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MOOSE SURVEY PROCEDURES DEVELOPMENT

by
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Volume I
Project Progress Report
Federal Aid in Wildlife Restoration
Project W-17-9, Jobs 1.17R, 1.18R and 1.19R

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JOB PROGRESS REPORT (RESEARCH)

State: Alaska

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Project No.: W-17-9 Project Title: Big Game Investigations

Job No.: 1.17R Job Title: Development of Sampling Procedures for Censusing Moose

Job No.: 1.18R Job Title: Determination of Sightability of Moose During Aerial Census

Job No.: 1.19R Job Title: Standardization of Moose Census Techniques in Alaska

Period Covered: August 1, 1976 through June 30, 1977

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 refined for possible additional use in Alaska.

Forty-four 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 1:64,000 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 air speed 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 using transect/contour methods with a search intensity of approximately 4 to 5 min/mi^2. A second, more intensive search (9-13 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.

Significantly more moose were seen during the intensive searches than during transect/contour surveys in all three physiographic areas, a fact which demonstrates the advantages of increased search effort over transect/contour surveys.

Snow cover was identified as an environmental factor having considerable impact upon sightability. However, its influence was greater during transect/contour surveys. 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 and 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 denser habitats by late winter, thus reducing sightability.

The effect of light on sightability was minor compared with 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.

Although the effects of moose density on sightability are unknown, density may be related to mean aggregation size, which does have a decided effect on sightability. The density values derived from intensive sampling during this study probably represent maximum values for the area surrounding the quadrat, because each quadrat generally contained at least one (collared) moose. A reduction in absolute moose density within quadrats occurred between early and late winter because of calf mortality and dispersal of adults.

Large aggregations of moose were seldom missed during either transect/contour or intensive surveys of quadrats. The mean aggregation size of groups missed during transect/contour surveys was similar to the mean size for all groups observed; the range in size of those aggregations missed during intensive searches was consistently low.

Activity of moose has a decided effect on sightability. The activity of moose missed during transect/contour surveys but seen during intensive searches did not differ substantially from observed activity of all moose; however, radio-collared moose missed during intensive searches were generally lying down.

CONTENTS

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 sportsmen, nutrition, pathogens, extension of range, etc. To meet demands by 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; accordingly, we have selected this area of technique development for study. A completely satisfactory census method has not yet been devised for moose (Timmermann 1974).

Accurate population estimates are extremely difficult to obtain because of the behavior of moose and the type of forested habitat they prefer.

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 grossly inaccurate because of two major problems: 1) determination of transect width is difficult; 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 are searched intensively were first introduced in the 1950's (Cumming 1957, Lumsden 1959, Trotter 1958). 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). Establishing the location of quadrat boundaries is a major problem on terrain for which ground references are scarce (Evans et al. 1966). Nonetheless, quadrat sampling appears to be the best starting point for the development of more precise census methods.

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

Development of Sampling Systems

Evans et al. (1966) described a sampling procedure that potentially can provide a relatively high degree of precision, i.e. stratification and randomly sampled quadrats. This basic concept was adopted here with some modification. The area to be censused must be stratified on the basis of moose density; therefore, rapid and efficient methods of estimating relative density were investigated. Densely forested areas were the most difficult in which to determine relative density and required intensive search. Relative moose density in very open habitats was assessed during aerial transect surveys. Moose observed along flight lines were recorded on maps to assist in stratification. Also, the location of moose recorded during composition counts proved useful in stratifying areas. Once an area was stratified, randomly selected sample plots were chosen on a 1:64,000 scale map with 0.1 inch square grid overlay. Irregular 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, that point was discarded. 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 rejected.

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. 1). 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, one square mile sample quadrats permanently defined by roads and section lines were located for training and practice.

A portion of GMU 20A was chosen in which to test the sampling procedures because it offered diverse habitat types and terrains and past studies provided considerable knowledge of moose populations. During November 1976 random sampling units were selected and drawn on a 1:64,000 scale map; however, inadequate snow conditions prevented stratification of the area and application of census methods.

Determination of Sightability of Moose

The basic requirement for calculating sightability error is the determination of moose missed during a survey. To fulfill this requirement moose were instrumented with radio transmitters to allow positive location and identification. Forty-four moose were immobilized with M-99 and Rompun (Appendix II) in GMU 20A and 20B and equipped with brown radio-collars supplied by AVM Instrument Company, Carbondale, Illinois. No colored ear streamers (flags) were placed on any of the animals. Bulls, cows without calves, and cows with calves were collared in nearly equal proportions to determine differential sightability. Ages of moose were determined by tooth sectioning techniques (Gasaway et al. submitted for publication).

Sightability of radio-equipped moose was determined as follows: 1) the general location 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 was believed to encompass the radio-collared moose (at no time was the specific location identified); 3) the quadrat was surveyed using a transect sampling technique in flat terrain and a contour flight path in hills or mountains which simulated standard survey methods employed by the Department of Fish and Game; and 4) following the first survey, the quadrat was searched intensively with a circling pattern on the flats (Fig. 2) and close contour flights in the hills (Fig. 3). Occasionally a second intensive search was made if the collared moose was not located during phases 3 or 4.

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 approxi-

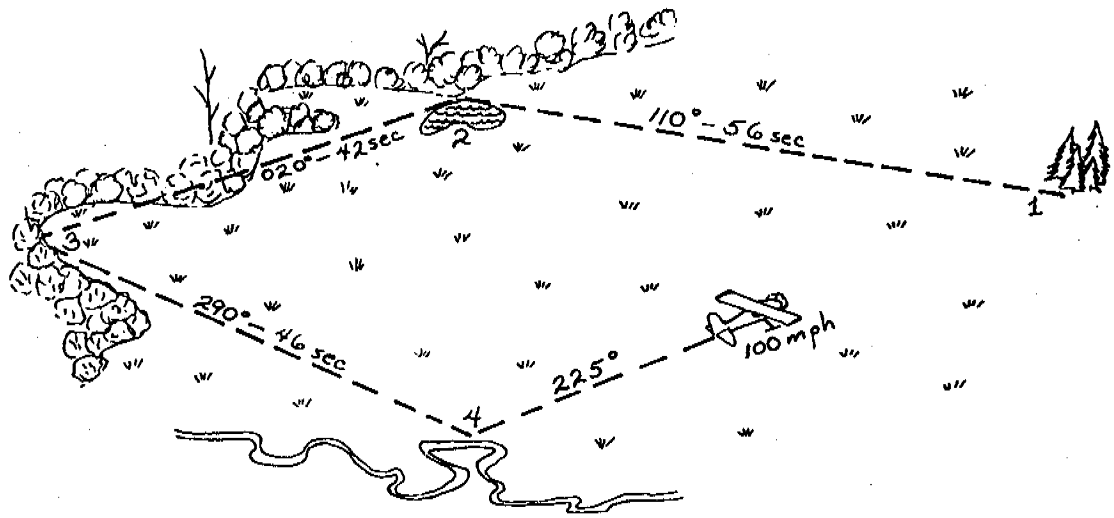

Figure 1. Laying out a quadrat in flat terrain using; 1) a clump of spruce, 2) a pond, 3) an irregular border of herbaceous bog, and 4) an oxbow in a creek as quadrat corners. Heading, air speed and time are used to determine length of each boundary, and allow calculation of quadrat area.

mately 70 mph indicated airspeed (IAS) (75 mph true airspeed in the Bellanca Scout used in 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 mph IAS. Hence, search intensity was regulated by the radius of the circles rather than by the interval between transects or contours. The radii of the circles 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 (Fig. 2). Vegetational patterns, streams, and ponds served as ground references during the search pattern. The pilot was always aware of quadrat boundaries. However, if inclusion 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.

Initial contour surveys in hilly terrain were flown between 70 and 80 mph IAS; 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. Observations were commonly made from only one side of the aircraft - generally the downslope aspect. 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. In hilly terrain subalpine ridges, creek bottoms, and areas burned within 5-25 years were consistently searched, whereas dense stands of black spruce (*Picea mariana*) generally were omitted or given minimal search effort. 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 the 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.

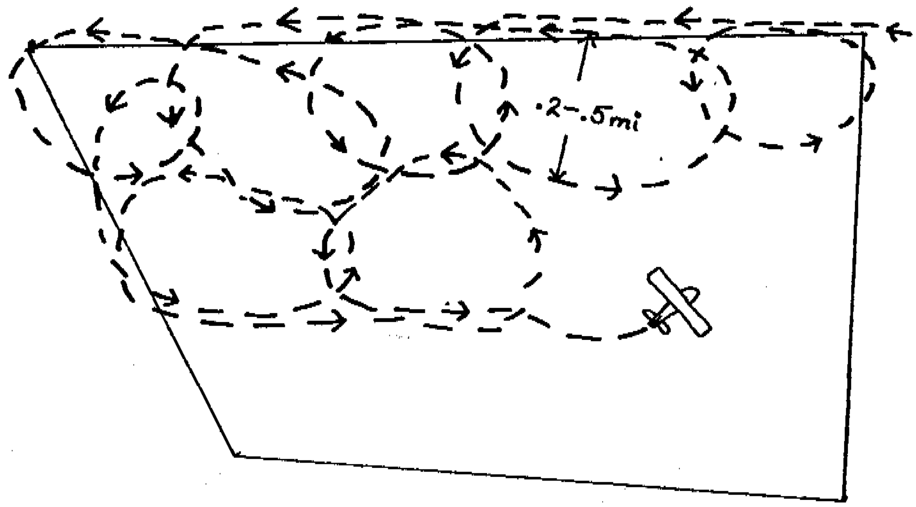

Figure 2. Flight pattern (top view) used during intensive search of flat terrain illustrating the elongated, overlapping parallel circling pattern to ensure complete coverage of a quadrat.

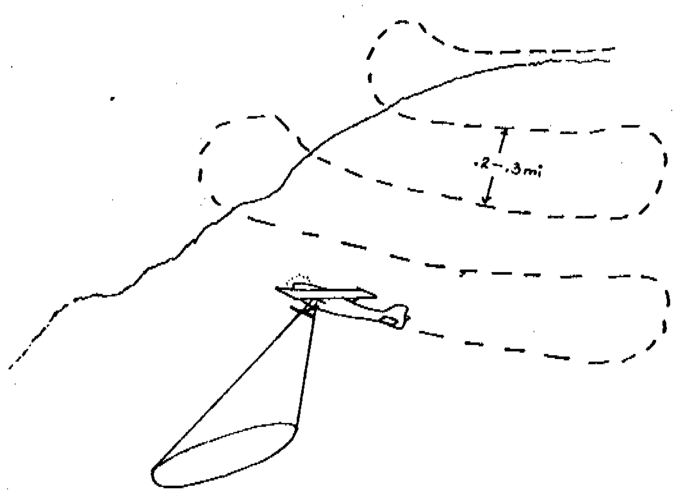

Figure 3. Flight pattern used during intensive search of hilly terrain illustrating closely spaced contour pattern and downslope view.

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

During each survey the following data were recorded: number of moose seen, sex, age, activity, habitat selected, habitats available, aggregation size, 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.

Activity occuring when moose were first seen (lying or standing) was recorded for all sightings, and this initial activity was duplicated on the forms during additional repetitive surveys of the quadrat regardless of the activity occuring when moose were seen a second time; the only exceptions were the radio-collared moose, for which current activity was recorded for repeated observations. By continuously recording initial activity for uncollared moose, biases in estimating daily activity patterns derived from these data were minimized, whereas actual activity data of all collared moose observations were useful in interpreting why they were missed during summer surveys.

The habitat type in which all moose were initially observed was recorded. Alternate habitat types available to moose were assessed by recording habitats which existed within an estimated 200 yards of a single moose or at the center of an aggregation of moose. The percent of each available habitat type was estimated for collared moose only. A numerical relative sightability index (1 to 5) rated the influence of the habitat selected on sightability of collared moose; one indicated adverse conditions, such as dense mature spruce, while five was indicative of moose in a herbaceous habitat.

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.

Weather, snow conditions, and lighting were broken into several components in an effort to determine the influence of each on sightability. The age and appearance of snow were arbitrarily categorized as fresh, moderately old, and old. These and other ratings were very 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, moderately bad, or bad. Quadrats with complete snow cover or complete cover plus snow on trees and shrubs (usually fresh snow) were classified as good. Quadrats with some low vegetation showing were classified as moderately bad and those quadrats with distracting amounts of bare ground showing as bad. 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 moderately bad or bad.

If a radio-collared moose was not sighted during the final intensive search survey, it was electronically located 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.

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 is in preparation; it illustrates and describes the basic procedures for quantifying and interpreting population parameters.

Training sessions and workshops will be held for Department biologists beginning in fall 1977. Assistance will be offered in initiating population monitoring programs to insure continuity of techniques between teams of resource specialists so that long-term changes in moose populations can be detected.

FINDINGS

Development of Sampling Systems

Quadrat identification: Identifying a predetermined, randomly selected sample unit from the air on flat terrain was a major obstacle in the sampling scheme. The feasibility of using several types of quadrat sample units was investigated. Attempts were made to describe randomly selected, one mile^2 quadrats corresponding to sections on 1:64,000 scale maps. Sections provided a good sample frame from which to draw sample units in the Matanuska Valley (Bishop unpubl. data). To lay out a one mile^2 plot, airspeed indicators were calibrated for 70 and 100 mph IAS over known distances (48 and 36 sec/mi, respectively); hence, at a constant airspeed and with no wind a mile could be estimated by flight time. The directional gyro in the aircraft provided a means for making 90 degree heading changes which, in conjunction with a known speed, could be used to describe the four sides of the sample unit. This method was tested near North Pole, where roads and brushed section lines describe one mile^2 units. A high degree of precision was obtained in describing and duplicating known sections of land that were defined by survey lines and roads. When flying specific times and headings we were generally within 100 yards of each corner of the section. However, when this method was applied on the Tanana Flats it immediately became apparent that there was no way to define and remember the corners of the units because unique geographic or vegetational features were rarely present. Therefore, this type of unit was discarded. Round sample units radiating from a single identifiable physiographic feature were attempted and discarded because of the difficulty of precisely defining boundaries.

Eventually, irregular polygons described by unique physiographic features at each corner and boundaries defined and measured by airspeed, time, and heading proved to be a useful and relatively efficient system for describing sample units from the air on flat terrain. Physiographic features, such as clumps of deciduous trees or openings of herbaceous bog, were usually present; these made convenient corner markers which were easily identified and remembered for short periods of time. Figure 4 demonstrates 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 had negligible influence on the ground speed of the aircraft when winds blew 15 mph or less. The sample units were later drawn to scale and the area determined with a compensating polar planimeter.

Some error was associated with quadrats laid out as described above. Starting and finishing points rarely matched precisely when the scale drawings were made. The first and last quadrat legs were redrawn so the observed discrepancy could be averaged (Fig. 5). This provided a means of assessing the magnitude of possible errors in estimating quadrat area. The mean maximum and mean minimum errors as a percentage of the average area were 10 and 9 percent, respectively (Table 1). Initially, 70 mph IAS was used to lay out the quadrats, but speed was increased to 100 mph IAS in an effort to proportionally reduce the influence of wind on the ground speed of the aircraft. Inadequate sample size at 100 mph IAS (Table 1) prevents a meaningful comparison of the two treatments at present.

