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MOOSE SURVEY PROCEDURES DEVELOPMENT

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JOB PROGRESS REPORT (RESEARCH)

State:	Alaska		
Cooperators:	William C. Gasaway, Stephen D. DuBois, and Samuel J. Harbo		
Project No.:	W-17-11	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: July 1, 1978 through June 30, 1979

SUMMARY

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

Seventy-seven 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 related to type and intensity of the survey, environmental factors and moose behavior. Field work was initiated in October 1976 and continues through the present.

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

Each quadrat was established to encompass a radio-collared moose, the approximate location of which was determined by the pilot from an altitude greater than 1,000 feet above the ground. Each quadrat was

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

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

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

Snow quality had a measurable effect on sightability during transect/contour searches. Moose sightability declined as snow quality declined, and habitat selection and activity of moose interacted with snow to influence sightability. The adverse effects of poor snow on sightability during transect/contour searches can generally be overcome by intensive searches of the area.

The type and intensity of light were found to have no quantitative effect on sightability of moose during aerial surveys.

A census of GMU 20A and that portion of 20C east of the Nenana River was conducted to test modifications of previous census trials during 1977 and 1978 and to better evaluate moose numbers in an area where the impact of wolf predation on moose is under study. This area, 6,460 mi^2, was divided into three study areas and each stratified into high, medium, low, and zero moose density zones. Sample units were drawn on a 1:63,360 scale map and numbered. A random sample of these units was selected for survey. Search intensity was similar to that used to determine sightability of moose during transect/contour searches so estimation of the actual number of moose present could be made. For all three study areas combined, a total of 2,902 $\pm$ 359 or 483 moose at 80 and 90 percent confidence intervals, respectively, were estimated to have been possible to see.

The estimated number of moose corrected for sightability error was 3,511 ± 421 and 597 at 80 and 90 percent confidence intervals, respectively. When estimations of moose numbers were made individually for the three study areas, confidence intervals were unacceptably wide. Optimum allocation of sampling effort indicated how we could have improved the precision with the present effort and how much greater effort would have been needed to achieve 80 and 90 percent confidence intervals which ranged between ± 10 to 20 of the mean.

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 hunters, nutrition, pathogens, extension of range, etc. To meet demands of research and management for increasingly sophisticated data on moose populations, it is necessary to refine and improve data gathering techniques.

One of the greatest problems in effective moose management and research has been the inability to accurately estimate numbers of moose. Accurate population estimates are extremely difficult to obtain because of the behavior of moose and the type of habitat they prefer. A completely satisfactory census method has not yet been devised for moose (Timmermann

1974). Accordingly, we have selected this area of technique development for study.

Aerial surveys and censuses of large mammals generally underestimate the number of animals present because some animals are not seen during the census (Caughley and Goddard 1972). Therefore, sightability estimates of the proportion of animals seen under varying survey methods and environmental conditions are needed to correct estimates of actual animal numbers. In the words of Caughley (1970):

> Sightability may be defined as the probability that an animal within an observer's field of search will be seen by the observer. The probability is determined by the distance between the animal and the observer; by such characteristics of location as thickness of cover, background, and lighting; by such characteristics of the animals as color, size, and movement; and by observer's eyesight, speed of travel, and level of fatigue.

Few sightability estimates exist for moose or other large animals from which reliable correction factors can be developed for moose censuses. Sightability estimates for moose in four, 1-mi^2 pens were reported by LeResche and Rausch (1974). They found that experienced, current observers saw an average of 68 percent of the moose under the experimental conditions, although the search methods employed and habitat and terrain types available limited the application of findings to other situations. Novak and Gardner (1975) estimated 90-percent sightability of moose during aerial transect surveys over 25 km^2 plots in a forested portion of Ontario. As a basis for calculating sightability they assumed that all moose present during the aerial surveys were later found by intensively searching plots in a helicopter. Floyd et al. (1979) reported seeing 50 percent of the radio-collared deer in 1.3 to 26 km^2 forested test plots intensively surveyed. Several studies have demonstrated that increasing search intensity increased sightability of moose and population estimates (Fowle and Lumsden 1958, Evans et al. 1966, Lynch 1971, Mantle 1972); however, an unknown proportion of the moose present were not seen during the most intensive searches which prevented sightability values from being calculated.

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

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

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

Assuming that less than 100-percent sightability of moose will be achieved under most circumstances, regardless of the methods employed, we sought to define aerial search patterns and intensities that would provide relatively high and predictable sightability values under a variety of conditions. These search patterns and sightability values would then be used in the development of census procedures. The sampling designs for the census methods under consideration in Alaska utilize small sample areas and are modifications of the random-stratified procedures reported by Siniff and Skoog (1964) and Evans et al. (1966). The more popular linear transect sampling methods were rejected because of the problems of adapting them to the specific terrain and habitat types found in Alaska. However, transects have been used extensively for censusing some species in other portions of the world, and extensive studies have been carried out to evaluate variables influencing sightability of mammals and methods of correcting population estimates based on transects (Jolly 1969, Caughley and Goddard 1972, Pennycuick and Western 1972, Caughley 1974, Caughley et al. 1976). Nonetheless, quadrat sampling appears to be the best starting point for the development of more precise census methods.

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

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

OBJECTIVES

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

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

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

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

STUDY AREA

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

METHODS

Determination of Sightability of Moose

The basic requirement for calculating sightability error is to determine the number of moose missed during a survey. To fulfill this requirement moose were instrumented with radio transmitters to allow positive location and identification. Forty-four, 8 and 25 moose were immobilized during 1977, 1978 and 1979, respectively, in GMU 20A and 20B with M-99 and Rompun (Gasaway et al. 1978a). Moose were equipped with radio collars supplied by AVM Instrument Company, Carbondale, Illinois and Telonics, Mesa, Arizona. A representative cross section of the population was collared including bulls, cows with calves, cows without calves and yearlings. The AVM radio collars were brown in color to prevent bias associated with collar visibility. Telonics collars were white. No colored ear streamers (flags) were placed on any of the animals. Ages of moose were determined by tooth sectioning techniques (Sergeant and Pimlott 1959, Gasaway et al. 1978b).

Sightability of radio-equipped moose was determined as follows: 1) the general location (within 0.75-1 mile) of an instrumented moose was identified from an altitude greater than 1,000 feet above ground level by the pilot only; 2) a quadrat was laid out which generally encompassed the radio-collared moose (at no time was the specific location identified); 3) the quadrat was surveyed by the pilot and observer using simulated standard ADF&G methods consisting of transect sampling techniques in flat terrain and a contour flight path in hills or mountains; and 4) following the first survey, the quadrat was searched intensively with a circling pattern on the flats (Fig. 1) and close contour flights in the hills (Fig. 2). In a few cases a circling pattern was substituted for close transects during intensive searches in the hills.

On flat terrain with few map references, physiographic features were used to describe sample quadrat units from the air. These quadrats were usually in the shape of an irregular polygon with objects such as recognizable clumps of trees or herbaceous bogs serving as corner markers. Boundaries were flown at a constant speed of 100 mph indicated airspeed (IAS) and timed with a stopwatch to provide the length of each boundary. The directional gyro in the aircraft provided a means of determining the heading for each side of the quadrat (Fig. 3). With this method it was possible to lay out a quadrat of determinable size. This method was tested and found to be relatively accurate near North Pole, Alaska, where roads and brushed section lines described known areas of land. Fig. 4 illustrates how a quadrat established in this manner would look from the air. This system functions best when there is no wind. However, if the direction and velocity of the wind can be estimated and the wind velocity is relatively low, corrections can be made for ground speed with a simple flight computer. When there was a cross wind, the heading between two corners was obtained by aligning the aircraft with a line passing through both corners, reading the heading from the directional gyro and making the appropriate crab angle in heading so the flight path reached the far corner. The crab angle has negligible influence on the ground speed of the aircraft when wind velocity is 10 mph or less. The sample units were later drawn to scale and their area determined with a compensating polar planimeter. Training and experience were required for observers and pilots to consistently locate and accurately lay out quadrats in flat terrain.

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

The intensity of search (min/mi^2) during surveys was related to airspeed and width of the interval between flight lines during transect

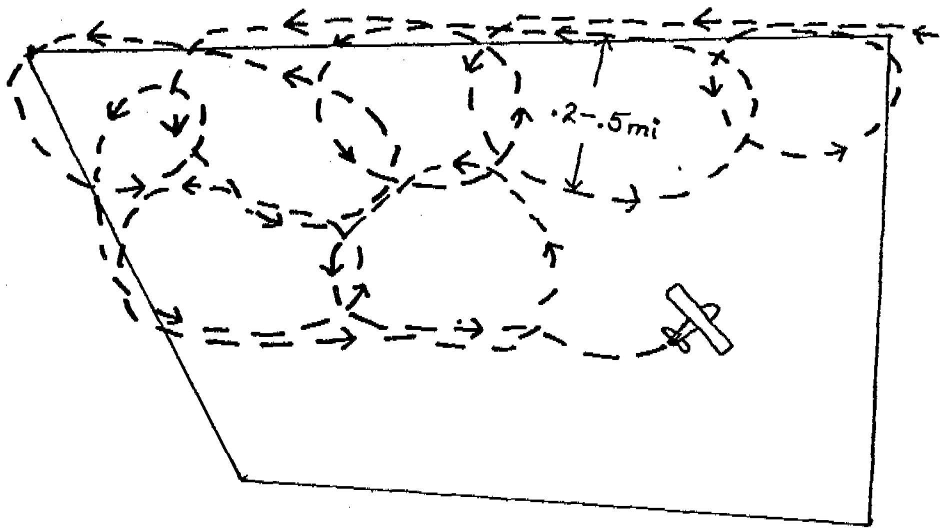

Fig. 1. Flight pattern (top view) used during intensive search of flat terrain illustrating the elongated, overlapping parallel circling pattern to ensure complete coverage of a quadrat.

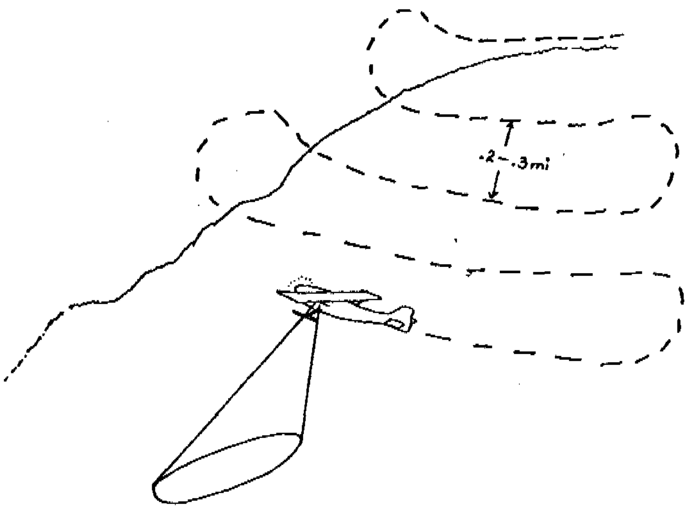

Fig. 2. Flight pattern used during intensive search of hilly terrain illustrating closely spaced contour pattern and downslope view.

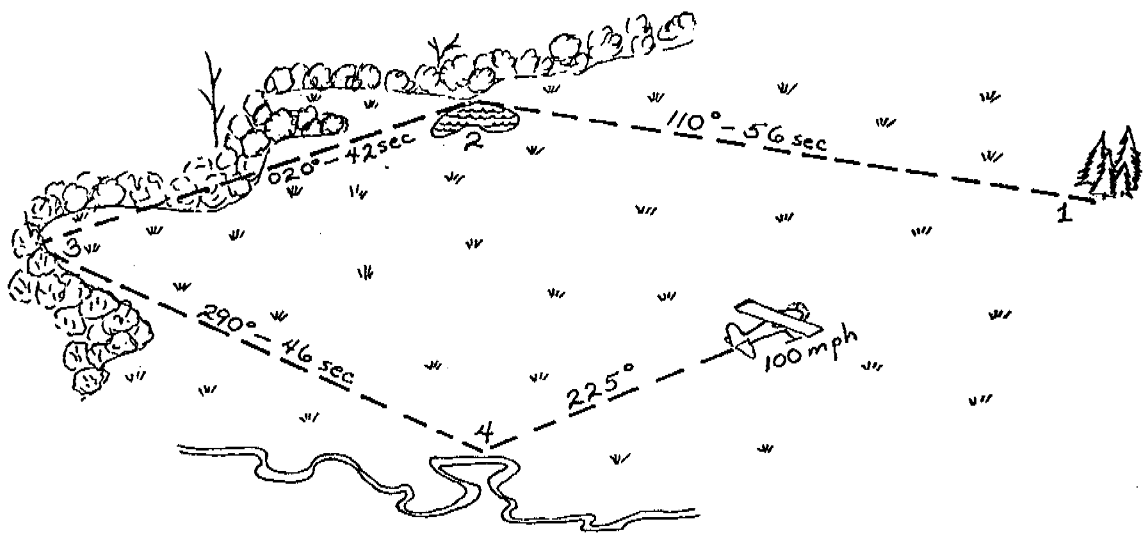

Fig. 3. Laying out a quadrat in flat terrain using: 1) a clump of spruce, 2) a pond, 3) an irregular border of herbaceous bog, and 4) an oxbow in a creek as quadrat corners. Heading, airspeed and time are used to determine length of each boundary, and allow calculation of quadrat area.

