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MOOSE SURVEY PROCEDURES DEVELOPMENT

BY
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JOB FINAL REPORT (RESEARCH)

State: Alaska

Cooperators: William C. Gasaway, Stephen D. DuBois, and Samuel J. Harbo

Project No.: W-17-9 through W-17-11, W-21-1 and W-21-2 Project Title: Big Game Investigations

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

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

Job No.: 1.19R Job Title: Standardization of Techniques for Estimating Moose Abundance

Period Covered: July 1, 1980 through June 30, 1981

SUMMARY

Moose sightability during aerial surveys was determined and methods for estimating numbers and sex and age composition of moose were developed. A techniques manual was drafted incorporating the pertinent sightability findings, and two training workshops were held. Personnel attending workshops conducted five population estimation surveys during November 1980 and estimated moose numbers were greater in each area than biologists had previously realized. The new survey method provides more representative sex and age composition data than traditional composition surveys used by the ADF&G. Calf:cow ratios were substantially underestimated by use of traditional composition surveys.

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BACKGROUND

The greatest problem in effective moose (*Alces alces*) management and research is the inability to accurately estimate their numbers. Accurate population estimates are extremely difficult to obtain because of moose behavior and the type of habitat they prefer. A completely satisfactory method of inventorying moose has yet to be devised (Timmermann 1974), therefore, we selected this area of technique development for study.

Aerial survey methods for large mammals generally underestimate the number of animals present because some animals are not seen during surveys (Caughley and Goddard 1972). Therefore, sightability estimates for animals seen under varying survey methods and environmental conditions are needed to correctly estimate actual animal numbers. In the words of Caughley (1974):

> 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. Sightability estimates for moose in four, 2.6 km^2 pens were reported by LeResche and Rausch (1974). They found that experienced observers who had recently conducted surveys saw an average of 68 percent of the moose under their experimental conditions. Unfortunately, search methods employed, terrain, and habitat 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 intensive searching of the plots by helicopter. Floyd et al. (1979) reported seeing 50 percent of the radio-collared deer in 1.3 to 26 km^2 forested test plots when these areas were intensively surveyed. Several studies have demonstrated that increasing search intensity increased moose sightability and population estimates (Fowle and Lumsden 1958, Evans et al. 1966, Lynch 1971, Mantle 1972); however, an unknown proportion of the moose present was probably not seen during even the most intensive searches. This, of course, precluded calculation of sightability.

In Alaska, variations of 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, these data have been extrapolated to form crude estimates of population size, but the technique is generally considered inadequate for population estimation. Basically, the transect method involves flying parallel lines at prescribed altitudes and airspeed and counting moose seen in prescribed transect widths (Banfield et al. 1955). Population estimates derived in this manner 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 the transect method was inadequate for the needs of wildlife management agencies and that quadrat sampling methods for the estimation of moose abundance should be adopted. However, Thompson (1979) proposed a variation of the transect method that overcomes some of the difficulties with past transect methods.

Aerial surveys in which quadrats were exhaustively searched were first introduced in the 1950's (Cumming 1957, Trotter 1958, Lumsden 1959). Quadrat sampling tends to give higher estimates of moose numbers than transect methods. For example, Evans et al. (1966) and Lynch (1971) found that transect surveys 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 thoroughly searched until the observer is satisfied that further searching will not reveal 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. The number of undetected moose varies according to the density of canopy cover, environmental factors, moose behavior, and pilot/observer effectiveness (LeResche and Rausch 1974).

Given that less than 100 percent sightability of moose was achievable, we tested aerial search patterns, and intensities in search of combinations which would provide high sightabilities under varying conditions. These search patterns and sightabilities were then used in the development of population estimation procedures. Our sampling design was a modification of the random, stratified procedures reported by Siniff and Skoog (1964) and Evans et al. (1966). Linear transect sampling methods were rejected because they were not adaptable to specific terrain and habitat types found in Alaska.

Findings from our research were used to produce a preliminary technique manual for the estimation of moose population size. Workshops have been used to introduce biologists to this survey method.

OBJECTIVES

To develop sampling procedures for estimating moose abundance 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 survey methods.

To demonstrate the relationship of search intensity and method to numbers and sex and age composition of moose seen so biases in observed sex and age ratios can be interpreted and minimized.

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

STUDY AREA

The study area is diverse and represents most habitat and terrain types used by moose in Interior Alaska. 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 and Salcha Rivers in Game Management Unit (GMU) 20B and much of GMU 20A.

METHODS

Methods used to estimate sightability of moose and develop the sampling scheme have been described in previous reports (Gasaway 1977, 1978, 1980; Gasaway et al. 1979).

RESULTS AND DISCUSSION

Development of a Sampling System

A moose population estimation techniques manual (Appendix I) describing the sampling design was drafted. This manual is the final report for Job 1.17R.

Determination of Moose Sightability

Analysis of sightability data continued during the reporting period. Sightability data applicable to May and June surveys were analyzed and reported in Gasaway et al. (1979) and are currently being prepared for publication. Analysis of winter sightability data has not advanced beyond that reported in Gasaway et al. (1979).

Improvements were made in the application of a sightability correction factor (SCF) to population estimation survey data (Appendix I). The SCF was adjusted upward by 3 percent to account for moose not seen during the intensive searches in early winter (Gasaway et al. 1979). Additional refinements to the SCF are being made by calculating a variance component for the SCF and will be incorporated into the manual. This variance component is necessary to accurately estimate the confidence interval (CI) about the estimated number of moose. It will result in a wider CI for a specified probability.

Standardization of Moose Survey Techniques

The moose population estimation manual (Appendix I) provides guidelines for Alaska Department of Fish and Game personnel conducting moose surveys. The manual serves both as a training aid during 2-day workshops on population estimation techniques and as a field reference.

Biologists produced 5 population estimates during November 1980 using techniques presented in the manual and at the workshops. Each survey resulted in an estimated population larger than expected based on presurvey data (Table 1). For example, upper and lower Nowitna River surveys produced population estimates that were four times greater than the expected number of moose in those areas.

Two factors account for the large discrepancy between expected and estimated moose numbers in the Nowitna surveys. First, very little previous survey effort had occurred there, and second, moose were thought to be scarce because they were scattered at a low density throughout a very large, heavily forested drainage.

Precision of moose population estimates is defined by the width of the 90 percent CI about the population estimate. We suggest that a 90 percent CI equal to or less than 20 percent of the estimated number of moose is acceptable for many uses

(Appendix I). However, the acceptable level of precision must be established by biologists for each study area. These precision levels will vary with study objectives or management needs. Confidence intervals ranged from 4 to 19 percent of the population estimates for the five population estimates produced in November 1980 (Table 1). Narrower CI's could have been attained by surveying a larger percentage of the sample units in each survey; however, costs would have increased.

The costs of all five surveys were high (Table 1), due primarily to three factors. First, population estimates in small areas required a very high percentage of the areas to be sampled, and this increased costs per unit area. Two of the surveys (CA3 and Tok) covered quite small areas 274 mi^2 and 450 mi^2 of moose habitat. A more detailed discussion of the cost of estimating populations in small areas is found in Appendix I. Second, all population estimates were conducted in remote areas which increased aircraft charter costs as well as food and lodging expenses for personnel. The third factor contributing to high costs was the vast expanse of some survey areas such as the upper and lower Nowitna drainages. Because of the size and remoteness of the Nowitna, aircraft had to fly up to 4 hours round trip just to reach distant sample units. Experience gained during the 1980 surveys will result in more accurate cost estimates in the future.

Numbers of moose seen on sex and age composition surveys substantially underestimated the number of moose in three areas where both composition surveys and population estimation surveys were conducted; approximately 65 percent of the estimated population was seen on these sex and age composition surveys (Fig. 1). Rough population estimates should be possible from composition survey data by multiplying the number of moose seen by a SCF. Because sightability of moose can vary drastically among composition surveys throughout Alaska and within a single survey area among years, more data are needed to develop sightability correction factors for sex and age composition surveys conducted under variable conditions.

The stratification process can be used alone to provide a rapid and inexpensive measure of moose distribution in large areas where little or no prior knowledge is available. Stratification allows for a rapid and systematic accumulation of data in a form that maximizes knowledge. The number of moose seen during three stratification flights (Fig. 1) was approximately 30 percent of the estimated population. Therefore, multiplying the number of moose seen by three and four gives a crude estimate of moose abundance in those areas. Stratification also produces a moose distribution map containing relative moose densities. These data provide a basis for selecting sites for composition or trend surveys, initiating management strategies, and addressing resource use issues.

Population estimation surveys produced higher calf:cow ratios than sex and age composition surveys (Table 2). These differ-

Table 1. Results of population estimation surveys during November 1980.

Game Management Unit, Count Area	Area of Moose Habitat (mi^2)	Sightability Correction Factor[1]	Estimated No. Moose	90% Confidence Interval (% of Estimate)	Cost ($)	Estimated Number of Moose Relative to the Number Expected
13, CA3	274	1.06	501	9	3,000	higher density than expected
13, CA7+14	945	1.06	2,105	19	8,000	higher density than expected
12, Tok River	450	1.38	872	4	4,000	expected 700 moose
21, Upper Nowitna	3,800	1.11	1,891	16	25,000	expected 400 moose
21, Lower Nowitna	2,770	1.19	2,376	18	15,000	expected 600 moose

[1] Sightability correction factor calculated during the survey times 1.03 for moose not seen during intensive search (see Appendix I for details).

