searches in the same areas. Sightability was generally greater during October-November than during February-March for both search intensities. The snow conditions in experimental quadrats were sometimes below acceptable levels (comparable to a "Poor" rating in this study) for ADF&G composition surveys; therefore, data from transect/contour searches for these quadrats were not included in Tables 2 and 3. The elimination of these data will provide sightability values for quadrats surveyed with the low intensity search more comparable to ADF&G composition surveys.

Table 2. Percent of Radiocollared Moose Seen in Three Physiographic Areas During Transect/Contour Surveys and Intensive Searches of Quadrats. Transect/Contour Data for Quadrats with Snow Given a "Poor" Rating Have Been Excluded.

	% Collared Moose Seen (No. of Quadrats)					
	Tanana Flats		Tanana Hills		Mtn. Foothills	
Date	Tran/Con	Int	Tran/Con	Int	Tran/Con	Int
Oct/Nov	86(29)	100(32)	100(6)	83(6)	90(10)	100(10)
Feb/Mar	61(18)	90(20)	73(37)	91(44)	33(6)	70(10)

Table 3. Percent Radiocollared Moose Seen in Quadrats as Categorized by Dominant Habitat Type. Transect/Contour Data for Quadrats with Snow Given a "Poor" Rating Have Been Excluded.

	% Collared Moose Seen (No. of Quadrats)			
	Transect/Contour		Intensive Search	
Dominant Habitat	Oct/Nov	Feb/Mar	Oct/Nov	Feb/Mar
Shrub dominated				
Recent burn	87(15)	73(15)	100(16)	94(18)
Subalpine	100(7)	67(3)	100(7)	100(3)
Forest-Shrub mixtures				
Shrub dominated	100(14)	55(11)	100(15)	93(14)
Deciduous dominated	67(3)	83(6)	100(3)	100(7)
Spruce dominated	100(8)	58(43)	89(9)	83(46)

Sightability of moose within each dominant habitat type during intensive searches was generally equal to or greater than sightability during transect/contour searches. Seasonally, sightability of moose was greater during October-November than during February-March. Few moose were missed in any habitats except spruce-dominated forest during intensive searches. But even under the most adverse conditions in spruce forest, 89 and 83 percent of the collared moose were seen during October-November and February-March, respectively (Table 3). Only during October-November did transect/contour searches provide relatively high sightability values in all habitat types (except deciduous where n=3); even then they were more variable than those produced by intensive searches during the same period.

The method used to lay out quadrats for sightability surveys provided the pilot with some general knowledge of the location of the collared moose, even though he had not visually located the animal, and this might bias results. This can be tested by comparing the number of collared moose seen during all transect/contour searches divided by the number of collared moose seen during all intensive searches with the same calculation for uncollared moose present in the quadrats (Table 4). If sightability estimates were influenced, the ratio for collared moose should equal the ratio for uncollared moose. If bias occurred because of knowledge gained during the quadrat layout, the ratio for collared moose would be higher. Table 4 shows consistent differences between these percentages; hence, bias can be demonstrated which will cause an overestimation of sightability. However, the differences are small.

Table 4. Percent of Moose Seen During All Intensive Searches That Were Also Seen During Transect/Contour Searches.

Date	Type of Moose	% of Moose Seen During Intensive Searches That Were Seen During Transect/Contour Searches (no. moose seen during intensive)
Oct/Nov	collared moose	87(47)
	uncollared moose in quadrat	81(236)
Feb/Mar	collared moose	72(65)
	uncollared moose in quadrat	70(186)
Above periods combined	collared moose	79(112)
	uncollared moose in quadrat	76(422)