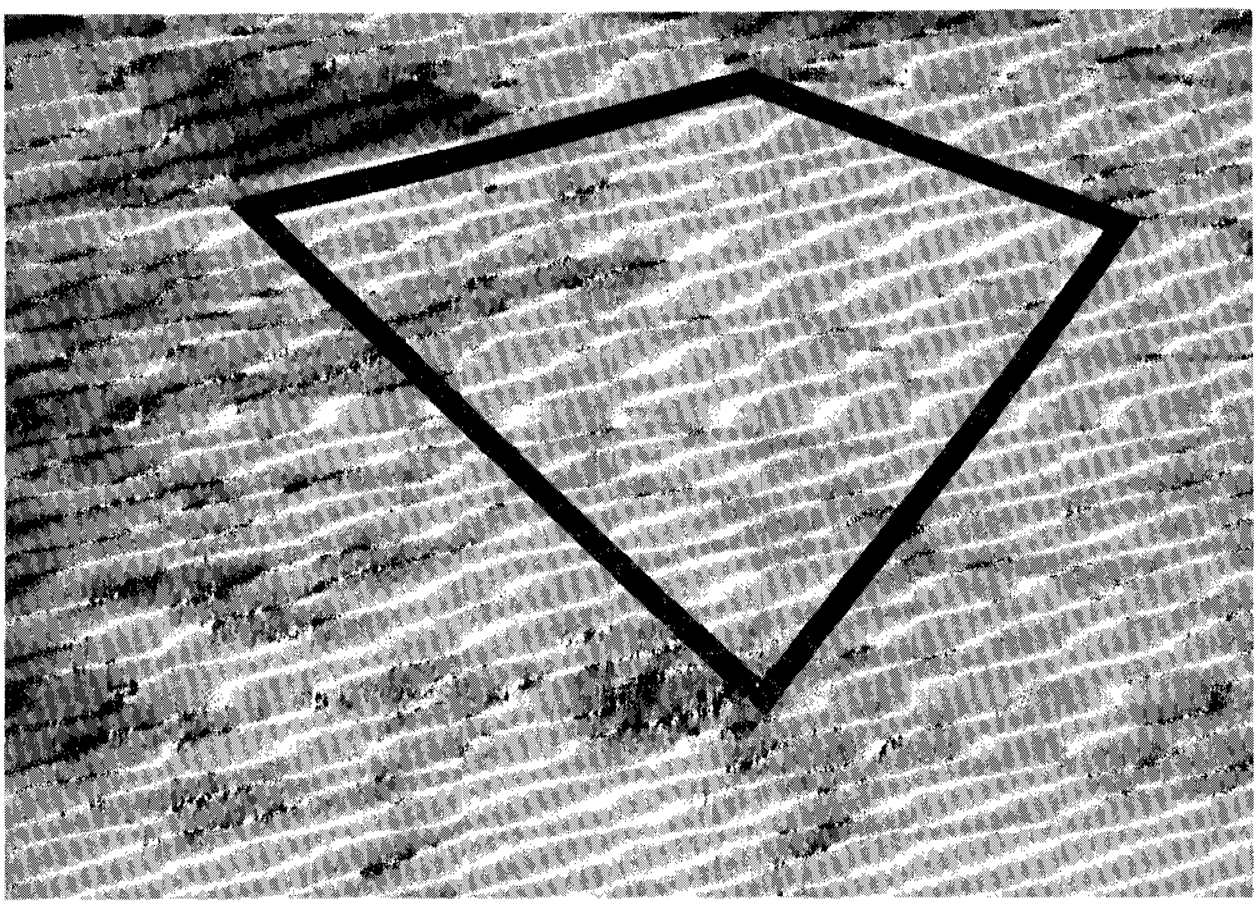

Fig. 4. An aerial view of a quadrat laid out by physiographic features, airspeed and heading on flat terrain.

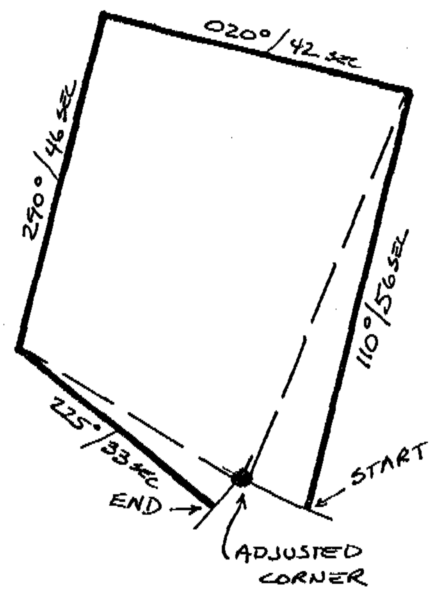

Fig. 5. When drawn to scale, quadrat legs seldom matched perfectly. Quadrats were then adjusted by altering the angle of the two disjunct sides.

and contour flight patterns. Transect surveys were conducted at approximately 70 mph IAS (75 mph true airspeed in the Bellanca Scout used for most of this study) with approximately 0.5-mile transect intervals. The distance between transects could be closely regulated because the approximate size of the sample quadrat was known. The observer and pilot searched an area approximately 0.25 miles wide on each side of the flight line. All flight lines were extended at least 0.5 miles beyond the quadrat boundaries so moose could not be seen during turns to establish the subsequent flight line. Search time during transect patterns was not recorded because that time was regulated by the flight speed and pattern. Also, efforts to precisely define quadrat boundaries detracted from search efficiency. The theoretical search time using the above values was 1.6 min/mi^2 if no moose were seen; however, the actual time was greater and varied with the number of moose seen because at least one low pass was made over each aggregation of moose to determine the sex and age of individuals. If we were uncertain whether an observed moose was in or out of the sample unit during the transect flight, the boundary was flown after completion of the transect survey and the location of the moose with respect to the quadrat was determined.

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

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

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

When flying contours, the most productive view for the observer was downhill, since the top aspect of trees predominated and creek bottoms were visible (Fig. 6). Equally important, the observer could continue to view downhill into the quadrat during turns at the heads of valleys because turns were 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) or when surveying very steep slopes. With the aircraft in this attitude it is possible for both the pilot and observer to have a top aspect of vegetation.

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

During each survey the following data were recorded: time of day, number of moose seen, aggregation size, sex, age, initial activity, initial habitat selected, habitats available, weather, snow conditions, type and intensity of light, and a relative sightability index for the collared moose. A sample data form is shown in Appendix I.

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

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

Snow conditions were broken into several components in an effort to determine the influence on sightability. The age and appearance of snow

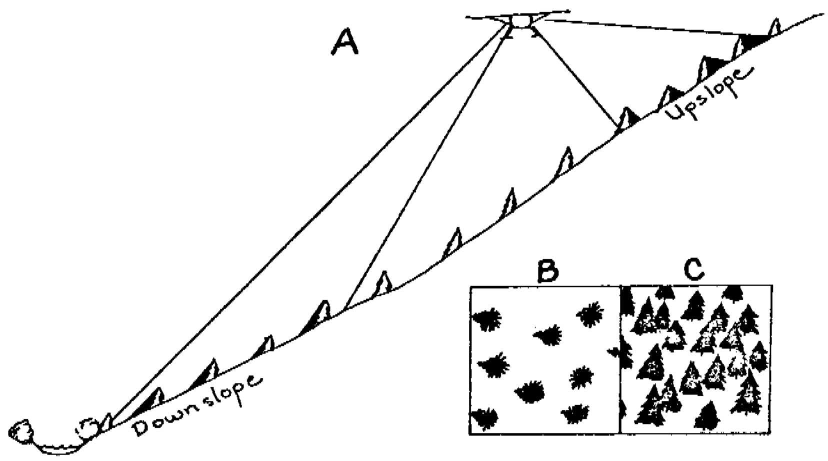

Fig. 6. (A) Amount of hidden ground and perspective of terrain obtained by viewing upslope and downslope during a contour flight; (B) Observer's view downslope illustrating top aspect of trees; and (C) Observer's view upslope illustrating side aspect of trees.

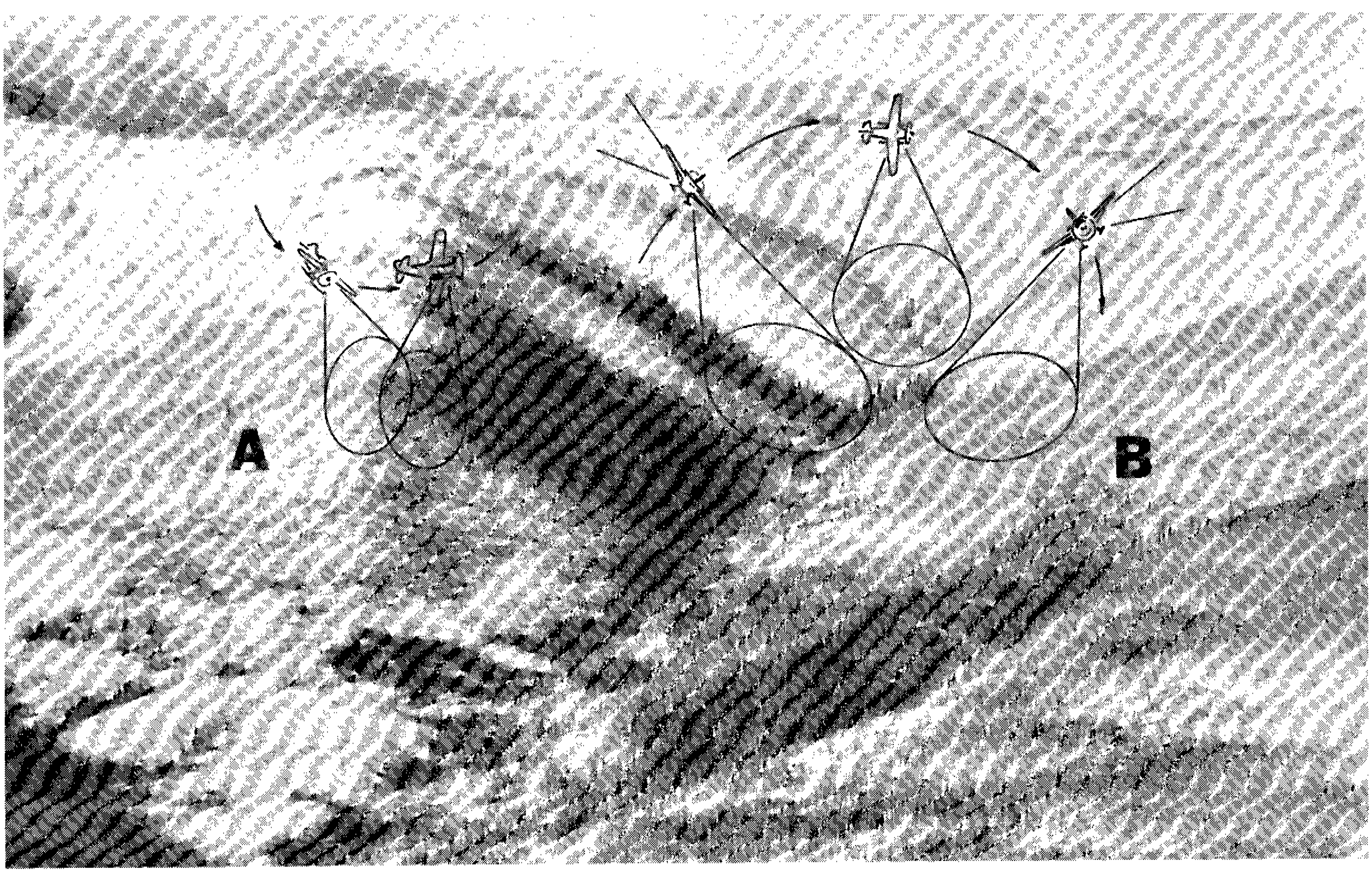

Fig. 7. Observations were best made from the low side of the aircraft when surveying (A) noses of ridges and (B) heads of canyons.

were categorized as fresh, moderate or old. These ratings were subjective because the aging process for snow involves many factors which modify its appearance. Snow cover was then categorized as: 1) complete, 2) some low vegetation showing or 3) distracting amounts of bare ground or herbaceous vegetation showing. An additional category--snow on limbs of trees and shrubs--was recorded when it occurred, despite the ground cover present at the time. During the analyses of the effects of snow condition on sightability, a combination of snow cover and age of the snow was used to categorize snow condition as good (Fig. 8), or moderate to poor (Fig. 9). Table 1 lists snow age and cover relationships and their quality classification.

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

Development of Sampling Systems

Study Area

A census was conducted during November 1978 in GMU 20A and a small portion of GMU 20C in an attempt to improve the quality of moose abundance estimates. The census area included the Tanana Flats and mountains of the Alaska Range between the Delta River on the east, the Nenana River on the west, the Tanana River on the north and the crest of the Alaska Range on the south. This area of 6,460 mi^2 was divided into three study areas: the Tanana Flats, Alaska Range Foothills East and Foothills West (Fig. 10).

Vegetation in the Alaska Range is characterized as an upland climax community (LeResche et al. 1974). Willows (*Salix* spp.) are found along streams and intergrade into a shrub zone and eventually into alpine tundra on ridgetops and higher elevations. Spruce (*Picea* spp.), aspen (*Populus tremuloides*) and birch (*Betula papyrifera*) are characteristic of lower elevations. Vegetation on the Tanana Flats is primarily a mixture of coniferous and deciduous forest, shrub-dominated seres following wildfire and herbaceous bogs. Habitat is described in detail by LeResche et al. (1974) and Coady (1976).