Sample units in the hills and mountains were easily identified and laid out using topographic features as boundaries or, occasionally, straight lines between two physiographic features. The layout of these quadrats should present no significant problem once the observer and pilot become familiar with using 1:64,000 scale maps from the air.

Stratification of area to be censused: The stratification of an area into high, medium and low moose densities is an extremely important step in the census procedure. Stratification is also one of the most difficult tasks to accomplish because distribution of moose is aggregated and is highly dependent upon habitat types, local abundance, weather, phase of seasonal movement pattern and other factors. It became apparent that a substantial amount of survey effort will be required prior to stratification. The distribution data from previous years was and will continue to be a valuable aid in stratification; therefore, flight routes and moose observations should be placed on maps during all routine S&I surveys. We feel that surveys specifically for the purpose of stratification should take the form of widely spaced transects (3 to 5 miles) in flat terrain, while in hills and mountains contour type survey patterns should be applied in a systematic fashion so all habitat types and terrains are lightly sampled. In some areas with a tall, dense vegetation canopy intensive search methods must be combined with transects and contour surveys to estimate relative moose density. The results of relative density estimates from this light sampling effort can be extrapolated to physiographically similar adjacent areas, and the entire area can

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

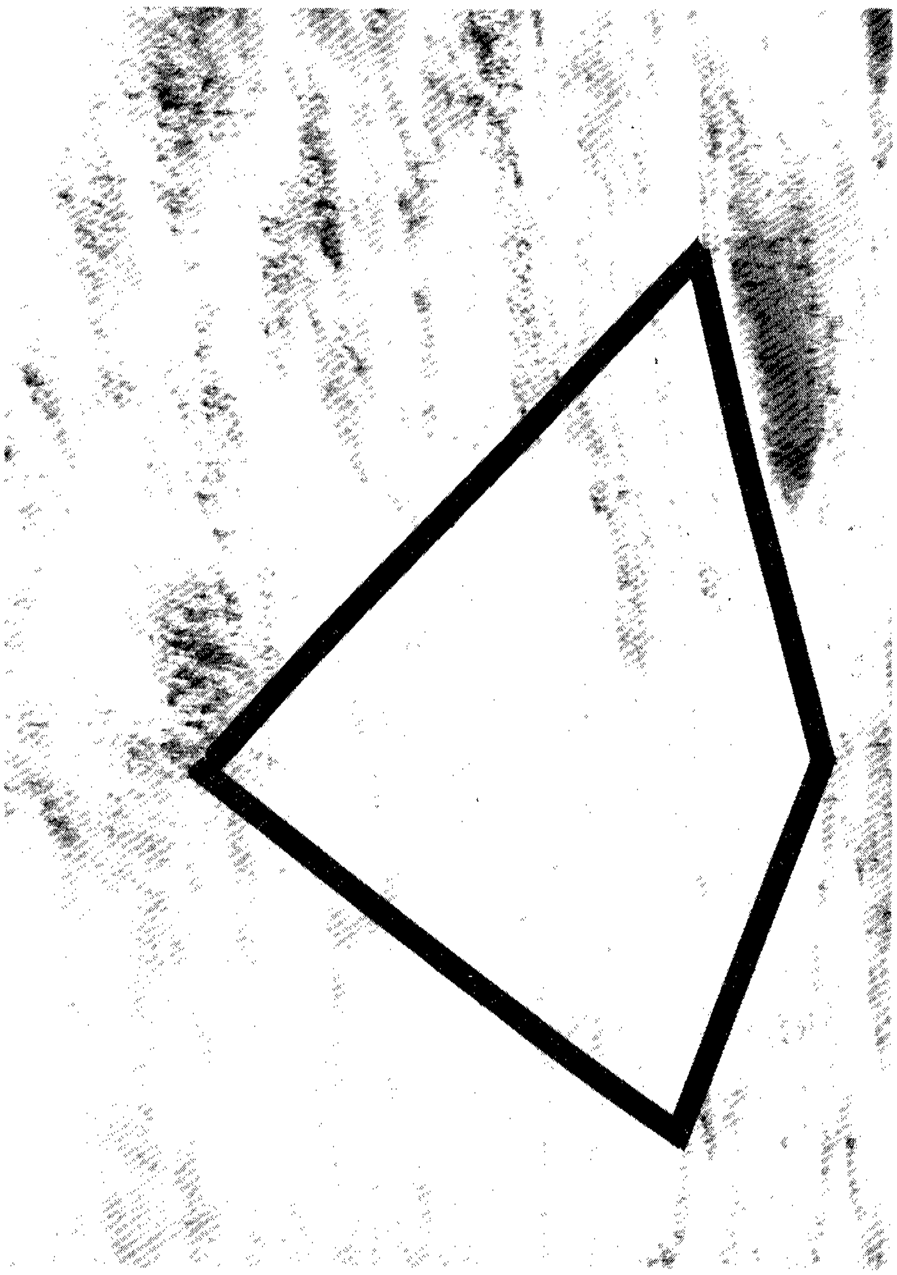

Table 1. Variation in estimated area of quadrats laid out by flight time, indicated airspeed and relative bearings on the Tanana Flats.

Indicated Airspeed	Wind	Sample Size	Average Area (SD, Range) (mi^2)	From Average Size (SD, Range)	
				Maximum	Minimum
70	None	16	0.9 (0.3, 0.4-1.5)	9(9, 0-31)	8(7, 0-23)
70	Present	6	1.0 (0.1, 0.8-1.1)	12(4, 8-19)	13(5, 7-21)
100	None	4	1.9 (2.5, 0.6-6.6)	7(3, 3-11)	9(2, 7-11)
Grand means		26	1.1 (1.0, 0.4-6.6)	10(8, 0-31)	9(6, 0-23)

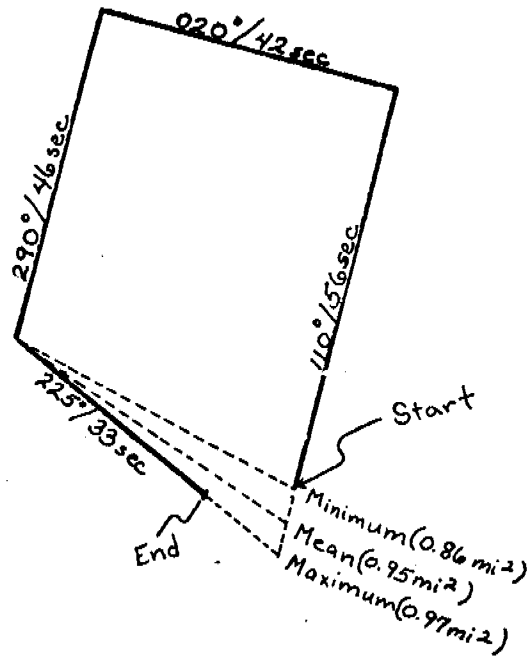

Figure 5. When plotted, quadrat legs seldom match perfectly. Discrepancies were averaged, minimized and maximized to assess magnitude of errors.

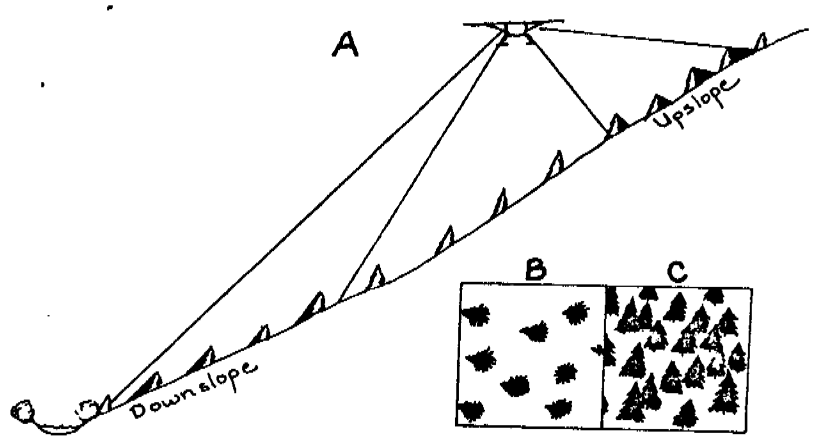

Figure 6. A) Amount of hidden ground and perspective of terrain obtained by viewing upslope and downslope during a contour flight; B) Observer's view downslope illustrating top aspect of trees; C) Observer's view upslope illustrating side aspect of trees.

then be stratified into three density levels. At this time little effort has been directed toward stratification techniques; however, this problem will be studied more thoroughly during the coming year.

Selection of sample plots: Sample units vary in size and shape; therefore, they had to be selected in proportion to their area to ensure equal probability that each area was sampled.

Two methods were used to select the sample units. The first was to draw all possible sample units on a map and then randomly select the required number. The second was simpler and did not require that all sample units initially be drawn on a map. The borders of each sample unit were drawn on a map as the randomly selected points were located. This was continued until the desired number of sample units had been selected. The latter method is significantly faster, however, if the area is one which will be censused frequently, in which case mapping all possible sample units definable by physiographic features would be useful for reducing the time expenditure immediately prior to the census.

The sampling intensity required to increase precision of estimates of moose densities will be investigated at a later date, after the census method has been applied on a trial basis.

Flight patterns for intensive search method: Over flat terrain a continuous circling pattern proved more efficient than closely spaced transects. The observer was in the most efficient flight mode (LeResche and Rausch 1974) for the major portion of the total search time. Additionally, the pilot had the freedom to maneuver the plane over islands of dense forest and provide a vertical view of those areas where moose are most difficult to see. In hilly and mountainous terrain flight lines generally followed the contours. The most productive view for the observer was downslope, since the top aspect of trees predominated and creek bottoms were visible (Fig. 6). Equally important, the observer can continue to view downslope 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 pilot and observer to have a top aspect of vegetation similar to that shown in Fig. 6B.

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; 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.

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

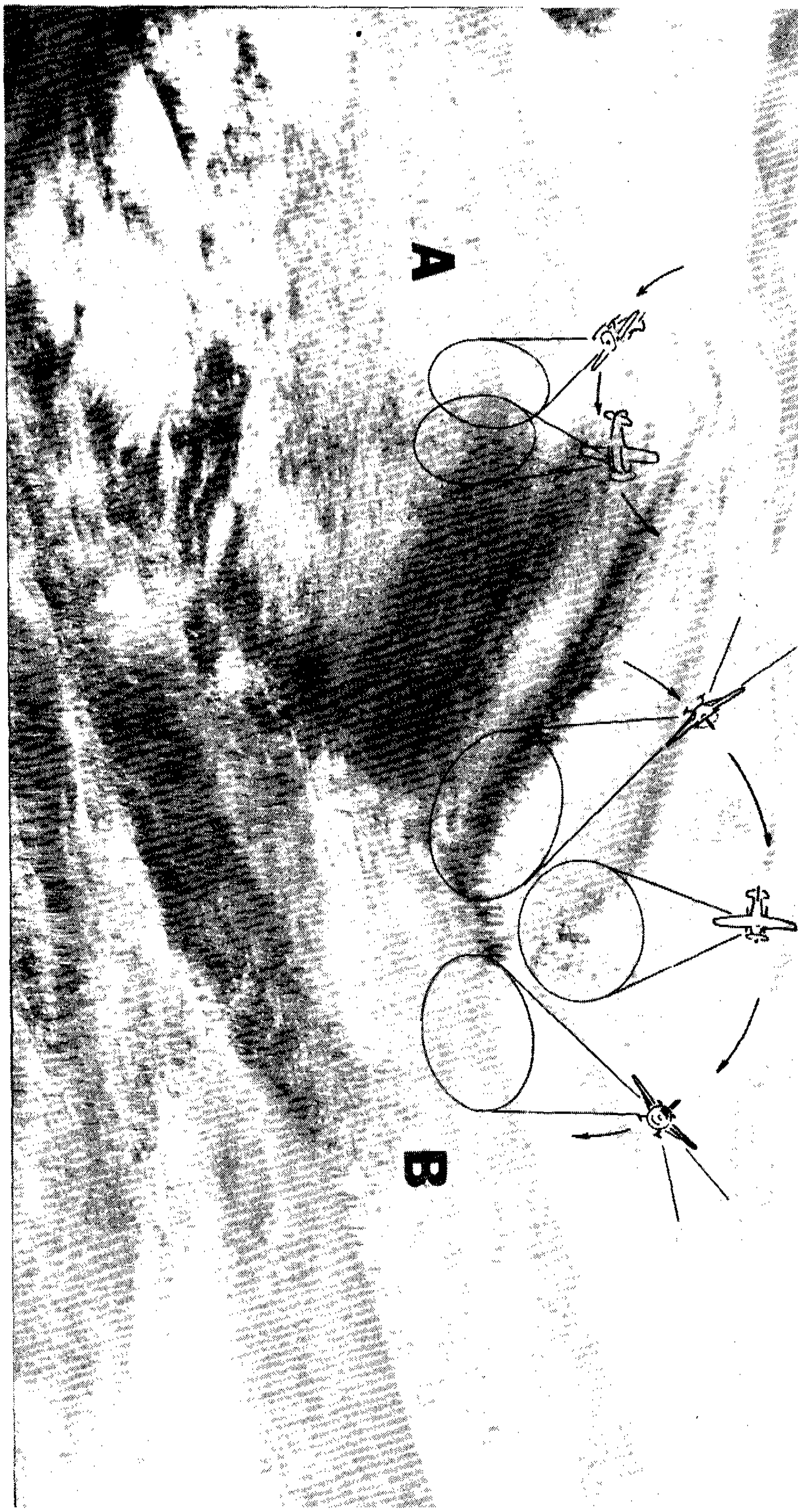

Table 2. Time searched per square mile during surveys conducted between 1974 and 1977 in Interior Alaska.

Type of Survey	Period	$\overline{X}$ min/mi^2 (Range, SD) Flats	Hills	Foothills/mountains	Source of Data
Composition Counts[1] in Game Management Units					
20A		1.4 (1-1.9)	-	1.9 (1.5-2.2)	Game Division
20B		-	2.1 (1.5-3.0)[3]	-	Files
13		0.8	-	1.2	"
Transect/contour		-[2]	5.0 (2.1-9.2, 2.3)	4.3 (2.3-8.9, 2.4)	Present Study
Intensive		13.2 (7-20, 2.7)	9.5 (4.5-13.5, 2.6)	10.0 (4.6-11.8, 3.3)	"

[1] These are examples of typical surveys conducted by the Game Division. Transects were used over flat terrain while contour flights were flown in irregular terrain.

[2] 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.

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

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. Additional information concerning sightability during spring and summer is presented in Appendix IV.

Search time: Sightability of moose during aerial surveys was determined with two search intensities. The lower intensity search was made in an attempt to duplicate standard transect/contour moose survey techniques used by the Game Division in Alaska for composition surveys. However, duplication was difficult: search time per mi^2 during the Game Division's moose composition surveys ranged from 0.8 to 3.0 min per mi^2, while mean time spent on comparable counts during the present study was 4 to 5 min per mi^2 (Table 2). This difference in search time was attributed to differences in the flight patterns, i.e. 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, usually timbered tracts of the survey area. The effect of this practice during composition surveys was to reduce mean time spent per unit of area to relatively low values which could not be duplicated when relatively small quadrats were sampled. In the present study, time spent during intensive searches was substantially greater than that spent during transect/contour searches, averaging 9 and 13 min/mi^2 in hills and flats, respectively (Table 2).