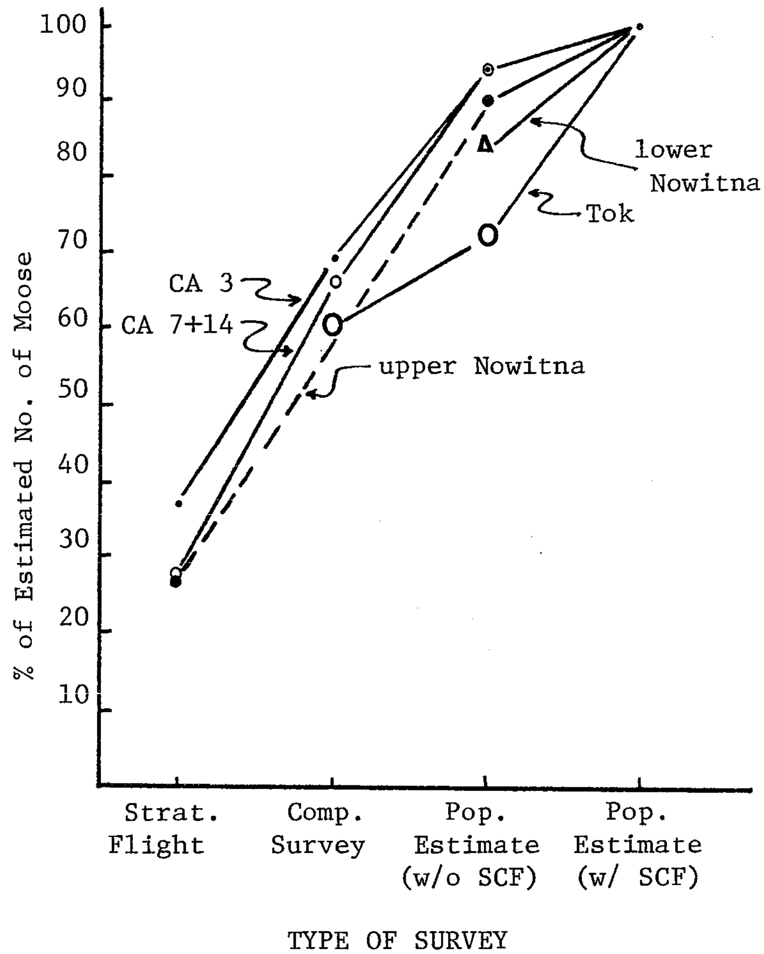

Fig. 1. The percentage of moose seen or estimated by surveys during November 1980.

Table 2. Sex and age ratios in moose populations calculated from composition survey and population estimation survey data.

Game Management Unit, Count Area	Calves/100♀					Males/100♀		
	Composition Survey		Population Estimation Survey			Composition Survey	Population Estimation Survey	
	Pooled Data[1]	N	Pooled Data[1]	Unbias[2] Method	N	Pooled Data	Pooled Data	Unbias Method
13, CA3	31	344	44	45	459	37	30	29
13, CA7+14	23	1,393	32	32	742	13	13	13
12, Tok River	20	525	24	26	526	25	26	29
21, Upper Nowitna			27	26	434		71	69
21, Lower Nowitna			34	34	405		71	74

[1] Ratio calculated from all moose observed.

[2] Ratio weighted by the composition and number of moose within each stratum (see Appendix I for details).

ences are caused by bias. The composition survey method contains greater bias than population estimation surveys because sightability of moose is lower and a smaller portion of low moose density area is generally surveyed. These two factors result in unrepresentative, low calf:cow ratios from composition survey data because cows with calves are more frequently missed during low to moderate intensity searches (Table 3), and because cows with calves are disproportionately abundant in areas of low moose density (Fig. 2). So far, we have been unable to detect consistent differences in bull:cow ratios produced between the two survey techniques.

The calculation of population composition ratios from population estimation data is described in Appendix I. The population composition ratios are calculated for each stratum in the survey area; an overall ratio is then calculated using weighted estimates for each stratum. Previously, we suggested simply pooling all moose observed during population estimation surveys and then calculating composition ratios.

The new and old methods of calculating composition produced quite similar values for November 1980 data (Table 2); however, larger differences can occur with certain combinations of sampling effort and distribution of calves among strata.

In those areas where both a population estimation survey and sex and age composition survey were done in the same area (Tok, CA3, and CA7+14 in Table 2), ten calves:100 cows was the mean increase in the ratio.

No insurmountable problems were encountered during the 5 population estimation surveys in November 1980. The techniques manual (Appendix I) has been revised to solve or minimize the problems that were identified.

RECOMMENDATIONS

A more comprehensive population estimation manual should be prepared during the next 2 years. Analysis of sightability data should be completed and written up for publication. Workshops should be continued so that personnel can learn methods for making population and composition estimates. The method should be applied when population estimates and representative composition data are needed for management and research.

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Table 3. Composition of moose missed during moderate intensity aerial surveys.

Survey Conditions and Intensity	Calves/100 Cows	Number of Cows
Moose seen on first search at 4 min/mi^2	34	120
Additional moose observed when re-searched at $12/min/mi^2$	41	29

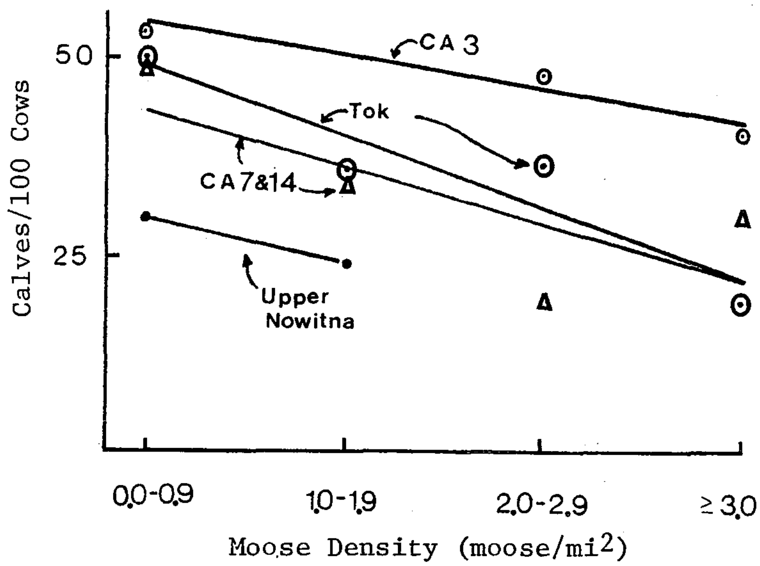

Fig. 2. Calf:cow ratios of moose with respect to moose density in sample units surveyed during the estimation of population size, November 1980. Lines were fit by linear regression.

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JOB PROGRESS REPORT (RESEARCH)

State: Alaska

Cooperators: William C. Gasaway, Stephen D. DuBois, and Diane J. Preston

Project No.: W-21-2 Project Title: Big Game Investigations

Job No.: 1.26 R Job Title: Movements of Juvenile Moose

Period Covered: July 1, 1980 through June 30, 1981

SUMMARY

During 1980, radio collars were placed on 10 yearling offspring of radio-collared cows to continue monitoring dispersal of subadult moose from a low-density, rapidly growing population. Additionally, nine 2-year-old moose and three 3-year-old moose were available for study from previous collarings. Subadult moose were usually relocated twice per month to assess dispersal from the home range occupied by the offspring while accompanying its dam. Radio collar malfunctions and hunters claimed a total of 8 subadult moose from the sample. Extensive overlap between the home range of the subadult moose and the home range it occupied while accompanying its dam was recorded for all remaining subadult moose. No long-range dispersal was recorded.

CONTENTS

BACKGROUND

The extent of dispersal from a moose (Alces alces) population can alter the management strategy for that population and adjacent populations which may receive dispersing moose. Therefore, it is useful to predict when dispersal may occur, which sex and age classes are prone to disperse, and the approximate magnitude of dispersal.

Expansion of moose range through dispersal has been documented in North America (Houston 1968; Mercer and Kitchen 1968; Peek 1974a, 1974b; Coady 1980), the Soviet Union (Likhachev 1965; Yurlov 1965; Filonov and Zykov 1974), and Europe (Pullainen 1974). In those studies for which age specific dispersal was determined, yearling and 2-year-old moose dispersed more frequently than adults (Likhachev 1965; Houston 1968; Peek 1974a; Roussel et al. 1975; Lynch 1976). Adult bull and cow moose were relatively faithful to previously established seasonal home ranges (Houston 1968; Goddard 1970; Berg 1971; Saunders and Williamson 1972; Phillips et al. 1973; LeResche 1974; Coady 1976; VanBallenberghe 1977, 1978). Therefore, the fidelity that adult moose demonstrate toward their home ranges minimizes their role in the colonization of new ranges through dispersal.

Dispersal of moose appears to be associated with relatively high population density (Likhachev 1965; Yurlov 1965; Houston 1968; Filonov and Zykov 1974; LeResche 1974; Peek 1974a, 1974b; Irwin 1975; Roussel et al. 1975; Coady 1980). Although not specifically stated by most of the above authors, the densities of moose populations from which dispersal was recorded may have approached or exceeded the carrying capacity of the range based on our interpretations of information presented in those studies. Dispersal from a moose population that was clearly at low density relative to carrying capacity was found only in Mercer and Kitchen (1968).

Many moose populations in Alaska are presently at low densities relative to the carrying capacities of their ranges. Management of moose should consider dispersal patterns of moose in these low-density populations as well as in populations with densities closer to carrying capacity.