Stratification of Area

Within each of the three study areas, the sample units which were various-sized plots and which are described in more detail below, were stratified into high, medium, low and zero densities of moose (Fig. 11). Stratification was done by S. DuBois, W. Gasaway, L. Jennings and D. Haggstrom. Because the latter two individuals had no experience in stratification, a training flight was conducted on 7 November 1978 to standardize each observer's criteria for determining relative moose densities so strata would be comparable within the entire area. On 9 November 1978 the area was stratified, each biologist being responsible for approximately one-fourth of the total area.

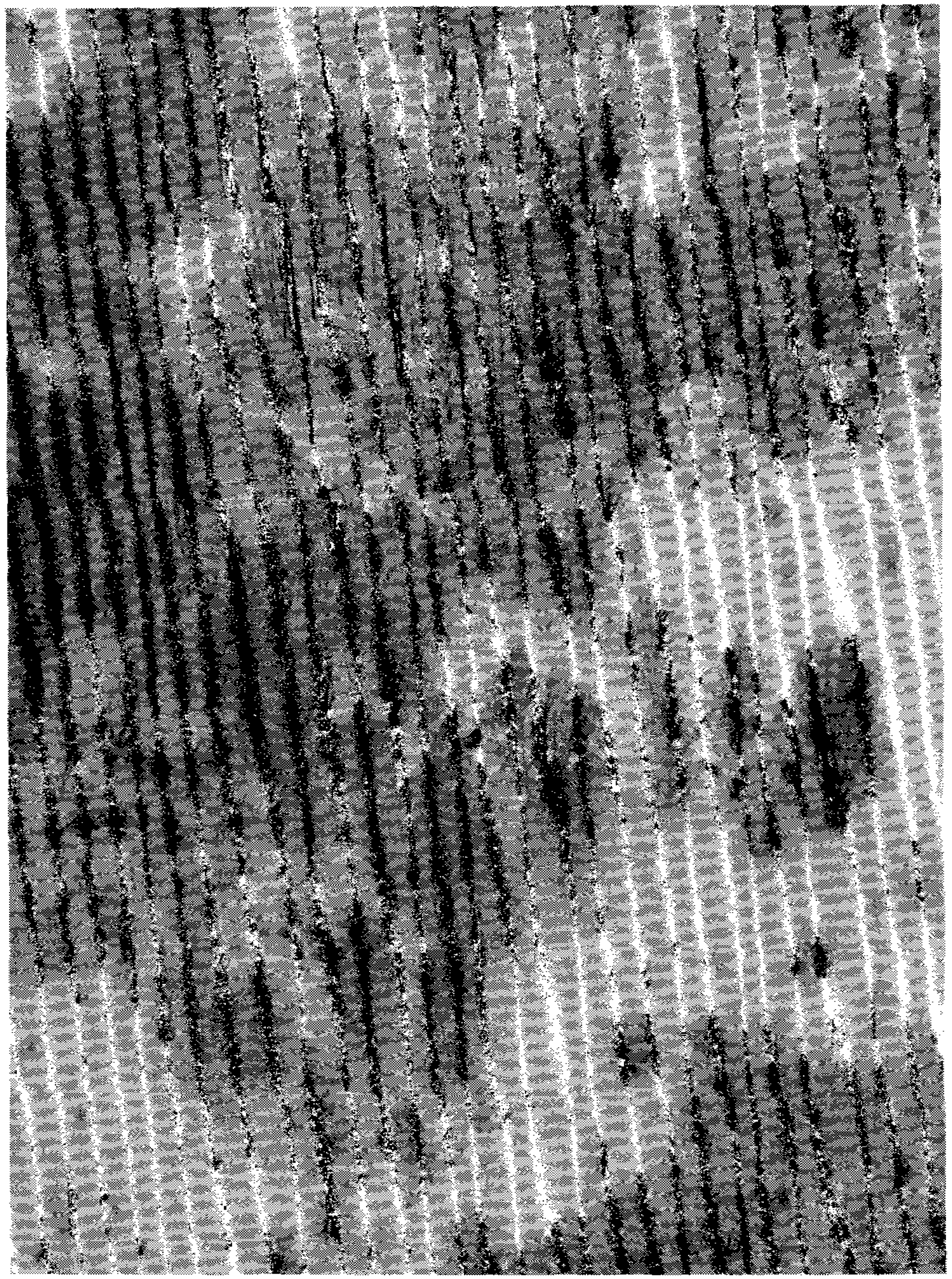

Fig. 8. Good snow conditions with complete cover and snow on trees.

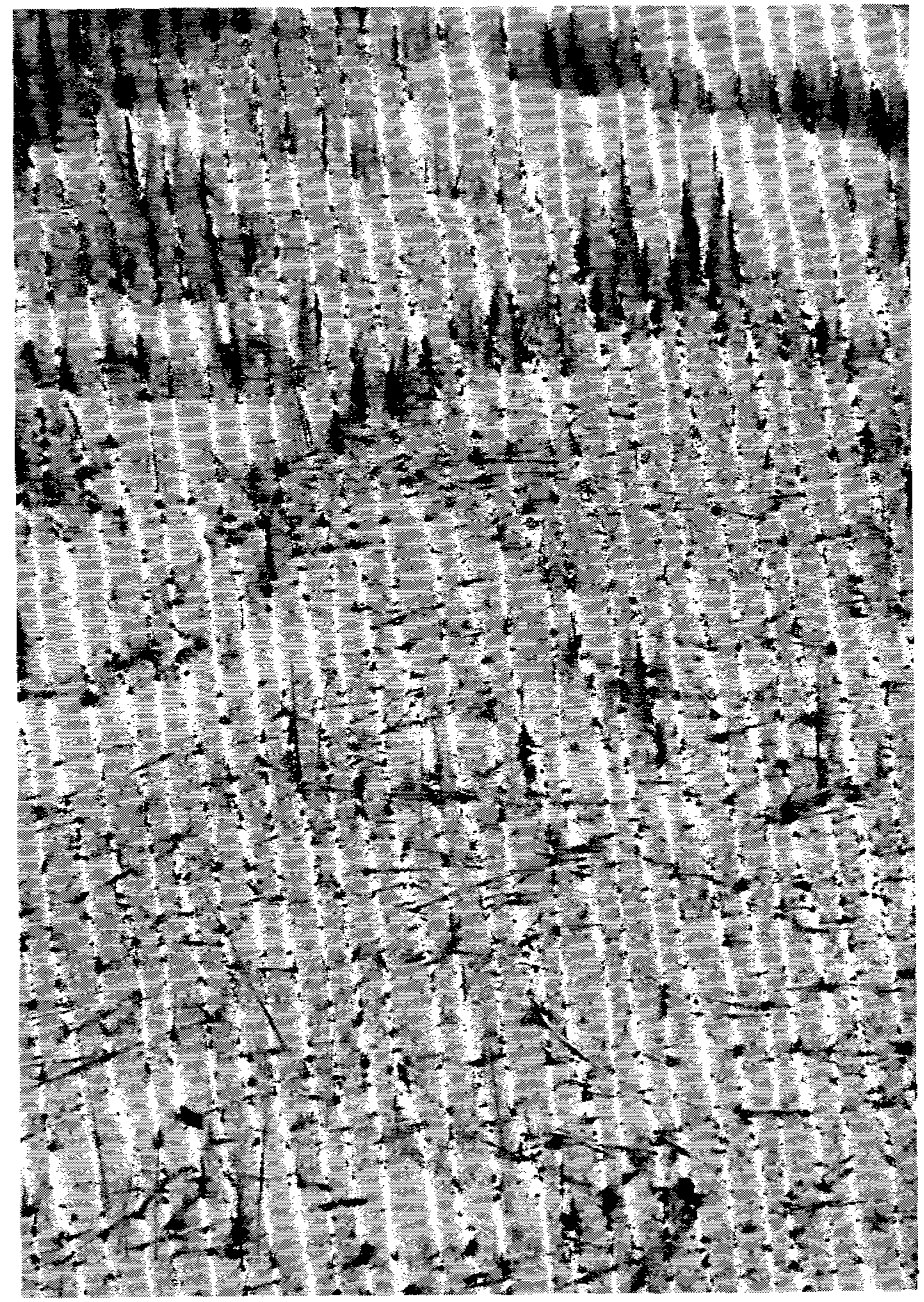

Fig. 9. Bad snow conditions with distracting amounts of bare ground showing.

Table 1. Classification of snow conditions for sightability of moose during aerial surveys.

Age of Snow	Coverage	Classification
Fresh	Complete	Good
	Some low vegetation showing	Moderate
	Bare or herbaceous vegetation ground showing	Poor
Moderate	Complete	Good
	Some low vegetation showing	Moderate
	Bare or herbaceous vegetation ground showing	Poor
Old	Complete	Moderate
	Some low vegetation showing	Poor
	Bare or herbaceous vegetation ground showing	Poor

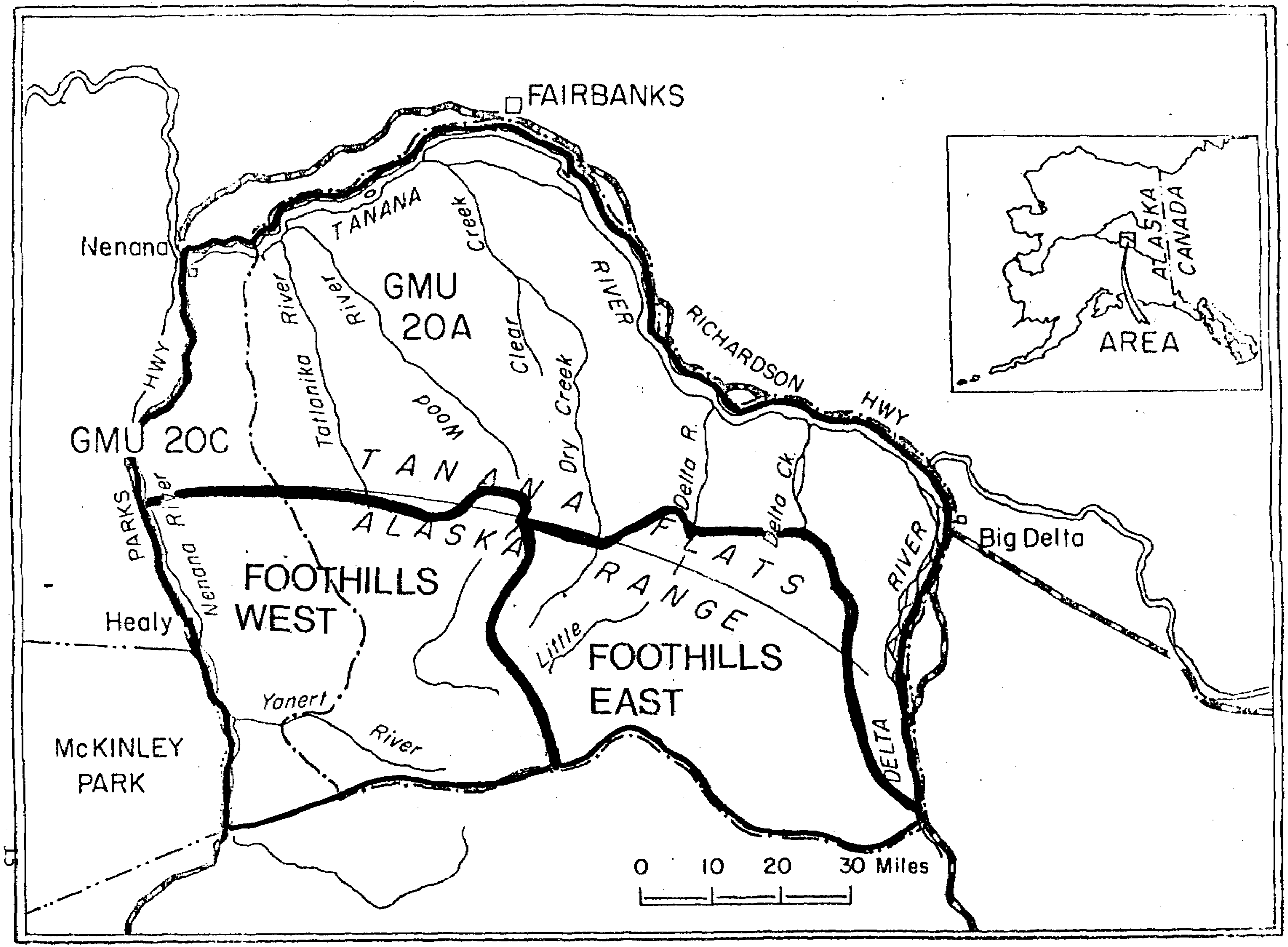

Figure 10. Tanana Flats and Alaska Range foothills east and west study areas for November 1978 census.