Sightability of collared moose in quadrats was directly related to search time per unit of area. Disregarding the influence of other variables, sightability was greater during the intensive search than during the transect/quadrat survey in all three major physiographic areas (Table 3). Relatively high sightability was achieved under a wide variety of environmental conditions during intensive searches, whereas a lower and more variable proportion of moose was seen during transect/contour searches (Table 3). The differential in both collared and uncollared moose seen during the transect/contour survey and intensive search was similar with the exception of the two groups with only six collared moose (Table 4). Therefore, these data suggest that the sightability of both collared and uncollared moose differs very little in spite of the general location of the collared moose learned by the pilot while defining the quadrat.

Snow conditions: The quality of snow cover had a profound influence on sightability of moose during transect/contour surveys. However, no impact on sightability was detected during intensive searches; approximately 90 percent of collared moose were seen regardless of snow conditions (Table 5). Ninety percent more moose were seen during intensive searches than during transect/contour surveys under bad snow conditions (Fig. 8), whereas the difference was only 21 percent under good snow conditions (Fig. 9, Table 5). Therefore, the adverse effect of poor snow conditions on sightability can generally be negated by intensive search techniques.

Effects of light: The type and intensity of light during surveys appeared to affect sightability somewhat, but its influence was small

Table 3. Percentage of collared moose seen during transect/contour (Search 1) and intensive search (Searches 2 and 3) surveys of quadrats receiving both search types.

	% Collared Moose Seen (No. of Quadrats)						
	Tanana Flats		Tanana Hills			Foothills	
Date	Search 1	Search 2	Search 1	Search 2	Search 3	Search 1	Search 2
Oct/Nov	78 (23)	100 (23)	100 (6)	83 (6)	-	-	-
Feb/Mar	77 (13)	92 (13)	50 (16)	81 (16)	100 (2)[1]	33 (6)	83 (6)

[1] Only 2 of the 16 quadrats were given a second intensive search during which both collared moose were located.

Table 4. Moose seen during the transect/contour survey as a percentage of moose seen during the first intensive search.

		% of moose seen during intensive search that were seen during transect/contour surveys (n)		
Date	Type of moose	Tanana Flats	Tanana Hills	Foothills
Oct/Nov	Collared Moose	78 (23)[1]	120[3] (6)	-
	Uncollared Moose	82 (150)[2]	90 (39)	-
Feb/Mar	Collared Moose	84 (13)	62 (16)	40 (6)
	Uncollared Moose	77 (69)	63 (43)	65 (20)

[1] Number of quadrats.
[2] Number of moose seen during the intensive searches of quadrats.
[3] One collared moose was seen during contour survey but was missed during the intensive search.

Table 5. The influence of snow conditions on sightability of moose in quadrats. Values in parentheses indicate number of quadrats in analysis.

	Snow conditions		
	Good	Moderately bad	Bad
% collared moose seen during transect/contour searches	78 (41)	67 (12)	36 (11)
% collared moose seen during intensive searches	90 (41)	92 (12)	91 (11)
% increase in all moose seen during intensive compared to transect/ contour searches	21 (44)	28 (13)	90 (11)
% of quadrats where moose were missed during transect/contour search and found during intensive search	39 (44)	46 (13)	73 (11)

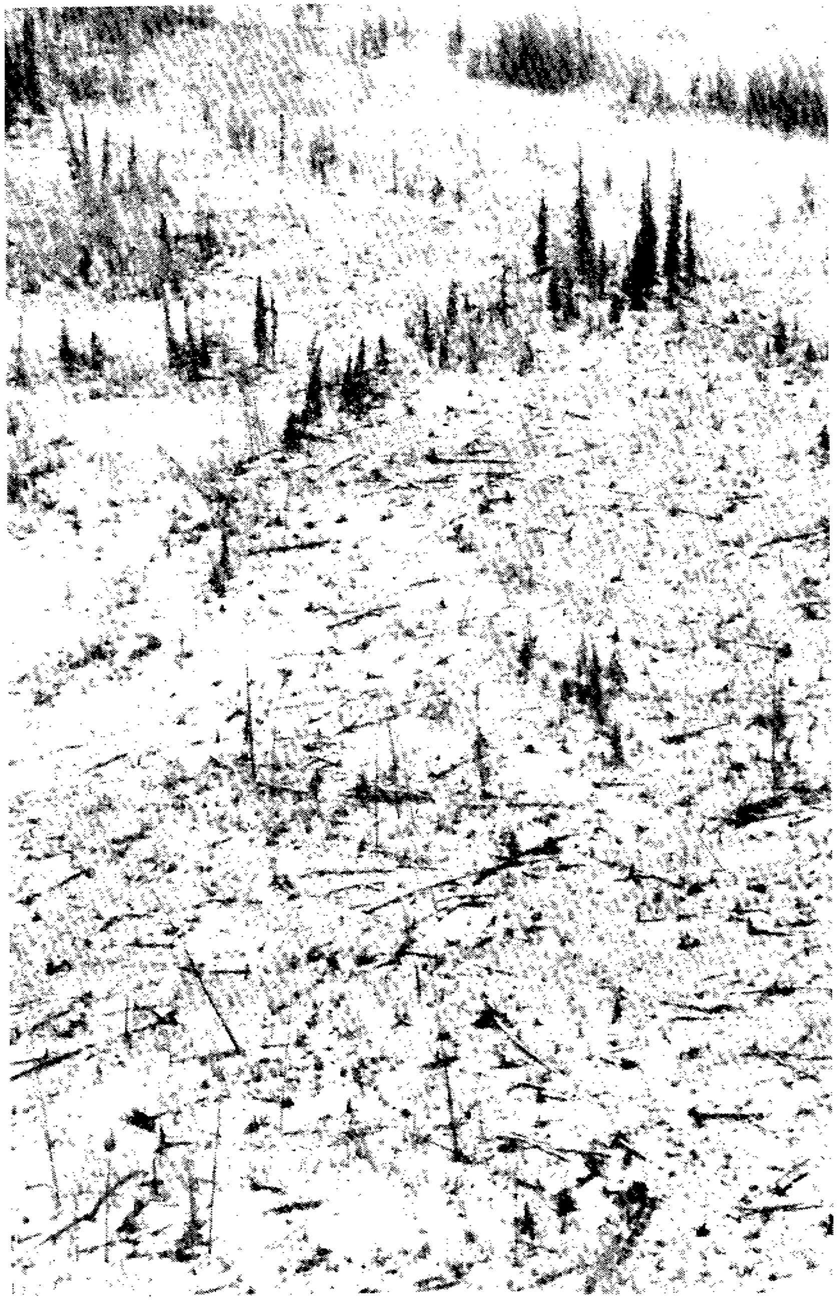

Figure 8. Bad snow conditions with distracting amounts of bare ground showing.

Figure 9. Good snow conditions with complete cover and snow on trees.

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

Table 6. Sightability of moose under various light types and intensities. Values in parentheses indicate number of quadrats. Data from early and late winter are combined.

	Light Type		Light Intensity				
	Flat	Bright	Low[1]	Medium[2]	High[3]		
% collared moose seen in transect/contour survey	65 (37)	84 (25)	25 (4)	76 (41)	71 (17)	100 (8)	70 (33)
% collared moose seen in intensive search	97 (37)	88 (24)	100 (4)	98 (41)	81 (16)	100 (8)	97 (33)
% of all moose seen during intensive search that were seen during transect/contour survey	77 (40)	80 (26)	61 (4)	82 (44)	71 (18)	89 (8)	79 (36)
Combinations of Type & Intensity	N/A	N/A	Low/ Flat	N/A	Bright/ High	Bright/ Medium	Flat/ Medium

[1]All quadrats surveyed under low intensity light were flat/low combinations.

[2]Quadrats surveyed under medium intensity light were either flat/medium or bright/medium combinations.

[3]All quadrats surveyed under high intensity light were bright/high combinations.

compared with that of other variables. Flat lighting with no shadows was produced by clouds between the observer and the sun; bright light accompanied by strong shadows was produced on clear days (Fig. 10). Shadows and bright light also caused sightability problems during spring and summer surveys (Appendix IV).

Sightability of moose under flat and bright light differed very little (Table 6). The influence of type of light alone on sightability appears unclear in the data presented in Table 6, presumably because of the integral relationship between type and intensity of light. Various combinations of type of light (bright or flat) and intensity of light (high, medium or low) produced highly diversified conditions under which to view moose. Extremes in lighting were most disadvantageous. Low intensity-flat lighting appeared to be the most difficult under which to view moose during transect/contour surveys because of low contrast between moose and their background (Table 6). With greater search intensity these light conditions did not appear to be as limiting. On the other extreme, high intensity-bright light created harsh, distracting shadow images. The adverse effects of high intensity-bright light appeared greatest in spruce-dominated habitats, where dense canopies cast large shadows during winter, reducing contrast between moose and background and distracting the eyes (Fig. 10). Additionally, this type of lighting created problems when looking toward the sun causing glare and silhouetting of objects, including moose. The only beneficial effects of high intensity-bright light were that colors appeared more vivid and fresh tracks stood out well, serving as clues to the presence of moose. Sightability of moose during surveys appeared greatest when medium intensity light occurred in conjunction with either flat or bright light (Table 6).

<u>Habitat selection and its influence on sightability</u>: Habitat selection by moose may be the variable with the most profound influences on sightability. As height and density of vegetation increase, sightability decreases, particularly for transect/contour surveys. Therefore, an understanding of habitat selection by moose is necessary to define the habitat-related problems which will be encountered during moose censuses. Habitats selected by moose on the Tanana Flats during late October and early November were predominately herbaceous bog or open shrub types. Although forest types were available to most moose on the Tanana Flats, they were selected by only approximately 15 percent of the moose (Tables 7 and 8). However, by mid to late winter habitat preferences of moose on the Tanana Flats shifted to taller and more dense habitat types. During this period the use of forest and tall shrub habitats by moose increased substantially, while use of both herbaceous bog and low shrub habitats declined (Tables 7 and 8).

Similarly, moose in the Tanana Hills demonstrated a preference for shrub-dominated sites during early winter, although to a slightly lesser extent than moose on the flats (Tables 7 and 8). By late winter habitat selection by moose in the hills had shifted to habitats dominated by forest types (63 percent of all moose and 74 percent of collared moose observed) (Tables 7 and 8). Availability of forested habitat types was greater for moose in the hills and probably accounted for their generally greater selection of forested sites during early and late winter. The effect of this shift was a reduction in sightability of moose during late winter from that of early winter.

Table 7. Comparison of habitat selected by collared moose, alternate 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[1] (%) H	LS	TS	D	SS	S	L
Tanana Flats	Oct/Nov	Selected	26	15	54	17	6	–[2]	6	2
		Avail.	27	63	100	41	30	–	63	37
		% Cover	27	19	50	11	6	–	9	4
	Jan/Feb/ Mar	Selected	46	4	43	20	9	2	15	7
		Avail.	47	68	77	32	30	26	51	11
		% Cover	13	17	38	18	17	3	7	Trace
Tanana Hills	Nov	Selected	8	0	38	25	0	13	25	0
		Avail.	8	25	50	63	0	13	63	0
		% Cover	8	9	23	26	0	5	37	0
	Jan/Feb/ Mar	Selected	25	4	4	18	16	36	22	0
		Avail.	25	8	40	44	40	60	44	0
		% Cover	16	3	13	13	21	30	21	0
Alaska Range Foothills	Jan/Feb/ Mar	Selected	24	8	40	16	12	12	12	0
		Avail.	24	54	71	25	29	42	38	0
		% Cover	6	8	15	28	24	18	7	0

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

[2] No specific category was made for sparse spruce forest until January 1977.

Table 8. Comparison of habitats selected by all moose and alternate habitats available to the moose in quadrats during transect/contour and intensive searches.

Area	Month		No. of Moose	Habitat Types[1] (% Frequency) H	LS	TS	D	SS	S	L
Tanana Flats	Oct/Nov	Hab. Select	170	14	51	19	5	-[2]	6	5
		Hab. Avail	131	66	93	48	36	-	58	28
	Jan/Feb/ Mar	Hab. Select	133	7	29	31	14	4	12	4
		Hab. Avail	135	66	69	52	36	27	40	7
Tanana Hills	Nov	Hab. Select	45	0	33	42	3	2	19	0
		Hab. Avail	41	5	63	71	20	2	56	0
	Jan/Feb/ Mar	Hab. Select	56	5	7	25	24	21	18	0
		Hab. Avail	56	11	32	45	46	48	50	0
Alaska Range Foothills	Jan/Feb/ Mar	Hab. Select	58	5	50	19	7	7	12	0
		Hab. Avail	58	43	71	28	33	55	33	0

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

[2]No specific category was made for sparse spruce forest until January 1977.

Moose in the foothills and mountains of the Alaska Range demonstrated a preference for shrub-dominated sites (69%) during late winter, in spite of a relatively high availability of forested habitat types (Table 7 and 8). No seasonal habitat shifts were determined for this area because snow conditions precluded observations during early winter.

To investigate the effect of major habitat types within a quadrat on the sightability of moose, quadrats were sorted into broad categories based upon the dominant habitat of the quadrats (Table 9). Sightability during transect/contour surveys was markedly lower in forest-dominated quadrats, particularly those dominated by spruce forest (Table 9).

During intensive searches spruce-dominated quadrats appeared to be the only category in which a uniformly high sightability of moose could not be achieved (Table 9). Within the above habitat categories, sightability of moose was dependent primarily on the specific habitat selected among the diverse available habitats. However, the camoflage quality of certain habitats in combination was suspected to have a detrimental, though unmeasurable, effect on sightability. The ability of observers to see moose during transect/contour surveys decreased as height and density of the canopy increased (Table 10). Similarly, relative sightability indices assigned by the observer at the time the moose was first sighted tend to reflect the increasing difficulty of observing moose in tall, dense vegetation (Table 10).

Activity of moose missed on the first survey was related to habitat. No standing moose were missed in either herbaceous or shrub habitat types, but standing moose were commonly overlooked in tall growth forms. Trees were effective visual barriers to both standing and lying moose, whereas shrubs were barriers primarily to lying moose. Spruce was an effective visual barrier to moose during intensive searches; four of the six moose missed were in spruce. A fifth moose could not actually be seen, but the radio signal suggested that the animal was associated with tall shrub and spruce in a steep canyon bottom.

Activity: The activity of moose (standing or lying) has a decided effect on sightability, and, therefore, additional data concerning diurnal and seasonal activity patterns are needed to interpret biases that occur in sightability data. Observations of activity at first sighting of all radio-collared moose and members of their aggregations and of moose seen during all searches of quadrats indicate that 60 and 64 percent, respectively, of the moose were lying down during early and late winter (Table 11). There appeared to be no major differences in activity among males, cows without calves, and cows with calves during either winter period, although the sample sizes were very small. Analyses of diurnal activity patterns have not been undertaken at present, and no patterns were obvious during surveys. The activity of moose missed during transect/contour surveys did not differ substantially from observed activity of all moose; however, those moose missed during intensive searches were generally lying down (Table 12).

Aggregation size: Moose aggregation size was greater during late October and November than during late winter (Table 13). Adults not associated with calves dispersed into small groups by late winter; about 50 percent of the adults were observed alone (Table 13). During both time periods the mean aggregation size of groups containing cows with calves was slightly larger than that of groups consisting only of

Table 9. Percent collared moose seen in quadrats as categorized by dominant habitat type. Data from early and late winter were combined. Values in parentheses are the number of quadrats.

