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MOOSE SURVEY PROCEDURES DEVELOPMENT

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SUMMARY

Because of inherent inadequacies of transect and contour surveys as census methods, the quadrat sampling technique described by Evans et al. (1966) was investigated and modified for additional use in Alaska.

Fifty-two moose were equipped with radio collars in three distinct physiographic areas in Interior Alaska (Tanana Flats, Tanana Hills and foothills of the Alaska Range) to assess variations in sightability due to type and intensity of the survey, environmental factors and moose behavior. Field work was initiated in October 1976.

Several techniques were used to locate and define quadrats. In hilly terrain quadrat boundaries were established and drawn on 1:63,360 scale topographic maps using readily distinguishable features, such as ridgetops and creeks. On flat terrain physical features represented on maps, such as creeks or vegetational patterns, were used as boundaries when possible. However, when such features were not available on maps, quadrat boundaries were defined by straight lines between corners charted from physiographic features identified from the air. The length of each side of the quadrat was determined by flying that boundary at a known airspeed and recording the heading. Area was calculated from a scaled plot of the boundaries.

Each quadrat was established to encompass a radio-collared moose, and the approximate location of the animal was determined by the pilot from an altitude greater than 1000 feet above the ground. Each quadrat was then searched in a manner comparable to previous surveys conducted by the Alaska Department of Fish and Game, and consisted of transect/

contour surveys with a search intensity of approximately 4 to 5 min/mi^2. A second, more intensive search (10-13 min/mi^2) was then made of each quadrat. The numbers of moose seen by both pilot and observer were recorded during each search; these observations indicated the differences in sightability of moose using the two survey methods. Numerous environmental and behavioral factors were also recorded to allow an assessment of their impacts upon sightability.

More moose were seen during the intensive searches than during transect/contour surveys in all three physiographic areas. Snow cover was identified as an environmental factor having considerable impact upon sightability. However, its influence was greater during transect/contour surveys than during intensive searches. The adverse effects of snow quality were largely overcome by intensive search effort.

Habitat selection by moose was the most critical factor affecting sightability. Moose utilizing open habitats, such as herbaceous or low shrub types, were easily seen regardless of search intensity. However, moose using denser habitats, such as deciduous, coniferous and mixed forest types, often were overlooked during the initial transect/contour survey but were seen later during intensive search of the quadrat. Spruce-dominated quadrats were the only habitat category in which uniformly high sightability could not be achieved with intensive search effort. Moose selected more open habitats during early winter, but selection shifted to habitats types with denser and taller canopies by late winter, thus reducing sightability of moose.

The effect of light on sightability was minor compared to the effects of snow condition and habitat type. Moose were most often missed when extreme light conditions prevailed, i.e. in flat-low or bright-high light intensity.

Activity of moose has a decided effect on sightability. Lying moose were more difficult to see than standing moose during transect/contour surveys and intensive searches. Moose missed during intensive searches were generally lying down.

A portion of the Tanana Flats in Game Management Unit (GMU) 20A and part of the Little Chena River drainage, GMU 20B, were selected as areas to begin development of moose census techniques. Transect flights to determine moose density were flown through Count Area 4, GMU 20A, in late November 1977. The survey area was stratified into regions of high, medium, low and very low moose density and random survey points were selected within each stratum. Quadrats that averaged 2 to 3 sq. mi. in area were established around each point and surveyed intensively. Population estimates were generated for each stratum but the 95-percent confidence limits equaled approximately 38 percent of the mean estimate and were considered excessive. The variance was due primarily to a wide range of moose densities that were encountered within individual strata. The area was restratified, but confidence intervals were still unacceptable for the revised population estimate. Intensive quadrat searches are impractical for censusing moose on the Tanana Flats, and other survey procedures for this area are under study.

Transect flights were flown through the upper part of the Little Chena drainage during mid-March 1978. The area was subdivided into strata of high, medium and low moose density. Random survey points were selected for each stratum and quadrats were established and searched intensively around each point. Population estimates were calculated and resulted in 95-percent confidence limits of $\pm$ 47 percent of the estimated total moose. Although this variance was excessive, intensive surveys appear to be feasible in the hilly and mountainous terrain with additional improvement. Continued field development of the technique is warranted.

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BACKGROUND

More intensive management of moose (*Alces alces*) populations in Alaska is required now than at any time in the past. Human demands on the moose resource increase annually while moose populations decline in much of Alaska. Ecological impact studies to assess the effect of industrial development on moose populations are becoming increasingly important, as are studies to monitor moose populations which are rapidly changing in size because of such factors as natural and artificial habitat alteration, predation, high levels of harvest by hunters, nutrition, pathogens, extension of range, etc. To meet demands of research and management for increasingly sophisticated data on moose populations, it is necessary to refine and improve data gathering techniques.

One of the greatest problems in effective moose management and research has been the inability to accurately estimate numbers of moose. Accurate population estimates are extremely difficult to obtain because of the behavior of moose and the type of habitat they prefer. A completely satisfactory census method has not yet been devised for moose (Timmermann 1974). Accordingly, we have selected this area of technique development for study.

Aerial surveys and censuses of large mammals generally underestimate the number of animals present because some animals are missed during the census (Caughley and Goddard 1972). Therefore, sightability estimates of the proportion of animals seen under varying survey methods and environmental conditions are needed to correct 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 observer's eyesight, speed of travel, and level of fatigue" (Caughley 1974).

Few sightability estimates exist for moose or other large animals from which reliable correction factors can be developed for moose censuses. Sightability estimates are reported by LeResche and Rausch (1974) for moose in four, 1-mile-square pens. They found experienced, current observers saw an average of 68 percent of the moose under the experimental conditions, although the search methods employed and habitat and terrain types available sharply limited the application of findings to other situations. 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 they 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 sightability of moose and population estimates (Fowle and Lumsden 1958, Evans et al. 1966, Lynch 1971, Mantle 1972); however, an unknown proportion of the moose present were seen during the most intensive searches which prevented sightability values from being calculated.

In Alaska, transect surveys have been used extensively to obtain sex and age composition data. When compared from year to year these data provide useful insight into population trends. In a few cases transect data have been extrapolated to form crude estimates of population size, but the technique is usually not considered adequate as a census tool and is not used as such. Basically, the transect method involves flying parallel lines at prescribed altitudes and counting moose seen in prescribed transect widths (Banfield et al. 1955). However, estimates of population numbers thus derived are inaccurate because of two major problems: 1) determination of transect width is difficult, and 2) the number of unseen moose is not known and varies greatly with habitat types and environmental factors. Timmermann (1974) concluded that the transect census method was inadequate for the needs of wildlife management agencies and that quadrat sampling methods for the census of moose should be adopted.

Aerial surveys in which quadrats were searched intensively were first introduced in the 1950's (Cumming 1957, Trotter 1958, Lumsden 1959). Quadrat sampling tends to give higher estimates of moose numbers than those obtained by transect methods. For example, Evans et al. (1966) and Lynch (1971) found that transect censuses provided population estimates of only 25 and 67 percent, respectively, of estimates obtained by the quadrat method.

Using the quadrat sampling technique, each randomly selected plot is searched intensively until the observer is satisfied that further searching will not yield additional moose. The increased counting effort per unit of area increases the percentage of moose seen compared with the transect method and accounts for the higher and more accurate population estimates. This method assumes that all moose are seen in a quadrat, although some animals are inevitably missed (W. Troyer and J. Davis, pers. comm.). The number of undetected moose varies according to the density of canopy cover, environmental factors, moose behavior, and pilot and observer effectiveness (LeResche and Rausch 1974).

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 utilize small sample areas and are modifications of the random-stratified procedures reported by Siniff and Skoog (1964) and Evans et al. (1966). The more popular linear transect sampling methods were rejected because of the problems of adapting them to the specific terrain and habitat types found in Alaska. However, transects have been used extensively for censusing some species in other portions of the world, and extensive studies have been carried out to evaluate variables influencing sightability of mammals and methods of correcting population estimates based on transects (Jolly 1969, Caughley and Goddard 1972, Pennycuick and Western

1972, Caughley 1974, Caughley et al. 1976). Nonetheless, quadrat sampling appears to be the best starting point for the development of more precise census methods.

Other factors such as differential seasonal distribution of moose with regard to sex, age and reproductive status must be understood if census data are to be representative of the population being investigated. Sampling schemes must be developed for various habitats and terrain. Correction factors must be developed that will compensate for the influences of environment, habitat and behavior on sightability of moose. Observed sex and age ratios must be evaluated with respect to sample size and differential behavior patterns.

Findings from the above research must be combined with existing information to produce a detailed techniques manual for resource managers. Field application of census techniques must be demonstrated to survey personnel during workshops and training sessions.

OBJECTIVES

To develop sampling procedures for moose census methods and to evaluate moose survey methods presently employed.

To quantify the sightability of moose in relationship to habitat, environmental factors, diurnal and seasonal behavior patterns, sex, age and aggregation size, and to calculate sightability correction factors for variables when appropriate and/or minimize the influence of variables in the design of census methods.

To demonstrate the relationship of search intensity and method to numbers and sex and age composition of moose seen so that optimum search efforts and techniques can be incorporated into the census design and biases in sex and age ratios can be minimized and interpreted.

To prepare an illustrated manual describing the application of census methods and the calculation of population parameters and to assist game biologists in application of census techniques through workshops and field training programs.

STUDY AREA

The study area is diverse and represents most habitat and terrain types selected by moose. Included are mountains, mountainous foothills, rolling hills, flats, and both forested and subalpine river channels. Botanical descriptions of habitat types were reported by Coady (1976) and include alpine, herbaceous, low shrub, tall shrub, deciduous and coniferous types. The study area includes drainages of the Chena River in Game Management Unit (GMU) 20B and Salcha River in GMU 20C and much of GMU 20A.

METHODS

Determination of Sightability of Moose

The basic requirement for calculating sightability error is to determine the number of moose missed during a survey. To fulfill this requirement moose were instrumented with radio transmitters to allow positive location and identification. Forty-four and eight moose were immobilized in GMU 20A and 20B with M-99 and Rompun (Gasaway et al. 1978a) during 1976 and 1978, respectively, and equipped with radio collars supplied by AVM Instrument Company, Carbondale, Illinois. A representative cross section of the population was collared including bulls, cows with calves, cows without calves and yearlings. The radio collars were brown in color to prevent bias associated with collar visibility, and no colored ear streamers (flags) were placed on any of the animals. Ages of moose were determined by tooth sectioning techniques (Sergeant and Pimlott 1959, Gasaway et al. 1978b).