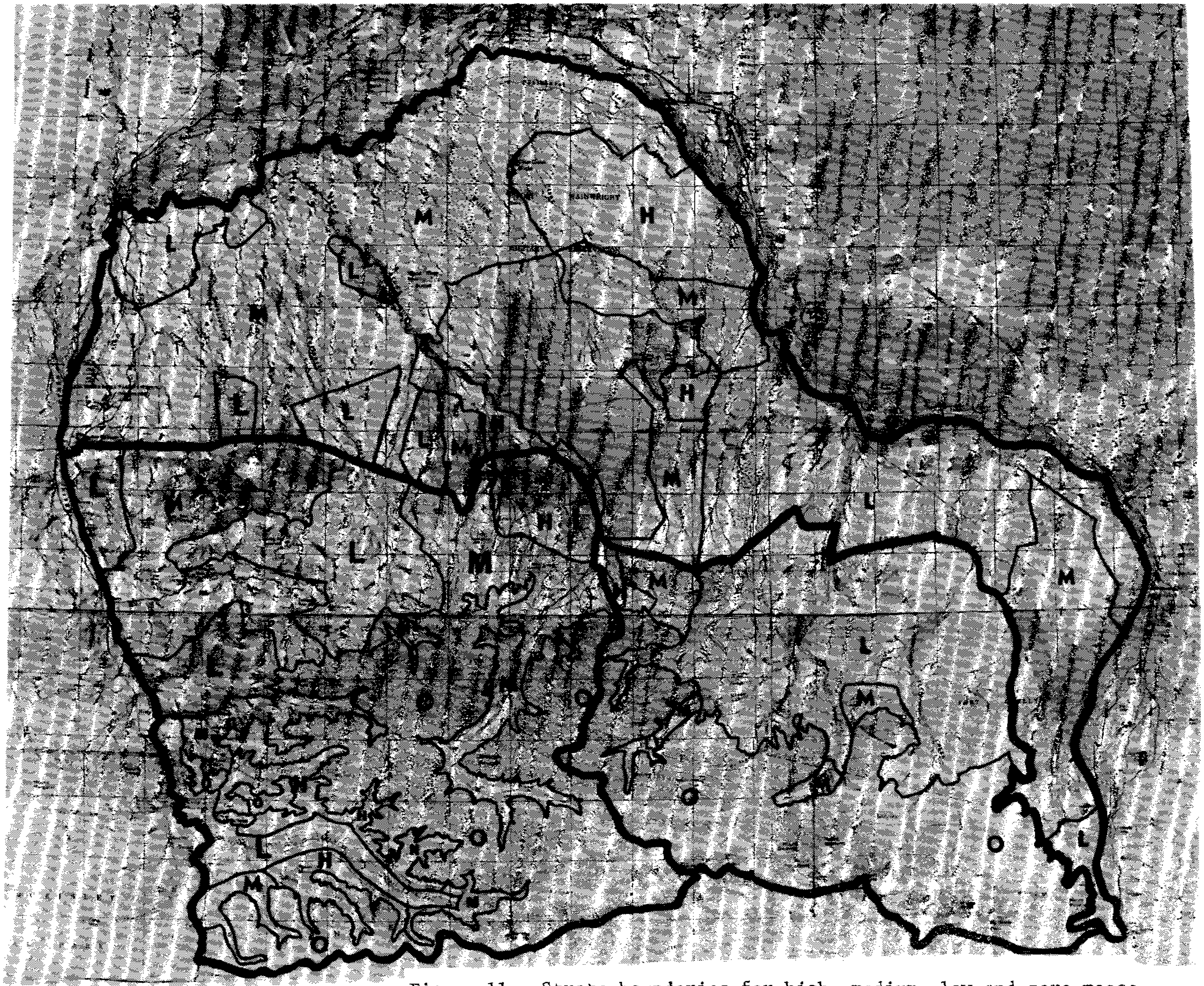

Figure 11. Strata boundaries for high, medium, low and zero moose density areas during November 1978 census.

Stratification was based on the relative density of moose, moose tracks observed and particularly on habitat types. The density of moose within habitat types is often predictably and relatively uniform; hence, once relative densities are determined in an area, habitat becomes a useful basis for stratifying areas adjacent to the observed flight path.

Aircraft used during stratification were Piper Super Cubs, a Cessna 185 and a Helio Courier. The area to be stratified was too large to allow systematic coverage of the entire area. Therefore, relative moose density observed along the flight path was commonly extended up to 2 miles in similar habitat types and irregular flight paths were used, particularly in the foothills. During these flights, strata boundaries were determined and recorded on 1:63,360 topographic maps. Strata boundaries were then transferred to a map of the entire area containing sample units. Where they bisected sample units, strata boundaries generally were rerouted to coincide with sample unit boundaries. However, strata boundaries were allowed to bisect some sample units where moose density differed markedly within the sample unit.

Boundaries of the high and medium strata were placed a short distance into the adjacent lower density areas. This was done to compensate for localized movements of moose across strata boundaries from an area of higher density to an area of lower density. If no such allowances were made for localized movements that could occur during a census, it would substantially increase the variance of the low and medium strata population estimates.

An attempt was made to make the sample units approximately 15 mi^2 in size. However, the size varied from 9 to 35 square miles. This wide range in size was caused, in part, by the splitting of some sample units into two units when the strata borders bisected them. Irregularities of natural features (e.g. drainages, distinctive vegetation discontinuities and pronounced topographic features) which served as the boundaries of sample units, also contributed to size variation.

An attempt was made to standardize all sample units in each stratum of the foothills study area with respect to the diversity of habitat types within each. For example, if the drainage system in a draw served as the boundary between two units, the stream itself would be the boundary. Hence, both sample units bordering the stream would have similar amounts of riparian habitat. Because of the relative scarcity of natural boundaries in the flats study area, the above consideration had little influence in determining sample unit boundaries there.

Selection of Sample Units

All sample units in the three study areas were outlined and numbered on a 1:63,360 scale map. A simple random sample was then drawn in each stratum. Mylar overlays containing random points of variable densities were used in the selection of sample units to be surveyed. The overlays were haphazardly spread over the map and those sample units overlain by a point were selected. Sampling was without replacement, meaning that a sample unit was selected for surveying only once despite the number of random points that may have fallen within its bounds. By using overlays of various point density, and with repeated placement of overlays, it was possible to add as many or as few points necessary to reach a desired sampling intensity. Sample units were selected within a single stratum at one time, until the desired sampling intensity was achieved. Sample units were drawn and recorded in sequence so that surplus units could be discarded in the reverse order of selection if necessary.

Survey Methods

Five biologists conducted the aerial census using four Piper Super Cubs and a Helio Courier. Each observer had 1:63,360 scale topographic maps on which the sample units were outlined. These predetermined sample units were located from the air. Due to the size of the sample units, it was frequently necessary to fly the perimeter and verify the boundaries before beginning the survey.

Surveys were flown at an airspeed of about 70 mph IAS and an altitude of about 300 feet above the ground. Over flat terrain transect lines were flown at approximately 0.5 mile intervals. In hilly or mountainous terrain an average of 4 minutes per square mile was spent circling and flying contour routes. By making search intensities comparable to data collected during the sightability portion of this study, it was possible to correct for sightability errors described elsewhere in this report. Both the observer and the pilot searched the area.

Data recorded for each sample unit included snow condition, light levels, weather, time of day, dominant habitat and search time. Detailed descriptions of the criteria for these data are described elsewhere in this report.

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 Alaska conditions will be prepared. The manual will illustrate and describe basic techniques for quantifying and interpreting population parameters. Portions of this report will serve as a basis for the manual.

Training sessions and workshops will be held for ADF&G biologists. Assistance will be offered in initiating population monitoring programs to insure continuity of techniques between teams of resource specialists. This should result in the accurate detection of long-term changes in moose populations.

RESULTS AND DISCUSSION

Determination of Sightability of Moose

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

This study showed the following variables have measurable effects on the sightability of moose during early and late winter: search time, moose activity, habitat selection, aggregation size and snow conditions.

Search Time

Sightability of moose during aerial surveys was determined using two search intensities. The lower intensity search was made in an attempt to duplicate standard transect/contour moose survey techniques used for composition surveys by the ADF&G. However, duplication was difficult: search time per mi^2 during ADF&G moose composition surveys ranged from 0.8 to 3.0 min/mi^2 over large areas, while mean time spent on comparable counts during the present study was about 5 min/mi^2 (Table 2). This disparity in search time was attributed to differences in the flight patterns. Composition surveys traditionally "high-grade" certain areas by searching only areas of relatively high moose density or areas where moose are easily seen, thereby neglecting large, densely timbered tracts. The effect of this practice was to reduce mean time spent per unit of area to relatively low values that could not be duplicated with the small quadrats sampled during the study. Time spent during intensive searches was substantially greater than that spent during transect/contour searches, averaging 9.7, 11.0 and 12.9 min/mi^2 in hills, mountains and flats, respectively (Table 2).

Sightability Values

Sightability values were summarized according to major topographic features (flats, hills and mountains) and dominant vegetation types. Disregarding the influence of other variables, sightability was greater and more consistent during intensive searches than during transect/contour surveys in all three major topographic areas (Table 3). Relatively high sightability was achieved under a wide variety of environmental conditions during intensive searches in mountainous, hilly and flat terrain. Lower and more variable proportions of moose were generally seen during transect/contour searches in the same areas. Sightability was generally greater during October-November than during February-March for both search intensities. The snow conditions in experimental quadrats were sometimes below acceptable levels for an ADF&G composition survey or census; therefore, data from transect/contour searches for these quadrats were not included in Tables 3 and 4. The elimination of these data provided a more realistic sightability value for quadrats surveyed with the low intensity search.

Table 2. Time searched per square mile during surveys conducted between 1974 and 1979 in Interior Alaska.

Type of Survey	Mean min per mi sq (Range) Flats	Hills	Mtn. Foothills
Composition Counts[a] in Game Management Units			
20A	1.4(1-1.9)	-	1.9(1.5-2.2)
20B	-	2.1(1.5-3.0)[c]	-
13	0.8	-	1.2
Present Study			
Transect/Contour	-[b]	4.9(2.1-14.8)	4.9(1.5-11.3)
Intensive	12.9(5.3-21.5)	9.7(4.5-26.2)	11.0(2.9-22.6)

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

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

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

Table 3. Percent of radio-collared moose seen during transect/contour surveys and intensive searches of quadrats. Transect/contour data for quadrats with snow given a "poor" rating have been excluded.

	Percent Collared Moose Seen (No. of Quadrats)					
	Tanana Flats		Tanana Hills		Mtn. Foothills	
Date	Tran/Con	Int	Tran/Con	Int	Tran/Con	Int
Oct/Nov	84(31)	100(34)	88(17)	89(18)	83(12)	100(12)
Feb/Mar	57(21)	87(23)	73(37)	89(44)	60(45)	94(48)

Table 4. Percent radio-collared moose seen in quadrats as categorized by dominant habitat type. Transect/contour data for quadrats with snow given a "poor" rating have been excluded.

	Percent Collared Moose Seen (No. Radio-collared Moose)			
	Transect/Contour		Intensive Search	
Dominant Habitat	Oct/Nov	Feb/Mar	Oct/Nov	Feb/Mar
Shrub-dominated				
Recent burn	90(21)	73(15)	100(20)	94(18)
Subalpine	100(8)	80(10)	100(8)	100(16)
Forest-Shrub mixture				
Shrub-dominated	80(15)	61(23)	100(15)	97(29)
Deciduous-dominated	83(6)	100(9)	100(6)	100(10)
Spruce-dominated	85(13)	51(51)	86(14)	86(56)
Total	88(64)	63(108)	97(63)	92(130)

Sightability of moose within each dominant habitat type was consistently higher during intensive searches than during transect/contour searches. During intensive searches, few moose were missed in any habitats except spruce-dominated forest. But even under the most adverse conditions in spruce forest, 86 percent of the collared moose were seen during October-November and February-March (Table 4). Only during October-November did transect/contour searches provide relatively high sightability values in all habitat types, although they were still more variable than those produced by intensive searches during the same period.

Table 5 provides a means to evaluate the presence and magnitude of bias in the above sightability estimates. The method used to lay out quadrats for sightability surveys provided the pilot with some general knowledge of the location of the collared moose, even though he had not visually located the animal. The presence of this bias was determined by dividing the number of collared moose seen during all transect/contour searches by the number of collared moose seen during all intensive searches and comparing this figure to the same calculation for uncollared moose known to be present in the quadrats. If sightability estimates contain bias, the percentage of collared moose seen should be larger than the percentage of uncollared moose seen because knowledge gained during the quadrat layout enhanced the chance of sighting the collared moose. Table 5 shows consistent differences between these percentages; hence, bias can be demonstrated which will cause an overestimation of sightability. However, the differences are very small and therefore the overestimation resulting from this bias should be slight.

Environmental Factors Affecting Sightability

Habitat Selection

The environmental variable with the most profound influence on moose sightability may be habitat selection. As the height and density of vegetation increase, sightability decreases, particularly during transect/contour surveys. Therefore, an understanding of habitat selection is necessary to define the habitat-related problems which will be encountered during moose censuses. During early (October, November, December) and late (January, February, March) winter, moose in all three physiographic areas demonstrated greater selection for shrub habitat types than forest types when compared to the percentage and frequency of each type of cover available (Table 6). Combining observations from the three areas for October through December and January through March, 80 and 60 percent, respectively, of the moose selected habitat types with low canopies (herbaceous, low shrub and tall shrub). However, the proportion of habitats selected varied somewhat among the three areas and appears directly related to availability (Table 6). Shifts in seasonal habitat preferences were noted between early and late winter. A strong preference for low shrub types in all areas during early winter changed to an increased selection of tall shrub and forest types during late winter. Forest types as a group, however, were never used in greater proportion than their availability (% cover) as shrub types were.

Table 5. Percent of moose seen during all intensive searches that were also seen during transect/contour searches.