This study was designed to investigate the frequency, direction, and distance of dispersal as well as the age and sex of dispersing moose in a low density moose population. The population selected for study had an estimated peak density of approximately 0.8-0.9 moose/km during the late 1960's (Bishop and Rausch 1974); however, reappraisal of past data suggests the density may have been nearly twice the earlier estimates. During the mid-1960's, heavily browsed vegetation and winter die-offs suggested that these moose exceeded the carrying capacity of the range. Density had declined to approximately 0.23 moose/km by 1975 as a result of severe winter weather, malnutrition, high harvest by hunters, and high rates of wolf (Canis lupus) predation (Bishop and Rausch 1974; Gasaway et al. 1979). Following harvest reductions since 1975 and wolf control since 1976, this population has steadily increased through 1979. The mean density of moose in the study area had increased to an estimated 0.27 moose/km by fall 1978 (Gasaway et al. 1979), and it is still considered to be below the range's carrying capacity. This is a preliminary report on a continuing study.

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 moose 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 those 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

The study area in Interior Alaska (Fig. 1) includes the lowlands of the Tanana Flats, the rolling hills of the Tanana Hills, and the alpine zones and mountainous terrain of the north side of the Alaska Range. The Tanana Flats is a mosaic of habitat types, ranging from herbaceous bogs to deciduous and white spruce (Picea glauca) forest and including shrub-dominated seres following wildfires. Habitat of the Tanana Flats is described in detail by LeResche et al. (1974). Vegetation on hillsides and river bottoms of the Tanana Hills is influenced by aspect of the slope. Warm, well-drained soils support white spruce, quaking aspen (Populus tremuloides), and paper birch (Betula papyrifera)

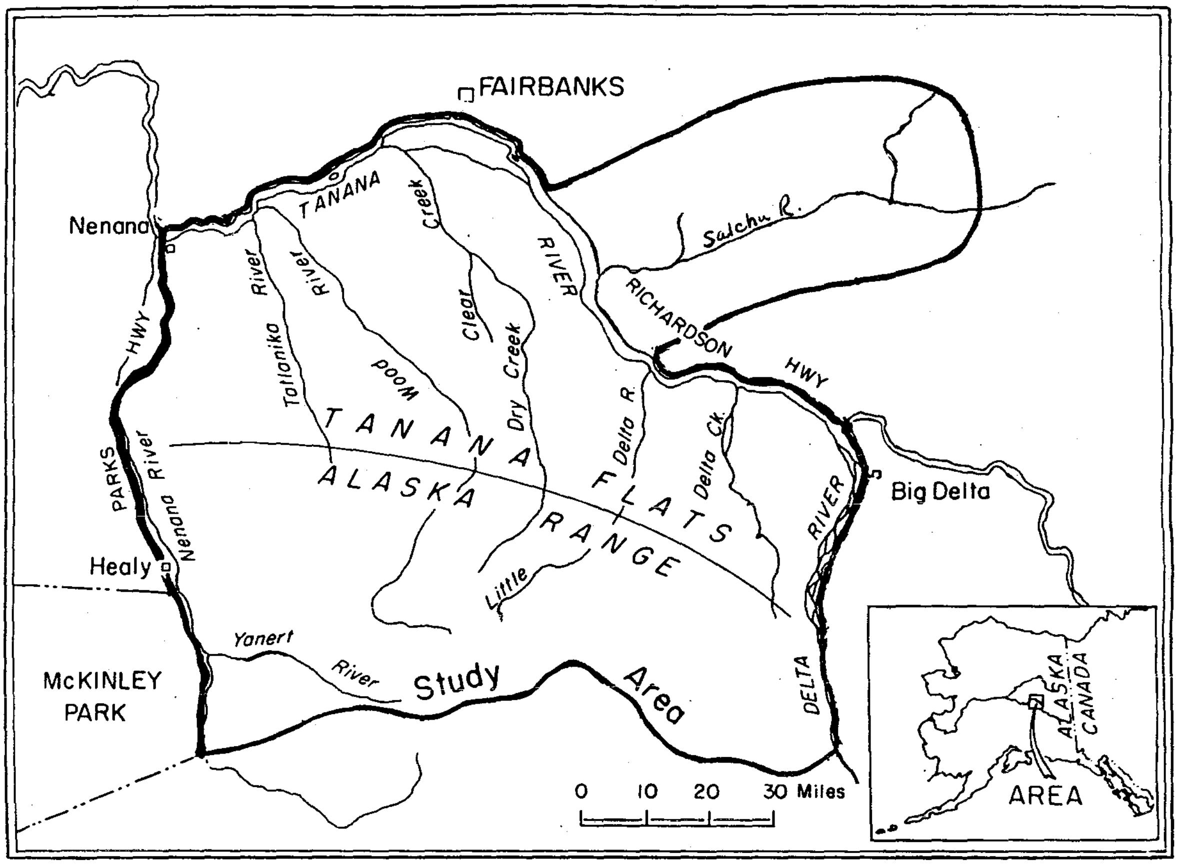

Fig. 1. The study area in interior Alaska.

whereas extensive stands of black spruce (*Picea mariana*) grow on water-saturated, cold soils. Shrub communities are located along creek and river bottoms and in recent burns. 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, aspen, and birch are characteristic of lower elevations.

METHODS

Radio collars were placed on 10 yearling offspring of radio-collared cows in early May 1980 prior to separation of the dam and offspring. Each pair had been radio-tracked for the previous 12 months. Yearlings were immobilized with a mixture of 5 mg M99 (Etorphine hydrochloride, D-M Pharmaceuticals, Inc., Rockfield, MD), 200 mg Rompun, (Xylazine hydrochloride, Chemagro Division of Bay Chemical Corp., Kansas City, MO), and 375 national formulary units Wydase (Wyeth Laboratories, Kent, WA) injected by a dart fired from a Palmer Capture Gun. Radio collars (Telonics, Mesa, AZ) were placed on each moose, and a yellow canvas visual collar 15 cm wide with 13 cm high black numbers was attached to each radio collar.

Moose were generally located twice per month from fixed-wing aircraft, although during some months they were located only once. Locations were plotted on 1:63,360 topographic maps or 1:60,000 aerial photographs. Movements of yearlings, their dams, nine 2-year-olds, and three 3-year-olds, were monitored. All moose other than yearlings had been collared in previous years (Gasaway et al. 1980).

We defined dispersal as the spatial separation between the home range of the independent offspring and the home range occupied by the offspring while accompanying its dam. Hence, the extent offspring disperse can range from no dispersal, if the offspring remains within the home range occupied while associated with its dam, to lengthy distances if the offspring moves to a new home range.

No qualitative analysis was performed on dispersal data collected from July 1980 to June 1981. Rather, a subjective evaluation was performed to determine if new data seemed to confirm or alter the conclusions we reached after analyzing dispersal data from previous cohorts of subadult moose (Gasaway et al. 1980). Convex polygons enclosing the year-round home range of independent subadult moose during their first year of independence were drawn. The home ranges of the independent yearling were compared to their home ranges during the year they were with their dams.

RESULTS AND DISCUSSION

Radio collar malfunctions and moose hunters claimed a total of 8 subadult moose from the available sample during the reporting period. Four of the 10 radio collars placed on yearling moose failed within 3.5 months of collaring, and one radio collar fell off within 2 weeks of collaring. Hunters also shot two 2-year-old moose in September 1980, and radio collars failed on two 3-year-olds. The remaining five yearlings, seven 2-year-olds, and one 3-year-old were relocated 21-25 times each from 1 July 1979 to 1 June 1980.

Extensive overlap between the home range of all subadult moose and the home range they established while accompanying their dams was recorded. No long-range dispersal was documented during this reporting period. Convex polygons showing the overlap between the home ranges of the yearling moose and their dams are shown in Fig. 2. Based on a subjective evaluation of the new data we found no reason to alter our earlier conclusions pertaining to dispersal of subadult moose from a low-density population (Gasaway et al. 1980). A detailed discussion on the management implications of dispersal from a low-density moose population can be found in Gasaway et al. 1980.

RECOMMENDATIONS

Continue analysis of dispersal data and preparation of a manuscript discussing the results.

ACKNOWLEDGMENTS

We thank Larry Jennings for assistance with fieldwork.