Sightability of radio-equipped moose was determined as follows: 1) the general location (within 0.75-1 mile) of an instrumented moose was identified from an altitude greater than 1000 feet above ground level by the pilot only; 2) a quadrat was laid out which generally encompassed the radio-collared moose (at no time was the specific location identified); 3) the quadrat was surveyed by the pilot and observer using simulated standard ADF&G methods consisting of transect sampling techniques 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 circling pattern on the flats (Fig. 1) and close contour flights in the hills (Fig. 2). 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 or herbaceous bogs serving as corner markers. Boundaries were flown at a constant speed of 100 mph indicated airspeed (IAS) and timed with a stopwatch to provide the length of each boundary. The directional gyro in the aircraft provided a means of determining the heading for each side of the quadrat (Fig. 3). With this method it was possible to lay out a quadrat of determinable size. This method was tested and found to be relatively accurate near North Pole, Alaska, where roads and brushed section lines described known areas of land. Figure 4 illustrates how a quadrat established in this manner would look from the air. This system functions best when no wind exists. However, if the direction and velocity of the wind can be estimated and the wind velocity is relatively low, corrections can be made for airspeed with a simple flight computer similar to a sliderule. When a cross wind was present the heading between two corners was obtained by aligning the aircraft with a line passing through both corners, reading the heading from the directional gyro and making the appropriate crab angle in heading so the flight path reached the far corner. The crab angle has negligible influence on the ground speed of the aircraft when winds blow 10 mph or less. The sample units were later drawn to scale and the area

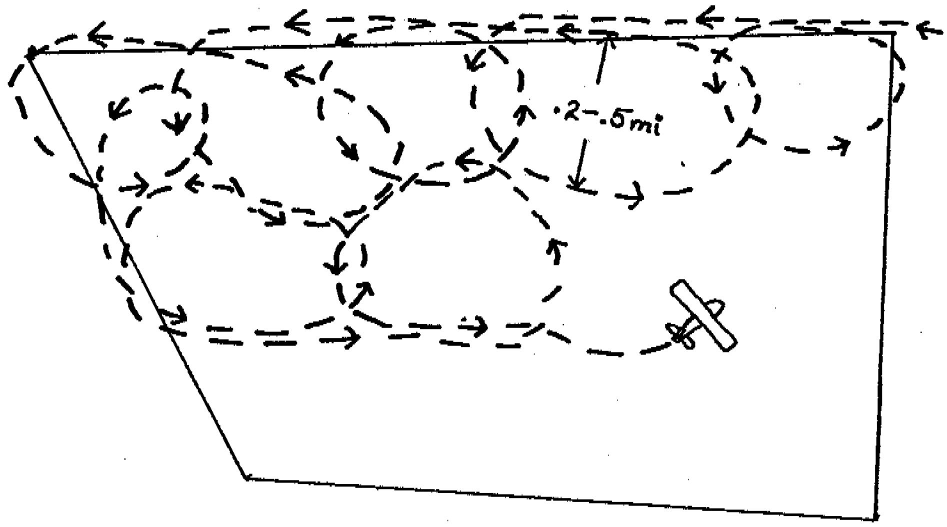

Fig. 1. Flight pattern (top view) used during intensive search of flat terrain illustrating the elongated, overlapping parallel circling pattern to ensure complete coverage of a quadrat.

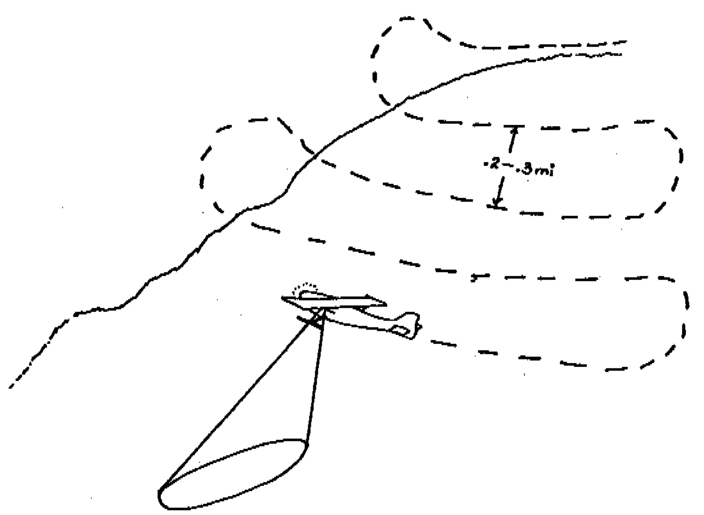

Fig. 2. Flight pattern used during intensive search of hilly terrain illustrating closely spaced contour pattern and downslope view.

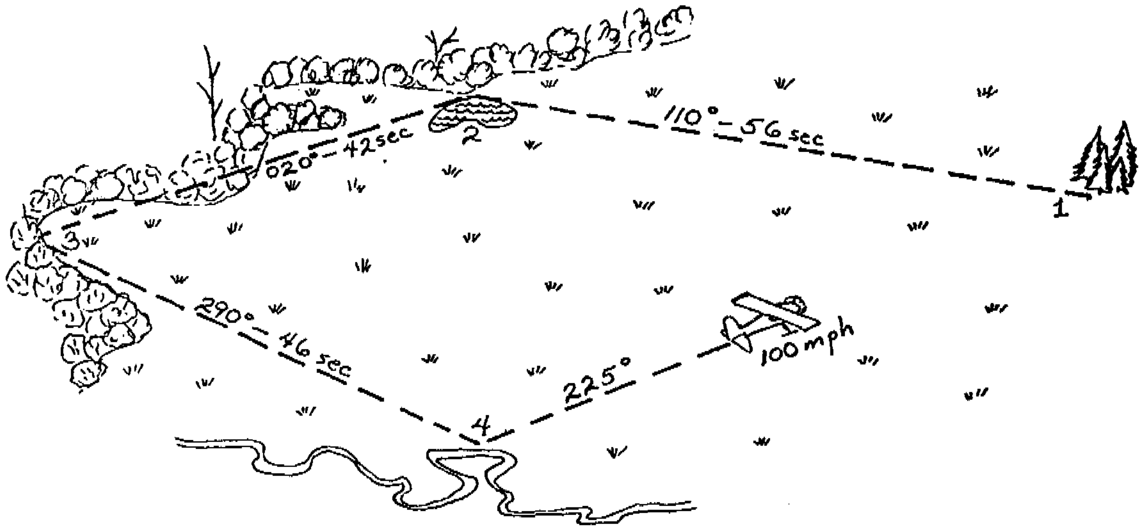

Fig. 3. Laying out a quadrat in flat terrain using: 1) a clump of spruce, 2) a pond, 3) an irregular border of herbaceous bog, and 4) an oxbow in a creek as quadrat corners. Heading, airspeed and time are used to determine length of each boundary, and allow calculation of quadrat area.

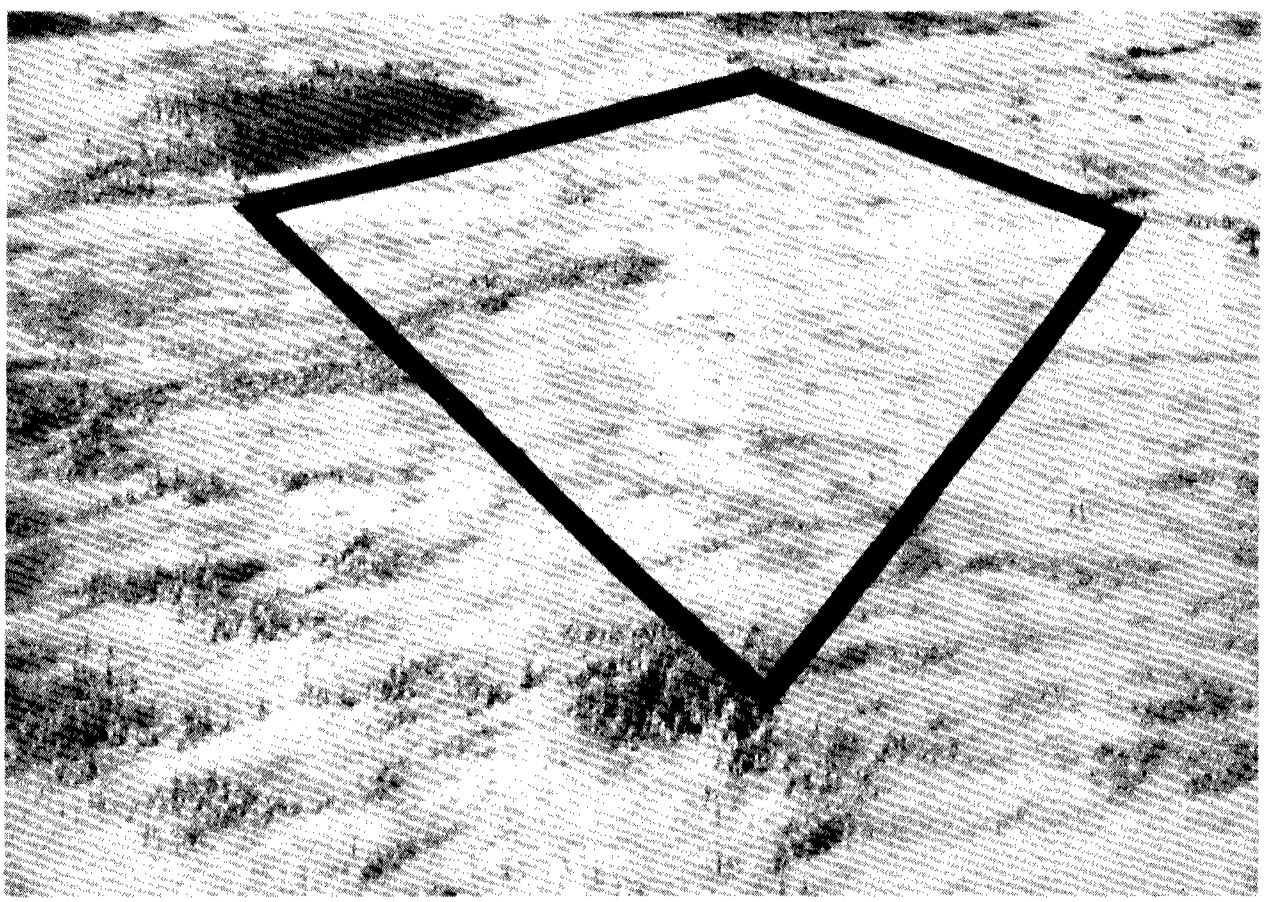

Fig. 4. An aerial view of a quadrat laid out by physiographic features, airspeed and heading on flat terrain.

determined with a compensating polar planimeter. Training and experience were required for observers and pilots to consistently locate and accurately lay out quadrats in flat terrain.