Date	Type of Moose	Percent moose seen during intensive searches that were also seen during transect/contour searches (no. moose seen during intensive searches)
Oct/Nov	collared moose	85(60)
	uncollared moose in quadrat	83(277)
Feb/Mar	collared moose	69(105)
	uncollared moose in quadrat	67(335)
Above periods combined	collared moose	75(165)
	uncollared moose in quadrat	74(612)

Table 6. 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; % Cover; % Hab Avail	No. of Moose	Habitat Types[a] (%) H	LS	TS	D	SS	S	L
Tanana Flats	Oct/Nov/Dec	% Selected	88	6	66	20	4	1	3	1
		% Cover	85	8	54	17	5	5	7	3
		% Avail	89	35	97	55	24	15	15	26
	Jan/Feb/Mar	% Selected	186	3	38	23	7	11	12	6
		% Cover	154	3	32	21	9	16	14	4
		% Avail	188	24	76	50	36	43	48	21
Tanana Hills	Oct/Nov/Dec	% Selected	56	0	48	16	6	20	10	0
		% Cover	56	1	28	18	9	19	24	1
		% Avail	56	4	66	57	30	45	50	2
	Jan/Feb/Mar	% Selected	135	1	27	20	20	18	15	0
		% Cover	126	1	24	18	22	19	17	1
		% Avail	136	1	52	57	49	49	44	1
Alaska Range Foothills	Oct/Nov/Dec	% Selected	33	0	48	27	6	9	9	0
		% Cover	33	1	45	24	11	10	10	0
		% Avail	33	9	79	55	33	27	30	0
	Jan/Feb/Mar	% Selected	166	3	40	23	7	21	7	0
		% Cover	145	5	26	22	13	25	8	0
		% Avail	164	24	74	55	47	63	25	0

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

The influence of habitat selection on sightability is shown in Table 7. Moose were missed during transect/contour surveys in all habitat types except herbaceous, but generally they were missed more frequently as canopy height and density increased. Similarly, during intensive searches the percentage of overlooked collared moose increased with canopy height and density. However, the percentage of overlooked moose was substantially lower than on transect/contour surveys in each habitat type. Moose in spruce forest appear to be the only ones that have proven difficult for observers to see during intensive searches. The percentage missed in larch was greater than that for spruce forest, but the sample size was too small to draw any conclusions.

Activity of Moose

The activity of moose (standing or lying) has a definite effect on sightability during aerial surveys, with lying moose being the most difficult to see. Estimates of moose activity were 56 and 58 percent lying during early and late winter, respectively, based on initial observed activity of all moose seen in quadrats. Sixty-one percent of the radio-collared moose seen during both early and late winter were lying (Table 8). On transect/contour searches during early winter, lying moose were missed in about equal proportions to their occurrence in the population. During late winter, when moose are more difficult to see, lying moose were missed in greater proportion than their occurrence in the population. Due to the low number of radio-collared moose missed during intensive searches in early winter, no conclusions can be drawn. During late winter lying moose were missed during intensive searches at a much higher rate than they occurred in the population.

Another approach to assessing the influence of activity on sightability is to compare the probabilities of missing radio-collared moose in lying and standing positions. During transect/contour flights, 35 and 20 percent of lying and standing collared moose, respectively, were missed. During intensive searches, 7 and 5 percent of lying and standing moose were missed. Therefore, the probability of missing a lying moose during transect/contour flights will be almost twice as great as for a standing moose. During intensive searches the chances of missing a lying moose are about one-third greater than for a standing moose.

A greater proportion of lying moose were missed in low canopies than in tall canopies for both search intensities (Table 7). Therefore, although activity has a definite effect on moose sightability, this influence decreases somewhat as canopy height and density increase. Due to activity alone, moose standing in low canopies have a greater chance of being seen than moose standing in tall canopies. Although spruce forest was by far the most difficult habitat in which to see moose during both types of searches, the highest proportion of lying moose missed during transect/contour searches was in tall shrub. Tall shrub commonly grows in dense stands that form an effective visual barrier to lying moose.

Table 7. Percent of radio-collared moose missed during transect/contour and intensive quadrat surveys by habitat type and activity. Quadrats with poor snow were excluded for the transect/contour searches only. Early and late winter observations are combined.

	Habitat Types[a]							
	H	LS	TS	D	SS	S	L	Total
TRANSECT/CONTOUR								
% collared moose missed	0	7	24	25	35	76	67	28
(no. of moose)	(4)	(57)	(45)	(12)	(23)	(28)	(3)	(165)
% missed that were lying	-	50	90	67	63	74	50	72
(no. of moose)		(4)	(10)	(3)	(8)	(19)	(2)	(46)
INTENSIVE								
% collared moose missed	0	1	4	7	8	27	33	7
(no. of moose)	(4)	(67)	(48)	(14)	(24)	(30)	(3)	(189)
% missed that were lying	-	100	100	100	50	75	100	77
(no. of moose)		(1)	(1)[b]	(1)	(2)	(8)	(1)	(13)

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

[b] Activity was unknown for an additional moose missed.

Table 8. The percent lying moose seen and missed during all quadrat surveys and radio locations.

	Date	Percent lying moose (no. of moose)
Initial activity of all moose seen during all quadrat searches and radio locations	Oct/Nov/Dec Jan/Feb/Mar	56(606) 58(1035)
Initial activity of radio-collared moose seen in all quadrat searches	Oct/Nov/Dec Feb/Mar	61(69) 61(165)
All moose missed during transect/ contour survey and seen during intensive survey	Oct/Nov/Dec Feb/Mar	54(59) 67(124)
Collared moose missed during transect/contour survey	Oct/Nov/Dec Feb/Mar	60(10) 72(50)
Collared moose missed during intensive search	Oct/Nov/Dec Feb/Mar	50(2) 80(10)

Snow Quality

The quality of snow cover can be an important factor influencing sightability of moose during aerial surveys. Variables so far identified as having a major influence on sightability are moose activity, habitat selection and search intensity. Therefore, the interrelationships of snow with these variables were investigated to determine when and to what extent snow quality alters sightability of moose.

Table 9 presents our data in such a manner that good, moderate and poor snow quality can be compared while other major variables are held constant. For data from transect/contour searches there is a generally consistent relationship of declining sightability of moose with declining snow quality for each combination of habitat and activity. Hence, snow quality has a measurable effect on sightability. However, declining snow quality does not reduce sightability to the same extent for all activity and habitat combinations during transect/contour searches. For example, moose standing in nonspruce habitats had only a slight decline in sightability between good and poor snow. Moose lying in spruce, however, which are difficult to see at any time, became very difficult to see with moderate and poor snow when compared to good snow (Table 9). Within a snow category, e.g. good, sightability of moose progressively declines in the following order: nonspruce-standing, nonspruce-lying, spruce-standing and spruce-lying (Table 9). This order suggests the relative importance of activity and habitat variables on sightability of moose.

Because snow conditions do have a profound impact on sightability during transect/contour searches, certain sets of conditions should be avoided rather than depending on the application of large correction factors for unobserved moose. These conditions can be found in Table 8. Potentially, the worst period occurs during late winter when the selection of coniferous forest by moose is greatest. As an example, if 60 percent of the moose were lying and moderate snow conditions prevailed, only 30 out of 100 moose selecting spruce would be seen during transect/contour surveys. This is too low to be useful for censuses. Hence, the importance of knowing seasonal habitat selection patterns for moose in areas to be managed becomes clear. During fall, when few moose select spruce, this level of snow related sightability would not be a factor affecting the quality of population estimates.

Adverse effects on sightability caused by deterioration of snow quality can generally be overcome by increasing the survey effort per unit of area to levels used for intensive searches. With this search intensity most moose were seen regardless of the combination of snow quality, activity and habitat selected (Table 8). However, moose in spruce with poor snow were still extremely difficult to see. The major problem encountered when using intensive searches during censuses was the high variation in the estimated number of moose resulting from the small size of sample units and the few units sampled. If this can be overcome in the sample design, intensive searches should minimize the effects of variables on sightability and simplify the application of correction factors.

Table 9. The influence of snow on activity, habitat selected and search intensity.

	Percent Radio-collared Moose Seen During Quadrat Searches (no. of moose)											
	Transect/Contour Search						Intensive Search					
	Standing			Lying			Standing			Lying		
Habitat Selected	Good	Mod	Poor	Good	Mod	Poor	Good	Mod	Poor	Good	Mod	Poor
Nonspruce[a]	94 (32)	93 (14)	85 (13)	82 (44)	78 (27)	44 (9)	100 (31)	100 (31)	100 (13)	98 (40)	93 (27)	100 (9)
Spruce[b]	70 (10)	50 (8)	0 (1)	55 (20)	17 (12)	0 (4)	78 (9)	88 (8)	0 (1)	90 (21)	83 (12)	75 (4)

[a] Includes herbaceous, low shrub, tall shrub, deciduous forest and larch.

[b] Includes spruce forest and sparse spruce forest.

Light

It has not been demonstrated using quantitative data that sightability during surveys is affected by type and intensity of light. Based on subjective impressions, however, observers feel that lighting does have an influence on sightability. Cloud cover produces flat light with no shadows, while bright light accompanied by strong shadows occurs on clear days. Various combinations of light type (bright or flat) and intensity (high, medium and low) produced diversified conditions under which moose were viewed. The extremes in light combinations were expected to reduce moose sightability (low/flat and high/bright). However, no significant relationship between sightability and light type was detected after the influences of snow quality and habitat selected on sightability were considered. Table 10 provides a partial summary of these data and a detailed display and discussion of data will be provided in the final report. At this time the conclusion reported last year that "type and intensity of light during surveys appeared to affect sightability, but their influence was small compared with that of other variables" (Gasaway 1978) should be disregarded because with additional data no unequivocal effect of light can be demonstrated.

Bias in Sightability Estimates

An attempt was made to prevent the pilot from determining the general location of the radio-collared moose while laying out quadrats. At no time did the pilot knowingly fly directly to or visually locate the radio-collared moose, and yet it still was possible to establish boundaries around a radio signal from an altitude of 1,000 feet without locating the animal. If moose were seen in the quadrat prior to the survey, however, there was no way to visually determine if they were collared. Both radio-collared and nonradio-collared moose had equal chances of being seen and those moose that were occasionally spotted were generally very easy to see and would have been observed anyway.

Once the quadrat boundaries were established, transect/contour and intensive searches were flown systematically with no consideration given to the location of moose within the quadrat. The distance between transect/contour flight lines was not altered nor was the intensive circling pattern shifted to facilitate seeing a moose. Data suggest, however, that the area near the collared moose may have been searched with more intensity than other parts of the quadrat (Table 5). We feel that bias was relatively small and was likely insignificant based on the differences in sightability reflected in Table 4.

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

Table 10. Sightability of moose under various light types and intensities. Values in parentheses indicate number of quadrats. Only quadrats which had good or moderate snow quality are included.

	Low/ Flat	Low/ Bright	Medium/ Flat	Medium/ Bright	High/ Bright
<u>OCT/NOV/DEC</u>					
% collared moose seen in transect/ contour surveys	60(5)	100(2)	92(37)	80(10)	90(10)
% collared moose seen in intensive searches	100(3)	100(2)	97(35)	100(10)	90(10)
<u>FEB/MAR</u>					
% collared moose seen in transect/ contour surveys	63(8)	75(4)	59(29)	68(19)	63(48)
% collared moose seen in intensive searches	100(8)	100(4)	90(31)	94(18)	87(47)

was done by Floyd et al. (1979), but it would have been prohibitively expensive considering distances involved. Another approach would be to use one aircraft and have the pilot lay out quadrats which periodically include or exclude radio-collared moose. The latter procedure was used initially but was abandoned because of the slow rate of data collection. The procedure we finally adopted minimized the pilot's knowledge of the general location of the collared moose to the extent that there were occasional failures to include the collared animal within the quadrat.

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

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

2. Sightability data for collared moose did not differ greatly from data for uncollared moose in quadrats.

3. Actual search time expended was relatively short (2.1 to 26.2 minutes, Table 2); hence, peak mental and visual acuity was maintained during the experimental situation and can be expected during normal, routine quadrat census activities as well.

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

Consistency Between Trend Surveys

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

Consistency in search pattern and effort per unit of area is imperative for trend surveys because increased search effort is directly related to the proportion of moose seen (Tables 3 and 4) (Fowle and Lumsden 1958, Evans et al. 1966, Novak and Gardner 1975). The search pattern and sampling design can take several forms but the method selected must remain the same from year to year. Varying the search pattern can alter efficiency and in turn alter the proportion of moose seen from one year to the next.

Consistency between surveys can be maintained only when observer experience and currency, environmental variables and season of the year are relatively constant. LeResche and Rausch (1974) demonstrated the necessity of using only experienced, current observers and pilots. The quality of snow cover can also alter sightability of moose (Table 6, LeResche and Rausch 1974) and fresh snow can be a requirement for some surveys (Novak and Gardner 1975). Daily activity of moose, migratory movements and habitat selection vary with the season of year and alter sightability. For example, during one ADF&G moose survey conducted at the time of rut in early October, 75 percent of 106 moose were standing while during later October, November, February and March slightly under half the moose seen were standing (ADF&G files). Since the sightability of standing moose was greater than for lying moose (Tables 8 and 9), a greater percentage of the moose probably was seen during the early October survey than during a survey conducted later in the winter. Habitat selection by moose was different in early and late winter during the present study and during studies by Coady (1974, 1976), Lynch (1975) and Peek et al. (1974), with moose selecting a greater proportion of forest types during late winter. Sightability of moose declined as use of forest types increased, thus demonstrating the need for seasonal consistency in survey timing. It appears to us that early winter is preferable to late winter for trend surveys utilizing a low intensity search effort in Interior Alaska. Sightability will be higher at that time due to the selection for low canopies by moose and frequent snowfall which provide good survey conditions. Lynch (1975) found the same to be true in Alberta. The late winter period can still be utilized for low intensity trend surveys, but lower sightability and greater variability in survey conditions must be recognized.

Our efforts to duplicate routine transect/contour surveys used by ADF&G were unsuccessful; therefore, any attempt to apply our sightability values to previous survey data must be done with caution. At best, sightability values serve as guidelines for determining the proportion of animals not seen under a variety of survey conditions. Regardless, educated guesses of moose densities in survey areas are being made on the basis of sightability data. The greatest problem with correcting the results of low intensity transect/contour surveys is that the proportion of moose seen is relatively sensitive to changes in numerous variables which are difficult to describe quantitatively.