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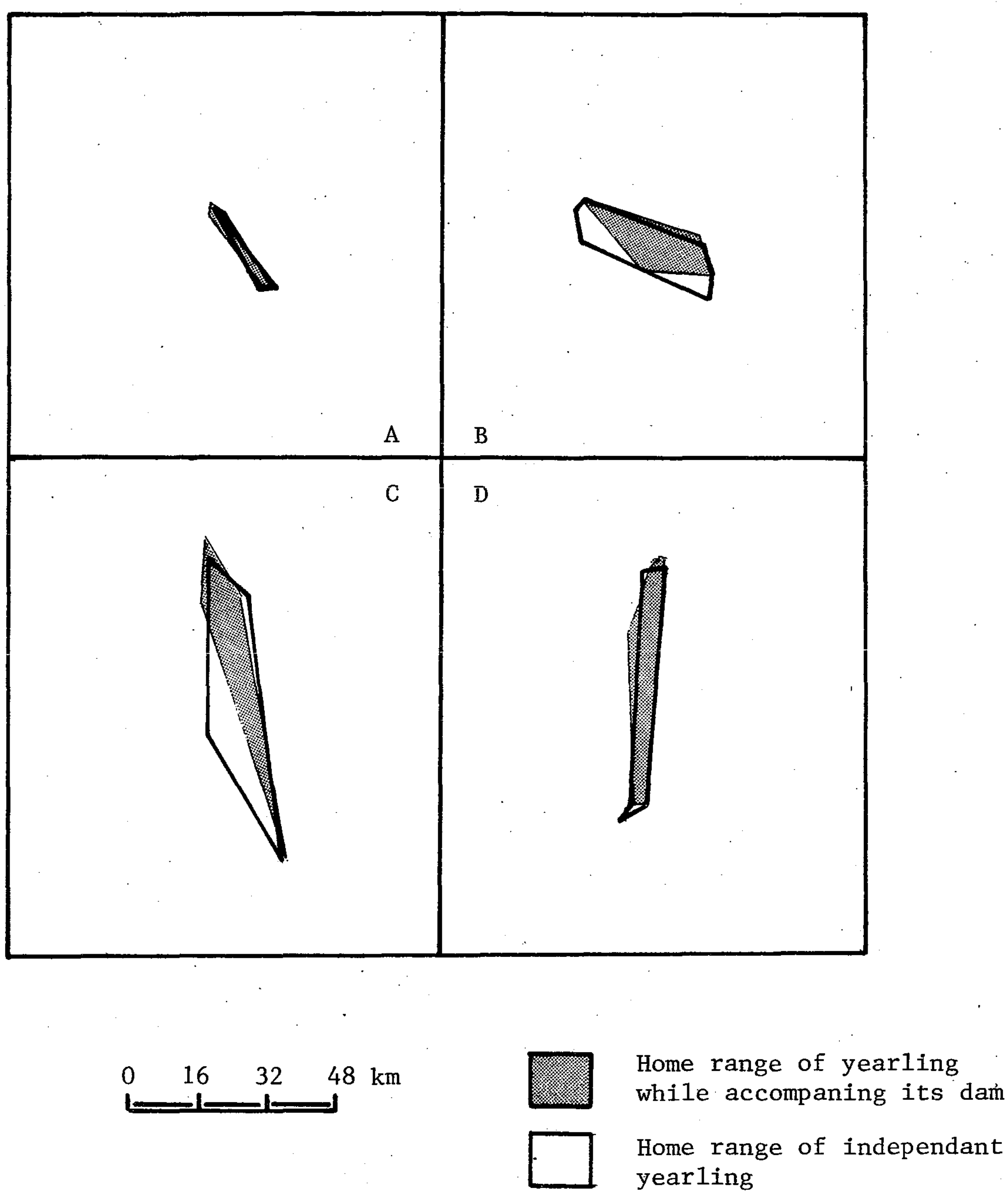

Fig. 2. Home ranges of 4 subadult moose in Interior Alaska.

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CONTENTS

Introduction

Estimates of moose population size and composition are often requirements of successful management and research programs. Methods of estimating these population parameters need to be unbiased and contain a measure of precision or goodness, i.e., a confidence interval with a known probability level.

This manual describes a method of estimating population size and composition that minimizes bias and measures the precision of the population estimates. The manual functions as a survey training aid, field reference, and a means of maintaining consistency in surveys. The method is suited for most terrain and habitat occupied by moose in Alaska, and the sampling scheme is compatible with the distribution of moose in Alaska.

This manual is in an intermediate stage of development. A more comprehensive version will be produced, but in the meantime, this manual provides adequate guidelines for conducting surveys and calculating results.

APPENDIX I

ESTIMATING MOOSE ABUNDANCE AND COMPOSITION

by

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I. Selection of the Survey Area

A. The initial selection of a study area may be based on major factors such as one of the following situations:

1. A particular river drainage the biologist desires to study
2. A discrete moose population that requires a population estimate
3. An area that will be influenced by industrial development such as a pipeline or dam.

B. Once the study area has been identified, the biologist must then consider the size of the area to be surveyed.

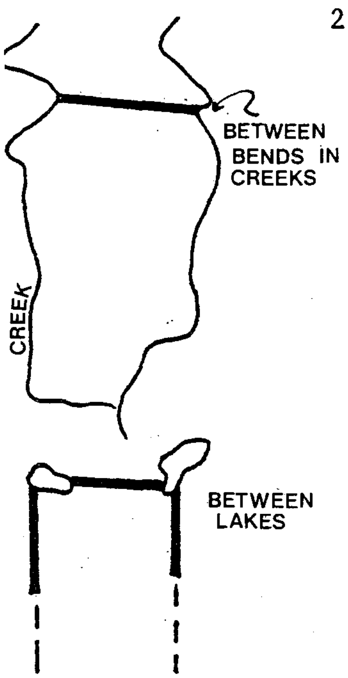
1. The survey area must be small enough to be sampled adequately and rapidly. It may be necessary to survey only a portion of the entire study area at a time in order to accomplish this goal.
2. The biologist also needs to consider other variables that may influence the quality of the population estimate such as economics, logistics, and weather.
   a. Economic considerations include such factors as the available budget and projected cost of the survey.
   b. Logistical considerations include the availability and number of aircraft, qualified pilots and observers, fuel. etc.
   c. Weather considerations include the dominant weather patterns at the time of the proposed survey and the likelihood of a prolonged stretch of good flying weather to allow the survey to be completed in a timely manner.

II. Defining Sample Units

A. A sample unit (SU) is the smallest delineated portion of the survey area that has a probability of being selected and searched in its entirety for moose.

B. All possible SU's are drawn in pencil on a 1:63,360 scale map of the survey area.

1. The size of SU's should range from 12-15 mi^2; however, some may be out of this range because of the lack of sufficient natural boundaries. Avoid making SU's smaller than 8 mi^2 and larger than 20 mi^2. Sample unit area is large compared to most other sampling methods used for estimation of numbers of moose. Experiments in Alaska have demonstrated that sampling variance and confidence interval width can be reduced by the use of large SU's.



g. 1. Straight nes between topo- aphic references e used to define ges of sample units.

2. Boundaries of SU's are generally creeks, rivers, and ridges; however, straight lines between two identifiable points can be commonly utilized when necessary topographic features are not present on the map. Forks or bends in creeks, lakes, or peaks on ridges are convenient points of origin for straight boundary lines (Fig. 1). SU boundaries drawn on maps must be identifiable from the air. The person drawing SU's should be familiar enough with the area and topographic features on maps to draw boundaries that are easily identified from the air.

a. There will be occasions when boundaries become vague due to uniform topography. At that time boundaries should be selected which have a very low probability

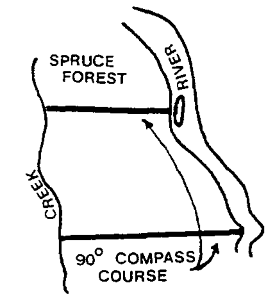


Fig. 2. Compass courses can be used to define edges of sample units when no topographic features are available.

of having moose along them. For example, dense spruce forest may have a very low moose density, hence a poorly defined boundary through it presents little problem because few moose will be encountered. A compass or visual heading may be flown across the area while observations are made from only one side of the aircraft. This flight path establishes the boundary, and subsequent flight lines are made towards the interior of the SU (Fig. 2).

4. Moose distribution within the survey area should also be taken into consideration while drawing SU boundaries. Attempt to draw SU's that encompass large areas having similar moose distribution. Avoid drawing boundaries where concentrations of moose are thought to occur.

   a. An example of optional ways of drawing SU's is taken from the Yanert River drainage during fall where moose concentrate at or above timberline.

      1) Sample Unit A (Fig. 3A) was drawn to include alpine areas from the upper limit of moose habitat (4000' contour) on the north side of the river, a lowland portion of the drainage, and alpine habitat on the south side of the river. Therefore, SU-A probably contains a heterogeneous mixture of moose densities ranging from high density on the side hills to low density in the river bottom. This SU can be divided (see below) in a manner that can

Fig. 3A, B, and C. Example of drawing a SU to include areas of varying densities of moose and redrawing it to enclose areas of similar moose density.