Dominant Habitat Type	% collared moose seen		
	Transect/Contour Survey	1st Intensive Search	2nd Intensive Search
Shrub Dominated Recent Burn	92 (12)	92 (12)	-
Shrub Dominated Subalpine	0 (1)	100 (1)	-
Forest-Shrub Mixtures			
Shrub Dominated	72 (29)	100 (26)	
Deciduous Dominated	78 (9)	100 (9)	-
Spruce Dominated	56 (16)	75 (16)	80 (5)
Total	72 (67)	92 (64)	

Table 10. Percentage of collared moose seen during transect/contour surveys by habitat type, activity of those missed, and relative sightability value for all collared moose at first sighting. Data from early and late winter combined. Values in parentheses are the number of quadrats surveyed.

	Habitat Types[1]											
	H	LS	TS	D	SS	S	DXS	TSXL	LSXL	LSXTS	HXLS	Totals
% collared moose seen	100 (3)	89 (19)	71 (17)	57 (7)	100 (3)	50 (8)	0 (3)	0 (1)	100 (1)	100 (1)	100 (2)	72 (65)
% missed that were lying	–[2]	100	100	33	-	50	67	100	-	-	-	71
$\overline{X}$ sightability index (Feb/Mar only)	-	4.6	3.5	3.5	3.5	2.5	2.3	3	-	-	-	3.5

[1] Habitat Types: H = Herbaceous, LS = Low Shrub, TS = Tall Shrub, D = Deciduous Forest, SS = Sparse Spruce Forest, S = Spruce Forest, L = Larch Combinations represent mixtures.

[2] No collared moose were missed.

Table 11. Initial activity (lying, L; standing, S) of radio-collared moose, members of their aggregations and moose seen during quadrat surveys expressed as percentages. Values in parentheses equal the sample size.

Period	Males		Females w/o calves		Adults[1] w/o calves		Females with calves		All moose	
	L	S	L	S	L	S	L	S	L	S
Oct/Nov	61	39	61	39	-	-	56	44	60	40
	(87)		(75)				(45)		(207)	
Jan/Feb/Mar	-	-	-	-	64	36	64	36	64	36
					(150)		(50)		(200)	

[1] Sex identification was difficult during late winter, therefore, adult males and females were combined.

Table 12. Activity of moose (lying, L; standing, S) missed during surveys. Values in parentheses equal the sample size.

	% Activity (n) L		S
All moose missed during transect/contour survey and seen during intensive survey	67	(69)	33
Collared moose missed during transect/contour survey	71	(17)	29
Collared moose missed during intensive search	83[1]	(6)	17
% of aggregations missed during the transect/contour survey containing a collared moose in which all moose were lying	68 (19)		

[1]One of the 6 moose could not be located primarily because of terrain and vegetation restrictions. This moose could have been lying which could increase the percentage lying to 100%.

Table 13. Moose aggregation sizes observed during searches of quadrats during early and late winter.

Period	Mean aggregation size (range, no. of groups): groups containing adults only	groups of adults containing a cow w/calf	all groups containing calves	all groups combined	% lone[2]: M	F	% lone (M,F or c)	Mean aggregation size (range, no. of groups): groups with collared moose missed during transect/contour surveys	groups missed during all intensive searches
Oct/Nov	2.1(1-13,63)	3.5(3-4,10)	2.4(2-4,42)	2.2(1-13,105)	31(42)	28(86)	35(105)	2.4(2-4,5)	
									1.5(1-2,6)[1]
Feb/Mar	1.4(1-6,57)	4(--,1)	2.2(2-4,25)	1.7(1-6,84)	—	—	52(84)	1.6(1-3,14)	

[1] Moose from all periods combined.

[2] Percentage lone male and percentage lone female were determined as percentage of all groups containing males and of all groups containing females, respectively.

adults, but the range in aggregation size was smaller for groups containing calves. The mean aggregation size of groups missed during surveys was similar to the mean size for all groups, although the range in size of those aggregations missed was consistently low (Table 13). A comparison of composition survey data previously collected by the Game Division with aggregation data from this study suggests that mean aggregation sizes for the same sex and age categories may vary with population density over time. Mean aggregation sizes were greater during the early 1960's than during the 1970's. During both transect/contour surveys and intensive searches in present studies, the probability of missing a large aggregation of moose was low. If greater mean aggregation sizes observed during periods of high moose density are related, in part, to a lower percentage of single and paired animals (commonly cow-calf pairs), sightability of moose should be greater during such periods. Moose density-aggregation size relationships will be investigated further to assess effects on sightability.

Density of moose: Moose density in quadrats utilized by collared moose was greatest on the Tanana Flats, intermediate in the Tanana Hills, and lowest in the Alaska Range (Table 14). These moose density values were not representative of the general areas, since the quadrats had a high probability of containing a radio-collared animal. Only six quadrats, when established, failed to encompass the collared moose. Since the mean aggregation size was greater than one (Table 13), minimum density values would generally be expected to exceed one. The density values in Table 14 are probably representative of the highest moose densities in each area at the time and serve as expected values for the high density strata during a census.

A reduction in absolute moose density within quadrats occurred between early and late winter (Table 14) as a result of declining aggregation size (Table 13), calf mortality and dispersion of moose within the study area. An apparent reduction in moose density, attributable primarily to the increased preference of moose for closed-canopy habitats and the resulting decrease in sightability, also occured during winter. However, sightability alone could not account for the magnitude of this change.

Calf survival: The survival of 19 calves associated with 18 cows at the time of collaring was monitored during quadrat census work and radio-tracking flights. Four calves are known to have died (21%) and the fate of two others is unknown. Therefore, known survival of the calves from August to early March was at least 68 percent and may have been as high as 79 percent. Loss of calves reduced mean aggregation size (Table 13), and, therefore, decreased sightability of cow moose, particularly during late winter, when mean aggregation size was small. Additional information concerning probable causes of calf mortality are presented in Appendix V.

DISCUSSION

Development of Sampling Systems

The proposed quadrat census methods and those described by Evans et al. (1966), Bishop (1969) and Bergerud and Manuel (1969) are more complex

Table 14. Density of moose observed in all quadrats during transect/contour (Search 1) and intensive search (Search 2).

Period		Tanana Flats		Tanana Hills		Foothills/Mtns	
		Search 1	Search 2	Search 1	Search 2	Search 1	Search 2
Oct/Nov	Moose/mi^2, $\overline{X}$ (SD)	6.0 (4.4)	6.8 (4.9)	3.0 (3.6)	3.6 (4.1)	-	-
	No. of quadrats	27	24	7	7	0	0
	Quadrat area; $\overline{X}$ (Range)	1.0 (.35-1.6)	1.0 (.4-1.6)	1.5 (.6-2.3)	1.6 (1.1-2.3)	-	-
Feb/Mar	Moose/mi^2; $\overline{X}$ (SD)	3.4 (3.1)	3.9 (2.8)	2.0 (1.5)	2.6 (2.3)	1.6 (1.9)	2.5 (2.4)
	No. of quadrats	14	14	16	15	7	7
	Quadrat area; $\overline{X}$ (Range)	1.5 (.6-5.6)	1.5 (.6-5.6)	1.1 (.6-1.7)	1.1 (.6-1.7)	1.7 (.7-2.9)	1.7 (.7-2.9)

than transect/contour methods currently employed by the ADF&G. Data from current surveys, however, do not provide accurate estimates of moose numbers and in many cases do not allow estimates to be made at all. Therefore, new methods must be adopted in most areas of Alaska if accurate estimates of moose populations are to be attained. Improved census methods will come only with substantial increases in cost and manpower. Hence, wildlife managers will have to carefully weigh the biological value of accurate population estimates against increased costs.

Sampling systems other than the random-stratified system suggested in this report could be adopted. All systems, however, have major shortcomings. Transect surveys are probably the most widely used aerial census method for ungulates. Because critics of the quadrat method are most likely to suggest the continued reliance upon the transect survey method, brief comments on the feasibility of adapting this method to census moose in Alaska are appropriate.

Use of the transect method is limited to relatively flat terrain because the area to be sampled is defined by markers on the aircraft that require a fixed relationship between the ground and the altitude of the aircraft (Pennycuick and Western 1972) (Fig. 11). Extensive areas of flat terrain are limited in Alaska. Variations in altitude above the ground or roll of the aircraft in light turbulence cause changes in the four boundaries used to define sample area (Fig. 11). Therefore, the area sampled per mile of flight becomes variable. Because of the extreme boundary length in relation to total area sampled, the number of decisions on whether a moose is in or out of the sample area increases.

The transect census method is also plagued by changing habitat types along the flight line which alter the sightability of moose (Fig. 12A). Although sightability correction factors can be developed, each habitat type encountered would require such a factor (Caughley 1974). Because of the complex habitat mosaic characterizing much of Alaska and because habitat type has such a profound influence on sightability of moose, the actual application of such correction factors to transect census methods would be unsatisfactory. Extensive stands of uniform habitat types utilized by moose do occur in some areas of Alaska; however, these are usually expanses of spruce or spruce-deciduous forest mixtures. In either case, sightability decreases rapidly as the search distance from the flight line increases (Fig. 12B, 13). Therefore, if the transect method were adopted for the special conditions in Alaska, the best approach would be to use a four-place airplane with two observers and a navigator-recorder as described by Sinclair (1972) and used in Africa.

Although problems and errors are also associated with the quadrat census method, it offers the advantage that search time can be altered according to habitat so that relatively high uniform sightability can be attained in all but spruce-dominated areas. This simplifies procedures for estimating moose numbers in areas characterized by heterogeneous habitat mosaics.

The major problem to overcome in application of the quadrat census method is delineation of quadrats in uniform habitat types. Such difficulties were particularly encountered in areas of flat terrain covered

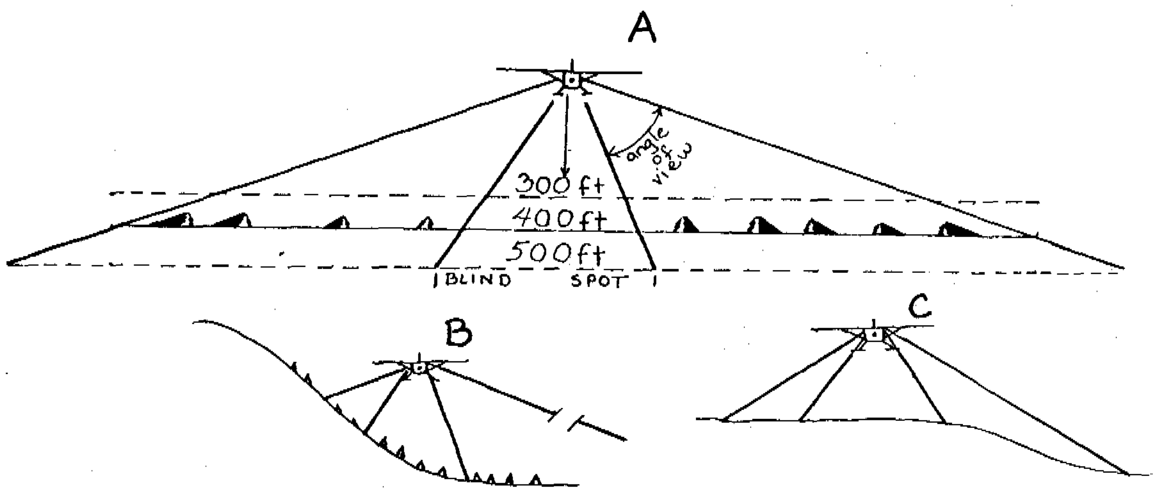

Figure 11. The effect variation in relative elevation of the aircraft (A) and terrain (B & C) on area sampled during transect surveys.

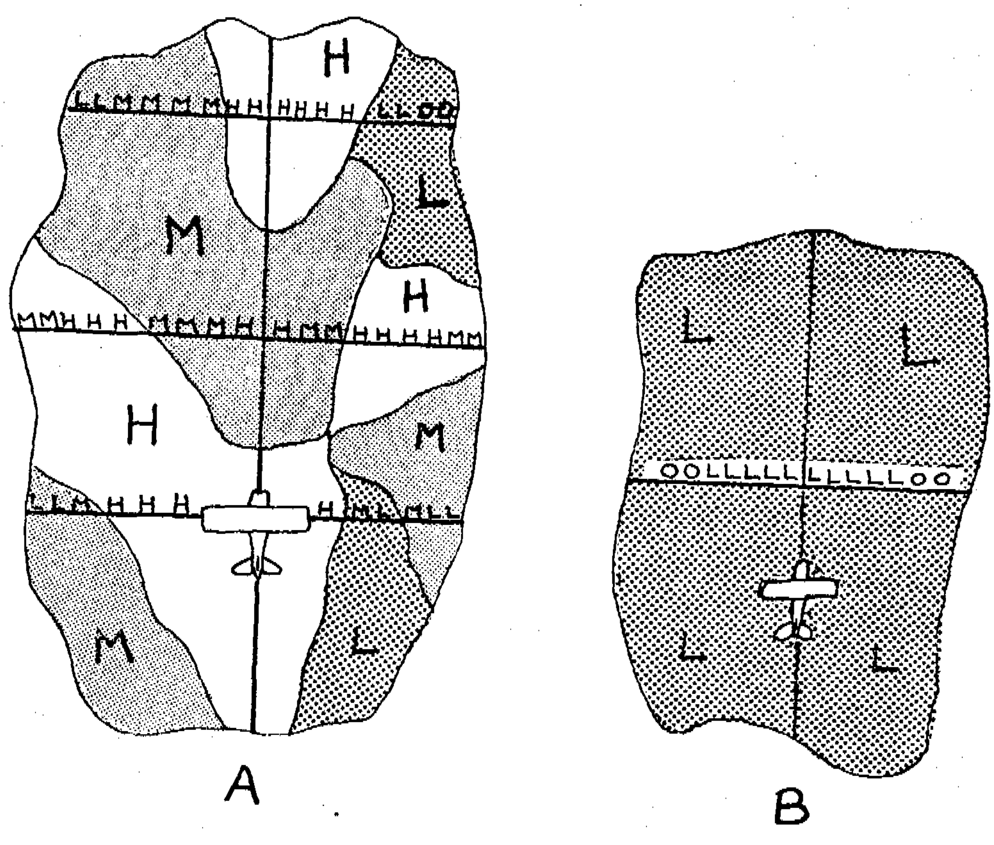

Figure 12. Variation in relative sightability of moose along a flight line which transects a habitat mosaic (A) and uniform habitat (B). Sightability: H = high, M = medium, L = low, 0 = zero.

Figure 13. Trees become an increasingly significant visual barrier as the distance from the flight line increases.

by dense spruce forest. Delineation of quadrats in these situations will require further study and development.

Determination of Sightability of Moose

The method used to determine sightability of radio-collared moose in quadrats may be criticized because both pilot and observer knew that there was a high probability (0.93) that the radio-collared animal would be 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. Without question, this is valid criticism. Although we were aware of this problem 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 this problem but would have been prohibitively expensive. Another approach using a single aircraft would be to have only the pilot lay out quadrats, periodically including or excluding radio-collared moose. The latter procedure was used initially but was abandoned because of the unexpectedly slow rate of data collection. The procedure finally adopted minimized the pilot's knowledge of the exact location of the collared moose but resulted in occasional failure (6 of 87 quadrats) to include the collared animal within the quadrat.