Environmental Factors Affecting Sightability

Habitat Selection

The variable which appeared to have the most profound influence on moose sightability was habitat selection. As the height and density of vegetation increase, sightability decreases, particularly during transect/contour surveys. During early and late winter moose in all three topographic areas demonstrated greater preference for shrub habitat types than forest types when compared to the percentage and frequency of each type of cover available within a 200-yard radius (Table 5). Combining observations from the three areas for October-November and February-March, 84 and 61 percent of the moose were seen in habitat types with low canopies (herbaceous, low shrub, tall shrub), respectively. However, the proportion of habitats selected varied among the three areas and appears directly related to availability (Table 5). Shifts in seasonal habitat preferences were noted between early and late winter. A strong preference for low shrub in all areas during early winter was replaced by an increased selection of tall shrub and forest types during late winter. Only in the Tanana Hills during late winter, where forest types were most abundant, did the radiocollared moose select forest types equal to the percent forest cover available (Table 5).

Moose were missed during transect/contour surveys in all except herbaceous habitat types, but generally they were missed more frequently as canopy height and density increased (Table 6). Similarly, during intensive searches the percent collared moose missed increased with canopy height and density, although the percent moose missed was substantially lower than on transect/contour surveys in each habitat type

Table 5. Comparison of Habitat Selected by Radiocollared Moose, Percent Frequency of Habitats Available to the Moose, and the Percent Cover of Each Available Habitat.

Area	Months	Hab Sel; Hab Avail; % Cover	No. of Moose	Habitat Types[a] (%) H	LS	TS	D	SS	S	L
Tanana Flats	Oct/Nov	Selected	57	9	67	15	3	2	4	1
		Available	58	42	100	54	25	11	54	30
		% Cover	58	10	57	14	5	3	7	3
	Jan/Feb/ Mar	Selected	105	6	31	24	7	13	13	6
		Available	106	41	70	54	41	38	50	21
		% Cover	72	6	28	20	11	16	15	4
Tanana Hills	Oct/Nov	Selected	15	0	47	20	3	7	23	0
		Available	15	13	67	53	13	13	67	7
		% Cover	15	0	21	16	14	18	30	1
	Jan/Feb/ Mar	Selected	56	2	23	21	14	23	17	0
		Available	56	4	54	55	32	46	48	2
		% Cover	47	1	27	19	14	20	20	T
Alaska Range Foothills	Oct/Nov	Selected	19	0	58	21	0	11	11	0
		Available	19	16	84	58	26	11	37	0
		% Cover	19	14	20	29	9	23	6	0
	Jan/Feb/ Mar	Selected	67	6	34	30	6	16	7	0
		Available	67	54	72	58	37	58	24	0
		% Cover	48	13	19	28	11	23	6	0

[a] Habitat Types: H = Herbaceous, LS = Low Shrub, TS = Tall Shrub, D = Deciduous Forest, SS = Sparse Spruce Forest, S = Spruce Forest, L = Larch

except sparse spruce. Moose in spruce forest appear to be the only ones that have proven difficult for observers to see during intensive searches. The percent missed in larch was greater than that for spruce forest; however, the sample size was too small to draw any conclusions.

Activity of Moose

Lying moose were more difficult to see than standing moose. Of all moose seen in quadrats, 56 and 59 percent were lying during early and late winter, respectively. However, disproportionately high numbers of lying moose were missed. The percent of moose lying among those moose

Table 6. Percent of Radiocollared Moose Missed During Transect/Contour and Intensive Quadrat Surveys by Habitat Type and Activity.

Oct 1976 - Mar 1978	Habitat Types[a] H	LS	TS	D	SS	S	L	Total
TRANSECT/CONTOUR								
% Collared Moose Missed	0	8	21	30	11	65	67	25
(no. of moose)	(3)	(40)	(34)	(10)	(9)	(23)	(3)	(122)
% Missed That Were Lying	-	33	100	67	0	73	50	70
(no. of moose)		(3)	(6)	(3)	(1)	(15)	(2)	(30)
INTENSIVE								
% Collared Moose Missed	0	2	3	8	13	28	33	9
(no. of moose)	(3)	(48)	(36)	(12)	(8)	(25)	(3)	(135)
% Missed That Were Lying	-	100	unk	100	100	71	100	82
(no. of moose)		(1)		(1)	(1)	(7)	(1)	(11)