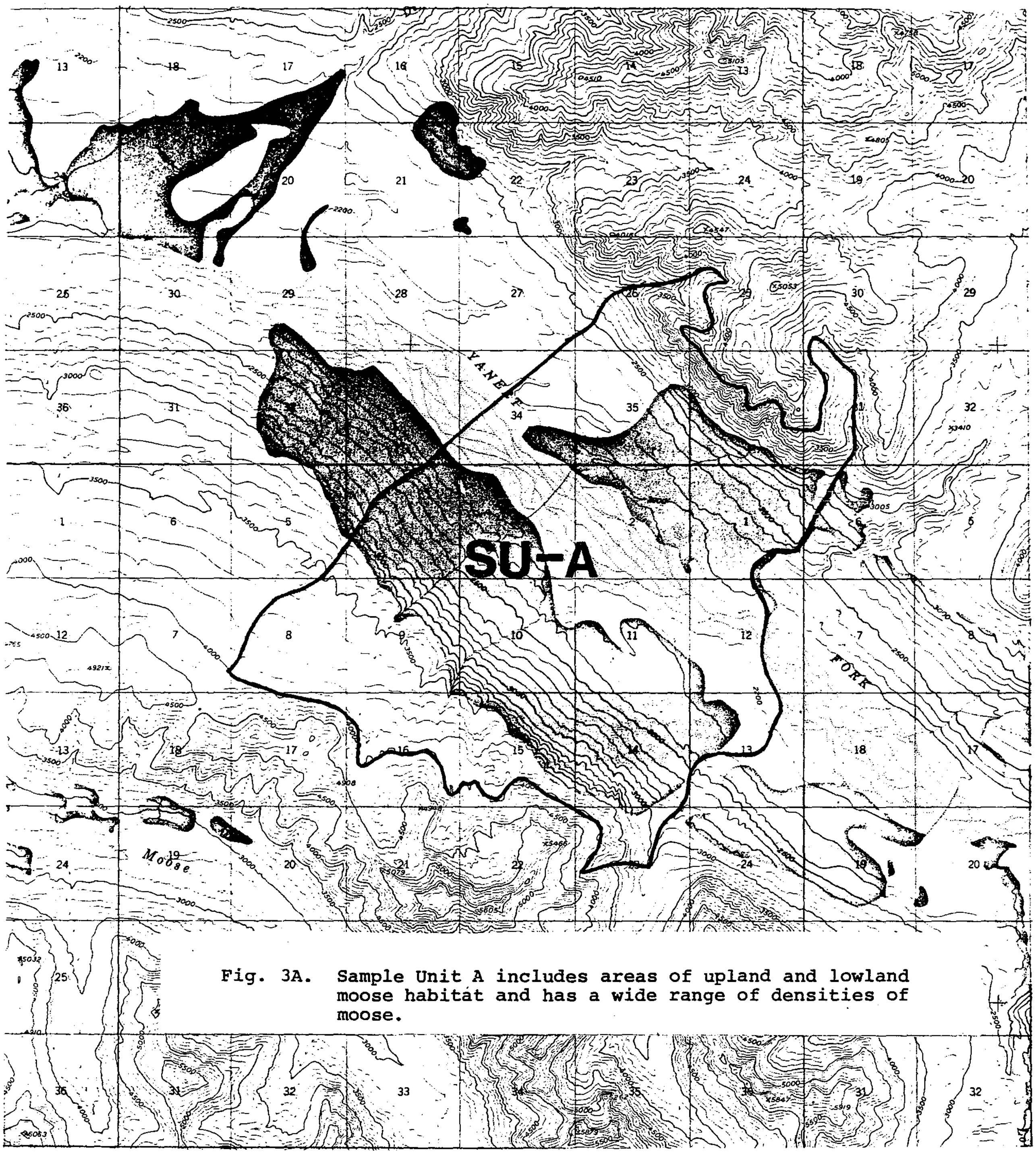


Fig. 3A. Sample Unit A includes areas of upland and lowland moose habitat and has a wide range of densities of moose.

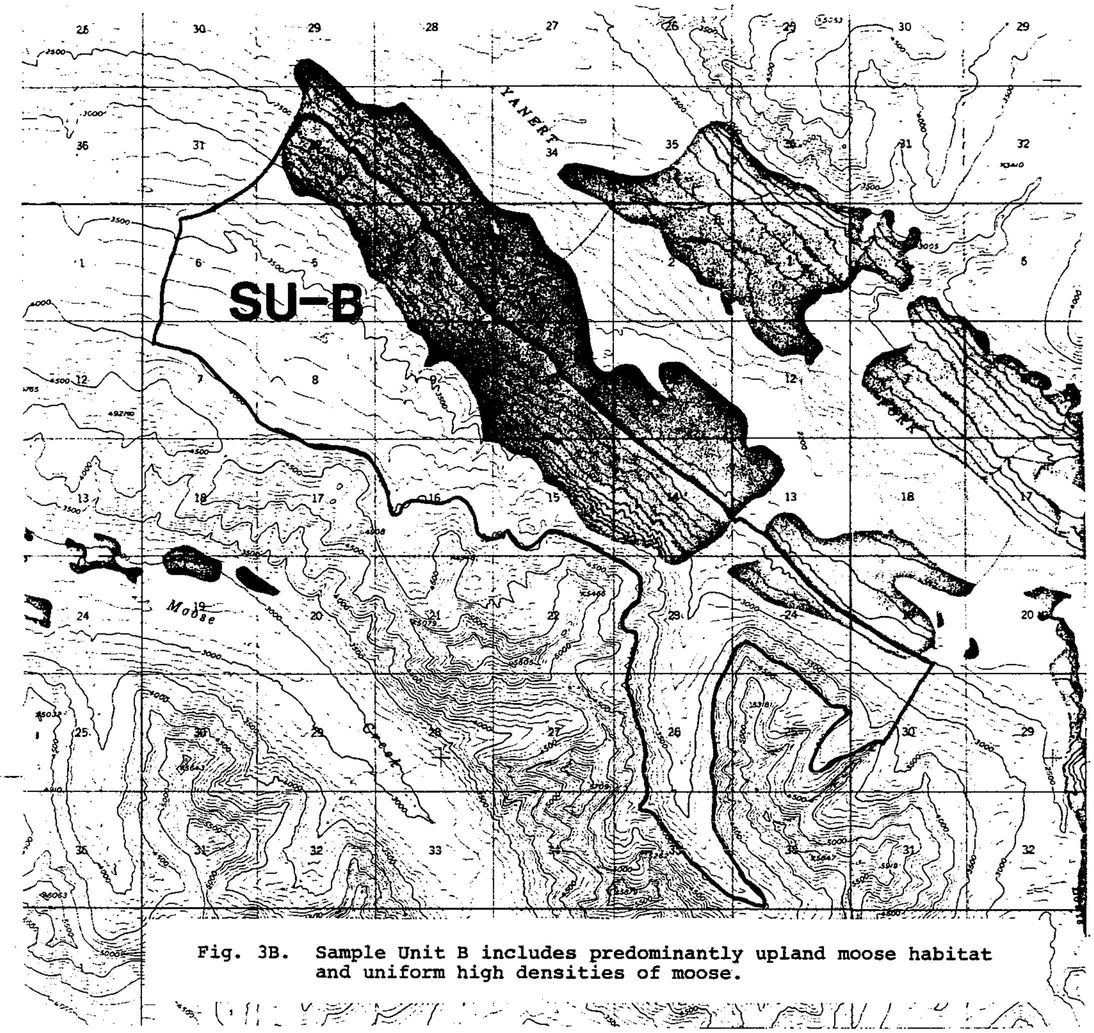


Fig. 3B. Sample Unit B includes predominantly upland moose habitat and uniform high densities of moose.

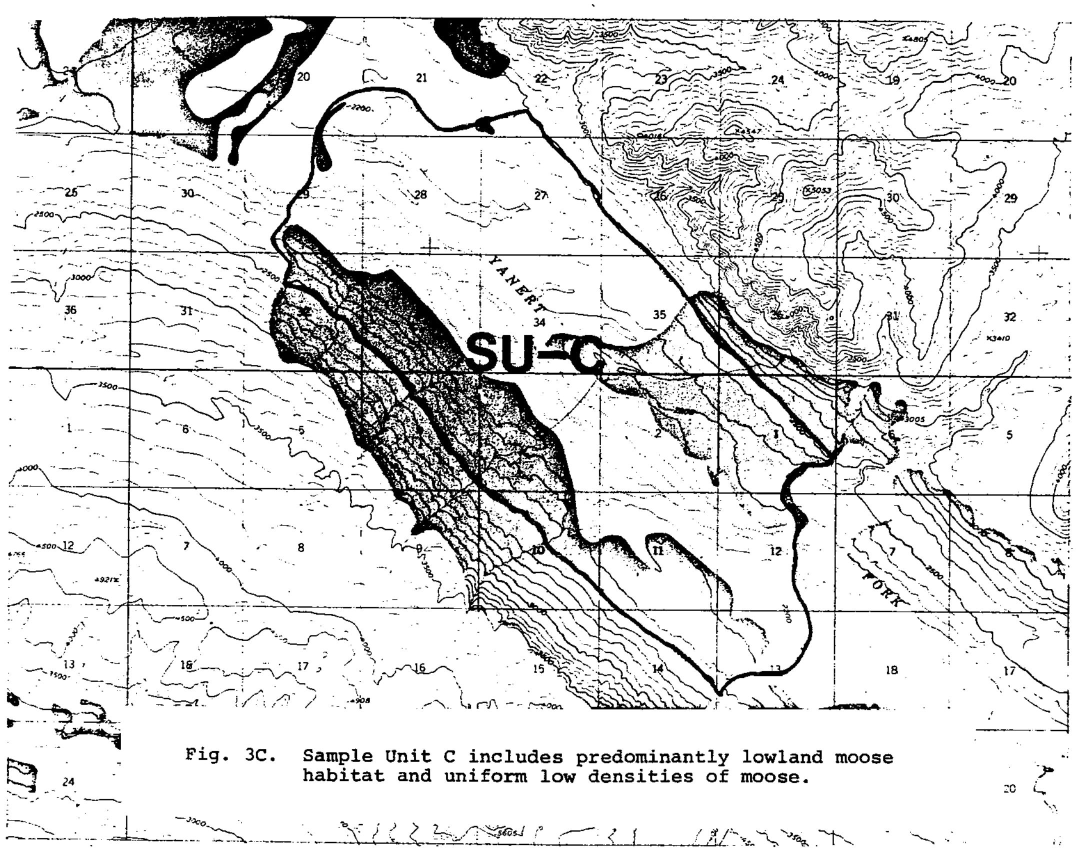


Fig. 3C. Sample Unit C includes predominantly lowland moose habitat and uniform low densities of moose.

lead to improved precision of the population estimate.

2) Sample Unit B (Fig. 3B) was drawn to enclose the predominantly subalpine and alpine habitat in anticipation of high moose densities relative to the lowlands. Sample Unit C (Fig. 3C) was drawn to incorporate mostly lowland habitat which should have a low moose density relative to SU-B.

   a) Sample Unit B and C therefore have subdivided the area into units that should have uniform moose distributions. This type of SU construction should result in a more precise population estimate than that from SU-A because stratification of SU's will be easier.