Some error was associated with quadrats laid out by this method. When scale drawings of each quadrat were made, starting and finishing points rarely matched precisely. We judged that the greatest source of error associated with laying out a quadrat was the angle between each side as determined by aircraft heading at the time the quadrat was laid out. Therefore we drew quadrats to scale by leaving the length of each side fixed and altering the angle of the two disjunct sides (Fig. 5). The method of making scale drawings differed during the first year of the study (Gasaway et al. 1977); however, those quadrats will be redrawn and their areas determined using the above method in future reports.

The intensity of search (min/mi^2) during surveys was related to airspeed and width of the interval between flight lines during transect and contour flight patterns. Transect surveys were conducted at approximately 70 mph IAS (75 mph true airspeed in the Bellanca Scout used for most of this study) with approximately 0.5-mile transect intervals. The distance between transects could be closely regulated because the approximate size of the sample quadrat was known. 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. Also, efforts to precisely define quadrat boundaries detracted from search efficiency. The theoretical search time using the above values was 1.6 min/mi^2 if no moose were seen; however, the actual time was 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. If we were uncertain whether an observed moose was in or out of the sample unit during the transect flight, the boundary was flown after completion of the transect survey and the location of the moose with respect to the quadrat was determined.

The intensive search pattern used over flat terrain consisted of a series of overlapping, irregular circles, 0.1 to 0.25 miles in radius, and flown at 70-80 mph IAS. Hence, search intensity was regulated by the radius of the circles rather than by the interval between transects or contours. The radii varied inversely with the density and height of the vegetational canopy; smaller circles were flown and greater search intensity was applied to forest-dominated habitat types than to shrub-dominated habitat. To insure that all areas in a quadrat were observed the search was begun at one corner and a series of circles was flown along one edge, followed by another series parallel to the previous one, until the entire quadrat had been covered. Vegetational patterns, streams and ponds served as ground references during the search pattern. The pilot was always aware of quadrat boundaries. However, if inclusion

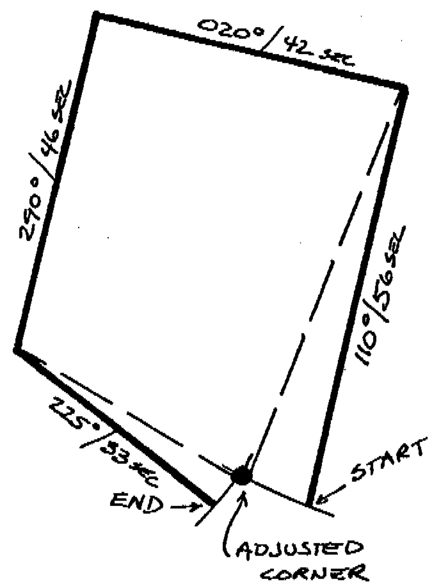

Fig. 5. When drawn to scale, quadrat legs seldom matched perfectly. Quadrats were then adjusted by altering the angle of the two disjunct sides.

or exclusion of a moose in the quadrat was uncertain, a flight directly between the two corners was made to determine the relative location of the moose.

Sample units in the hills and mountains were easily identified and laid out using topographic features such as creek bottoms and ridgetops or, occasionally, straight lines between two physiographic features. Quadrats were drawn on 1:63,360 maps.

Initial contour surveys in hilly terrain were flown between 70 and 80 mph IAS; the greater speeds were attained during periods of winds and turbulence. Flight lines were generally 0.3 to 0.5 miles apart but were subject to wide variation depending upon the terrain and habitat types. In an effort to duplicate traditional survey methods, only the sites where moose were easily seen or likely to be seen were searched during the initial contour survey. Subalpine ridges, creek bottoms and areas burned within 5-25 years were consistently searched in hilly terrain. Dense stands of black spruce (*Picea mariana*) were generally omitted or given minimal search effort. In mountainous terrain, creek bottoms and shrub-dominated habitats were searched most intensively. Search time was defined as the time actually spent observing within the quadrat and was recorded with a stopwatch. Hence, the watch was stopped when the flight path left the sample area or precluded observations of that area. Since concise geographic features defined the quadrats, identification of boundaries presented little problem in contrast to problems encountered on flat terrain. For this reason, uncertainty as to whether a moose was in or out of the sample area was rare.

When flying contours the most productive view for the observer was downhill, since the top aspect of trees predominated and creek bottoms were visible (Fig. 6). Equally important, the observer can continue to view downhill into the quadrat during turns at the heads of valleys because turns are generally made with the low wing pointed downslope (Fig. 7B). Viewing upslope (towards the hill) increased the side aspect of trees and resulted in a decreased proportion of exposed ground (Fig. 6).

There are, of course, occasions when an upslope view is advantageous, i.e. when making a steep bank around the nose of a ridge with the low wing pointed toward the slope (Fig. 7A). With the aircraft in this attitude it is possible for both the pilot and observer to have a top aspect of vegetation.

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 path were made over the sample area to increase the chance of sighting moose and to decrease total survey time.

During each survey the following data were recorded: time of day, number of moose seen, aggregation size, sex, age, initial activity,

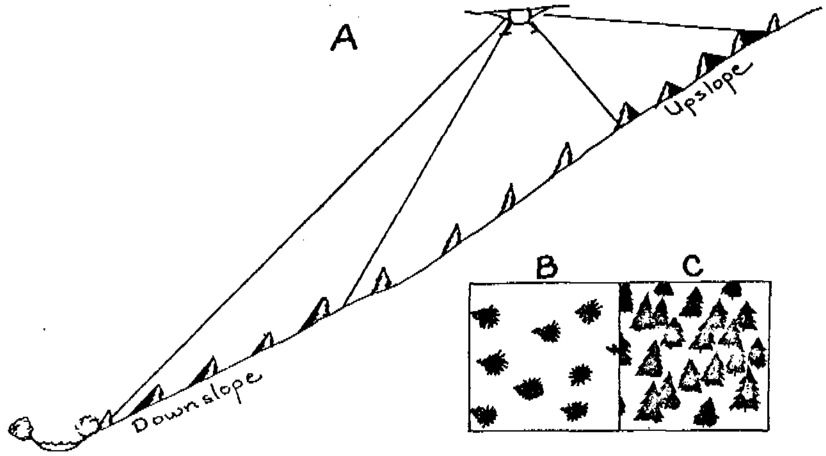

Fig. 6. (A) Amount of hidden ground and perspective of terrain obtained by viewing upslope and downslope during a contour flight; (B) Observer's view downslope illustrating top aspect of trees; and (C) Observer's view upslope illustrating side aspect of trees.

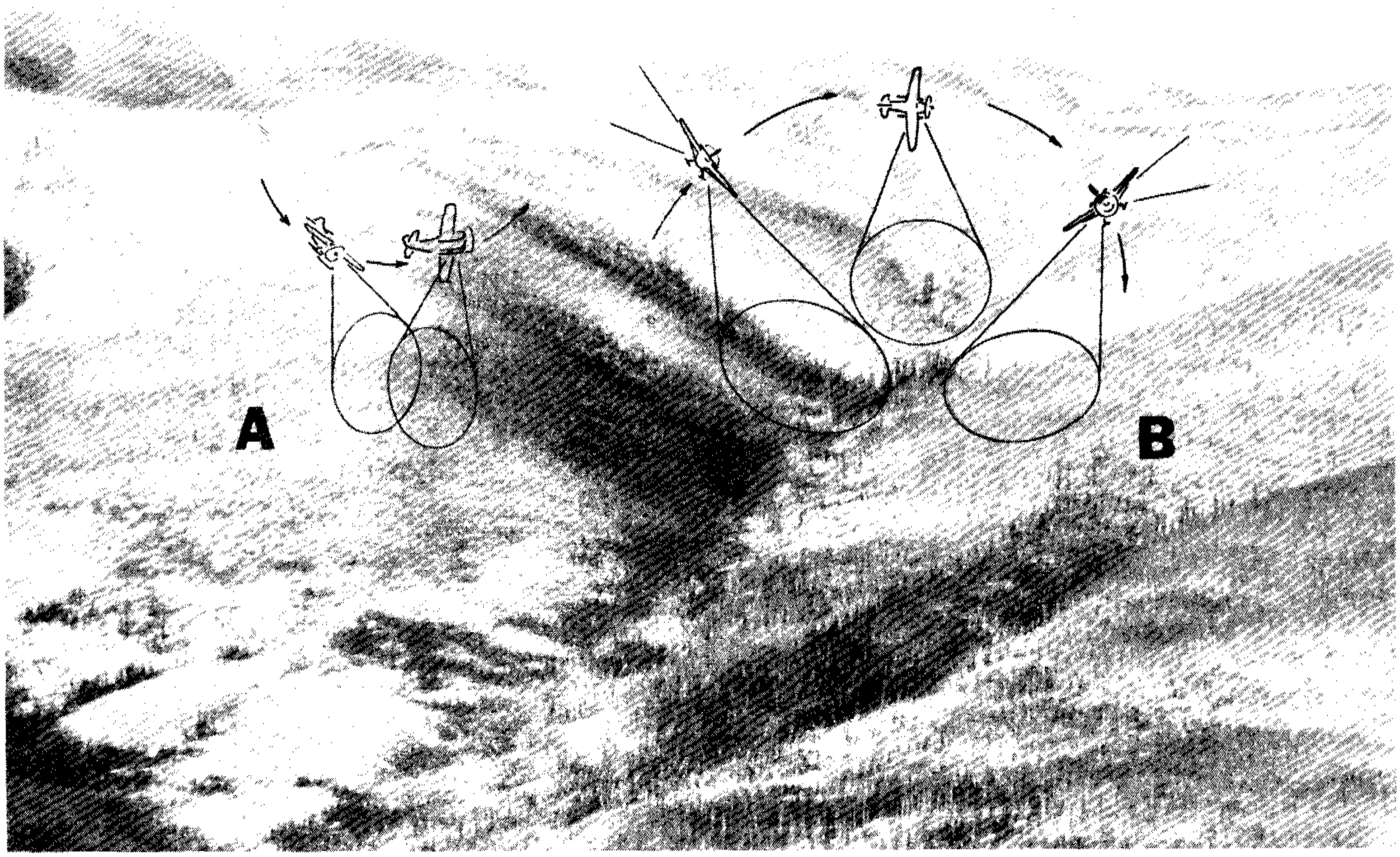

Fig. 7. Observations were best made from the low side of the aircraft when surveying (A) noses of ridges and (B) heads of canyons.

initial habitat selected, habitats available, weather, snow conditions, type and intensity of light, and a relative sightability index for the collared moose. A sample data form is shown in Appendix I.