[a] Habitat Types: H = Herbaceous, LS = Low Shrub, TS = Tall Shrub, D = Deciduous Forest, SS = Sparse Spruce Forest, S = Spruce Forest, L = Larch

which were missed during transect/contour and intensive searches was greater than the percent of lying moose among all moose observed (Table 7). Activity of moose missed during transect/contour and intensive searches was not closely related to habitat type in which the moose was located (Table 6). Apparently moose may be missed in any habitat type, particularly if they are lying down, but intensive searches outside spruce forests missed only lying moose.

Snow Condition

The condition of snow cover was an important factor influencing the sightability of moose during aerial surveys. Sightability values were relatively high regardless of snow condition during intensive searches, whereas during transect/contour surveys sightability was lower and generally varied with snow condition (Table 8). Therefore, the adverse effect of poor snow conditions on sightability can generally be negated by intensive search techniques.

Table 7. The Percent Lying Moose Seen and Missed During All Quadrat Surveys.

		% Lying Moose (no. of moose)
Initial Activity of All Moose Seen During All Quadrat Searches	Oct-Nov	56(518)
	Feb-Mar	59(593)
All Moose Missed During Transect/Contour Survey and Seen During Intensive Survey	Oct-Nov	57(53)
	Feb-Mar	65(91)
Collared Moose Missed During Transect/Contour Survey	Oct-Nov	71(7)
	Feb-Mar	65(34)
Collared Moose Missed During Intensive Search	Oct-Nov	100(1)
	Feb-Mar	80(10)

Table 8. The Influence of Snow Conditions on Sightability of Moose in Quadrats.

	Snow Conditions (no. of quadrats)					
	Oct/Nov			Feb/Mar		
	Good	Mod.	Poor	Good	Mod.	Poor
% collared moose seen during transect/contour searches	86 (36)	100 (9)	33 (3)	69 (49)	46 (24)	53 (15)
% collared moose seen during intensive searches	97 (36)	100 (9)	100 (3)	90 (48)	83 (24)	87 (15)
% increase in collared and uncollared moose seen during intensive compared to transect/contour searches	23 (37)	7 (10)	200 (3)	34 (50)	68 (25)	67 (15)

DISCUSSION

Consistency Between Trend Surveys

Many game departments base their moose management programs on population trend counts and/or sex and age composition surveys. Accurate trends in population estimates and composition can be achieved in this

manner, but only through rigorous adherence to a standard set of procedures and stipulations under which surveys are conducted. These procedures may provide biased values; however, bias is acceptable if it is rigorously controlled and is consistent among surveys. Sinclair (1972), for example, proposed trend surveys to monitor long-term fluctuations in mammal populations on the Serengeti Plains, Tanzania. In contrast, the lack of strict moose survey procedures in Alaska requires fairly large changes in population size to occur before trends become apparent. More rigorous survey procedures must be implemented for ADF&G to make better use of moose trend counts. Findings presented here and in previous studies of other investigators can be used as a basis for improvement.

Consistency in search pattern and effort per unit of area is imperative for trend surveys because the proportion of moose seen is directly related to changes in search effort (Tables 2 and 3) (Fowle and Lumsden 1958, Evans et al. 1966, Novak and Gardner 1975). The search pattern and sampling design can take several forms but the method selected must remain the same from year to year. Varying the search pattern can alter efficiency and in turn alter the proportion of moose seen from one year to the next.