Application of Sightability Correction Factors for Censuses

The accuracy of population estimates based on a census depends on reliable sightability correction factors to compensate for the number of moose missed during the survey. Instead of estimating the number of moose missed during a survey by generating a sightability correction factor, most census work has progressed on the assumption that all of the moose were seen. Examples are moose censuses on the Kenai Peninsula and Yukon Flats in Alaska (Evans et al. 1966) and in Ontario (Mantle 1972). On the Kenai National Moose Range, random-stratified sampling methods have been used to census moose since 1964 (Evans et al. 1966) and population estimates are reported by Bailey (1978). All estimates are uncorrected for the sightability of moose and it is probable that the actual number of moose present was consistently underestimated. Even during intensive searches we missed a total of 7 percent of the radio-collared moose, with as many as 27 percent of all moose selecting spruce forest being missed (Table 7). Therefore, it seems appropriate for biologists conducting these censuses to recalculate their data by applying correction estimates for moose missed during the search. These correction estimates could be generated independently or selected from the literature.

Great care must be exercised when selecting sightability values from the literature. All three studies reporting sightability estimates were carried out under differing conditions (LeResche and Rausch 1974, Novak and Gardner 1975 and the present report). Reported sightability values should only be used in areas where factors such as moose behavior are similar, habitats are comparable, and search patterns and intensities are duplicated with experienced, current survey crews. The importance of variation in habitat selection by moose among areas to sightabiltiy can be seen in Table 7. As the proportion of moose selecting coniferous cover increases, sightability will rapidly decline. Therefore, a good understanding of habitat selection by moose must be obtained to extrapolate previous sightability values to new areas.

Sightability correction factors can be applied most directly when moose populations are sampled with intensive quadrat searches. Intensive searches in an area would reduce sightability bias from such factors as environmental conditions or observer variability from one year to the next. We have demonstrated that intensive searches reduce bias from such factors as habitat in the quadrat (Tables 4 and 7) or variable snow conditions (Table 9). Every effort should be made to standardize survey conditions from one year to the next, however.

The dominant habitat present in a survey quadrat appears to be the most useful characteristic on which to base correction factors. The sightability of a moose in a quadrat is directly affected by the dominant habitat surrounding that animal.

Development of Sampling Systems

The first trial moose census, based on techniques developed during the sightability portion of this study, was conducted during late November-early December 1977. The census encompassed an area of 281 square miles on the Tanana Flats in Count Area 4 of Game Management Unit 20A. The estimated number of moose was 166, however the sample variance was great. Confidence intervals (C.I.) were 77 percent of the estimated number of moose at the 95 percent level and were deemed excessive (Gasaway 1978).

Two factors contributed substantially to the wide C.I. A large variance was due in part to poor stratification, with strata boundaries being so specific that localized moose movements significantly altered the moose density among the strata. Also, survey quadrats were too small, averaging 2.4 square miles in area, and resulted in a wide range of moose densities that were observed among sample units within a single stratum (Gasaway 1978).

A second trial census was conducted in mid-March 1978 on a 337-square-mile portion of the Little Chena River drainage in GMU 20B (Gasaway 1978). The area was stratified with boundaries of the high strata encroaching into the adjacent medium or low areas and the medium strata boundaries encroaching into the low density areas. This provided buffer zones around the higher density areas. Survey quadrats were also enlarged slightly to an average of 3.0 square miles. These modifications in technique were incorporated in an attempt to reduce variance associated with the population estimate. One hundred twenty-five moose were estimated to be present; however, the 95 percent C.I. was ± 47 percent of the estimated moose present and was again excessively large (Gasaway 1978).

Despite the problems associated with variance of the Count Area 4 and GMU 20B population estimates, we determined that continued field development of the census technique was warranted.

A census of GMU 20A and a small portion of 20C was undertaken between 9 November and 8 December 1978 in an effort to resolve problems encountered in previous censuses. The area to be censused coincided with the ADF&G wolf control area so that moose population estimates would assist in interpreting wolf-moose relationships in the area. The area (6,460 sq mi) was much larger than either of the two previous censuses which introduced new problems. However, considering the vast area over which the ADF&G has management responsibility, census methods must have the capability of providing relatively precise population estimates for large areas.

Censuses require more manpower and money per unit of area than are normally expended on standard survey and inventory activities. However, this commitment is necessary to make precise estimates of wildlife population size. The overall sampling effort was determined by the financial and manpower resources available for sampling as well as the survey conditions encountered on sampling flights. A total of 71 sample units were surveyed. An attempt was made to initially allocate the effort in each study area so that the sampling intensities in the strata were in the proportion of 1:2:3 for the low, medium and high strata, respectively. The zero density stratum received no sampling effort. In order to optimize sampling effort, the sample variance for moose density in each stratum was calculated as the survey progressed. Hence, occasional analyses were made of where the remaining survey resources should be placed. The end result was to reduce effort in strata that had a uniform density and increase effort in those strata which varied most in density among sample units. Various factors such as snow conditions, unsuitable flying conditions in certain areas, etc., precluded meeting the most desirable sampling schedule. The strata areas and sampling efforts for each are listed in Table 11.

Table 11. The sizes and sampling efforts for strata in the three study areas.

	Tanana Flats			Foothills East			Foothills West		
	Low	Med.	High	Low	Med.	High	Low	Med.	High
Strata Totals									
Area (mi^2)	1144.0	1388.0	294.0	566.0	108.0	17.0	440.0	729.0	198.0
Sample Units	74	93	19	42	8	1	32	55	17
Sampled									
Area (mi^2)	125.1	150.4	78.0	84.1	38.2	17.0	97.6	183.1	85.1
Sample Units	5	10	6	6	3	1	6	11	7
% of total area	10.9	10.8	26.5	14.9	35.3	100.0	22.2	25.1	43.0

The estimates of the total number of moose were based on a ratio estimator; the ratio was the number of moose seen divided by the area (mi^2) surveyed. Hence, an estimate of the population ratio is an estimate of moose density; density times total area gives an estimate of total number of moose. Tables 12, 13 and 14 give the sample values and the estimates of density, variance of the density estimate, total number of moose, and variance of the estimated total for the Tanana Flats, Foothills East and Foothills West, respectively.

The estimates of total number of moose in each study area and the variance for each estimate are given in Table 15. The variances of all estimates are fairly large, with the standard deviations exceeding 10 percent of the associated estimated total. In an effort to determine if variation could have been reduced, optimum allocation was attempted. Optimum allocation is the process of distributing the available effort in such a manner as to minimize the variance of the mean estimate of moose, i.e. getting the most precision for the least money.

Optimization was accomplished using the estimates of the variance about the strata ratio lines; those were obtained from the sample data. The allocation of sample units among strata did not change in the Foothills East study area, and changed only moderately in the other two. The estimated variances based on optimum allocation of 21 sample units in the Tanana Flats area and of 24 units in the Foothills West area were 22,578 and 25,860, respectively. Therefore, the precision of the estimates could have been improved had effort been better optimized.

An estimate of the number of moose in a study area is important to the game manager, however it is of limited value unless the quality of that estimate can be specified. Although it is impossible to know the true number of moose present in the study area, it is possible to describe a range of values or interval in which the true value is likely to lie. This range or interval is the "Confidence Interval" (C.I.) and the specification of such an interval is as important in moose population estimation as the estimation of the number of moose (Simpson et al. 1960). A C.I. can be thought of as that interval on either side of the estimated number of moose that includes the true number of moose a specified percent of the time, i.e. 90 percent. Unfortunately, as the C.I. is decreased, the confidence that the true number of moose is within the range also decreases. In each case the biologist must decide whether it is better to be nearly sure that the number of moose lies within some large range, or to be less sure that it lies in a smaller range. No statistical technique is available to make that decision. It is solely up to the wildlife biologist to choose the level of confidence for each case (Simpson et al. 1960). Ideally, a narrow C.I. with a high probability of containing the true number of animals is desired, such as a 95 percent C.I. which is ± 5 percent of the estimate. Wildlife biologists cannot usually expect levels of confidence this great when making population estimates because the large sampling effort required makes it prohibitive. Therefore, a reasonable compromise must be sought and accepted for moose population estimates. We suggest that levels of confidence between 80 and 90 percent with C.I. widths of ± 10 to 20 percent of the estimated number of moose should be acceptable to biologists for most purposes.

Table 12. Tanana Flats sample data and associated estimates.

	Stratum					
	Low		Medium		High	
Sample Unit	Moose (no.)	Area (mi^2)	Moose (no.)	Area (mi^2)	Moose (no.)	Area (mi^2)
1	7	22.1	3	8.2	21	13.6
2	4	35.0	13	14.3	27	20.6
3	0	20.1	4	12.1	2	6.2
4	4	29.6	0	14.4	15	10.8
5	2	18.3	6	9.6	25	16.0
6			11	27.7	24	10.8
7			5	16.4		
8			5	16.2		
9			6	21.1		
10			4	10.4		
Sample Total	17	125.1	57	150.4	114	78.0
Estimates						
Moose/mi^2	0.14		0.38		1.46	
Variance of moose/mi^2	0.002		0.010		0.018	
Total moose	156		526		430	
Variance of total moose	2617		19,265		1556	

Table 13. Foothills East sample data and associated estimates.

Sample Unit	Low: Moose (no.)	Low: Area (mi^2)	Medium: Moose (no.)	Medium: Area (mi^2)	High: Moose (no.)	High: Area (mi^2)
1	8	9.9	14	13.8	29	17.0
2	2	13.5	15	14.2		
3	0	9.4	4	10.2		
4	14	19.6				
5	0	14.7				
6	2	17.0				
Sample Totals	26	84.1	33	38.2	29	17.0
Estimates						
Moose/mi^2	0.31		0.86		1.71	
Variance of moose/mi^2	0.019		0.022		0	
Total moose	175		93		29	
Variance of total moose	6,087		257		0	

Table 14. Foothills West sample data and associated estimates.

Sample Unit	Stratum: Low Moose (no.)	Low Area (mi^2)	Medium Moose (no.)	Medium Area (mi^2)	High Moose (no.)	High Area (mi^2)
1	14	14.1	16	19.1	96	12.3
2	13	21.5	3	12.3	63	11.4
3	18	18.7	9	26.3	40	13.1
4	7	13.9	20	22.4	28	19.1
5	4	9.3	20	11.6	1	7.3
6	2	20.1	14	13.7	17	10.0
7			3	15.2	41	11.9
8			26	16.3		
9			13	18.7		
10			17	16.7		
11			4	10.8		
Sample Totals	58	97.6	145	183.1	286	85.1
Estimates						
Moose/mi^2	0.59		0.79		3.36	
Variance of moose/mi^2	0.019		0.016		0.545	
Total moose	261		577		655	
Variance of total moose	3,678		8,503		21,366	

Table 15. Estimates of the number of moose, and their variances, for the three study areas.

Area	Estimated number of moose	Variance
Tanana Flats	1,112	23,438
Foothills East	297	6,344
Foothills West	1,493	33,547
Above Combined	2,902	63,329

The undesirable alternative in Alaska is to continue the present system of making the "best guess" with no definable degree of confidence.

Table 16 specifies the sample sizes needed to achieve 80-90 percent C.I. of a width $\pm$ 10 to 20 percent of the estimated total moose (i.e. 90% C.I. = estimated total $(\hat{y}) \pm 0.1\,\hat{y}$) for each stratum in all three study areas and for the total for each study area. The sampling efforts required for the study area C.I. are based on optimum allocation.

The estimates of variance about the ratio lines which are used to determine the sample size needed to meet the C.I. requirements and serve as the basis for optimum allocation are based on small sample sizes (Table 11). Therefore, they are subject to considerable error. The required sample sizes listed in Table 16 are indicative only of the magnitude of sampling intensity needed and not the specific sample size needed. The sample sizes required or the C.I. of each study area total may be slightly larger than necessary since a weighted Student's "t" critical value was calculated following the procedure outlined by Steel and Torrie (1960:81); that procedure gives slightly conservative values for Student's "t."

The actual sampling effort fell short of that required for the 80 percent level with a $\pm$ 0.20 percent width except for the Foothills West study area. This indicates that for small study areas the effort expended per unit of area must be increased to attain an acceptable level of precision for moose population estimates. The degree of increased effort is indicated in Table 16.

Combining the three study areas into one large area improves the degree of confidence and narrows the width of the C.I. over that of individual study areas. An estimated total of 2,902 moose was possible to see in the area, i.e. without correction for sightability errors. The 80 and 90 percent C.I. calculated from the 71 sample units surveyed were 12 and 17 percent of the estimated number of moose, $\hat{y} \pm 359$ and 483, respectively. Therefore, the entire area was sampled adequately to achieve a level of precision that is considered acceptable for most purposes.

The actual number of moose present in the study areas can be estimated by correcting the observed number of moose for sightability errors as presented elsewhere in this report. Corrected moose densities and new estimates of total moose are found in Table 17. A total of 3,511 moose was estimated in the entire area. Two sightability values were applied depending on the quality of snow at the time of the survey. For units with good or moderate quality snow conditions, 88 percent of the moose present were assumed to have been seen; 65 percent were assumed seen in areas with poor snow. Data in Table 4 indicate that there were only small differences in sightability of radio-collared moose regardless of the dominant habitat in which the quadrat was located and whether good or moderate snow was present. Therefore, the mean sightability for these data was applied to census data. We do not have a good estimate of sightability of moose under poor snow conditions during early winter, and a value was selected that was slightly greater than the 58 percent

Table 16. The sample sizes needed to give 80 and 90 percent confidence intervals that are no wider than the estimated number of moose per stratum ($\hat{y}$) $\pm$ a specified percent of $\hat{y}$.