In spite of inherent shortcomings of the procedure used, we suspect that sightability estimates contain little bias 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 were similar to data for uncollared moose in quadrats; and,

3) Actual search time expended was relatively short (4.5 to 20 minutes, Table 2), hence, maintenance of peak mental and visual acuity was accomplished during the experimental situation and can be expected during normal, routine quadrat census activities.

One problem that could not be 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. This was partially offset when moose seen in open habitat during the initial search moved to heavier cover in response to the aircraft and as a result were missed during the intensive search.

Another problem was the influence of the initial search on moose activity and subsequent sightability during the second search. On at least three occasions moose were observed reacting to the aircraft at a distance of from 0.1 to 0.2 mile. This disturbance factor could cause moose missed during the initial search to stand, thereby making them more visible during the intensive search. Moose missed on the first search displayed activity similar to that recorded for all moose seen, suggesting that little disturbance was caused by the initial search. However, these data can be used to argue both for and against a disturbance factor affecting sightability during intensive search. First, moose lying down would more likely be missed during the initial search, as was the case with intensive searches. Therefore, the similarities between activity of all moose and those missed during initial search suggest that there may have been a disturbance effect. Conversely, these data may also suggest that there is no discernible effect of aircraft on activity and that activity has little bearing on sightability during transect/contour surveys. To further complicate the analysis, on more than one occasion moose observed standing during the initial search were observed lying during the intensive search. Therefore, a conclusive statement concerning the influence of the initial search on activity during subsequent searches cannot be made at this time.

The profound influence of snow quality on sightability during transect/contour surveys demonstrates the requirement for consistent snow conditions during transect/contour surveys if they are to be used to indicate trends in moose numbers. The effect of snow quality on sightability was negligible during intensive searches, although some unintentional compensation for poor snow conditions probably occurred through increased search intensity (time). A major advantage of using the intensive search method to obtain population estimates is that it is not influenced significantly by the normal range of snow conditions encountered from year to year.

Variations in seasonal habitat selection by moose can also have profound effects on sightability and influence optimum timing of censuses. In the present study, as well as in those by Coady (1974 and 1976), the shift in habitat selection was from types dominated by open, low canopies during early winter to forest-dominated types during late winter. This change in habitat preference made sighting moose it increasingly difficult during late winter aerial surveys. Hence, with respect to sightability, early winter may be the preferable period for conducting moose censuses in those areas in which this habitat shift occurs. Late winter nonetheless offers some distinct advantages for censusing moose which compensate for reduced sightability, i.e. longer day length, deeper snow, concentrations of moose in certain habitats in some years, restricted movement patterns and a longer period of favorable environmental conditions for censuses. In the future, greater use of the late winter period will have to be made in order to extend our knowledge of moose population sizes and dynamics.

Although topography was not quantified in the present study, it was an important factor influencing sightability. The adverse effects of irregular topography consisted of limitations on search time and search pattern as a result of relief and continuous variation in the observer's view of habitat and moose. Contour flight paths required less time expenditure per unit of area over irregular terrain than over flat terrain (Table 2). The effective search effort was reduced even more than the min/mi^2 figures reflect because flight duties necessitated that the pilot contribute less time as an observer in hills and mountains. In irregular terrain the distance between observer and ground is in constant flux as small creeks and gullies are crossed. This forces the observer to continuously alter his conception of search image to compensate for his varying height above the ground. Steep terrain prevented varying the flight path, whereas flat terrain allowed freedom to maneuver the aircraft into optimum viewing configurations. The ability to freely maneuver the aircraft was particularly helpful when searching dense vegetation types on flat terrain. As a result of these factors, sightability of moose in the present study was greater over flat terrain than in hills or mountains.

Unusually low snowfall combined with warm, windy weather precluded extensive study of sightability in foothill/mountain terrain in the Alaska Range. Given the poor snow conditions, sightability was substantially lower than could have been expected under optimal snow conditions. For example, sightability was 33 percent with a search intensity of 4.3 min/mi^2 during transect/contour surveys in the present study, while with a similar mean search intensity and better snow conditions, 83 percent of 30 radio-collared moose were observed in a foothill area during a 1973 transect/contour survey (Coady, unpubl. data). This demonstrates that in the Alaska Range area, which is dominated by low shrub and sparsely forested habitat, relatively high sightability of moose can be achieved with moderate search intensity and good snow conditions.

Only general statements can be made concerning conditions associated with radio-collared moose that were missed during transect/contour surveys. During these initial searches, misses occurred under a variety of circumstances; hence, numerous factors were responsible for the sightability values obtained. The factors most frequently associated with misses were bad or moderately bad snow conditions and small aggregations in which individual moose were usually lying down. Neither aggregation size nor moose activity, however, appeared to differ significantly from mean values observed for all moose. Total observer experience and currency of observer experience may have affected sightability in the present study, as it did for LeResche and Rausch (1974). Six of 19 misses of collared moose during transect/contour surveys occurred during the first 7 quadrats surveyed in each of the October/November and February/March sampling periods.

More specific statements can be made concerning reasons for missing radio-collared moose during intensive searches. These moose tended to be alone or in pairs, bedded in or associated with spruce forests in irregular terrain under bright, high intensity light conditions. In other words, moose missed during intensive searches were generally associated with a combination of adverse factors. Sightability will vary with the prevalence of these factors at different times in different areas, but such combinations of adverse factors will continue to occur at a more or less predictable rate and cause some moose to be missed.

Our efforts to duplicate routine transect/contour surveys used by the Game Division were unsuccessful; therefore, the application of our sightability values to previous survey data must be done with caution. Sightability values best serve as guidelines for expected sightability under a variety of survey conditions. These values may be useful to interpret past Game Division surveys only if the following are known:

environmental conditions under which the survey was conducted; the specific areas searched; and the intensity of search. In most cases all of these parameters were not described. Mean search intensity during early and late winter surveys made by the Game Division generally ranged from 1 to 2.5 min/mi^2. However, search intensity during any one survey varies greatly from area to area, i.e. one area may be disregarded completely while another area may receive 5 to 10 min/mi^2 search effort. In many portions of survey areas the search intensity may have been comparable to that applied during initial searches in the present study; however, defining areas of comparable survey intensity is difficult.

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. This will entail surveying other areas of the state where radio-collared moose are being used in existing investigations.

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.

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 H LS 5 TS 20 D 2 SS 15 S L
	4	1/S			2/SS					3	H LS TS 2♀ D 1♂ SS S L
	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 ___

APPENDIX II

IMMOBILIZATION OF FREE RANGING MOOSE WITH A MIXTURE OF ETROPHINE (99) AND XYLAZINE HYDROCHLORIDE (ROMPUN)

(Short Paper Submitted to JWM)

The immobilizing drugs M99, etrophine hydrochloride, (D-M Pharmaceuticals Inc., Rockfield, MD) and Rompun (xylazine hydrochloride, Chemagro Division of Bay Chemical Corp., Kansas City, MO) have recently been approved for use in free ranging wild animals in the United States. Although these drugs have been commonly used in combination for many species of African ungulates with excellent success (Harthoorn, The Chemical Capture of Animals, pp316-342, Bailliere Tindall, London, 1976, 416pp), their combined use on free ranging moose (Alces alces gigas) has not been previously reported. The use of M99 alone has recently been reported by Franzmann and Arneson (J. Zool. Anim. Med. 5(2):26-32, 1974) and Roussel and Patenaude (J. Wildl. Manage. 39(3):634-636, 1975). Until recently, the commonly used immobilizing drug for moose was Anectine (succinylcholine chloride), which has inconsistent effects on Alaskan moose. About 30 percent of the moose we have injected with Anectine during routine collaring programs were not immobilized, while the same dose caused respiratory distress or death in other moose. The purposes of this paper are to evaluate the use of a mixture of M99 and Rompun for immobilizing moose, to recommend dosages, and to briefly compare its advantages and disadvantages to those of Anectine.

Using this drug mixture, 48 adult moose were immobilized during August and October 1976 in Interior Alaska, and 67 adult female moose were immobilized during April 1977 on the Alaska Peninsula. Radio collars were installed on moose in Interior Alaska and Alaska Peninsula moose were immobilized to assess physical condition and pregnancy rates and to install visual collars. Projectile syringes (7 and 10cc) fired from Palmer Cap-Chur Guns (Palmer Chemical & Equipment Co., Inc.) were used to deliver immobilizing drugs. All moose were pursued and darted from a helicopter. Although most animals were darted in the hindquarter, several were hit in the back and flank. The antagonist to M99, M 50-50 (diprenorphine, D-M Pharmaceuticals, Inc.) was administered intravenously (IV) into the jugular vein.

Immobilization. Induction time (IT) was the interval between initial injection and when the moose went down. The mean IT of 16 minutes (range 5-50) for all moose immobilized with a single injection did not differ significantly with dosage rate or between sexes (Table 1). There was considerable variation, however, in the number of moose which did not react to or were only weakened by the initial injection. Forty-three percent of 14 moose darted with the smallest dose during August (5 mg M99/200 mg Rompun) either manifested no response or required a second dose, but only 13 percent of 96 moose receiving greater doses failed to go down with the first injection. Thirty-six percent of the moose given the smallest dose showed no reaction to the drug, compared to only 4 percent of the moose receiving greater doses (Table 1). Moose given the smallest dose demonstrated the greatest muscle control while immobilized, making them more difficult to collar and handle. The average time of immobilization for all moose was about 35 minutes (range 9 to 55 minutes).

Moose manifesting a partial response to the drug were darted a second time with 3 mg M99, which completed the immobilization (Table 1). The reason for partial response in two cases was incomplete injection of the drug resulting from malfunction of the weak inertia firing device which forces the rubber plunger forward. Other moose either received an initial dose that was too light, or the drug could have been absorbed slowly by injection into either fat or subcutaneous space. Failure to react to the drug could have resulted from any of the above factors plus total, or near total, malfunction of the injection system. For example, four of the non-reacting moose were successfully immobilized with a second full dose and the first darts were found to have malfunctioned (Table 1). One barrel had split in the rear threaded portion allowing gases to escape, and the inertia firing device failed in the other darts. The other non-reactors may have been hit with malfunctioning darts also.

Recovery. Recovery time (RT) is the interval between the injection of the antagonist and the time when the moose stands. Mean recovery time ranged from 2-4 minutes for all doses of immobilizing drugs and antagonist except during October, when bull moose averaged 9 minutes RT (Table 1). In addition to their longer RT these bulls were the weakest and least coordinated upon recovery. This recovery response by bulls was probably related to their generally poor physical condition following the rut.

Although there was no apparent relationship between RT and the dose of immobilizing agent or antagonist (Table 1), some variation was noted in strength and coordination of moose after they regained their feet. Best recovery was observed when Rompun comprised about 30 percent by volume of the immobilizing dose and when M 50-50 was administered at a rate equal in volume to the total dose of combined immobilizing drugs. For a dose of 7 cc M99 and 3 cc Rompun the best recovery characteristics were obtained by injecting 10cc of M 50-50. Greater percentages of Rompun or smaller doses of M 50-50 resulted in poor coordination upon standing. Maximizing the rate of full recovery reduces the probability of post-immobilization accidents or fatal encounters with predators. On three occasions the jugular vein was missed with the antagonist resulting in no recovery response. A second full dose of M 50-50 was given and normal recovery followed.

Mortality. Four of 26 moose were believed to have died as a result of immobilization or handling during August (Table 1). The length of time these moose survived after immobilization is not known, but evidence suggests that it was less than two days. Examination of the carcasses indicated that these animals likely did not succumb from violent accidents or encounters with predators. Three of these moose were dosed with a 40 percent Rompun mixture (6 mg M99/400 mg Rompun), and the fourth received 7 mg M99/300 mg Rompun, but stood up and staggered off before M 50-50 injection could be given. Therefore, all four moose could be expected to have had a prolonged recovery which may have resulted in their deaths. In an effort to minimize mortality during October and April, residual effects of the tranquilizer were reduced by increasing the M 50-50 dose and reducing the proportion of Rompun in the initial dose (Table 1).

Capture myopathy (Harthoorn, op. cit., pp. 103-106) may have been involved in the death of these animals, although it has not been observed in Alaskan moose which have been previously immobilized. Hyperthermia may also have contributed to the death of these moose. August air temperatures were warm, reaching 27°C during the day with bright sunlight. Stress from pursuit and darting, as well as the reduced capacity to thermoregulate while immobilized, may have elevated body temperatures to critical levels (Harthoorn, op, cit., pp54, 74-75). Rompun was used during the present study in combination with M99 to reduce hyper-excitability and hyperthermia, which result with the use of M99 alone in moose (Franzmann and Arneson op. cit.) and in other ungulates (D. Kelleyhouse, California Fish and Game, pers. comm.). Roussel and Patenaude (op. cit.) reported significantly elevated body temperatures of moose during winter when immobilized with only M99 (40.5°C, range 38.0 - 42.8°) compared with hand-captured and restrained moose (39.3°C, range 38.0° - 40.4°). They attributed observed differences in body temperature to the pursuit of the animals rather than to the pharmacodynamics of the drug. Because no body temperatures were recorded during the present study, we can only speculate that hyperthermia may have contributed to the observed mortality. Potential hyperthermic problems were reduced during October and April when winter conditions existed, and no mortality was documented in moose immobilized during this period. Because drug use was modified for these studies this lack of mortality cannot be attributed to lower ambient temperatures, however.

Cost. The cost of immobilizing moose with M99/Rompun is relatively high compared with other drugs. The cost of the drugs was about $60.00 per moose handled, using 7 mg M99/300 mg Rompun and 20 mg M 50-50. This cost figure includes occasional darts that missed and second doses of M99 and M 50-50 in the frequency required in this study. By comparison, Anectine costs less than $1.00 per animal under comparable situations. In spite of the high drug costs, we had substantial savings in overall expenses compared with collaring programs using Anectine. The largest cost reduction was in helicopter time required per moose immobilized. M99 immobilized moose more consistently than Anectine, and moose moved shorter distances after being darting. As a result, the number of darts lost was substantially reduced.

Recommendations and Conclusions. The preferred dose for free-ranging Alaskan moose weighing 450-640 kg was 7 mg M99/300 mg Rompun and 20 mg M 50-50. It is recommended that moose not be pursued and immobilized with these drugs when ambient temperatures are high.

Based on our experience the combination of M99/Rompun is superior to Anectine for immobilizing moose. Advantages are lessened problems with overdosing, respiratory distress, and regurgitation of rumen contents and improved consistency of immobilization which reduced operating expenses and the number of moose escaping with darts. Recovery was rapid and because it was controlled by the biologists it became possible to thoroughly process each moose. The disadvantages of M99, Rompun, and M 50-50 are their high initial cost and the need for a narcotic license to purchase the M99 and M 50-50.

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Table 1. The response of free ranging moose to a mixture of immobilizing agents M99 and Rompun and antagonist M 50-50.