The habitat type in which all moose were initially observed was recorded as herbaceous, low shrub, tall shrub, deciduous forest, spruce forest, sparse spruce forest or larch. Alternate habitat types available to moose were assessed by recording habitats which existed within an estimated 200 yards of a single moose or from the center of an aggregation of moose. The percent of each available habitat type was estimated for collared moose only.

The locations of moose in relation to topographical features (hillside, alpine ridgetop or creek bottom) were recorded in irregular terrain to provide insight into site selection. This information will also be useful in stratifying areas.

Snow conditions were broken into several components in an effort to determine the influence on sightability. The age and appearance of snow were categorized as fresh, moderate or old. These ratings were subjective because the aging process for snow involves many factors which modify its appearance. Snow cover was then categorized as: 1) complete, 2) fresh snow on limbs of trees and shrubs, 3) some low vegetation showing and 4) distracting amounts of bare ground showing. During the analyses of the effects of snow condition on sightability, snow cover was used exclusively to categorize snow condition as good, moderate or poor. Quadrats with complete snow cover or complete cover plus snow on trees and shrubs (usually fresh snow) were classified as good (Fig. 8). Quadrats with some low vegetation showing were classified as moderate and those quadrats with distracting amounts of bare ground showing were rated poor (Fig. 9). The latter two classifications were usually associated with moderately old and old snow, respectively, although certain environmental conditions, such as strong winds or rapid thaw, could cause relatively fresh snow to be classified as moderate or poor.

If a radio-collared moose was not sighted during the intensive search, it was located electronically and the probable reasons for missing it were recorded. Finally, black and white photos were taken of each quadrat to provide a visual description of habitat and terrain.

Development of Sampling Systems

Evans et al. (1966) described a sampling procedure of stratification and randomly sampled quadrats that potentially can provide a high degree of precision. This basic concept was adopted here with some modification. The area to be censused must be stratified on the basis of moose density prior to sampling. Therefore, rapid and efficient methods of estimating relative density were investigated. Relative moose density in survey areas was assessed during aerial transect surveys. Moose observed along flight lines were recorded on topographic maps to assist in stratification. Also, the location of moose recorded during ADF&G fall composition counts was used as a basis for stratification. Once an area was stratified, randomly selected sample plots were chosen on a 1:63,360 scale map

Fig. 8. Good snow conditions with complete cover and snow on trees.

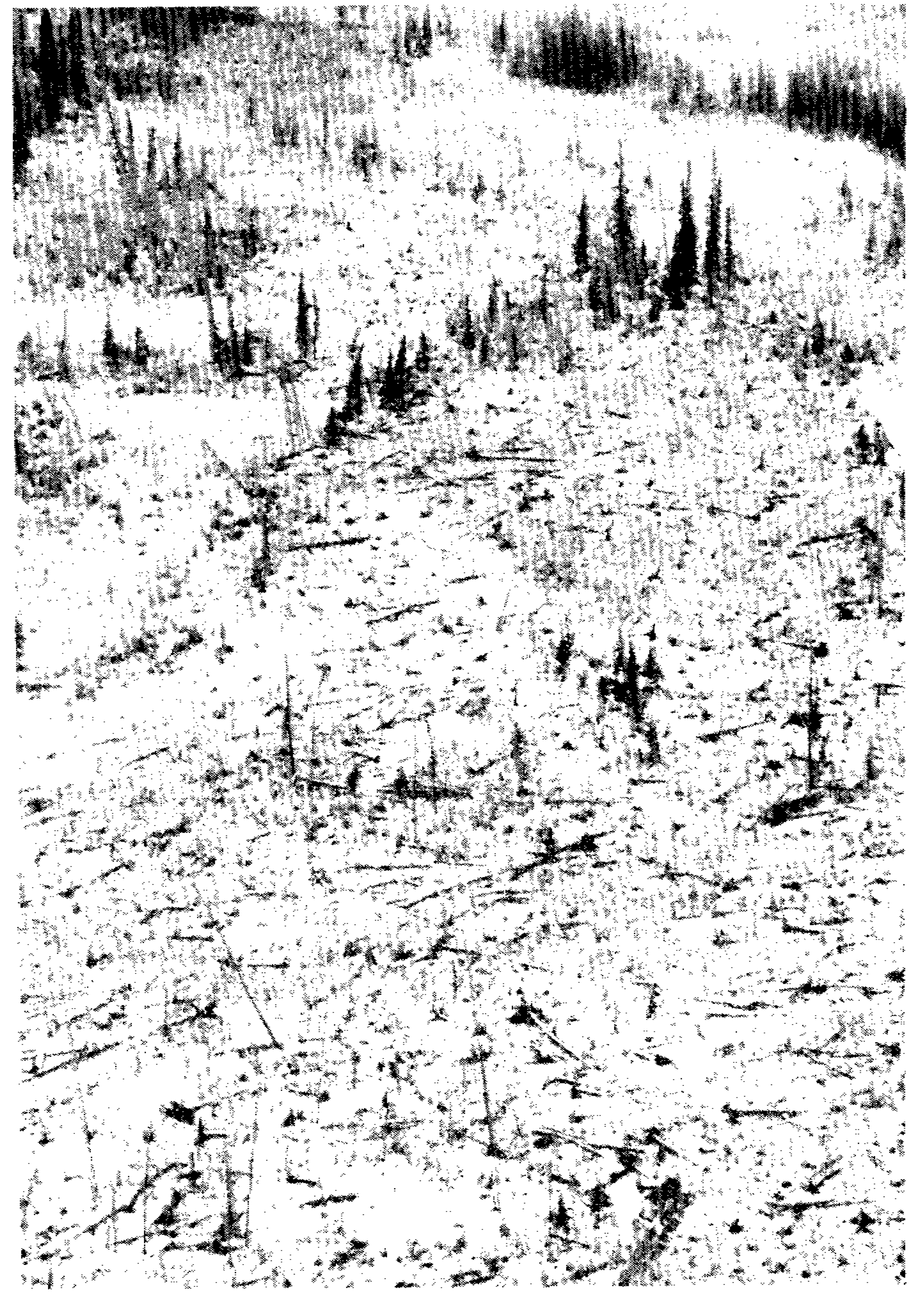

Fig. 9. Bad snow conditions with distracting amounts of bare ground showing.

with either a 0.1-inch-square grid overlay or a computer printout of random points. Quadrats were defined on maps by identifiable geographic features. When no geographic features could be used to define a quadrat on flat terrain, a random point was placed on the map to indicate the area where a quadrat should be constructed during the census by methods described below. If a subsequently selected random point fell within a previously defined quadrat, the survey data from that quadrat were counted twice during data analysis. In areas where specific quadrats could not be defined on the map by physiographic features, random points falling within 0.75 miles of a previously selected random point were included in a single quadrat.

Identification of sample plots on flat terrain with few ground references was difficult. Alternate approaches examined were both uniform quadrats and irregular polygonal quadrats formed by readily identifiable vegetation clumps or geographic features at each corner. Legs of these quadrats were defined by aircraft heading and calibrated airspeed (Fig. 3). Training and experience were required for observers and pilots to consistently locate and accurately lay out quadrats in flat terrain with uniform habitat stands. Therefore, 1-square-mile sample quadrats permanently defined by roads and section lines were located for training and practice.

Portions of GMU 20A and 20B were chosen in which to test the sampling procedures because they offered diverse habitat types and terrains and past studies provided considerable knowledge of moose populations.

Standardization of Moose Census Techniques

To promote continuity and accuracy among the numerous individuals and organizations requiring census information, methods of assessing moose population dynamics must be standardized. Therefore, a manual of techniques designed specifically for conditions in Alaska will be prepared; it will illustrate and describe the basic procedures for quantifying and interpreting population parameters.

Training sessions and workshops will be held for Department biologists. Assistance will be offered in initiating population monitoring programs to insure continuity of techniques between teams of resource specialists so long-term changes in moose populations can be detected.

RESULTS AND DISCUSSION

Determination of Sightability of Moose

Factors determining sightability of moose on aerial surveys are complex. Variables can be divided into three broad categories: 1) environmental, 2) pilot-observer and 3) the behavior of moose. Environmental conditions, such as weather, snow cover, light, terrain and vegetative cover, alter sightability. The efficiency of the pilot-observer team depends upon mental conditions, comfort, experience, type of aircraft, method of sampling and search intensity. The moose is a source of additional variation because of differential habitat selection, behavior patterns and activity schedules when grouped by sex and reproductive status. The difficulty lies in isolating and quantifying these variables.

The present study has identified the following variables as having measurable effects on the sightability of moose during early and late winter: search time, moose activity, habitat selection, aggregation size, snow conditions, lighting and terrain.

Search Time

Sightability of moose during aerial surveys was determined using two search intensities. The lower intensity search was made in an attempt to duplicate standard transect/contour moose survey techniques used for composition surveys by the ADF&G in Alaska. However, duplication was difficult: search time per mi^2 during ADF&G moose composition surveys ranged from 0.8 to 3.0 min/mi^2 over large areas, while mean time spent on comparable counts during the present study was 4 to 5 min/mi^2 (Table 1). This disparity in search time was attributed to differences in the flight patterns. 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 of this practice 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 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 mountainous, 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 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 more realistic sightability values for quadrats surveyed with the low intensity search.

Sightability of moose within each dominant habitat type was greater during intensive searches than during transect/contour searches and 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-

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.

Table 2. Percent of radio-collared moose seen during transect/contour surveys and intensive searches of quadrats. Transect/contour data for quadrats with snow given a "poor" rating have been excluded.

	Percent 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 radio-collared moose seen in quadrats as categorized by dominant habitat type.

	Percent 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)

November and February-March, respectively (Table 3). Only during October-November did transect/contour searches provide relatively high sightability values in all habitat types, although they were more variable than those produced by intensive searches during the same period.