Consistency between surveys can be maintained only when observer experience and currency, environmental variables, and season of the year are relatively constant. LeResche and Rausch (1974) demonstrated the necessity of using only experienced, current observers and pilots. The condition of snow cover can also substantially alter sightability of moose (Table 5, LeResche and Rausch 1974) and fresh snow can be a requirement for some surveys (Novak and Gardner 1975). Daily activity of moose, migratory movements, and habitat selection vary with the season of year and alter sightability. For example, during one moose survey conducted at the time of rut in early October, 75 percent of 106 moose were standing (ADF&G files), while during later October, November, February, and March slightly under half the moose seen were standing. Since the sightability of standing moose was greater than for lying moose (Table 7), a greater percentage of the moose probably were seen during the early October survey than during a survey conducted later in the winter. Habitat selection by moose was different in early and late winter during the present study and during studies by Coady (1974, 1976), Lynch (1975), and Peek et al. (1976), with moose selecting a greater proportion of forest types during late winter. Sightability of moose declined as they increased use of forest types, thus demonstrating the need for seasonal consistency in survey timing. It appears to us that early winter is preferable to late winter for trend surveys utilizing a low intensity search effort in interior Alaska because of high sightability due to the selection for low canopies by moose and frequent snowfall which provides good survey conditions. Lynch (1975) found the same to be true in Alberta. The late winter period can be utilized for trend surveys; however, lower sightability and greater variability in survey conditions must be accepted.

Our efforts to duplicate routine transect/contour surveys used by the ADF&G were unsuccessful; therefore, any attempt to apply our sightability values to previous survey data must be done with caution. At best, sightability values serve as guidelines for determining the proportion of animals seen under a variety of survey conditions. Regardless, educated guesses of moose densities in survey areas are being made on the basis of sightability data. The greatest problem with correcting

the results of low intensity transect/contour surveys is that the proportion of moose seen is relatively sensitive to changes in numerous variables which are difficult to describe quantitatively.

Application of Sightability Correction Factors for Censuses

The accuracy of population estimates based on censuses depends on reliable sightability correction factors to compensate for the number of moose missed during the survey. Instead of estimating the number of moose missed during a survey by generating a sightability correction factor, most census work has progressed on the assumption that all moose were seen. Examples are moose censuses on the Kenai Peninsula and Yukon Flats in Alaska (Evans et al. 1966) and in Ontario (Mantle 1972). On the Kenai National Moose Range, random-stratified sampling methods have been used to census moose since 1964 (Evans et al. 1966) and population estimates are reported by Bailey (1978). All estimates are uncorrected for the sightability of moose and it is probable that the actual number of moose present was consistently underestimated. Even during intensive searches we missed a total of 9 percent of the radiocollared moose, with as many as 28 percent of all moose selecting spruce forest being missed (Table 6). Therefore, it seems appropriate for biologists conducting these censuses to recalculate their data by applying correction estimates for moose missed during the search. These correction estimates could be generated independently or selected from the literature.

Great care must be exercised when selecting sightability values from the literature, however. The three studies reporting sightability estimates were carried out under differing conditions (LeResche and

Rausch 1974, Novak and Gardner 1975, and the present report). For example, in Alaska LeResche and Rausch (1974) reported a lower sightability value for moose than was found in the present study (68 and 87 percent, respectively) for nearly comparable habitat and timing of surveys during winter. There are a number of factors which were responsible for these observed differences; however, the most influential factors are probably related to search patterns and search intensity. Pilots in LeResche and Rausch's study for the most part flew a search pattern of decreasing concentric squares over the 1-square-mile pens with only the moose seen by the observer recorded and were limited to a time of 15 minutes per mi^2. Using the concentric square pattern the plane spends a relatively high proportion of the time in straight flights; however, LeResche and Rausch found a disproportionately high number of moose were seen during the 90° turns at the end of each straight leg of the squares. To take advantage of the improved viewing conditions from a plane in a turning altitude, we used a search pattern of continuous circles during intensive searches over flat terrain and a combination of circling, turning, and contour flight paths over hills and mountains. Additionally, we deviated from the search path when a moose was observed, making a circle around it to determine its sex and/or age and to determine if other moose were nearby. Often moose not seen from the normal flight path and altitude were found. Moose seen by the observer and pilot were recorded during our search since this is the normal procedure used during actual field work. Also, we were not limited to any specific search time. We averaged 10 and 13 min/mi^2 over flats and hills, respectively; however, quadrats with relatively tall, dense vegetational canopies (similar to those used in LeResche and Rausch's study) received a higher than average intensity

search. Hence, for a comparable habitat we commonly searched longer than observers in LeResche and Rausch's study. The sum of these differences in survey procedures could easily account for the approximately 20 percent difference in sightability between the two studies. Reported sightability values should only be used in areas where factors such as moose behavior are similar, habitats are comparable, and search patterns and intensities are duplicated with experienced, current survey crews.