Month	Dose (mg) M99/Rompun	Dose (mg) M 50-50	Sex	Sample Size	Reaction To Initial Dose	Additional Dose (mg) M99/Rompun	Reaction Times (min) [$\bar{x}$ (range, n+)(SD)] IT	Reaction Times (min) [$\bar{x}$ (range, n+)(SD)] RT	Remarks
Aug	5/200	10-14	M	2	Immobilized	-	12(6-17)	4(3-5,3)	
		20	M	1	Weakened	3/100	33	*	
			M	1	No Reaction	-	-	-	
		10-14	F	6	Immobilized	-	15(8-22)(5)	3(_, 2-5,5)	
		14	F	1	No Reaction	6/400	42	*	Malfunction of 1st dart
			F	3	No Reaction		-	-	
	6/400	14	M	3	Immobilized	-	14(12-15)(2)	2(1-3,2)	2 died within 2 days
		14	F	6	Immobilized	-	18(10-30)(7)	4(1-11,5)	1 died within 2 days
	7/300	14-16	F	5	Immobilized	-	16(8-26)	3(2-5,6)	1 died within 2 days that didn't receive antagonist
		20	F	1	Weakened	3/-	27	*	
		16	F	1	No Reaction	7/300	-	*	Malfunction of 1st dart Partial injection
		-	F	1	No Reaction	-			
Oct	7/300	20	M	8	Immobilized	-	17(6-46,6)(15)	9(2-15,6)	Post Rut
		26	M	1	Weakened	3/-	50	-	Malfunction of 1st dart
		20	F	12	Immobilized	-	15(10-24)	3(2-5)	
		20	F	1	Weakened	3/-	62	*	1st dose injected in full
Apr	7/300	20	F	48	Immobilized	-	15(5-50,47)(9)	2-4(est.)	
		20	F	7	Weakened	3/-	-/_/	-*	
		20	F	2	No Reaction	7/300	-/_/	-*	Malfunction of 1st dart

\+ Sample size where differs from the number of moose darted.
The weight of moose was estimated to range between 450-500 kb and 500-640 kg for females and males, respectively.
* RT did not differ from RT of moose receiving a single dose, therefore all data were combined.
/_/ Time not recorded.

APPENDIX III

This is a Preliminary Draft of a Manuscript
Eventually to be Submitted for Publication.

Preliminary Observations on Factors Influencing Sightability of Moose during Spring and Summer Aerial Transect Surveys

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Abstract: Aerial transect surveys were evaluated as a means of assessing population size, initial calf production and calf survival to two weeks and one year of age. Collared moose were used to determine sightability of moose in the study area: approximately 36 and 24 percent of the moose were observed on surveys during May and June, respectively. Estimates of total moose in the study area were calculated from sightability values. The influences of habitat selection, activity patterns, aggregation size, weather and illumination on sightability of moose are discussed. The influence of biased aerial survey methods on sex and age composition estimates as well as sources of bias are discussed. Increasing search intensity, and therefore sightability of moose, was suggested as the means for reducing bias and variability in estimates of sex and age composition and population size.

INTRODUCTION

More intensive management of moose 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 due to a multitude of factors, e.g. natural and artificial habitat alteration, high levels of harvest by sportsmen, predation, nutrition, pathogens, extension of range, etc. However, a major hindrance to management and research efforts is the inability to accurately estimate numbers of moose and their sex and age composition. A completely satisfactory census method has not been devised for moose (Timmermann 1974). Accurate estimates of population numbers are extremely difficult to obtain because of the behavior of moose and the type of forested habitat they prefer.

Transect surveys are most commonly employed to determine the sex and age composition of Alaskan moose populations and are occasionally used as a census tool, i.e. a method of obtaining estimates of total numbers of moose. The transect method basically involves flying parallel lines at prescribed altitudes and counting moose seen in prescribed transect widths (Banfield et al. 1955). Two basic problems exist in using the transect census method: 1) a determination of width of sample transect is difficult; and 2) the number of moose not seen is unknown and highly variable. Timmermann

(1974) concluded that the transect census method was inadequate for the needs of wildlife management agencies and that quadrat sampling methods should be adopted for the census of moose.

Since the aerial transect survey method has been the one primarily relied upon in Alaska, the present study was undertaken to identify and evaluate fundamental biases of this method when used to estimate moose population size and sex and age composition during May and June. Means of reducing bias and variation in future estimates of these population parameters were sought as well as an understanding of existing biases in past survey data.

STUDY AREA

The study area included a 674 km^2 (260 mi^2) region of the Tanana Flats known as spring count area 1 (Fig. 1). The area is relatively flat, underlain by permafrost (Black 1958, Wahrhaftig 1965), and poorly drained. Small ponds and bogs are numerous.

The vegetation on the Tanana Flats was described by Coady (1976). His five major habitat types have been used in the present study for describing habitat selected by moose. The habitat types and their percent coverage are: herbaceous bogs (8), low shrub (58), tall shrub (8), deciduous tree (5), and coniferous tree (22).

A portion of this study area was selected for intensive study by conducting repetitive surveys (Fig. 1). This area was 91 km^2 (35 mi^2) and was generally similar to the rest of the study area with regard to terrain and vegetation. The estimated percent cover of each habitat type on the study area was herbaceous bog (5), low shrub (80), tall shrub (5), deciduous tree (1), and coniferous tree (9).

METHODS AND MATERIALS

Standard immobilizing techniques were used to capture 58 cow moose in the study area (Fig. 1) between 8 and 14 May 1975. Animals were darted from a helicopter with a Palmer Co. Cap-Chur gun and a 3 cc dart containing succinylcholine chloride (Anectine). Each immobilized moose was collared and metal tags placed in its ears. Collars manufactured by Denver Tent Company (Denver, CO) were 6 inches wide and 42 inches long with a 5 inch black number on a yellow background. Samples from each moose included a first incisor pulled for age determination, hair for mineral analysis, and a blood sample for physiological chemistry and serological analysis. A rectal palpation test for pregnancy was conducted on each animal.

Surveys were conducted between 12 May and 3 July 1975 and 1976. Parallel aerial transects were flown in a Piper Super Cub or Helio Courier at 70 $\pm$ 5 mph (113 km per hour), at 300 $\pm$ 100 ft (91 m) and at approximately 0.5 to 0.75 mi (0.8 to 1.2 km) intervals. Both pilots and observers searched for moose. The distance scanned on each side of the transect was approximately equal to one-half the transect interval.

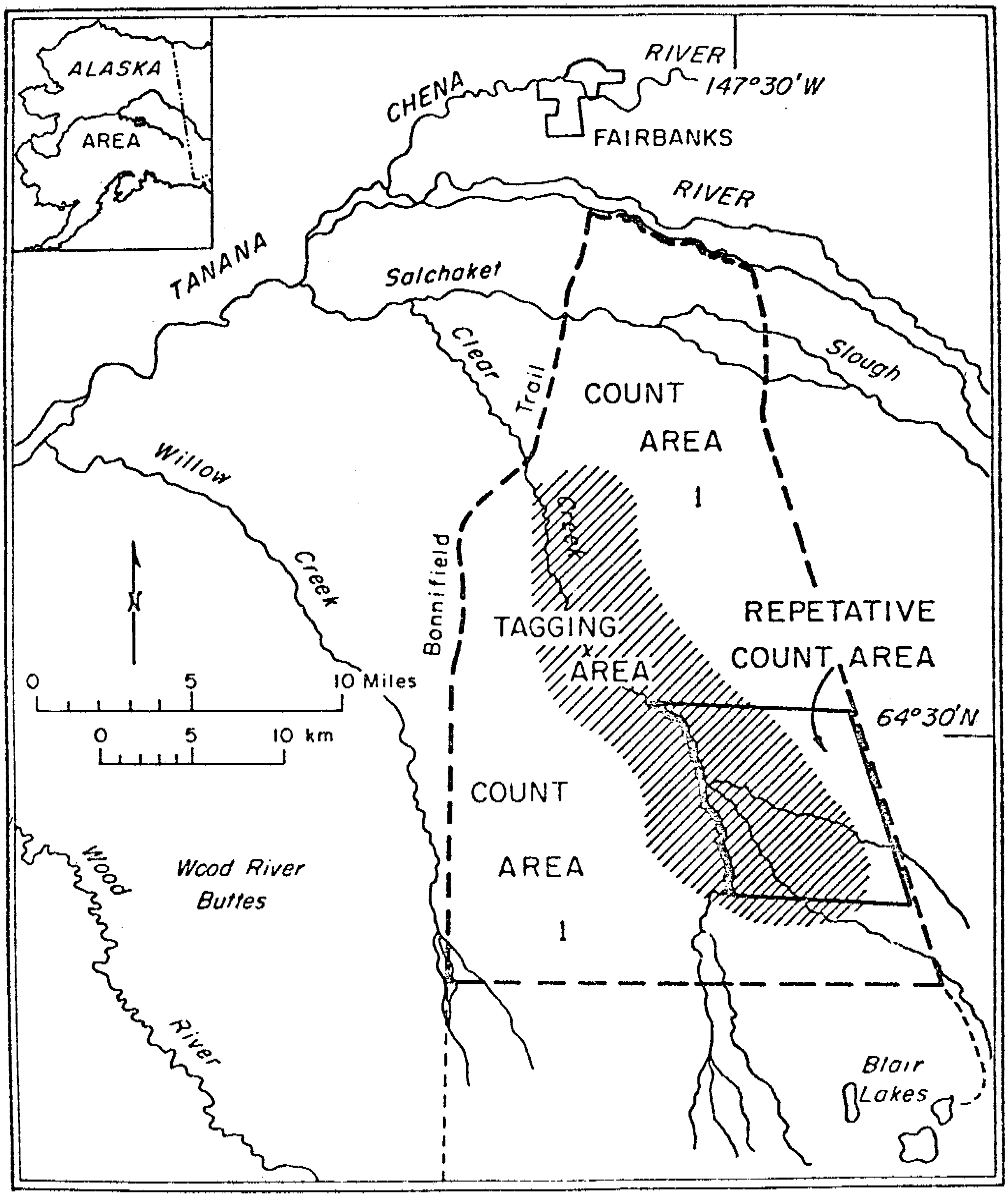

Fig. 1 The study area on the Tanana Flats, Alaska.

Although pilots and observers were not consistent between surveys, except during the series of 14 repetitive counts, all pilots and observers were experienced. When a moose was seen the pilot would deviate from the transect, make a low pass over the animal and circle to search for other moose. The transect was rejoined again at the departure point.

The sex and age of moose were determined (calf, yearling and adult) when possible. The criterion for sex identification was the presence or absence of antlers. Size, pelage color and muzzle shape were used to distinguish yearlings from adults. Collared moose were recorded during all surveys. Sightability of moose during a survey was defined as the percentage of collared moose observed; i.e., theoretical sightability could range from zero, if no collared moose were seen, to 100 with all moose seen.

The method used to determine the presence of a calf was described by Rausch and Bratlie (1965). Cows were closely observed up to five times in an effort to observe the calf. The frequency of overlooking newborn calves when they were present was estimated from 89 repeated observations of collared cows. Between late May and early July, individual cows observed two or more times and at least one of those times with a calf were used to calculate this error as follows: the number of observations where the calves were missed was divided by the total number of observations of cows with calves. A minimum error was estimated by including as misses only those observations of individual cows without calves which were preceded and followed by an observation of the cow with a calf. The upper limit of the error was calculated by including all possible misses that were detected, i.e. up to two observations of a cow without a calf at the end of a series of observations of that cow with a calf. In the latter situation the lack of a calf could result from overlooking a calf that was present, hence a valid miss, or from the true absence of a calf which was undetectable because of the lack of further observations.

Fourteen repetitive surveys were flown in a portion of the study area (Fig. 1) to determine the extent of variation in moose survey data attributable to diurnal behavior patterns of moose and environmental influences. Surveys were flown during four periods of the day: 0630-0825 hr, 1020-1240 hr, 1430-1700 hr, and 1840-2040 hr. The influence of cloud cover on sightability of moose was investigated on two clear, warm days and on two cloudy, cool days. Sex, age, habitat type and activity were recorded for each observed moose. Weather data were recorded for each survey period.

RESULTS AND DISCUSSION

Estimating sightability

Sightability of moose: A relatively small proportion of moose were seen during spring and summer aerial surveys based on observations of collared moose. Mean sightability of collared moose during May before leaves developed and during June after leaves developed was 36 and 24 percent, respectively (Table 1). These sightability estimates were only approximate; the exact number of collared moose in the surveyed

Table 1. Sightability of collared cow moose during aerial transect surveys over the Tanana Flats, interior Alaska during May and June of 1975 and 1976.

Month and year of survey	Estimated number of collared moose in count area	Sightability (% of collared moose seen)
May 1975	58	31
May 1975	55	33
May 1976	52	44
Mean and SD for May surveys		36(4)
June 1975	58	16
June 1975	58	31
June 1976	52	17
June 1976	52	23
June 1976 (repetitive counts)	15	33
Mean and SD for June surveys		24(5)

area could not be determined. For example, we considered 58 collared moose to be in the survey area shortly after collaring in May 1975. By June 1975 some animals may have moved out of the area, although surveys in adjacent areas suggested that no significant emigration had occured. The following year there was no way to firmly establish the number of collared moose returning, so we estimated the number of moose in the following manner. Most living moose in spring 1976 were assumed to have returned to the tagging area, since moose in this portion of Alaska exhibit very traditional movement patterns (Coady 1976). We assumed that the number of moose not returning was equal to the number dying. Thus, with an annual mortality rate of nearly 10 percent, about 52 moose may have been in the survey area in 1976. In spite of the crude manner of establishing the number of collared moose in 1976, the derived value was considered sufficiently accurate to demonstrate the approximate sightability of moose.

Estimates of population size and density: Using the current estimates of sightability (Table 1) and the number of moose seen in the study areas, the total number of moose in the study area was estimated (Table 2). This portion of the Tanana Flats currently supports some of the highest spring and summer densities (about 4 moose/mi^2) of moose known in Interior Alaska (Table 2). However, this density is relatively low compared to that existing during the early 1960's. Rausch (1962) reported seeing 8 moose/mi^2 in the same area during surveys in mid-June 1962. Based on current estimates of sightability, densities of up to 30 moose/mi^2 may have occurred during early summer. The small area selected for intensive study and repetitive counts had a moose density similar to the primary study area. An estimated 180 moose were present during June 1976 based on the mean number of moose seen during the 11 surveys in count periods 1 through 3 (Tables 2 and 3).

The potential for large errors in population estimates occurs when a small proportion of the moose are observed during aerial surveys. For example, during June, environmental factors, behavior of moose, quality and experience of pilots and observers, etc. could easily combine in such a manner that 16 percent of the moose were seen on one survey and 31 percent were seen on another (Table 1). When the number of moose seen is used as a population trend indicator or in calculations to estimate population size, as is done in Alaska, major errors may result.

Factors influencing sightability of moose

The three major factors that affect sightability are behavior of moose, environmental factors and pilot-observer effectiveness, all of which are interrelated.

Habitat: Moose select specific habitat types seasonally, and each habitat type will influence sightability characteristics of moose utilizing it (Coady 1974, 1976; Gasaway et al. 1977). The habitat classification used in the present study weighted the growth form of plants more than the species of plants (Coady 1976) and, therefore, was useful in evaluating relative sightability in these habitat types. Sightability of moose in

Table 2. Estimated number and density of moose in the Tanana Flats study area during May and June of 1974-1976.