Table 4 provides a means of evaluating bias in the sightability values. 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. The presence of bias was demonstrated by dividing the number of collared moose seen during all transect/contour searches by the number of collared moose seen during all intensive searches and comparing it to the same calculation for uncollared moose known to be present in the quadrats. If sightability estimates contain bias, the percent of collared moose seen should be larger than the percent uncollared moose seen because of knowledge gained during the quadrat layout. Table 4 shows consistent differences between these percentages; hence, bias can be demonstrated which will cause an overestimation of sightability.

Environmental Factors Affecting Sightability

Habitat Selection

The variable with the most profound influence on moose sightability may be habitat selection. As the height and density of vegetation increase, sightability decreases, particularly during transect/contour surveys. Therefore, an understanding of habitat selection is necessary to define the habitat-related problems which will be encountered during moose censuses. During early and late winter, moose in all three physiographic areas demonstrated greater selection for shrub habitat types than forest types when compared to the percentage and frequency of each type of cover available (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 and 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 types in all areas during early winter was replaced by an increased selection of tall shrub and forest types during late winter. Forest types as a group, however, were never selected in greater proportion than their availability (% cover) as shrub types were when the data were lumped. Only during late winter in the Tanana Hills, where forest types were most abundant, did the radio-collared moose select forest types equal to the percent forest cover available (Table 5).

The influence of habitat selection on sightability is shown in Table 6. Moose were missed during transect/contour surveys in all habitat types except herbaceous, but generally they were missed more frequently as canopy height and density increased. Similarly, during intensive searches the percent collared moose missed increased with canopy height and density. However, the percent moose missed was substantially lower than on transect/contour surveys in each habitat

Table 4. Percent of moose seen during all intensive searches that were also seen during transect/contour searches.

Date	Type of Moose	Percent 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)

Table 5. Comparison of habitat selected by radio-collared 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

Table 6. Percent of radio-collared moose missed during transect/contour and intensive quadrat surveys by habitat type and activity.

	Habitat Types[a]							
Oct 1976 - Mar 1978	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

type 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, but the sample size was too small to draw any conclusions.

Activity of Moose

The activity of moose (standing or lying) has a definite effect on sightability during aerial surveys, with lying moose being the most difficult to see. During early and late winter 56 and 59 percent, respectively, of all moose seen in quadrats were lying (Table 7). However, disproportionately high numbers of lying moose were missed during surveys. Among moose missed during transect/contour searches, the percent of lying moose was higher than the percent of moose estimated to be lying in the population (initial activity). Similarly, those moose missed during intensive searches contained a greater proportion of lying moose than did the sample used to estimate actual activity of moose (Table 7). Another approach of assessing the influence of activity on sightability is to compare the probabilities of missing collared moose in lying and standing positions. During transect/contour flights 31 and 18 percent of lying and standing collared moose, respectively, were missed. During intensive searches 11 and 5 percent of lying and standing moose were missed. Therefore, the frequency of missing a lying moose will be about twice as great as for standing moose.

Activity of moose missed during transect/contour and intensive searches was not closely related to the 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.

Snow Quality

The quality of snow cover was an important factor influencing the sightability of moose during aerial surveys. Sightability values were relatively high and seasonally consistent regardless of snow quality during intensive searches, whereas sightability was lower and generally varied with snow quality and time of year during transect/contour surveys (Table 8). Therefore, intensive search efforts can generally negate the adverse effect of poor snow conditions on sightability. Transect/contour surveys yielded high sightability values only during October-November when relatively good snow conditions existed and when moose were frequently selecting shrub habitat types.

Light

The type and intensity of light during surveys appeared to affect sightability, but their influence was small compared with that of other variables. Flat light with no shadows resulted from clouds. Bright light accompanied by strong shadows occurred on clear days. Various combinations of light type (bright or flat) and intensity (high, medium or low) produced diversified conditions under which to view moose. The extremes in lighting condition, low intensity/flat light and high intensity/bright light (Fig. 10), proved to be the most difficult for viewing

Table 7. The percent lying moose seen and missed during all quadrat surveys.

		Percent 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)

Fig. 10. Harsh shadows are created by vegetation under high intensity light. These shadows are distracting to the observer and lower sightability of moose.

moose. Only 64 and 67 percent, respectively, of the moose seen during intensive searches under each extreme condition were also seen during the transect/contour searches (Table 9). Medium intensity light, whether flat or bright, provided the greatest sightability of moose (with the exception of low/bright where n=2). If shadows are present with medium intensity light they are less distracting than shadows produced by high intensity light, but colors are still distinctive and glare is reduced.

The adverse effects of poor light conditions during transect/contour searches were largely overcome with intensive search effort. With intensive searches, 95 to 100 percent of the collared moose were seen under all light conditions except high/bright (Table 9).

Bias in Sightability Estimates

An attempt was made while laying out quadrats to prevent the pilot from determining the location of the radio-collared 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 radio-collared 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 radio-collared and nonradio-collared moose had equal chances of being seen and those moose that were occasionally spotted were generally very easy to see and would have been observed 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 a moose 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 radio-collared 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 radio-collared moose. The latter procedure was used initially but was abandoned because of the slow rate of data collection. The procedure we finally adopted minimized the pilot's knowledge of the general location of the

Table 9. Sightability of moose under various light types and intensities. Values in parentheses indicate number of quadrats. Data from early and late winter are combined.

	Low/ Flat	Low/ Bright	Medium/ Flat	Medium/ Bright	High/ Bright
% collared moose seen in transect/ contour surveys	55 (11)	100 (2)	72 (57)	89 (20)	72 (50)
% collared moose seen in intensive searches	100 (9)	100 (2)	96 (56)	95 (19)	82 (49)
% of all moose seen during intensive search that were seen during transect/ contour survey	64 (11)	90 (2)	79 (58)	79 (19)	67 (48)

collared moose to the extent that there were 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 did not differ greatly from data for uncollared moose in quadrats; 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.

One problem that was not resolved was the improved sightability of moose during the second search of a quadrat as a result of knowledge 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. During future quadrat surveys, the intensive search will be flown initially followed by the transect/contour survey.

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 results of previous studies can be used as a basis for improvement.

Consistency in search pattern and effort per unit of area is imperative for trend surveys because increased search effort is directly related to the proportion of moose seen (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 quality 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 ADF&G moose survey conducted at the time of rut in early October, 75 percent of 106 moose were standing while during later October, November, February and March slightly under half the moose seen were standing (ADF&G files). 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. (1974), 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. Sightability will be higher at that time 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 still be utilized for trend surveys, but lower sightability and greater variability in survey conditions must be recognized.

Our efforts to duplicate routine transect/contour surveys used by 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 not 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 of the 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 radio-collared 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. All three studies reporting sightability estimates were carried out under differing conditions (LeResche and Rausch 1974, Novak and Gardner 1975 and the present report). 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 (Table 9). 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.

Development of Census Procedures

A portion of the Tanana Flats in Game Management (GMU) 20A and part of the Little Chena River drainage, GMU 20B, were selected as areas to begin development of sampling procedures and for the standardization of moose census techniques in Alaska. Both regions have served as moose survey areas during past years, where previous surveys consisted of transect or contour flights designed to provide nearly complete coverage of each area. Based on those previous flights, widely different moose densities were expected in each area. Consequently, a stratified census design was developed and sample techniques were tested for both areas.

In those areas where sample units (i.e. those subareas or quadrats within which moose will be tallied) cannot be determined prior to sampling, or when it is inefficient to define all sample areas prior to selection, random sampling with probabilities proportional to size is necessary. Size is simply the surface area of the subarea, sample unit or quadrat.

The estimation scheme used with probability proportional to size sampling requires that the size of each selected sample unit be measured. That is necessary so that the moose density for the quadrat can be determined. Moose density rather than the number of moose per sample unit is used in estimation.

Let,

$\hat{T}$ = estimate of total number of moose in the total survey area

A = surface area of the total survey area

y_i = number of moose counted on the i^{th} sample unit

$\bar{y}_i$ = density of moose on the i^{th} sample unit (= y_i ÷ surface area of i^{th} sample unit)

$\hat{\bar{Y}}$ = estimated mean density for the survey area

n = number of sample units measured (n includes repeats. For example, if only 2 different sample units were selected, but one of them was selected 5 times, n would equal 6.)

s^2 = variance

Then,

$$\hat{\bar{Y}} = \sum^{n} \bar{y}_i/n,$$

$$\hat{T} = A \cdot \hat{\bar{Y}}$$

$$V(\hat{\bar{Y}}) = \frac{s^2}{n},$$

$$s^2 = \sum^{n} (\bar{y}_i - \hat{\bar{Y}})^2 /n\text{-}1, \text{ and}$$

$$V(\hat{T}) = A^2\ V(\hat{\bar{Y}}).$$

The expressions $V(\hat{\bar{Y}})$ and $V(\hat{T})$ are the variances of the estimates $\hat{\bar{Y}}$ and $\hat{T}$, respectively.

Note that with the above scheme the same sample unit can be repeatedly sampled. That is, sampling is with replacement. In actual practice, the sample unit will only be surveyed once, but its density value will be used in the estimation scheme once for every time the sample unit is selected. The finite population correction factor is not a part of the above variance formulae because of the repeated sampling possible for each sample unit.

The above estimators are unbiased estimators. If the sample units vary greatly in size, but the density tends to be relatively constant, this estimation scheme will be more precise than that based on simple random sampling. If, on the other hand, the large sample units have low density values whereas the small units have high moose densities, the above scheme probably will be less precise than would simple random sampling. If one had a choice between sampling with probabilities proportional to size or simple random sampling, an analysis of the relationship between sample unit size and moose density would be useful. However, in the Tanana Flats, no choice is possible. In the hills of the Little Chena River drainage, sample units are easier to define and locate. Several aspects of sampling are common to both sides, however.

Census of Tanana Flats

Count Area 4 of Game Management Unit 20A (Fig. 11) was selected in November 1977 as the first area on which we would evaluate the sample design.

Stratification Based on Early Winter Composition

ADF&G biologists flew a routine fall composition survey in the area between 10-15 November 1977, during which time the location and number of moose seen were plotted on 1:250,000 topographic maps. We transferred the data onto 1:63,360 topographic maps and used the information to subdivide the count area into strata of high, medium and low moose density.