Study Area	Confidence Level	Width of Interval	Sample Sizes Needed (total possible sample units) Stratum Low	Med	High	% Total Sampled
Tanana Flats	90%	$\pm(0.10)\hat{y}$[a]	23(74)	36(93)	12(19)	40
		$\pm(0.15)\hat{y}$	15	24	8	26
		$\pm(0.20)\hat{y}$	9	15	5	16
	80%	$\pm(0.10)\hat{y}$	17	27	9	30
		$\pm(0.15)\hat{y}$	9	15	5	16
		$\pm(0.20)\hat{y}$	8	12	4	13
Foothills East	90%	$\pm(0.10)\hat{y}$	37(42)	5(8)	1(1)	84
		$\pm(0.15)\hat{y}$	32	5	1	75
		$\pm(0.20)\hat{y}$	26	4	1	61
	80%	$\pm(0.10)\hat{y}$	32	5	1	75
		$\pm(0.15)\hat{y}$	26	4	1	61
		$\pm(0.20)\hat{y}$	19	3	1	45
Foothills West	90%	$\pm(0.10)\hat{y}$	8(32)	17(55)	17(17)	40
		$\pm(0.15)\hat{y}$	6	13	14	32
		$\pm(0.20)\hat{y}$	5	11	12	27
	80%	$\pm(0.10)\hat{y}$	7	15	16	37
		$\pm(0.15)\hat{y}$	5	11	12	27
		$\pm(0.20)\hat{y}$	4	9	9	21

[a] $\hat{y}$ = estimated number of moose in the study area.

Table 17. Density and total estimates for moose corrected for sightability error.

Study Area	Stratum	Observed Density (moose/mi^2)	Estimated Density (moose/mi^2)	Total Area (sq. mi.)	Total Estimated Number of Moose
Tanana Flats	Low	1.46	1.66	294	489
	Med	0.39	0.46	1388	634
	High	0.14	0.16	1144	183
Foothills East	Low	0.31	0.36	566	205
	Med	0.86	1.03	108	111
	High	1.71	1.95	17	33
Foothills West	Low	0.59	0.80	440	354
	Med	0.79	1.02	729	744
	High	3.36	3.83	198	758

[a] 88 percent sightability was assumed in sample units with good or moderate snow conditions and 65 percent sightability was assumed for sample units with poor snow.

sightability during late winter with poor snow present. Generally, censuses should not be conducted under poor snow conditions; however, due to low snow accumulation and high winds, we encountered poor snow conditions during a portion of the census. Rather than discontinue the census we chose to conduct some work under poor snow conditions.

The C.I. for the corrected estimate of 3,511 moose differed from those calculated for the uncorrected estimate. However, the difference should not be great. For the purpose of the present discussion, we assumed that the width of the C.I. for the corrected estimate had the same proportional relationship described for the uncorrected estimate of moose, i.e. 3,511 ± 421 and 597 for 80 and 90 percent C.I., respectively. Later reports will discuss the calculation of C.I. in greater detail.

RECOMMENDATIONS

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

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

3. Continue development of methods for stratifying and sampling areas.

4. Evaluate the influence of sample size and shape on the variance of the estimated number of moose during censuses.

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

6. Conduct a workshop during October 1979 to explain and demonstrate the census method.

7. Begin preparation of the census procedures manual.

ACKNOWLEDGMENTS

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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	med	lge	COWS/activ. W/O calf	W/1 calf	W/2 calf	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)X (D) SS S L
	2				1/S					1	(H) LS (TS)X (D) SS S L
	3					* 1/LL				2	60 (H) LS 5 (TS) 20 (D)X 2 SS 15 (S) L
	4	1/S			2/SS					3	(H) LS (TS)X 2ss (D)X 1d 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 (in habitat): Very poor (very dense) 1 2 (3) 4 5 Excellent (low veg)

Activity: / / Standing /✓/ Lying

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

JOB PROGRESS REPORT (RESEARCH)

State: Alaska

Cooperators: William C. Gasaway, Stephen D. DuBois and Karen L. Brink

Project No.: W-17-11 Project Title: Big Game Investigations

Job No.: IE-1.26 Job Title: Sightability and Movements of Juvenile Moose

Period Covered: July 1, 1978 through June 30, 1979

SUMMARY

Six short yearlings plus a 2-year-old female offspring of radio-collared cows were immobilized and radio-collared in May 1978. An accumulation of 19-21 months of seasonal movement data were available at the time for six of the seven adult cows. Yearlings and cows were usually relocated once a month between May 1978 and May 1979.

Offspring generally adopted movement patterns and seasonal ranges similar to their dams. However, one yearling remained on the Tanana Flats throughout the year while its dam migrated to the northern foothills of the Alaska Range.

Data pertaining to sightability of juvenile moose were also collected and results are reported under this cover in Job No. 1.18R.

Eleven adult cows that were radio-collared in 1976 were recollared in May 1979. Ten short yearlings of radio-collared cows, as well as additional adult cows, were also radio-collared. We will continue to monitor movements of yearlings and their dams.

CONTENTS

BACKGROUND

Alaskan moose (*Alces alces*) populations are being faced with ever increasing stress and demands from factors such as loss of habitat due to wildfire suppression, increased pressure from subsistence and recreational hunters, and development associated with an increasing human population. Moose populations that exist in close proximity to urban areas, such as those near Fairbanks in Game Management Unit (GMU) 20A, 20B and portions of 20C, often require more intensive management than herds in more remote areas.

GMU 20A has been impacted extensively by man in past decades. The Tanana Flats, in northern GMU 20A, receives extensive use from military bases in the Fairbanks area, and is used for activities such as ground-based winter maneuvers and bombing practice by fighter aircraft. GMU 20A also receives extensive summer and winter recreational use by Fairbanks residents. Regardless of persistent use by man, the Tanana Flats remains the largest known moose calving ground in central Alaska (Bishop and Rausch 1974).

The moose population in GMU 20A peaked in the mid-1960's when the herd may have numbered as many as 10-12,000 animals (Bishop and Rausch 1974). By 1976, however, the herd had declined to a low of 2,600-2,800 moose. A combination of factors including severe winters, high rates of wolf predation and heavy hunting pressure affected the decline. Moose numbers in GMU 20B and portions of GMU 20C followed similar trends. More detailed descriptions of Interior Alaska moose population fluctuations may be found in Bishop and Rausch (1974), Coady (1976a) and Gasaway et al. (1977).

Several factors are currently assisting the recovery of the GMU 20A moose herd. Since 1976, winters have been relatively mild and have resulted in good overwinter survival of calves and increased yearling recruitment. Moose hunting seasons have been reduced from 100 days to 10 days and harvest has declined from a total of 400-700 cow and bull moose to about 40 bulls per year since 1975. The Alaska Department of

Fish and Game also began a wolf (*Canis lupus*) reduction program in GMU 20A in February 1976. The wolf:moose ratio was reduced from 1:13 in 1975 to 1:30-35 between 1976 and 1978. Although an overall reduction in wolves occurred in GMU 20A, removal of wolves was not uniform over the entire area. The wolf population on the Tanana Flats was reduced to very low numbers while wolves are still relatively abundant in other portions of GMU 20A. In areas where the wolf population was effectively reduced, the moose herd is currently increasing at about 13 percent annually. As a result, fall and winter moose movements currently take moose from an area of GMU 20A with an increasing moose population and low wolf numbers to portions of GMU 20A and 20C, and all of GMU 20B, which have a declining moose population and relatively high wolf numbers. The movement of yearling moose into areas of high wolf density can have significant management consequences by providing additional moose for wolves and hunters and slowing the rate of decline in moose numbers. Dispersal of yearling moose from the established seasonal ranges of their dams into areas of high wolf density would also provide additional prey. However, the extent to which yearlings depart from traditional movements of their dams to emigrate into new areas is not known. Moose are traditional in their movements and usually return to the same summer and winter ranges during successive years (LeResche 1974, VanBallenberghe 1977). Based on movements of ear-tagged moose, Saunders and Williamson (1972) reported that there were no significant differences between the movements of young and old moose. Conversely, LeResche (1974) suggested that young moose should have more extensive local movements than adult moose.

Furthermore, if juvenile moose disperse more readily than adults, yearlings from GMU 20A may inflate the proportion of yearlings in fall composition counts and hunter kill in GMU 20B and GMU 20C, giving the impression of more productive herds than actually exist. Therefore, it is important to understand not only yearling movement and dispersal patterns, but also the sightability of yearling moose during aerial surveys.

Because a satisfactory census method for moose has not been devised (Timmerman 1974) and sightability of moose during aerial surveys was not known, we initiated a study in 1976 to determine sightability of moose during aerial surveys (Gasaway 1978). This sightability study used only adult radio-collared moose as controls during aerial surveys. It is not known to what extent the sightability of yearling moose may differ from that of adult moose when related to such factors as activity, habitat selection or aggregation size. Preliminary results of the sightability study are included under this cover as Job 1.18R.

OBJECTIVES

To determine sightability differences between yearling and adult moose and evaluate biases in sex and age ratios determined from composition surveys.

To determine the extent to which offspring adopt movement patterns different from those of the dam.

To determine the extent to which young adult moose contribute to breeding groups other than the ones in which they were produced.

To determine if yearling and young adult moose produced in rapidly increasing populations contribute substantially to adjacent declining populations through emigration, thereby reducing the predation burden on declining populations.

To determine the extent to which rapidly increasing populations can provide hunting recreation in adjacent areas as a result of emigration of young moose.

STUDY AREA

Game Management Unit 20A includes the lowlands of the Tanana Flats as well as the alpine zones and mountainous terrain of the Alaska Range. The Tanana Flats is a mosaic of habitat types ranging from herbaceous bogs to stands of deciduous and white spruce (*Picea glauca*) forest and includes shrub-dominated seres following wildfires. Habitat of the Tanana Flats is described in detail by LeResche et al. (1974) and Coady (1976b). Vegetation in the Alaska Range is characterized as an upland climax community (LeResche et al. 1974). Willows (*Salix* spp.) are found along streams and intergrade into a shrub zone and eventually into alpine tundra on ridgetops and higher elevations. Spruce (*Picea* spp.), aspen (*Populus tremuloides*) and birch (*Betula papyrifera* var. *humilis*) are characteristic of lower elevations.

METHODS

Seasonal Movements of Yearlings and their Dams

Forty-four adult moose were immobilized with M-99 and Rompun during August and October 1976 in GMU 20A and GMU 20B (Gasaway 1978). Moose were equipped with radio collars supplied by AVM Instrument Company, Carbondale, Illinois. A representative cross section of the adult population was radio-collared, including bulls, cows with calves and cows without calves. The moose were radio-collared in conjunction with Job No. 1.18R: Determination of sightability of moose during aerial surveys. Although the sightability project was not designed as a moose movement study, radio-collared moose were routinely relocated during sightability work. Periods of most frequent relocations included early winter (October, November and December) and late winter (January, February and March) 1976-1978, and May to June 1977-1978 when radio-collared cows were relocated several times per week. An attempt was made to relocate radio-collared moose at least once a month during all other times of the year, but longer gaps between observations were common.

Aircraft used to relocate moose included a Bellanca Scout, a Piper Super Cub PA-18 and a Helio Courier. A four-element Yagi antenna was mounted on each wing of the aircraft. Moose were relocated by equalizing signal strength on the antennaes, allowing the pilot to fly directly to the moose. As the aircraft approached and then passed the moose, signal strength would peak and then drop off sharply. Precise tracking of radio-collared moose was possible with this system. All moose relocations and movements were plotted on 1:63,360 topographic maps.

Six short yearlings of radio-collared cows were immobilized with M-99 and Rompun on 4-5 May 1978, and radio-collared with AVM transmitters. Short yearlings were immobilized prior to separation from their dam in the spring. At that time, an accumulation of 19-21 months of movement data were available on the cows, and nearly 12 months of movement data were available on the short yearlings during the time they accompanied their dams as calves. Several additional moose were also radio-collared in May 1978. One adult cow failed to produce a surviving calf in 1977 and was still accompanied by its 2-year-old female offspring in May 1978. The 2-year-old cow was radio-collared. An additional adult cow that had been tracked by radio from 21 October 1974 to 1 July 1975 (Coady 1976b) was also radio-collared along with her current short yearling. Yearlings and their dams were usually relocated at least once a month. They were often relocated more frequently during surveys associated with the sightability study.

Adult cows that were radio-collared in 1976 had an expected transmitter life of 3 years. On 9-16 May 1979, radio collars were replaced on 11 adult cows that were known to confine their movements to GMU 20A. Ten short yearlings of radio-collared cows were also collared, as well as four new adult cows. All moose were immobilized with M-99 and Rompun. Twenty-two moose were equipped with radio collars supplied by Telonics, Mesa, Arizona and three were equipped with AVM radio collars. All yearlings and their dams will be relocated at least once a month.

Determination of Sightability of Yearling Moose

The 1977 cohort of radio-collared yearlings was included in the sightability study during the winter of 1978-1979. Methods for determination of sightability of yearling moose are discussed in the sightability study (Job 1.18R) under this cover.