5. Each SU is given a unique number for identification. The numbers are color coded for rapid relocation on the map. Use one color for each 50 SU's and keep the color in a tight block (Fig. 4).

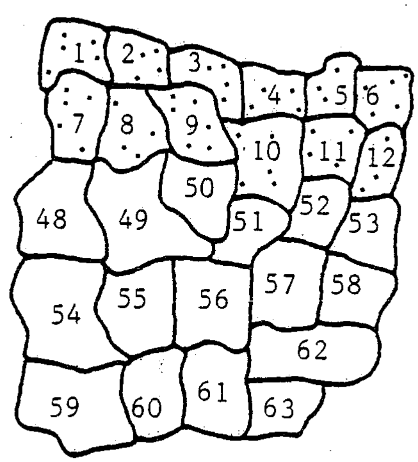


Fig. 4. Each sample unit should have a unique number and be color coded in groups of fifty.

III. Stratification of the Survey Area

A. Stratification is the partitioning of the survey area into several subunits (strata) with each stratum containing SU's of similar moose density but with moose density differing widely among strata.

1. Stratification of the survey area is one of the most IMPORTANT aspects of estimating moose abundance. Without accurate stratification, all time and money spent on the survey will be wasted because an imprecise population estimate will result.

B. Reasons for stratification of the survey area are:

1. The survey area is characterized by heterogeneous moose densities that vary from high moose density in some locations to low or zero moose density in others.

   a. Stratification divides the total moose population in the survey area into subpopulations that are characterized by homogeneous moose densities within each subpopulation (Fig. 5).

   b. When an accurate stratification is achieved, a relatively small sample from each stratum can be used to calculate an estimated moose density for the corresponding stratum. The strata estimates are combined to calculate a total population estimate.

   c. A population estimate from a properly stratified moose population will be more precise than an estimate calculated from a nonstratified population.

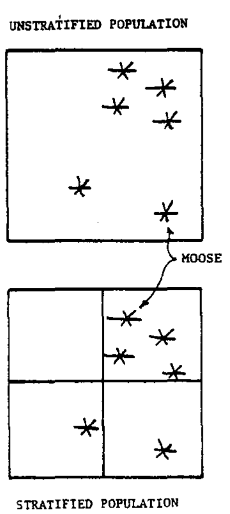


Fig. 5. Stratification is the process of subdividing the moose population into areas of homogeneous moose density.

2. Stratification allows a more precise population estimate to be made with a given amount of effort and dollars because increased sampling effort can easily be applied to strata where the sampling variance is greatest.
   a. The sampling variance among SU's in high density strata is generally greater than in lower density strata. Therefore, the variance can be reduced in the high density stratum by increasing the proportion of the area sampled. The result is a more accurate population estimate.

C. Several strata are generally formed.
1. The number of strata is based largely on the accuracy with which biologists are able to identify areas with homogeneous densities of moose.
   a. Generally, only 3-4 strata can be identified accurately.
2. Suggested possibilities for designations include the following:
   a. High moose density
   b. Medium moose density
   c. Low moose density
   d. Zero moose density
      1) The zero density stratum includes only those portions of the survey area that are non-moose habitat, such as large lakes or glaciated mountains.
3. Moose densities within strata designations are relative values within a particular survey area only.

a. For example, a high density stratum may contain 0.8 moose per mi^2 in one area, while in another area it may contain 3.2 moose per mi^2.

D. The stratification process.

1. In its simplest form, stratification is a process of superficially assessing the relative number of moose in each SU and placing SU's of similar densities into groups called strata.

2. Several biologists will generally participate in the stratification, so it is important for each biologist involved to have a similar concept of the moose density criterion for each stratum.

   a. This is referred to as "calibrating the stratifiers."

   b. Calibrating the stratifiers requires that each biologist be capable of subjectively evaluating moose densities within the census area and assigning SU's with comparable densities to the same strata.

   c. A practical method for calibrating each stratifier is to begin the initial stratification flight with all biologists in one aircraft until each person has a similar concept of the relative moose densities in the various strata and can then assign the same stratum classification to areas of similar moose density.

      1) During the calibration flights, be sure to look at all variations in moose density within the survey area.

a) Begin stratification in those areas that are most familiar and which have the highest and lowest densities.

(1) This method allows all biologists the opportunity to observe and discuss the various strata designations while together in the air.

(2) Once all stratifiers are thinking alike, they can then separate and complete the stratification more rapidly by working independently.

3. Spend the minimum flight time required to ACCURATELY stratify SU's.

a. Spend more time stratifying SU's that are difficult to classify and spend less time in the easy areas. Standardized transect flights over the entire SU are not necessary before stratifying. Remember that the stratification flight is only a superficial survey.

b. The best airplane for stratification is probably a C-185 because it is fast and will carry 2-3 biologists during the initial stratification.

1) Because stratification is essentially a superficial survey it is not necessary to have a slow flying survey aircraft, such as a Super Cub, even after the biologists have been "calibrated." Instead, a faster aircraft is more desirable for the entire stratification process. If the

only aircraft available for stratification is a slow-flying plane such as a Super Cub, have the pilot fly at cruising speed.

4. Stratification is based on a subjective evaluation of moose densities, and this evaluation is based upon any clues that will give an idea of moose density within and between SU's. The following clues should be used during stratification flights:

   a. Prior knowledge of moose distribution.

      1) Before the stratification begins, biologists will have some idea of where the highest and lowest moose densities occur. This knowledge will be based on such factors as previous surveys or habitat distribution.

         a) Since composition survey data from previous years can be used to facilitate stratification, it is a good practice to record the flight routes and locations of moose observed during all future composition surveys (Fig. 6).

   b. The number and distribution of moose seen during the stratification flight.

      1) The relative density of moose observed is usually the most useful clue for stratification. Remember that approximately 70 percent of the moose will be overlooked during stratification so other moose density clues should also be used.

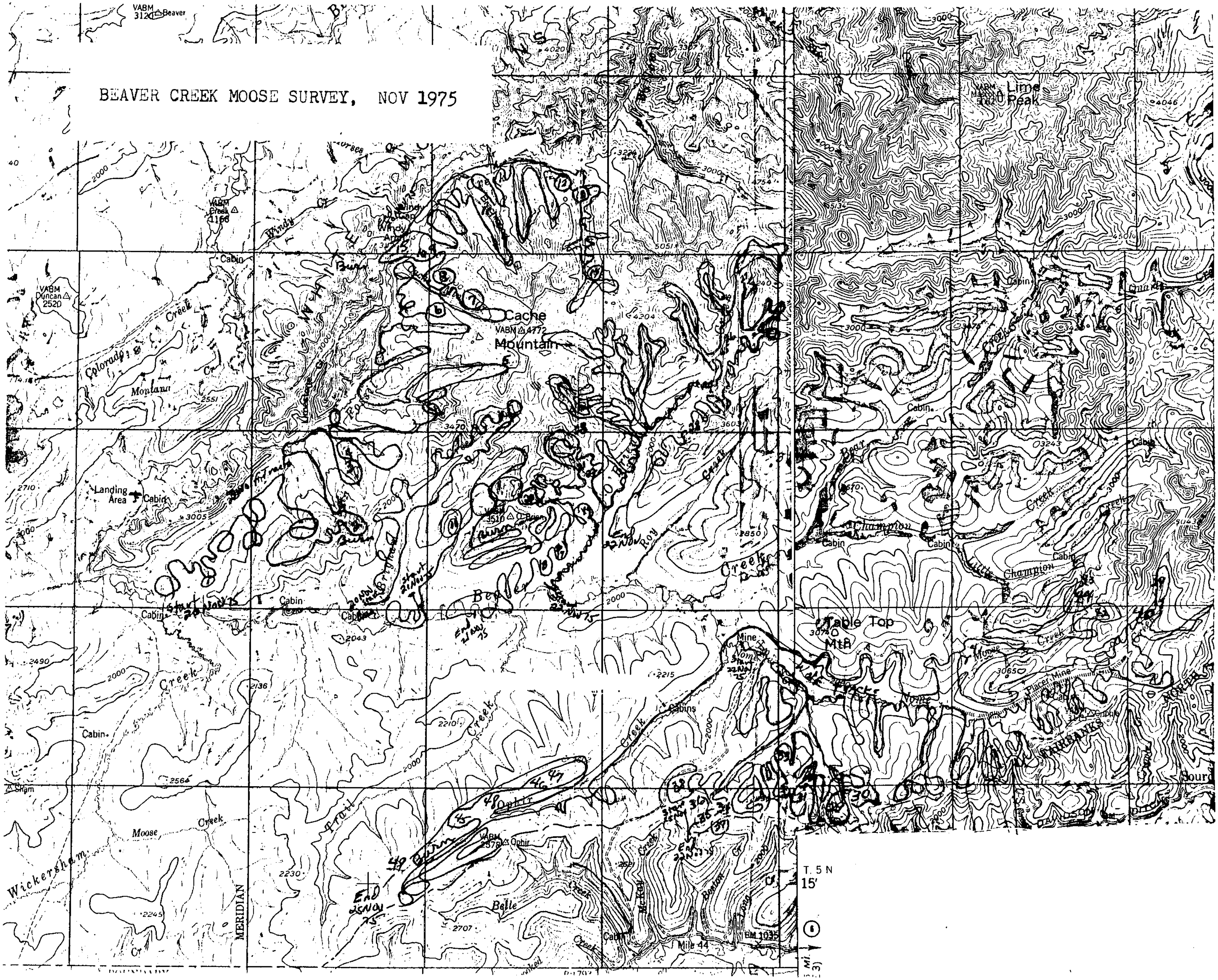


Fig. 6. Flight route and location of moose observed during an aerial survey, November 1975.

c. Density of moose tracks observed.