In order to evaluate the variance associated with sample intensity, 1-mile-square blocks were selected from the moose density map produced during the survey. Each square-mile section within the area and the number of moose recorded there were considered a sample unit, and population estimates were calculated with varying sample intensities. As would be expected, variance in the population estimate decreased with greater sampling intensity. Population estimates varied from 230 $\pm$ 117 moose (90% confidence interval) where n=30, to 230 $\pm$ 73.5 where n=60, to an estimate of 230 $\pm$ 44.8 moose where n=100.

As a trial to determine the variation in moose density that might be encountered during a census, 10 random points were selected in the medium strata and quadrats were surveyed at each point.

The quadrats were laid out and surveyed intensively with techniques described for our sightability study. Quadrats averaged 2.2 sq. mi. in area (range 1.2 to 4.2). Moose density ranged from 0.0 to 3.1 moose/sq. mi. (Table 10). No moose were seen in five of the quadrats and the remaining five quadrats had a range of 1 to 13 moose each.

Stratification Based on Transect Flights

The moose density and distribution we observed during the 10 quadrat surveys appeared to vary substantially from the moose distribution recorded during the winter composition survey. To determine if a difference existed, we flew transect surveys through the area on 22 November 1977. Transects were flown at 1-mile intervals and the number of moose seen and their location were plotted on 1:63,360 topographic maps. We found that moose distribution recorded during our transect flights did in fact vary significantly from the distribution of moose recorded

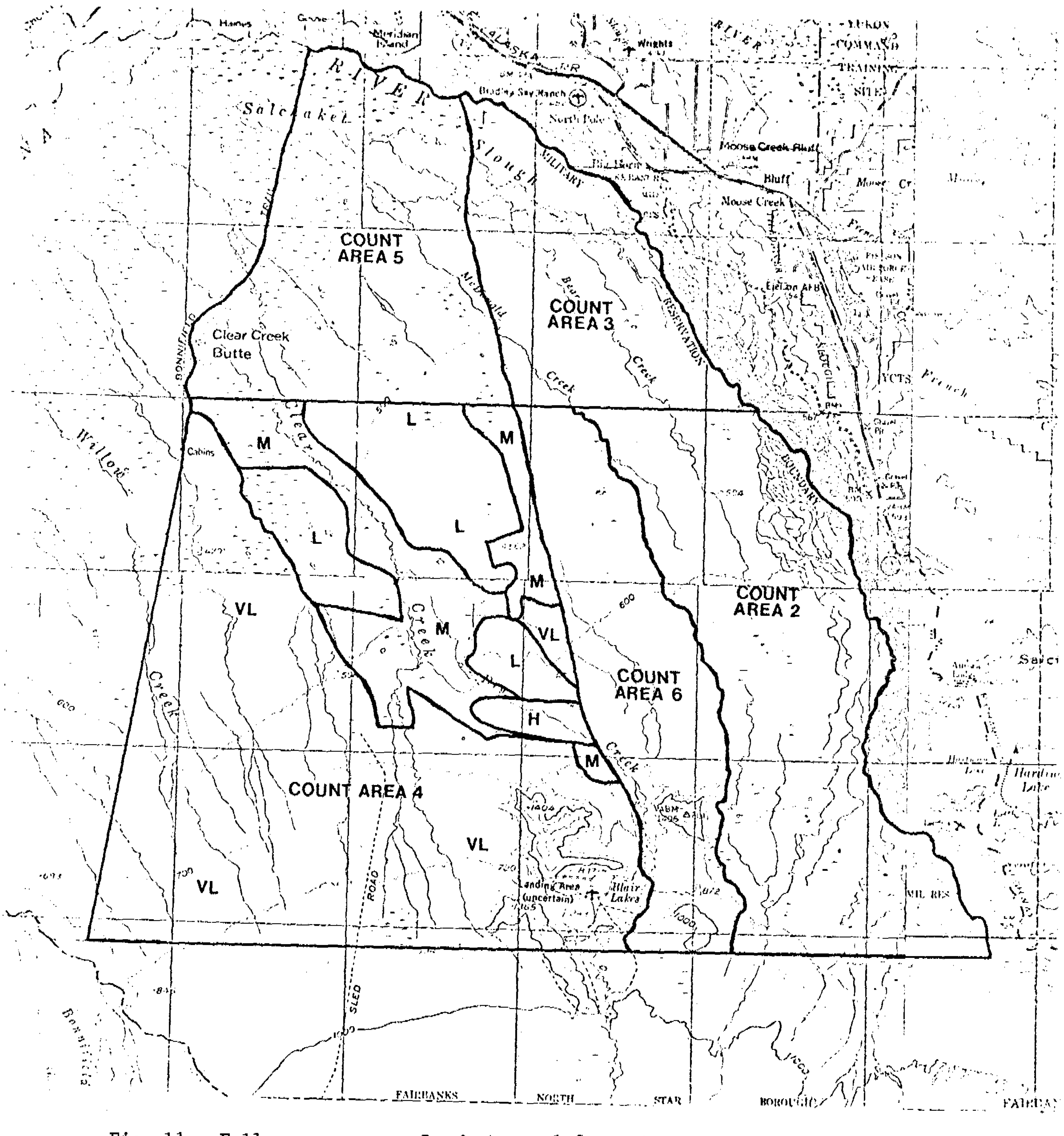

Fig. 11. Fall moose survey Count Areas 1-5 on the Tanana Flats with strata boundaries in Count Area 4.

Table 10. Quadrat size and moose density for Survey Quadrats (SQ) 1-10 from the Tanana Flats.

SQ #	Strata	Area/ sq. mi.	No. moose	Observed moose density/sq. mi.
1	Med	4.2	13	3.1
2	Med	3.7	5	1.4
3	Med	1.7	0	0.0
4	Med	2.4	2	0.8
5	Med	3.1	5	1.6
6	Med	2.0	1	0.5
7	Med	1.2	0	0.0
8	Med	1.7	0	0.0
9	Med	1.3	0	0.0
10	Med	1.4	0	0.0

during the composition survey. Two factors may have caused the disparity between the two surveys: 1) a general change in moose distribution had taken place between the time of the two surveys and/or 2) moose locations had been plotted inaccurately during the composition survey. As a result, the composition survey data were inadequate to be used as a basis for moose density stratification. Therefore, we stratified Count Area 4 into strata of high, medium, low and very low moose densities based on our transect flights.

An attempt was made to define very precise boundaries between strata, primarily on the basis of moose seen during transect flights. Little consideration was given to other factors such as type of habitat available, or the presence or absence of moose tracks in an area. If, for example, numerous moose were seen in the center of an extensive burn, the central area of the burn might have been classified high density while the surrounding burn was classified medium or low. Based on the information gained during those flights, a preliminary stratification into high, medium, low and very low density strata was made, with areas of 5.2, 50.6, 52 and 173 sq. mi., respectively.

Selection of Survey Quadrats

Random points were generated on overlays to aid in the selection of survey points within Count Area 4. Seven overlays were prepared ranging in density from 24 to 480 points/1800 sq. in. of overlay. To randomly select points, the overlays were haphazardly spread over a 1:63,360 topographic map showing the strata boundaries within the survey area. Points that fell within the area were then transferred onto the map. By using overlays of various point density, and with repeated placement of overlays, it was possible to add as many or as few points as needed until a desired sampling intensity was achieved.

Dr. Samuel Harbo proposed a more complex sampling technique based on probabilities proportional to size that is a relatively quick and easy way of selecting spatial sample units with probabilities proporional to size. He recommended using a plastic grid overlay so the smallest sample units would be covered by many grid intersections. That aspect is important to ensure that the probabilities of selection are truly proportional to size.

The sample points on the overlay should be preselected, with the number selected greatly exceeding the number of sample units that will be sampled during any one survey. By so doing, the task of selecting random points to be located on the overlay--a task that can be time-consuming--need be done only once for a number of surveys. The task can easily be done by a technician, once the procedures for selecting points are specified. The points should be selected using a coordinate system formed by specifying one side of the overlays as the X axis and the other as the y axis; the lines on each side should be sequentially numbered starting from zero at the intersection of the two axes. The axes should be permanently marked on the overlay. When a point is randomly selected from the overlay it should be sequentially numbered. The number should be written next to the point on the overlay, and the number and coordinates should be recorded on a data form. By recording that information on a data form, any point could easily be located on the overlay simply by reading its coordinates from the data form and then going directly to that part of the overlay. That aspect is important if the same overlay is used repeatedly.

At times the area to be surveyed might be much smaller than the overlay. In such a situation selecting points from the entire overlay would be very inefficient, for most points selected would fall outside the survey area. The overlay could be subdivided into small subdivisions, say quarters, and, if the subdivisions and the points on the data form are color coded, a selection of points only from that subdivision overlying the survey area could be made. Even if subdivisions of the overlay are used, the points initially selected and marked on the overlay, and which subsequently serve as the basis for selecting survey areas, should be selected for the total surface of the overlay and not on a subdivision by subdivision basis.

As mentioned above, the same overlay can be used repeatedly. When a sample is to be drawn, the overlay should be "randomly" placed over the survey area. Strict random placement is not necessary, but an effort should be made to align the overlay in a somewhat haphazard manner. Once that is done, the selection of points can be made using some selection scheme. For example, the first survey might consist of the first n random points, the next survey the next n + 1 to 2n points. Or, the first survey might consist of the 13th sample point and every N/n^{th} point thereafter (i.e. a systematic sample with the sampling interval the integer value closest to N/n). The next sample might then consist of another systematic sample based on a new starting point, say the 6th sample point. If the overlay is randomly positioned each time a sample of n points is to be drawn, the selection of the same point in different samples does not mean that the same sample area is selected. Even with that condition, a new overlay is warranted if a sample starts getting many points that are repeats from earlier samples, for caution is advised when any question of random selection is involved.

Sampling Intensity

Knowledge of within strata variances was lacking so optimum allocation of sampling effort could only be approximated. An approximation was developed by assuming that within strata standard deviations were proportional to strata moose densities. Those densities were estimated based on the transect survey data, and the sampling effort subsequently allocated. The allocation of effort consisted of selecting random points in each stratum; some points were located in the same sample unit, thus indicating repeated sampling of that unit. The number of units actually measured was determined by logistic considerations.

The greatest potential for variance in the total population estimate is associated with the individual estimates for the high and medium strata. Quadrats surveyed in the high and medium strata will probably contain the extremes in moose density. No moose will be found in some high density quadrats, while other quadrats will have large numbers of moose. Before reliable population estimates can be calculated it is necessary to reduce this variance to acceptable levels by sampling enough quadrats to generate a stable mean moose density/sq. mi. of area. Quadrats in the low strata, however, will exhibit less variability. Most low or very low density quadrats will have no moose and quadrats that do contain moose should have very few.