Date	Total moose seen	Extrapolated population estimate: A. moose seen corrected by mean sightability	Extrapolated population estimate: B. moose seen corrected by sightability on that survey	Density moose/mi^2 based on population estimates: A	Density moose/mi^2 based on population estimates: B	Moose per hour	Count time (hr)
16-17 May 1974	382	1060	n/a	4.1	n/a	52	7.4
17-20 May 1975	214	590	690	2.3	2.7	30	7.1
12 May 1976	163	453	371	1.7	1.4	20	8.0
2-3 June 1975	134	560	840	2.2	3.2	19	7.2
11-13 June 1975	343	1430	1110	5.5	4.3	33	10.4
10-16 June 1976	181	750	1070	2.9	4.1	19	9.5
30 June-2 July 1976	255	1063	1109	4.1	4.3	30	8.5
4-11 June 1976 (repetitive count area)	44	180	130	5.2	3.8	25	n/a

Table 3. Observed calf ratios during four periods of the day between 4 and 11 June 1976, on the Tanana Flats in interior Alaska.

Day	Period of Day																
	1				2				3				4				
	Total moose	F	M/100F	C/100F[1]	Total moose	F	M/100F	C/100F	Total moose	F	M/100F	C/100F	Total moose	F	M/100F	C/100F	Weather
1	–	–	–	–	23	11	64	9	27	8	175	50	17	6	100	33	clear, warm
2	53	27	44	22	46	18	83	44	53	22	64	50	21	10	70	30	cloudy, cool
3	50	23	78	26	46	21	71	19	49	23	78	26	40	16	88	31	cloudy, cool
4	41	17	100	24	41	20	45	40	52	25	56	32	–	–	–	0	clear, warm
Totals	144	67			156	70			181	78			78	32			
Means			70	24			66	30			77	37			84	31	

[1] symbols refer to sex and age: F = adult female, M = adult male, C = calf

the herbaceous type was relatively high because moose standing or lying protruded above the vegetation. These herbaceous areas were relatively uniform in color and texture. Sightability of moose declined rapidly as height of vegetation increased.

To comprehend the impact of habitat on differential sightability, habitat selection by bulls, cows without calves and cows with calves must be better understood. Currently, the best quantitative estimates of habitat selection by moose in Interior Alaska come from studies by Coady (1974 and 1976) utilizing moose instrumented with radios. However, further analysis of data will be required to discuss habitat selection, especially in the presently defined study area. For the general Tanana Flats area Coady reported that radio-collared moose during May more frequently selected forest types than moose observed during standard aerial surveys. This suggests that deciduous and coniferous forests were effective visual barriers and that the proportion of moose in certain habitats was underestimated on aerial surveys. Therefore, the relative number of moose observed in each habitat type during the present study resulted from the combined influences of sightability and habitat preferences of moose and thus was not an absolute measure of habitat selection. The significance of biases associated with habitat selection and sightability is compounded by the fact that there is some segregation of portions of the moose population (bulls, cows, and cows with calves) by habitat type (Table 4, Coady 1976, LeResche et al. 1974). Hence, not only does variation exist in sightability of all moose among habitats, but variation in sightability of segments of the moose population occurs because of differential habitat selection. The profound and complex influence of the latter type of segregation on estimates of sex and age ratios can cause biases.

Repetitive counts conducted during four periods of the day demonstrated diurnal habitat preferences as well as differential habitat selection and sightability patterns between various segments of the population (Table 4). All groups of moose tended to select habitats containing vegetation with tall growth forms during early morning compared to other times of the day. This pattern was most pronounced in cows with calves, which appeared to avoid open areas early in the day (Table 4). Similar observations were reported by Bentley (1961) while making morning surveys. Correlated with this observation were low calf:cow ratios during early morning surveys (Table 3). Based on the sum of all observations, cows with newborn calves tended to select taller vegetation throughout the day, while no differences were apparent among other groups of moose (Table 4). These observations collaborate LeResche's (1966) findings that cows with calves in the Matanuska Valley tend to avoid openings to a greater extent than do other moose. The above data suggest that cows accompanied by calves during June selected habitats which reduced their sightability during aerial transect surveys; hence, their occurrence in the population and their absolute number will be underestimated.

Additional support for this conclusion was derived from ratios of 70 and 46 calves/100 cows for collared and uncollared cows, respectively. The primary reason for the difference in these ratios was the method of data collection. The data from uncollared cows were obtained from a

Table 4. Diurnal patterns of habitat selection by moose on the Tanana Flats during 4 to 11 June 1976.

Segment of population	% of moose observed in habitat types (n)																								
	Period of day																				All periods combined				
	0630–0825hr					1020–1240hr					1430–1700hr					1840–2040hr									
	AH	LS	TS	D	C[1]	AH	LS	TS	D	C	AH	LS	TS	D	C	AH	LS	TS	D	C	AH	LS	TS	D	C
Fw/o calf	8	68	19	3	3	23	71	6	0	0	29	68	9	0	0	29	64	7	0	0	21	66	11	1	1
			(37)					(31)					(35)					(14)					(117)		
F/calf	0	60	90	0	0	35	40	20	0	5	17	69	19	0	0	10	80	10	0	0	18	61	20	0	1
			(15)					(20)					(29)					(10)					(74)		
F/yrlg	21	50	14	0	14	22	72	6	0	0	31	62	8	0	0	25	50	25	0	0	25	60	11	0	4
			(14)					(18)					(13)					(8)					(53)		
M	23	53	21	0	2	25	62	8	2	0	21	76	3	0	0	22	78	0	0	0	23	67	9	1	1
			(47)					(95)					(58)					(27)					(175)		
All Moose	15	58	22	1	4	26	62	10	1	1	23	70	7	0	0	22	71	7	0	0	22	65	12	0	1
			(113)					(114)					(135)					(59)					(421)		

[1] Habitat types are AH = aquatic or herbaceous, LS = low shrub, TS = tall shrub, D = deciduous forest, C = coniferous forest.

survey in 1975 and in 1976. Repetitive surveys in the same area during 1975 and 1976 provided repeated observations of conspicuous collared cows and increased the probability of seeing the more secluded collared cows at least once. Only one observation of each collared animal was used to calculate the calf:cow ratio. This multiple search method for collared cows decreased the bias of estimating calf:cow ratios.

Moose activity: The activities of individual moose influence the probability of their being seen during a survey. This is particularly important during the snow free period of the year. Data collected during repetitive surveys in June demonstrated diurnal activity patterns for all moose, as well as differences between bulls and cows (Table 5). Therefore, the timing of surveys with regard to activity periods is important to obtain consistently high counts of moose.

Activity data obtained in the present study are biased because recumbent moose had a lower sightability during aerial surveys than standing animals, and the number of lying moose was underestimated. Therefore, as with habitat selection indices, present activity data represent a relative index rather than an absolute measure. A relatively consistent proportion of moose seen were standing during the first three periods of the day, while the percentage of both cows and bulls seen lying sharply increased during evening (Table 5). The decrease in activity of bulls during evening was greater than that of cows: about one-half of all bulls seen were lying down. Bull ratios did not decline during the evening flights as might be expected (Table 3). This may have been due to the increased affinity of bulls during evening for the herbaceous and low shrub habitats where sightability was highest (Table 4). Based on the above activity data during June, evening is the poorest time of day to conduct moose surveys to observe maximum numbers of animals. These findings are not consistent with observations of moose from the ground by Carol Linkswiler (pers. comm.) and one of the authors (W. Gasaway) during late summer and fall, which indicated that activity was greatest in early morning and evening. These observations suggest that maximum moose counts could be made during the above seasons in early morning and evening if suitable light exists.

Variation in number of moose seen: Repetitive counts during June demonstrated a consistent pattern between time of day and numbers of moose during each day (Fig. 2). The numbers of moose seen during early and mid-morning and mid-afternoon were quite similar and were followed by a decline during the evening survey. The most surprising finding was the high sightability of moose during mid-afternoon, when wind and turbulence were at the daily maximum. Hence, we concluded that surveys during mid-afternoon in June may provide data comparable to surveys earlier in the day. The limits on the use of this period are controlled by pilot and observer tolerance levels for wind and turbulence. It is of interest that the highest moose count obtained during this afternoon period was on the only day when our normal tolerance level for turbulence had been long surpassed.

Aggregation size: Aggregation size influences sightability of moose. Sightability of a moose in an aggregation is not only related to

Table 5. Activity of moose observed during 14 repetitive surveys between 4 and 11 June 1976 on the Tanana Flats.

	Number of Observations	Activity of Moose Standing %	Lying %
Period of Day (all moose combined)			
1	104	91	9
2	119	91	9
3	140	88	12
4	59	66	44
1-4	365	86	14
Type of Moose (all periods combined)			
F/calf	76	92	8
F w/o calf	120	92	8
F/yrlg	52	87	13
M	174	80	20

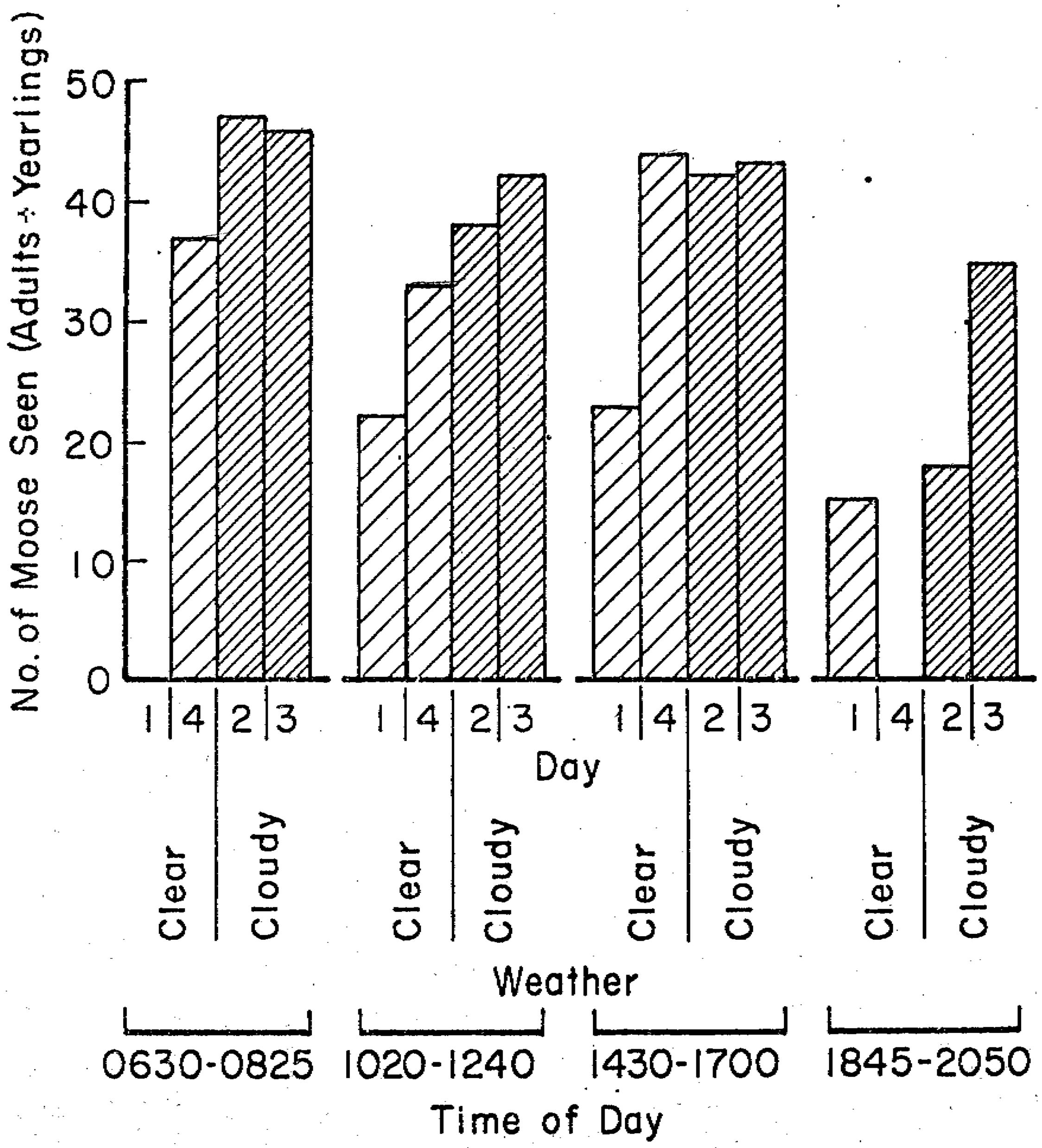

Fig. 2 Number of adult and yearling moose observed during 14 repetitive counts on 4 days between 4 and 11 June 1976 on the Tanana Flats, Alaska.

its selected habitat and activity but also to the activity and habitat chosen by its companions. Therefore, moose within an aggregation have varying sightability coefficients. Once the most visible moose is seen from the transect flight path, the probability that other aggregation members will be found sharply increases because the aircraft makes a low pass over the animal to facilitate sex and age classification and to search for other moose. Enumerating only those animals seen from the transect path is a useful and expedient survey method for species inhabiting grasslands or other low vegetation types such as that in Africa or on the plains of North America (Caughley and Goddard 1972). However, this method is not applicable to moose because of their selection of relatively dense habitat types.

The proportion of certain types of moose seen will be biased because aggregation size varies with sex, reproductive status and the time of year (Peek et al. 1974). In the present study the largest mean aggregations during May and June 1974 through 1976 were cows with yearlings, followed by cows with newborn calves; the smallest groups were adults without offspring (Table 6). However, in our evaluation of sightability, the newborn calf does not contribute to the probability of seeing the cow-calf pair because of its small size; hence, the effective aggregation sizes of cows with calves during May and June were reduced from 2.5 and 2.1 to about 1.5 and 1.1, respectively (Table 6), and cow-calf pairs became the smallest aggregations with respect to sightability. These aggregation sizes biased sex and age ratios obtained on aerial transect surveys as follows: cows with yearlings were overrepresented; cows without offspring and bulls were intermediately represented; and cows with newborn calves were underestimated. Bull ratios were distorted and their annual variation was, in part, dependent upon the proportion of cows with yearlings and calves. It is currently impossible to quantify these biases and apply the appropriate correction factors. However, wildlife managers should understand the type of biases affecting survey data on which management decisions are founded.

The total number of times individual collared moose were seen during the 14 repetitive counts provides additional insight into sightability biases stemming from the combined influences of numerous factors. The pattern was for cows with yearlings to be seen most frequently, followed by cows without offspring and cows with newborn calves (Fig. 3). Since those individuals most frequently seen will more consistently enter the data pool during routine surveys, sex and age composition values will contain biases. These biases will increase as the percent of moose seen during surveys declines from 100 percent, i.e. highly visible moose will comprise an increasing proportion of all moose seen. The mean sightability of collared moose during June was relatively low (24%); hence, the magnitude of biases was probably large. The mean sightability estimate of 24 percent is composed of sightability values for cows with yearlings, cows with calves and cows without offspring. Because these groups differ substantially in behavioral traits (Fig. 3), the sightability value is dependent upon the sex and age composition at the time the estimate was made. Therefore, the sightability estimate will increase rapidly as the proportion of cows with yearlings

Table 6. Mean size of moose aggregations observed during aerial surveys in interior Alaska during May and June of 1974 through 1976.