1) The abundance of moose tracks in an area will give a good clue of moose density if major movements of moose have not occurred since the last snowfall.

d. Quality and extent of moose habitat.

1) Habitat is one of the most important clues used in stratifying. Habitat type is easily observed from aircraft, and habitat type and moose density are often closely related. Ecotones should be used to anticipate significant changes in moose density.

2) Even though habitat is an important clue to moose density, in most situations SU's should not be stratified solely on habitat. Instead, combine habitat clues with direct observations of moose density to arrive at the final stratum classification. For example, a SU may have an abundance of high quality moose habitat, and yet the moose density may be very low. Based on habitat alone, the SU would probably be classified as high or medium moose density. But in reality, it should be classified as low moose density because very few moose actually occur there.

a) Stratification of SU's should be based solely on habitat only when large expanses of a homogeneous habitat type are encountered. A portion of a block of habitat should be stratified using direct observations of moose density and the remainder of the area can be stratified using habitat only.

(1) This procedure is best applied to low density areas only. For example, a 150 mi^2 block of muskeg and black spruce forest may be subdivided into 10 SU's of 15 mi^2 each. The entire area has virtually no moose. The biologist flies over 3 of the SU's noting the poor quality habitat and no moose or moose tracks. He places the 3 SU's in the low density stratum, and if he is confident the remaining 7 SU's also have a comparable low density of moose, he also classifies them as low density without flying over the SU's. These 7 SU's would be stratified based on habitat rather than moose density. SU's stratified solely on habitat should be noted. The reasons for distinguishing between the manner of stratification will

become important when restratification during the survey is discussed later.

5. Some SU boundaries should be redrawn during and after the stratification flight to make the density of moose within SU's more uniform and to minimize problems of moose movement between SU's.

   a. Two situations will arise that require the redrawing of certain SU boundaries.

      1) Some SU's will contain a wide range of moose densities within their boundaries despite the initial attempt to draw SU's having similar moose densities. If it is difficult to assign the SU's to a stratum, redraw the boundaries.

         a) For example, Fig. 7A illustrates 3 SU's (SU A, B, and C) which were drawn using topographic features. During the stratification flight, high densities of moose were observed in the upstream portion of each SU, and low densities of moose were observed in the downstream portion of each SU. The SU's were then redrawn (Fig. 7B) so that all of the high moose density was contained within SU-D. Sample units E and F were then classified as low density, and stratification was simplified and made much more accurate.

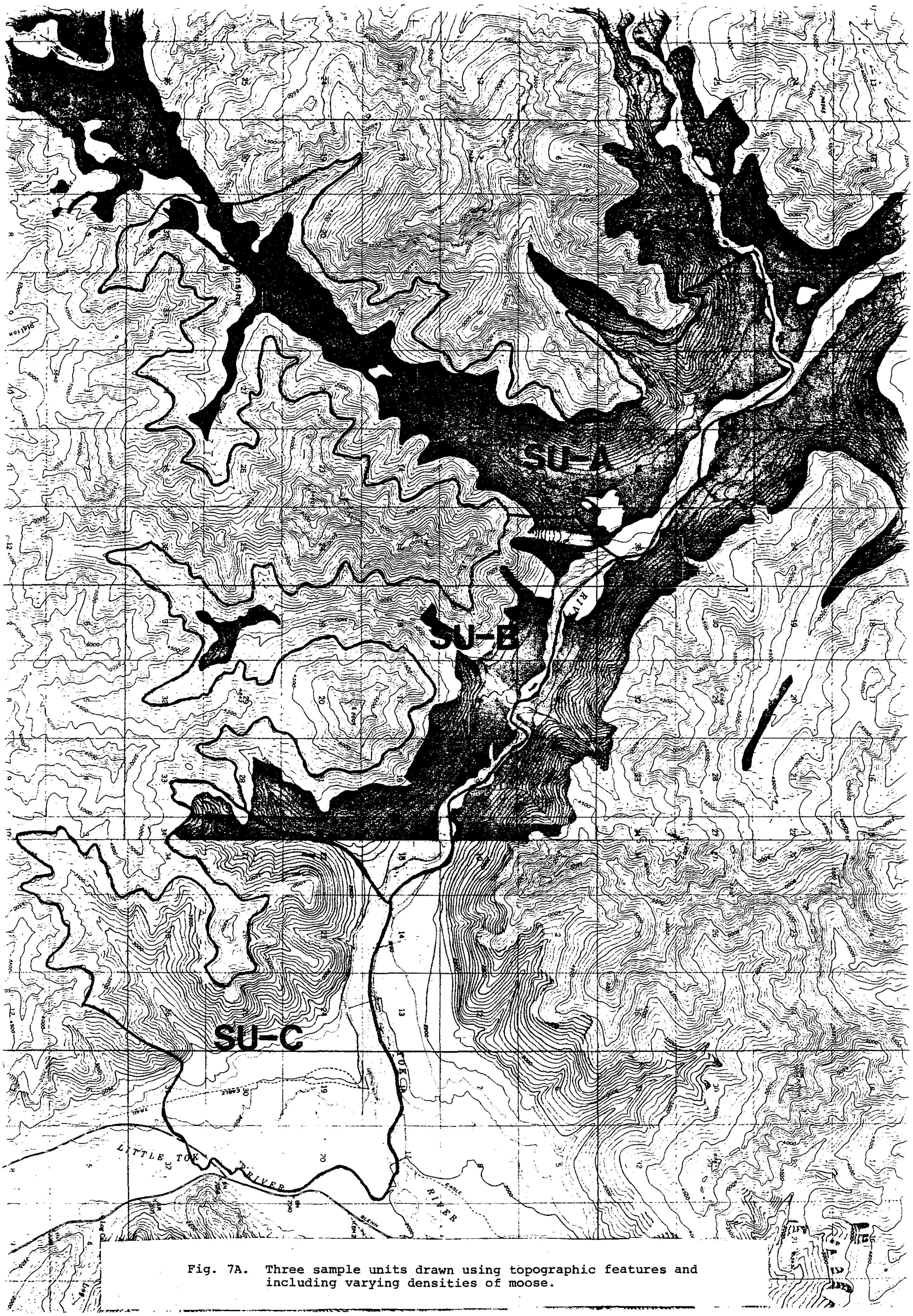


Fig. 7A. Three sample units drawn using topographic features and including varying densities of moose.

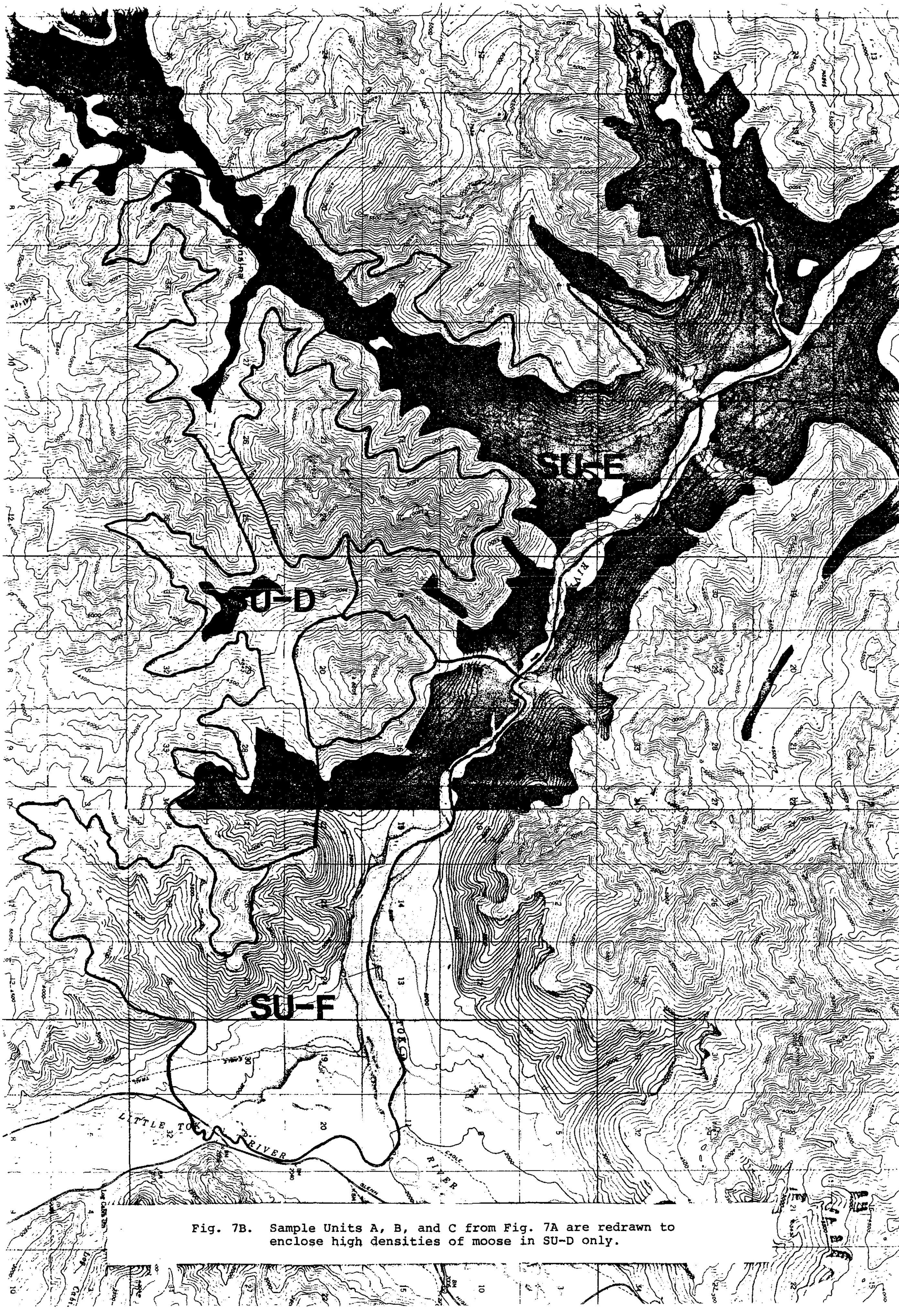


Fig. 7B. Sample Units A, B, and C from Fig. 7A are redrawn to enclose high densities of moose in SU-D only.