Quadrat Size

Specifying an allowable minimum size of 2 to 3 sq. mi. for the sample units seemed advisable. By making the sample units as nearly equal in size as the geography would allow, we hoped to reduce variance of the population estimate and make more efficient use of flight time. Large quadrats of 2 to 3 sq. mi. in area are also more likely to contain moose than small quadrats, thereby reducing the variance that results from quadrats having no moose. Therefore, large quadrats help reduce variance associated with inflated densities that result when an unusually large number of moose are found in a small quadrat.

Establishing Quadrats

On the Tanana Flats of GMU 20A, the sample units could not be defined, nor their boundaries determined, until the selected point was visually located by an observer in the air and the nearby distinguishing geographic features assessed. A sample area was then established for the selected point, based on techniques developed for the sightability study. In determining the area associated with a point, the sample area was not delineated so that the point tended to be centered on the area. Rather, the natural distinguishing features of the location determined the area boundaries. Consequently, the selected point could be anywhere within the sample area. To help ensure that the location of the selected point did not unduly influence the location of the sample unit's boundaries, the general vicinity was scrutinized from the air so that the boundaries of adjacent sample units could be roughly delineated. To ensure that the physiographic distinguishing features are not systematically excluded (or included) in the sample units, the middle of the feature (e.g. the middle of a stand of spruce trees) should be used as the "fix" for a corner of the sample unit.

However, it is not always possible to identify points in the middle of homogenous stands of vegetation. It then becomes necessary to use unique features such as the ecotone between two habitat types. Systematic exclusion or inclusion of the distinguishing features must be avoided. The investigator should make a subjective attempt to alternately exclude and include such features or, better yet, establish a set of rules for defining boundaries relative to physiographic features.

Census Results

Twenty-seven quadrats were surveyed in Count Area 4 from 25 November-6 December 1977. Quadrats were searched intensively with techniques used for the sightability study. Quadrat size averaged 2.4 sq. mi. (excluding the census of the single high density quadrat of 5.2 sq. mi.).

Moose density within quadrats ranged from 4.8 moose/ sq. mi. to 0.0 moose/sq. mi. (Table 11). Twenty-four percent of Count Area 4 was sampled, and ranged from 100 percent of the high density to 12 percent of the very low density (Table 12). The results of the actual sampling revealed an estimated total of 166 moose that could be seen in the area from the air. That estimate had a standard deviation of 63.6, which is equal to approximately 38 percent of the estimate. A 95-percent confidence interval would have limits of approximately 39 to 293, an unacceptably wide interval.

Most of the variance of the above estimate was contributed by the very low stratum. Of the total variance of 4,040, the very low stratum contributed 3,322. Most of that variance resulted from one sample unit having a density of 3.0 moose/sq. mi., the third highest densities recorded for any sample unit selected. The next largest contributor of variance was the low stratum, due substantially to one sample unit having a density of 4.8 moose/sq. mi., the largest density recorded for any sample unit. The medium stratum contributed only 207 to the total variance.

Variance was due to a wide range of moose densities that were encountered between quadrats within a single stratum. For example, Survey Quadrat (SQ) 26 was included in the low density stratum. But 10 moose were located within the 2.1-square-mile quadrat, resulting in a density of 4.8 moose/sq. mi. This is equal to the density found in the high stratum. Obviously, SQ 26 was not a low density area at the time we surveyed it and it was stratified incorrectly at the time of surveying. Several other quadrats also appeared to be stratified incorrectly.

Count Area 4 was stratified on 22 November 1977 and 15 days elapsed before the last quadrat was surveyed on 6 December 1977. Apparently a localized shift in moose distribution occurred during this time period. Our strata boundaries described the observed moose distribution too closely and the boundaries were so precise that they could not accommodate small changes in the distributional pattern without becoming obsolete. With these strata significant moose movements took place before we could complete the surveys of sample units.

It became apparent that the high variance associated with the population estimate was primarily due to an inadequate stratification of Count Area 4. Most of the variation was associated with the low and very low strata. Now realizing the problems associated with an exacting stratification based on moose observed on stratification flights, we again restratified Count Area 4 by lumping adjacent areas of similar habitat into the same stratum as well as trying to include a small strip of poorer moose habitat (often ecotonal) along the edges of the higher density strata.

The effect of the last restratification was to create a buffer zone around each stratum that would account for localized movement by moose in that area. As a result of restratification the medium density was enlarged from 50.6 sq. mi. to 85.4 sq. mi. at the expense of the low and very low strata (Table 13). By doing so, the low and very low strata

Table 11. Quadrat size and moose density for Survey Quadrats (SQ) 11-37 from the Tanana Flats.

SQ #	Strata	Area/ sq. mi.	No. moose	Observed moose density/sq. mi.
11	Med	1.7	0	0.0
12	Med	1.9	6	3.2
13**	Med	2.8	0	0.0
14*	Med	1.5	2	1.3
15**	Med	2.8	7	2.5
16	Med	3.1	2	1.6
17*	Med	2.4	3	1.3
18	Med	1.8	2	1.1
19	High	5.2	25	4.8
20	Med	2.6	3	1.2
21	Low	2.7	4	1.5
22*	Low	2.0	0	0.0
23	Low	2.9	0	0.0
24	Low	3.3	1	0.3
25	Low	2.9	3	1.0
26	Med	2.1	10	4.8
27*	Low	2.5	0	0.0
28	Low	2.0	0	0.0
29	Very Low	3.0	0	0.0
30	Very Low	2.2	0	0.0
31	Med	2.7	8	3.0
32	Very Low	2.3	0	0.0
33	Very Low	1.8	0	0.0
34	Very Low	2.7	0	0.0
35	Very Low	2.4	0	0.0
36	Very Low	1.6	0	0.0
37	Very Low	2.4	0	0.0
			Total = 76	

* Quadrats selected twice during random selection of quadrats. These data were included twice for the calculation of the population estimate.

** Quadrats selected three times during random selection of quadrats. These data were included three times for the calculation of the population estimate.

Table 12. Size of strata in Count Area 4 and percent surveyed.

Strata	No. quadrats	Total area/ sq. mi.	Area surveyed/ sq. mi.	Percent total surveyed
High	1	5.2	5.2	100
Medium	8	50.6	18.0	36
Low	9	52.0	23.0	44
Very Low	9	173.0	21.3	12
Total	27	280.0	67.5	24

Table 13. Size of strata in Count Area 4 after restratification.

Strata after restratification	No. quadrats	Total area/ sq. mi.	Area surveyed/ sq. mi.	Percent total surveyed
High	1	5.2	5.2	100
Medium*	13	85.4	30.6	36
Low	5	33.7	13.1	39
Very Low	8	156.5	18.6	12
Total	27	280.0	67.5	24

* Five quadrats within low and very low strata were incorporated into medium stratum after restratification.

variances should be reduced while increasing variance of the medium density stratum. The high density strata remained unchanged during the restratification.

To properly evaluate this new stratification, new sample units should have been drawn and surveyed. However, time and cost restrictions did not permit additional sampling. Consequently, the existing sample units were restratified on the new basis. Five quadrats were located in the restratified areas and changed from either low or very low density to medium density.

The new estimate of moose numbers was 156 with 4.8, 1.5, 0.2 and 0.0 moose/sq. mi. in the high, medium, low and very low density strata, respectively. The sampling variance for the estimated 156 moose was 660.7, giving a standard deviation of 25.7 and an approximate 95-percent confidence interval of 104 to 207. That interval constitutes limits that are approximately $\pm$ 33 percent of the estimated total. Again, the confidence intervals are unacceptably wide given the sampling intensities involved and the likelihood that the stratification was partly influenced by the sample information available. An entirely new set of sample units with the new stratification might have produced even higher variances. In spite of the wide confidence intervals resulting from the last restratification, the exercise was a valuable lesson in stratification strategy which was applied in later studies in GMU 20 that are discussed below.

Intensive searches of small sample plots do not seem very promising for the flats of GMU 20A. Locating and delineating the boundaries of sample units consumes considerable flight time, thus severely limiting the number of quadrats that can be surveyed. As a consequence, the likelihood of reducing the sampling variance to a manageable level is remote. Other survey procedures are now under study.

Stratification of Count Areas 2, 3, 5 and 6

With completion of the Count Area 4 survey, transect flights were flown in Count Areas 2, 3, 5 and 6 (Fig. 11). Transects were flown at 1-mile intervals and the number and location of moose seen were recorded on 1:63,360 topographic maps. The areas were stratified based on the transect flights but no quadrats were surveyed. The purpose of these stratifications was to make a rough comparison of moose densities in other areas of the Tanana Flats with that of Count Area 4.

Census of Little Chena River

During mid-March 1978 we began a census in the upper part of the Little Chena River in GMU 20B (Fig. 12).

Stratification

The Little Chena drainage is characterized by large areas of dense vegetation and hilly or mountainous terrain. These conditions make it difficult to gather moose density information from transect flights.