RESULTS AND DISCUSSION

Seasonal Movements of Yearlings and their Dams

Between May 1978 and May 1979, 14 moose (six yearlings, one 2-year-old and their dams) were relocated for a total of 232 resightings. Frequency of relocations varied between individuals, but the data indicate that offspring tend to adopt movement patterns and seasonal ranges similar to their dams. Observations did not suggest that this similarity resulted from extended maintenance of the social bond after the time of collaring in any of the seven pairs. With one exception, all short yearlings permanently separated from their dams at the time of collaring. One pair remained together for at least 12 days after collaring. They separated when the dam produced a new calf.

Figs. 1 and 2 show the movements of radio-collared moose between three physiographic regions of Interior Alaska (Tanana Flats, northern foothills of the Alaska Range and the Tanana Hills). Although the timing and extent of seasonal movements were distinctly different between cows, the data indicate strong fidelity to particular summer and winter ranges by individuals. For 3 consecutive years, radio-collared cows returned to the same summer and winter ranges. These findings are in agreement with those of Houston (1968) and VanBallenberghe (1977) who documented traditional use of certain seasonal ranges by individuals. Repeated use of specific migratory routes was also observed in the present study. Other studies have obtained similar results (Edwards and Ritcey 1956, Knowlton 1960, Houston 1968, LeResche 1972, Phillips et al. 1973, Roussel et al. 1974).

All collared cows occupied the lowland area of the Tanana Flats during summer. The fall movements of two cows were southward to winter range in the foothills of the Alaska Range. These movements were as much as 40.3 mi (straight-line distance) with elevational changes as great as 1,915 ft (Table 1). Migrations of two additional radio-collared cows eastward to the Tanana Hills were as great as 39.3 mi. The other three adults remained on the Tanana Flats throughout the year, suggesting that both migratory and nonmigratory moose occur in the area (Table 1).

With one exception, the data indicate yearlings exhibited the same migrations between summer and winter ranges as their dams. One yearling male remained on the Tanana Flats in an area of 75 mi^2, while its dam moved 40.3 mi into the northern foothills of the Alaska Range. Roussel et al. (1974), in Quebec, concluded that seasonal movement patterns were passed on from at least one generation to the next. However, the sample size in that study was also small. Data from both studies strongly suggest that the cow/calf bond, which continues throughout the first year (Denniston 1956; Altmann 1958, 1963; Stringham 1974), provides an opportunity for the calf to learn its dam's traditional migration route. Hence, association with its dam is not only advantageous to the calf for protection and obtaining forage through its first year of life, but it is also beneficial for learning movement patterns which assist in the location of optimal feeding and calving areas.

Data from this study show that the movement of migratory moose from lower to higher elevations begins in late summer and early fall (Table 1). An exception was a yearling male which did not begin movement until early January, although its dam moved onto her winter range between mid-August and early November. The timing of spring migration back to the Tanana Flats was highly variable. Movements began as early as December and extended over a period of 5 months.

Moose are capable of dispersal to new habitats where unutilized forage is available (Pulliainen 1974). Although our data give no indication of dispersal, the movements of one yearling differed from those of its dam. This indicates that deviation from the dam's traditional movements may occur. However, the frequency of dispersal may be

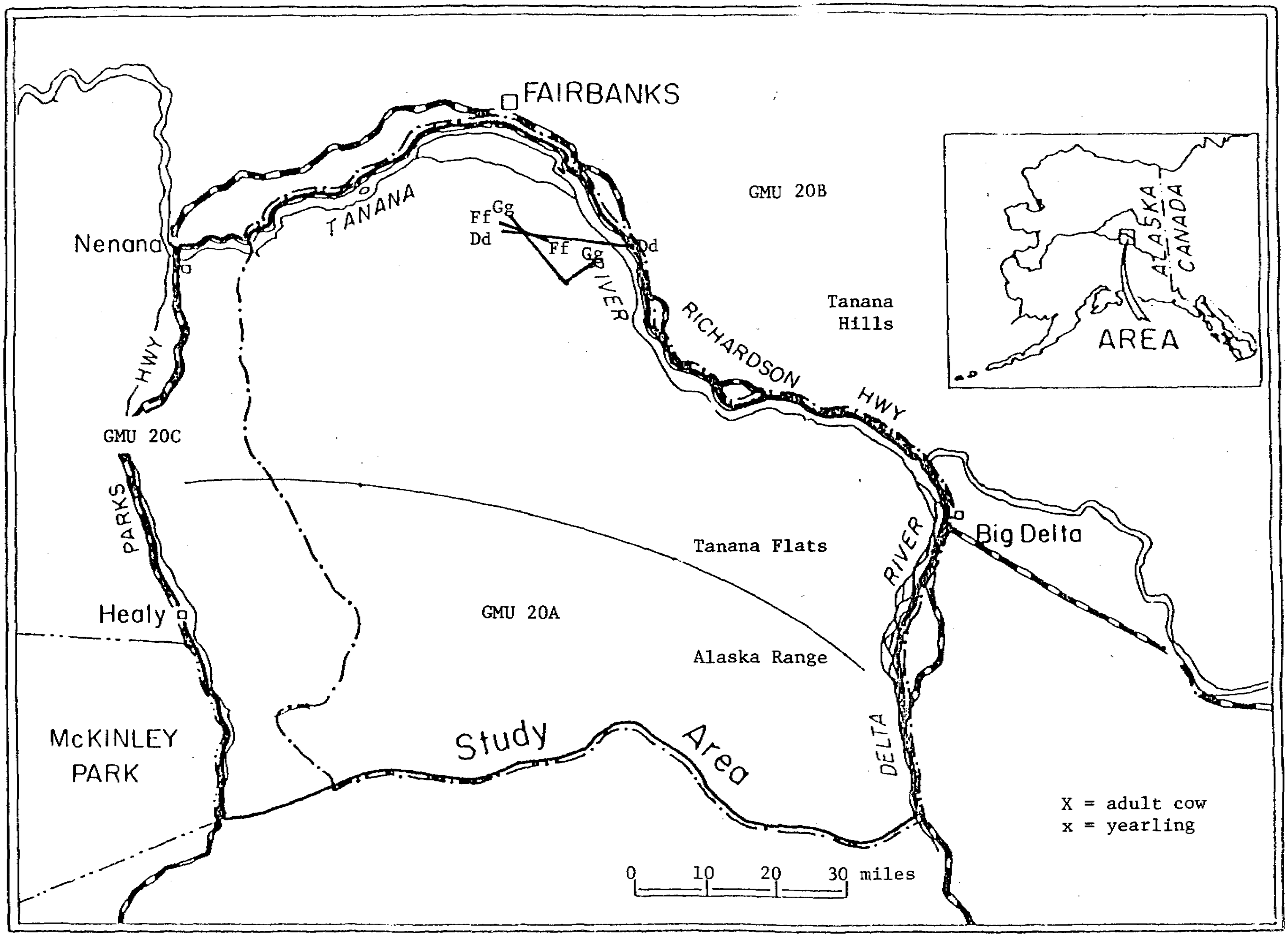

Fig. 1. Annual linear movements of nonmigratory dams and their yearlings, May 1978 to May 1979.

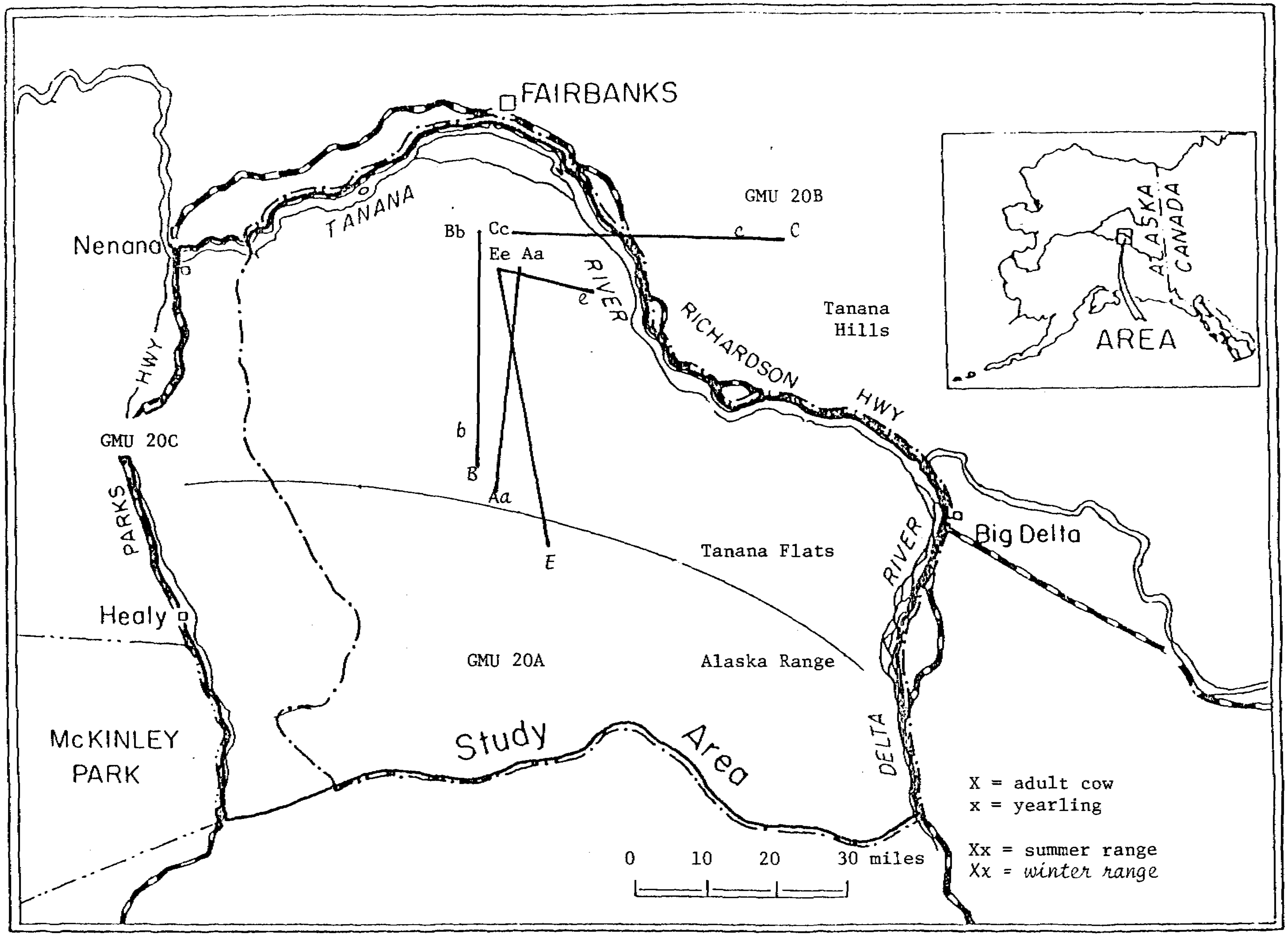

Fig. 2. Annual linear movements of migratory dams and their yearlings, May 1978 to May 1979.

Table 1. Seasonal occupancy of three physiographic regions by radio-collared yearling moose and their dams in Interior Alaska, May 1978-May 1979.

Moose No.	Sex and Age of Yearling/ Dam Pairs	Relocation Dates				Maximum Movement Distance (mi)[a]	Elevation (ft)[b] 15 May-31 Oct	Elevation (ft)[b] 1 Nov-14 May
		Tanana Flats	Foothills Alaska Range		Tanana Flats			
		Last	First	Last	First			
7703	F yearling	9/18/78	11/8/78	3/30/79	4/11/79	32.1	735	2035
7709	F adult	8/12/78	11/8/78	1/2/79	3/15/79	28.2	817	1348
7706	F yearling	9/18/78	11/8/78	11/30/78	1/5/79	29.1	540	1125
7724	F adult	7/3/78	11/8/78	11/30/78	1/1/79	38.8	485	2400
8652[c]	F adult	8/16/78	11/8/78	11/8/78	1/5/79	40.3	620	1175
		Tanana Flats	Tanana Hills		Tanana Flats			
		Last	First	Last	First			
7730	M yearling	1/5/79	2/26/79	4/16/79	4/27/79	32.6	515	1700
6915	F adult	8/16/78	11/3/78	4/11/79	4/16/79	39.3	496	1464
		Tanana Flats						
7737	M yearling	Remained on Flats				16.4	550	550
6916	F adult	Remained on Flats				18.6	561	583
7863	M yearling	Remained on Flats (died 8/16/78)				-	500	no data
7704	F adult	Remained on Flats				12.9	485	458
6914	F 2-year-old	Remained on Flats				15.1	580	600
6918	F adult	Remained on Flats (radio failure 7/3/78)				-	595	no data
7739[c]	M yearling	Remained on Flats				12.4	550	595

[a] Straight line distance between the two farthest relocation points during the study period.
[b] Mean elevation of relocations.
[c] Yearling/dam pair: yearling remained on Tanana Flats and dam moved into the northern foothills of the Alaska Range.

related to population density and habitat carrying capacity. Consequently, the rate of dispersal by yearlings from GMU 20A may increase as the population density there increases. A larger sample size would probably be necessary to detect any dispersal at this time.

Determination of Sightability of Yearling Moose

Preliminary results of the sightability of juvenile moose are included in the sightability study (Job 1.18R) under this same cover.

RECOMMENDATIONS

1. Continue the collection of sightability data to determine if sightability of yearling moose differs significantly from adult moose.

2. Continue monitoring the movements of yearling moose and their dams to determine if the movements of yearling moose result in dispersal to areas not traditionally used by their dams.

3. Radio-collar additional adult and yearling moose to increase sample size of current movement data.

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b Mean elevation of relocations.
c Yearling/dam pair: yearling remained on Tanana Flats and dam moved into the northern foothills of the Alaska Range

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