Period	Mean group size (number of groups) Groups containing adults only	Groups containing yearlings	Groups containing calves
May	1.6 (815)	2.6 (115)	2.5 (42)
June	1.3 (222)	2.1 (15)	2.1 (106)

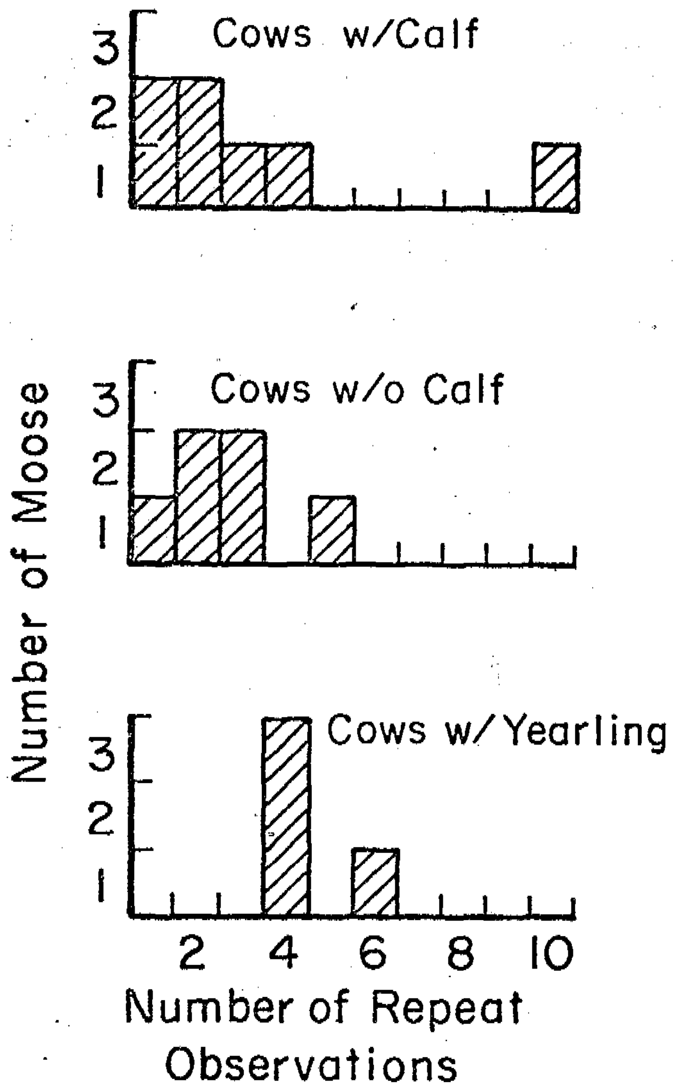

Fig. 3 The frequency of observation of individual collared moose during 14 repetitive surveys between 4 and 11 June 1976 on the Tanana Flats, Alaska.

increases and will decrease as the proportion of cows with newborn calves increases. These relationships are evident when the mean sightability value for June is compared with that of May when no newborn calves are present (Table 1). Relative sightability during May was 50 percent greater than that of June. However, this change was also due to leaf emergence, which further decreased sightability in June. Annual variation in sightability may also be expected to result from differential survival of calves.

Error in locating calves: The accuracy of cow:calf ratios is dependent, in part, on the ability of the pilot and observer to locate the calf after the dam is spotted. The secretive nature of young calves makes them very difficult to locate during aerial surveys (Rausch and Bratley 1965, Stringham 1974). Hence, omission of calves will further depress estimates of the cow:calf ratio. In the present study, 89 repeated observations of collared cow moose with calves between late May and early July demonstrated that calves were overlooked an estimated minimum of 7 percent and a maximum of 11 percent of the time. The best estimate of the true value probably is near the maximum, since these data contain two biases which reduce the estimated error. First, observers may have unknowingly searched harder for calves of collared animals and, second, a miss occurring on the first of the series of observations of a cow could not be detected. However, the latter bias was considered negligible because most counts were conducted after the peak of calving and after that time first observations included calves if calves were subsequently seen. A reasonable estimate of the number of moose calves overlooked during aerial surveys may thus be approximately 10 percent. Rausch's (1962) estimate of calves missed during aerial surveys based on the physical appearance and behavior of cows was greater (14%). However, the difference is probably attributable to differences in methodology and intensity of search.

The most likely reason for overlooking a calf during June was the considerable distance (up to a quarter mile) which can separate calves from cows (Rausch and Brattie 1965). Stringham (1974) observed the maximum cow-calf separation up to two weeks postpartum to be 100 yards; however, separation was usually less than 10 yards. Cow-calf separation commonly occurred when the cow entered large openings or deep water (Stringham 1974, LeResche 1966, Altmann 1963).

Influence of Environmental Factors on Sightability

Environmental factors affect sightability of moose by eliciting specific behavioral responses in moose and influencing pilot-observer efficiency. There have been a number of good papers on this subject covering species other than moose (Graham and Bell 1969, Goddard 1967, Mence 1969, Watson et al. 1969).

Illumination: Light intensity during surveys is a function of cloud cover, time of day and season. Optimal conditions for viewing moose were related to uniformity of lighting rather than intensity *per se*. Best conditions were found under light to moderate cloud layers which provided diffuse light, low contrast within clumps of vegetation and no shadows (Fig. 4). Under diffuse light moose were generally the predominant dark objects in the observer's field of search, with the exception of charred stumps in recent burns. The high contrast between the moose and its background allows a fairly simple and effective "search image" to be developed (Watson et al. 1969). Bright light under clear skies resulted in good viewing conditions only in uniformly lighted areas of aquatic and herbaceous habitats. The high contrast shadows produced in all other vegetation types (Fig. 4) had two adverse effects: 1) detail in shadows was difficult to see because the human eye cannot accommodate the rapidly changing light level; 2) dark shadows distracted observers psychologically alert to dark search images. Observers scan large areas rapidly until a search image is encountered, at which time total concentration is focused on one point. When constantly presented with false search images, observers focus on more specific points to discriminate between moose and artifacts; hence, shadows reduce the overall time spent scanning by competing for search time and consequently result in fewer moose being seen. This relationship of search time per unit of area to the number of animals seen has been discussed in detail by Caughley (1974) and Caughley and Goddard (1975), Caughley et al. (1976), and Pennycuick and Western (1972).

The thesis that diffuse light increases the sightability of moose during aerial transect surveys is supported by consistently greater numbers of moose seen on cloudy days (Fig. 2). The sole exception to this pattern was a single count on a clear afternoon (Fig. 2). From these limited data we cannot unequivocally demonstrate that the increase in moose seen on cloudy days was solely a function of improved lighting and not due to an increase in moose activity and selection of more open habitat. However, the data strongly suggest that light is a significant factor.

The proportion of moose seen on surveys throughout the day will change as sightability of moose varies with light intensity and angle of the sun's rays. During summer in Alaska the angle of incidence of the sun's rays striking the earth's surface is acute for several hours after sunrise and prior to sunset. Although adequate light intensity may be present during a portion of this period, the low angle of incidence creates long shadows which make it extremely difficult to see moose in tall vegetation. Additionally, backlighting and glare when looking in the direction of the sun reduce sightability of animals (Graham and Bell 1969, Watson et al. 1969). Surveys conducted 3 to 5 hours prior to sunset during June consistently yielded the lowest moose counts of the day (Fig. 2). However, reduced activity also contributed to the small number of moose seen in the evening. We recommend that evenings be avoided for surveys because of unfavorable light and low moose activity. Sightability of moose changes continuously during evening because of light and activity factors, making interpretation of data difficult for wildlife managers attempting to collect trend indicators of population size and composition. Surveys during very early morning were not evaluated in the present study. Adverse light qualities similar to those observed during evening surveys might be expected during this period, although Rausch (1962) recommended early morning as the most favorable time to count calf moose during June.

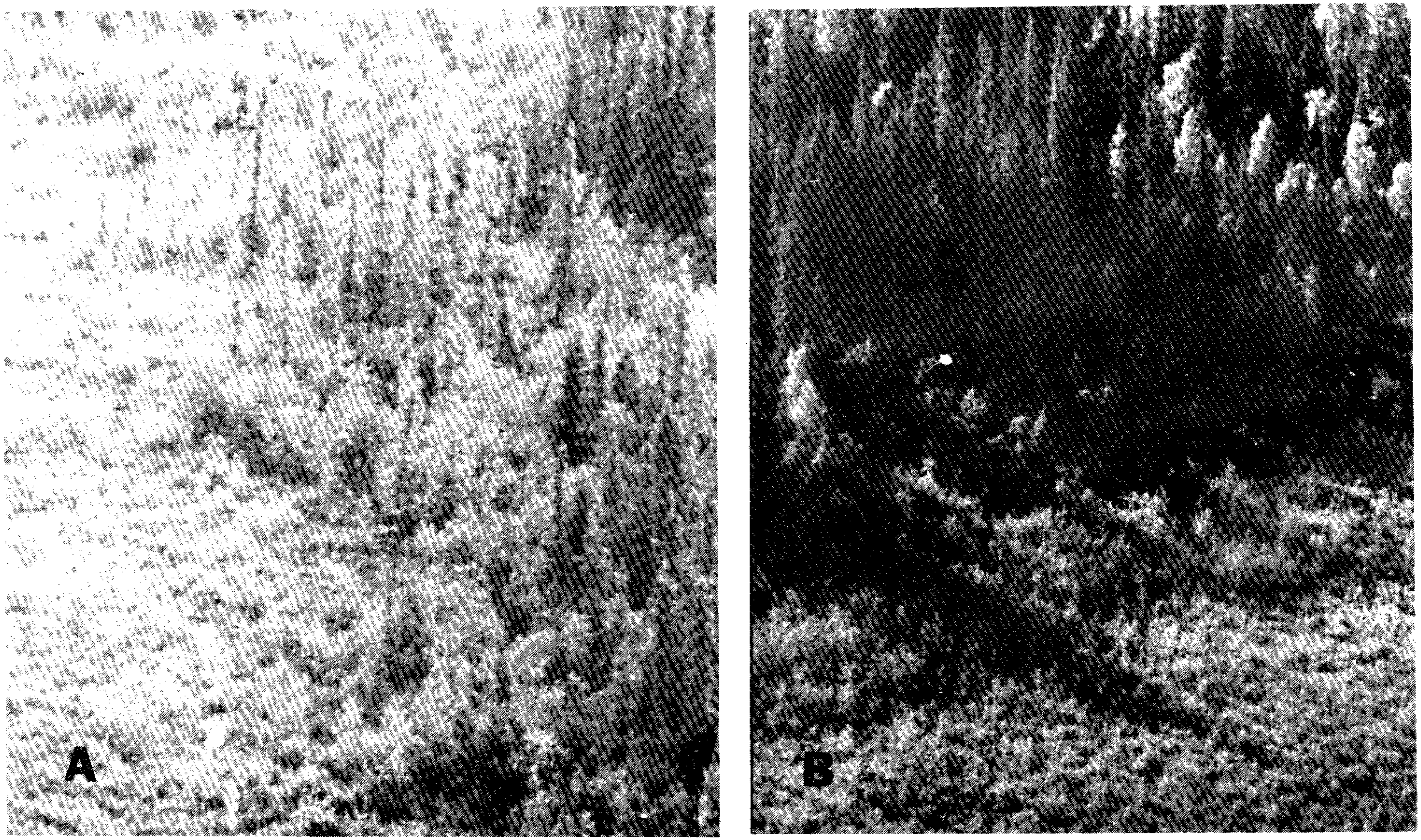

Fig. 4 A) Diffuse light producing low contrast within clumps of vegetation is optimal for observing moose; B) High contrast shadows from bright light decrease the sightability of moose.

Weather: Winds and turbulence adversely affect pilot/observer efficiency and reduce the sightability of moose. Ideally, surveys should be done with no wind or turbulence; however, ideal conditions rarely exist during summer in Interior Alaska. Winds to 15 mph and very mild turbulence were tolerated, although the rate of pilot fatigue increased as winds increased because of difficulties in maintaining the correct ground track on transects and while circling. During sunny periods in May and June, turbulence and winds caused by thermal convection currents generally increased throughout the day to a peak in late afternoon. As turbulence increased, observers often developed varying degrees of air sickness and both pilot and observer were rapidly fatigued. These factors certainly reduced their efficiency in sighting moose. In east Africa, where daily thermal convection activity is similar to that found in Interior Alaska during summer, Norton-Griffith (1976) found that counting efficiency declined during transect surveys as fatigue and turbulence increased. However, in Alaska the number of moose seen remained relatively constant on sunny days as adverse weather conditions increased (Fig. 2). If weather factors in Alaska adversely affect counting efficiency as the day progresses, then moose must become more visible during the day to maintain a relatively constant sightability (Fig. 2).

The knowledge of weather influences on moose behavior is limited at this time. It has been observed that moose increased their use of forests during windy periods in winter (Linkswiler pers. comm.). However, the opposite may be true during summer. Moose are plagued by biting flies and mosquitoes during summer and, as with caribou (Kelsall 1968), winds offer one of the few means of relief from insects. On clear, hot days winds may also offer an opportunity for moose to remain in openings exposed to the sun without elevating body temperature or expending excessive energy to thermoregulate. Air temperatures on the Tanana Flats reach 80° to 90°F (27-32°C); however, skin temperatures under dark pelage of moose may exceed that of air in direct sunlight and still air during summer. Hence, during summer, winds may allow moose to spend more time in the open habitat where sightability is high.

Variability in Sex and Age Ratios

Biases in sex and age ratios occur when variation in moose numbers and composition result from differential behavior among bulls, cows, and cows with calves (Bentley 1961, Rausch 1962). The influences of weather, habitat selection by moose, time of day, timing of surveys with parturition, aggregation size, and search effort in various habitats can easily alter the sightability factor of each portion of the moose population.

Variation in estimates of sex and age composition for moose within the study area was high (Table 3). This variation was caused ultimately by two factors: sampling intensity and movement into and out of the area. The latter source of variation was estimated to be small and was discounted as a major factor. Therefore, the true composition of the estimated 180 moose (Table 2) in the study area was assumed to remain constant during the 14 surveys. Theoretically, there would be no variation if 100 percent of the moose were included in the sample.

However, a total count is seldom achieved during surveys, so variation existed. As the sample decreased from 100 percent the potential for variation among samples increased. The present sample consisted of approximately one-fourth of the total moose present (Tables 1 and 2). It can be argued that less variation may have occurred if the sample size was increased, but this could be achieved only by increasing the area and time surveying if the transect survey method is utilized. However, a sample of 200 moose would have required about 8 hours of survey time covering 6 times the area.

Therefore, management of small populations (approximately 180 moose in the present example) requires reduction of variation in estimates of composition and population size. With low sampling intensity, the variation in data seen in Table 3 resulted from environmental and behavior factors affecting sightability and from random sampling errors. The former can be minimized by controlling the circumstances under which surveys are conducted, while the latter can be reduced by increasing the percentage of animals seen during surveys. Therefore, improved survey techniques utilizing a more intensive search pattern will be necessary during periods of the year when sightability of moose is low.

Application of Sightability Data to Other Areas

Relative sightability of moose on the Tanana Flats was higher in the study area because of the greater proportion of herbaceous and shrub-dominated habitat types than in adjacent portions of the Flats. Therefore, the 36 and 24 percent sightability values derived in May and June, respectively, are considered maximum values. Greater variability and bias in sex and age ratios will occur when the aerial transect method is applied to other, more densely vegetated areas. However, these sightability estimates may serve as useful guidelines for biologists working in other areas.

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