Sightability correction factors can be applied most directly when moose populations are sampled with intensive quadrat searches. Intensive searches in an area would reduce sightability bias from such factors as environmental conditions or observer variability from one year to the next. We have demonstrated that intensive searches reduce bias from such factors as dominant habitat in the quadrat (Table 3), variable snow conditions (Table 8), or different light intensities (unpubl. data). Every effort should be made to standardize survey conditions from one year to the next, however.

The dominant habitat present in a survey quadrat appears to be the best characteristic on which to apply correction factors. The sightability of a moose in a quadrat is directly affected by the dominant habitat surrounding that animal. Other factors such as habitat selected may be too variable for application, whereas a characteristic such as topography may be too general.

Bias in Sightability Estimates

An attempt was made while laying out quadrats to prevent the pilot from learning the whereabouts of the radiocollared moose. It was possible to establish boundaries around a collared moose from an altitude of 1000 feet without locating the animal. At no time did the pilot knowingly fly directly to or visually locate the radiocollared moose. If moose were seen in the quadrat prior to the survey, however, there was usually no way to visually determine if they were collared. Both radiocollared and non-radiocollared moose had equal chances of being seen and those moose that were occasionally spotted were generally very easy to see and would have been spotted anyway.

Once the quadrat boundaries were established, transect/contour and intensive searches were flown systematically with no consideration given to the location of a collared moose within the quadrat. The distance between transect/contour flight lines was not altered nor was the intensive circling pattern shifted to accommodate spotting or missing a collared moose or one seen during quadrat layout. Data suggest, however, that the area near the collared moose may have been searched with more intensity than other parts of the quadrat (Table 4). We feel that bias was relatively small and may be insignificant based on the data in Table 4.

The procedure for searching quadrats may be criticized because both pilot and observer knew there was a high probability that the radiocollared moose was in the quadrat. Therefore, it may be argued that the pilot-observer team may have been more efficient and alert than might be expected during routine census work. Although we were aware of these problems during project planning, there appeared to be no completely satisfactory and economically feasible solution. The use of one aircraft for laying out quadrats with and without collared moose and a second aircraft for making observations could have eliminated both problems but would have been prohibitively expensive. Another approach would be to

use one aircraft and have the pilot lay out quadrats which periodically include or exclude radiocollared moose. The latter procedure was used initially but was abandoned because of the unexpectedly slow rate of data collection. The procedure we finally adopted minimized the pilot's knowledge of the general location of the collared moose and even resulted in occasional failures to include the collared animal within the quadrat.

In spite of inherent shortcomings of the procedure used, we suspect that sightability bias was relatively small for the following reasons:

1) Since we were attempting a total count of moose in quadrats, uncollared moose provided the uncertainty in moose numbers that would be associated with actual field application of the quadrat census method;

2) Sightability data for collared moose differ from data for uncollared moose in quadrats, but not greatly; and,

3) Actual search time expended was relatively short (2.1 to 26.2 minutes, Table 1); hence, maintenance of peak mental and visual acuity was accomplished during the experimental situation and can be expected during normal, routine quadrat census activities as well if similar methods were used.

One problem that was not resolved was the improved sightability of moose during the second search of a quadrat as a result of prior knowledge of distribution of moose gained from the initial search. However, in most instances those moose seen during the low intensity transect/contour survey were highly visible and probably would have been seen during the intensive search, anyway. During future quadrat surveys, the intensive search will be flown initially followed by the transect/contour survey.

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