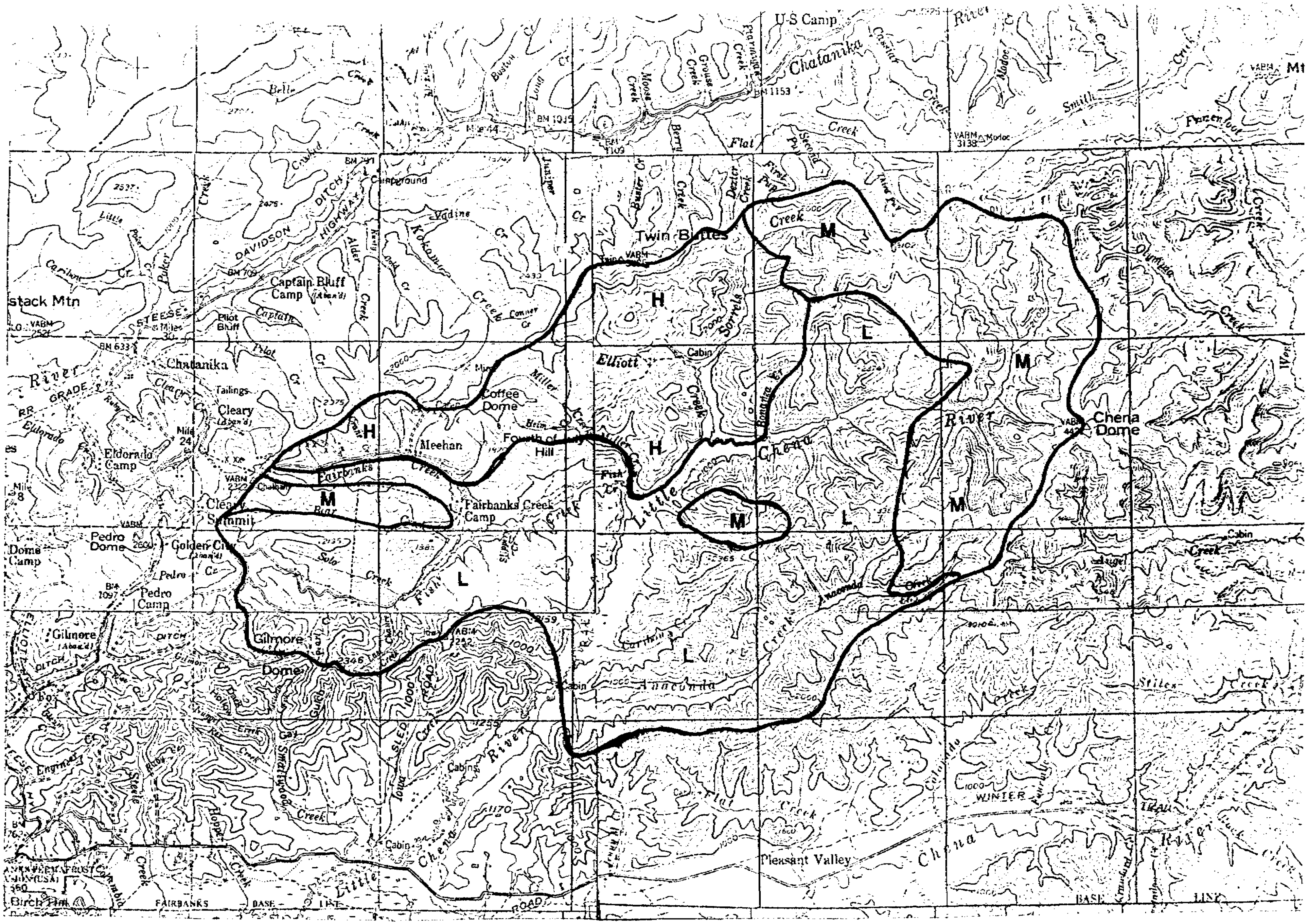

Fig. 12. High, medium and low moose density strata within the Little Chena River drainage.

However, observational flights through the area convinced us that moose density was correlated with habitat type, so we stratified the drainage by delineating the general habitat types on a 1:63,360 topographic map.

The high density stratum was limited to a burn and a ridgetop of young deciduous forest and totaled 67 sq. mi. in area. The medium density stratum totaled 81 sq. mi. and consisted of areas with numerous subalpine ridgetops with mature black spruce stands in the lowland portions, medium age stands of decidous forest or a small burn surrounded by black spruce forest. Mature stands of deciduous forest and black spruce forest were classified as low density and totaled 189 sq. mi.

Buffer zones were provided around each stratum so localized changes in moose distribution would not create excessive variance in the strata population estimates, particularly in the truly large areas classed as low moose density. If, for example, medium density, subalpine shrub habitat dominated a ridge system but was replaced by low density black spruce forest at lower elevations, the entire ridge would have been classified medium density. The lower elevation black spruce would serve as the buffer zone between the medium density and an adjacent low density stratum.

Selection of Survey Quadrats

Selection of sample units followed procedures described for Count Area 4 of the Tanana Flats.

Establishing Quadrats

The topography of the area, including ridgetops, streams, side drainages and gullies, provided quadrat boundaries that were easily and accurately determined on topographic maps and from the air. After random points were plotted on the topographic map, quadrats were drawn around each point. In contrast with the Flats, little flight time had to be devoted to locating the sample unit and its boundaries.

The sample units were defined so they tended to encompass similar ranges of vegetation types and hence moose densities. If a stream formed one boundary, the middle of the stream was the exact unit border so the riparian vegetation on one side of the stream would be in one unit and that on the other side in another unit. Also, if two side drainages formed two boundaries, but the exact middle of the drainage could not be determined, all the riparian vegetation in one drainage and none in the other would be included in the unit. By that means the sample units tended to be very similar in their vegetational patterns.

Surveying Quadrats

Quadrats were surveyed intensively using techniques described for the sightability study. Quadrats that shared a common boundary or were in close proximity were surveyed consecutively to avoid counting moose twice if they moved from one quadrat to another.

Census Results

Twenty-four quadrats were surveyed from 19-28 March; they averaged 3.0 sq. mi. in area (Table 14). Mean moose density was 0.9, 0.6 and 0.08 moose/sq. mi. in the high, medium and low strata. The survey area totaled 337 sq. mi. of which 21.4 percent was sampled.

The estimated number of moose that could be seen in the area from the air was 111. That estimate had a sampling variance of 689, with 404, 98 and 187 contributed by the high, medium and low density strata, respectively. The limits of the 95-percent confidence interval are approximately 59 to 163, or approximately $\pm$ 47 percent of the estimated total. The variance was unacceptably large, as in the Tanana Flats census. Sightability correction factors generated during the sightability study previously discussed were applied to the individual sample units. These correction factors, based on dominant habitat, increased the estimated number of moose from 111 to 125. The confidence interval, expressed as a percentage of the estimated number of moose, was unchanged, 47 percent. However, the design is efficient in terms of aircraft use when compared with routine transect surveys, and larger samples are possible. Furthermore, simple random sampling (equal probability) in each stratum probably would increase precision. The only drawback to simple random sampling is that it would require slightly more effort in delimiting all sample units on topographic maps prior to the aerial surveys.

Conclusion

Intensive surveys of selected sample units appear to be feasible in hilly and mountainous terrain. Relatively little flight time is spent in locating and delimiting sample units; the more intensive search effort undoubtedly increases sightability and, perhaps of more importance, may decrease its variability. A signficant advantage that the above survey methodology has over the continuous transect surveys is that valid variance can be generated for the estimates, leading to a reliable assessment of precision. Continued field development of the method is warranted.

RECOMMENDATIONS

1. Continue the collection of sightability data with emphasis on those physiographic areas and environmental conditions represented by small samples in the present report.

2. Intensify the study of seasonal habitat selection by moose in various areas.

3. Intensify the development of methods for stratifying and sampling areas.

4. Record flight routes and map moose located during all routine S&I surveys to aid in future stratification efforts.

Table 14. Quadrat size and moose density for Survey Quadrats (SQ) 38-62 from the Little Chena River drainage.

SQ #	Stratum	Area (mi^2)	No. moose seen	Observed moose/sq. mi.	Estimated moose present/sq. mi.
38	Low	2.96	0	0.0	0.0
39	Low	3.19	0	0.0	0.0
40	Low	2.64	0	0.0	0.0
41	Low	2.89	0	0.0	0.0
42*	Low	3.36	0	0.0	0.0
43	Med	3.22	2	0.62	0.62
44*	High	3.40	1	0.29	0.35
45	High	3.00	10	3.33	3.53
46	Med	3.45	2	0.58	0.7
47	Low	2.67	0	0.0	0.0
48	Low	3.15	2	0.63	0.76
49	Med	2.32	0	0.0	0.0
50*	Med	2.54	1	0.39	0.47
51	Med	2.82	3	1.06	1.28
52	Med	3.07	2	0.65	0.78
53	High	2.94	0	0.0	0.0
54	High	2.83	4	1.41	1.48
55	High	3.19	2	0.63	0.66
56	High	2.61	3	1.15	1.15
57	High	3.14	5	1.59	1.69
58	High	3.44	0	0.0	0.0
59	High	3.14	0	0.0	0.0
60	High	2.83	1	0.35	0.42
61	not used				
62	Low	3.37	0	0.0	0.0

* Quadrats selected twice during random selection of quadrats. These data were included twice for calculation of the population estimates.

5. Conduct a workshop to explain and demonstrate the census method.

6. Census a portion of GMU 20 on a trial basis.

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Appendix I. Form used for recording sightability during quadrat searches.

Quadrat No. SAMPLE Date 2 / 5 / 77 Time 1150 Page 1 of 2

Location: map quadrat FBX C-2 Pilot/Observer Gasaway - Kelleyhouse

Location description Salchaket Slough ; 6 to 7 mi No. of Clear Cr. Buttes

Habitat description Birch thickets interspersed with meadows with scattered black spruce — Forest dominated

Weather: High overcast, calm, no ppt, 8°F

SNOW Age: Fresh ✓ Moderate ___ Old ___

Cover: Complete ✓ Some low veg showing ___ Distracting amounts of bare ground showing ___ Snow on trees and shrubs ✓

LIGHT Bright ✓ Flat ___

INTENSITY High ___ Med. ✓ Low ___

Plot description: Area ___ sq. mi.

Aircraft Scout 417

Indicated Air Speed 100 mph

Legs:	Heading (°)	Time (sec)	Dist. (mi)	Wind Correction (mph)
1	052°	1:40		
2	328°	1:14		
3	232°	1:59		
4	107°	1:09		

Type of Survey: /✓/ Transect / / Contour / / Intensive

Time of Search (min): Contour ___ Intensive ___ (min:sec)

Indicated Air Speed 70 mph

Remarks ___

Cr/Hill/Rdg.	Agg. No.	BULLS/activ. yrlg	BULLS/activ. med	BULLS/activ. lge	COWS/activ. W/O calf	COWS/activ. W/1 calf	COWS/activ. W/2 calf	COWS/activ. W/ yrlg	Lone yrlg. act.	*Total Moose	HABITAT Upper line = % available Lower line = # moose in each X = selected
	1				1/S					1	H LS TS D SS S L
	2				1/S					1	H LS TS D SS S L
	3					*1/LL				2	60 5 20 15 H LS TS D SS S L 2
	4	1/S			2/SS					3	H LS TS D SS S L 2♀ 1♂
	5										H LS TS D SS S L
	6										H LS TS D SS S L

Total Moose = 7

*Collared Moose Data: Moose No. 7704 Visually located during survey No / / Yes /X/

Relative sightability: Very poor 1 2 3 4 5 Excellent
(in habitat) (very dense) (low veg)

Activity: / / Standing /✓/ Lying

F F/c F/cc F/yr M antler size and condition ___