2) The second situation requiring the redrawing of SU boundaries occurs whenever concentrations of moose are discovered on or near SU boundaries and the potential exists for moose to move between SU's. Localized movement of moose may occur between adjacent SU's from the time of stratification to the time a SU is surveyed. The problem is most critical for movements of moose from high or medium SU's to low density SU's.

   a) For example, if a high density SU is adjacent to a low density SU, the potential exists for a large number of moose to move across SU boundaries from the high density SU into the low density SU after stratification. If this movement occurred and the low density SU were surveyed, the actual density of this low density SU would be increased well above the average density of the low stratum, and the variance of the population estimate for the low density stratum would be increased. The result would be a less precise population estimate.

   b) Use of the following rule will help alleviate the problem of moose movement between SU's. Never draw SU boundaries near concentrations of moose: redraw SU's when concentrations of moose are found near SU boundaries.

c) Another solution to the problem of moose movement between strata is to include some lower density country within the perimeter of a high density SU whenever movements are anticipated. This area of low density country should help ensure that all moose within a medium or high density SU will still be there when the SU is surveyed.

(1) For example, suppose a burned area of 30 mi^2 is subdivided into two SU's of 15 mi^2, and each SU is stratified as high density. The two high density SU's are surrounded by SU's of black spruce forest that are classified as low density. A large number of moose may utilize the edge of the burn and wander between it and the spruce. Therefore, the best strata boundary would not be the ecotone between the two habitat types but would be somewhere inside the spruce forest thereby including the spruce forest that is influenced by the ecotone within the high density stratum (Fig. 8). A subjective judgment must be made to

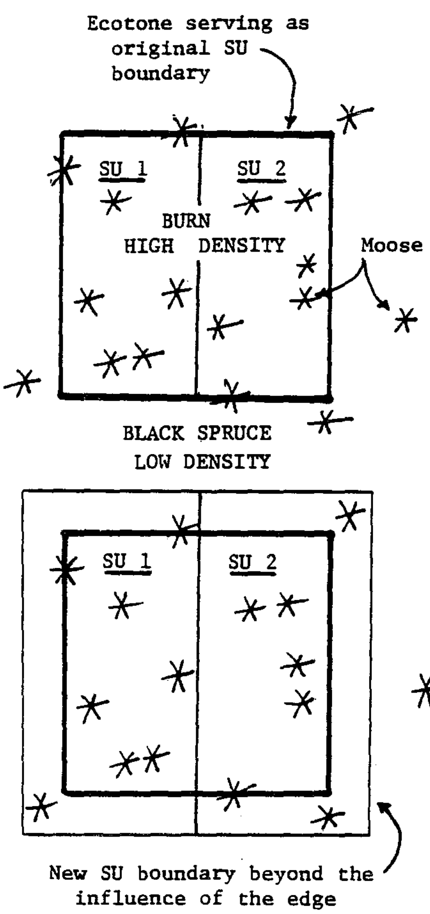


Fig. 8. Example of drawing SU boundaries to accomodate moose movements across strata boundaries.

determine where the influence of the edge grades into true low moose density. This is a difficult line to draw, and we generally recommend extending the higher density SU boundary 0.25 mi or more into the lower density area.

b. Sometimes the lack of identifiable topographic features precludes moving SU and strata boundaries when boundaries go through areas where moose concentrate.

1) An example is where SU's from the low and medium strata are separated by a creek. Usually the center of the creek is the boundary; however, since moose tend to concentrate along the riparian willow, many of the moose associated with the medium density SU could be using the shrubs along either side of the creek. To ensure these moose are counted in the medium density SU, the entire riparian willow strip can be included in the medium SU prior to surveying. This technique is very useful, but remember the decision to include the entire riparian strip <u>must</u> be done prior to observing the distribution of moose in the SU. Bias must be held to a minimum.

a) The simplest way to indicate this special boundary situation is to color the outside

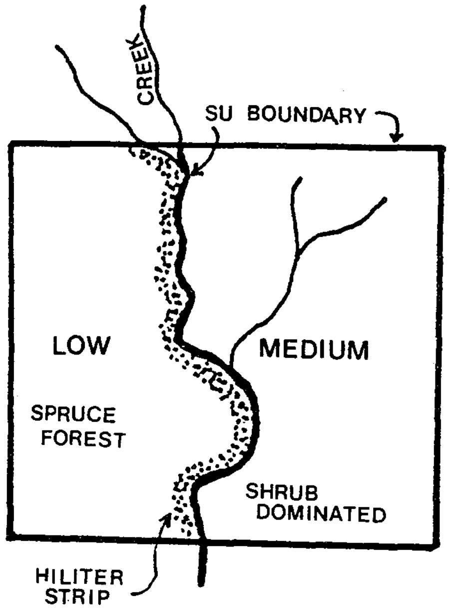


Fig. 9. Special survey conditions along strata boundaries are marked with a colored Hiliter marker.

of the higher density SU boundary with a colored marker (Hiliter) (Fig. 9). The marker can indicate any predesignated situation, i.e., the entire riparian strip, a 50-yard strip beyond the creek, or something similar.

b. Important: Even though many SU's will be redrawn after stratification, drawing all possible SU's prior to stratification is necessary and helps stratification proceed at a rapid pace.

c. To assist in redrawing SU's, flight routes and other notes should be recorded on 1:63,360 topographic maps during the stratification flight.

1) Information such as the location and number of moose observed, notes on habitat, occurrence of tracks, or any other clue that will assist with the stratification should be recorded.

E. Upon completion of the stratification, stratum classifications for SU's are transferred to an acetate overlay that covers the survey area map. Adjustments to SU boundaries made during stratification should also be transferred to the survey area map.

1. Hang the map and acetate overlay on a wall. Use a grease pencil to make notes on the map.

F. Changes in stratification during the survey.

1. Once the survey has begun, additional knowledge may reveal areas that were stratified incorrectly. This information may be gained while flying to and from SU's and while actually surveying SU's.

   a. If an error were made on the initial stratification, the area in question can be restratified even if some of the SU's have already been surveyed. The basis for the initial stratification, i.e., moose density or a non-moose density clue such as habitat, determines the manner in which the correction of the stratification is accomplished.

      1) When the initial stratification was based on observed moose density (i.e., abundance of tracks or numbers of moose seen), then SU's that have been counted prior to the change in boundaries must stay in the initial stratum category. The SU's that have not been surveyed may be changed to a new stratum and sampled at the intensity of the new stratum.

      2) When the initial stratification was based on factors other than observed moose density, then those SU's that have already been surveyed as well as those not yet surveyed may be reclassified to the new stratum.

      3) Therefore, during the stratification it is important to note those SU's that were stratified based on clues other than moose density.

G. Timing of stratification.

1. Stratification should be conducted just prior to the survey.

    a. Wait for proper survey conditions (snow, wind, and light) and then rapidly stratify the area. Begin surveying immediately upon completion of the stratification to minimize moose movements between SU's.

    b. Always survey adjacent SU's consecutively to minimize the effects of moose movements between SU's.

2. Be aware of the migratory movements of moose during the proposed survey period. If moose are migratory at this time, consider rescheduling the survey to a time period when moose are less mobile. If the survey cannot be rescheduled, then stratify and sample as quickly as possible.

H. The timing of moose surveys for moose population estimates conflicts with routine sex and age composition surveys during early winter. Unfortunately, the number of good flying days during early winter is very limited, and biologists may be tempted to conduct composition surveys and stratification flights simultaneously.

    a. The requirements of the two are unique enough that neither the composition survey nor stratification would be adequate if both were done simultaneously. However, if both types of surveys are to be made at nearly the same time, then mapping aggregations of moose during composition surveys first can speed up the stratification.

b. Be aware that sex and age ratios collected during a survey, as described in this manual, are not comparable with ratios obtained during a composition survey. The differences in the data will be discussed later.

IV. Selecting Sample Units

A. SU's to be surveyed are selected by a simple random sampling procedure.

1. From a table of random numbers (Table 1), select SU's by their unique identifying numbers. Sampling is without replacement of SU's selected. List SU's in the order of selection on a sheet of paper. Select more SU's than you think will be needed. Indicate the stratum classification of each SU by placing a symbol (L, M, H) along side each SU number. On a second sheet of paper, arrange in a column all low density SU's listed on the above sheet so that SU's are in the order of selection. Do the same for SU's from the remaining strata.

B. The order in which SU's are surveyed is important.

1. At least five SU's should be surveyed in each stratum, and these SU's can be done in the most efficient order. However, after the first five or a greater predetermined minimum number of SU's to be surveyed, SU's should be surveyed in the order in which they were selected within each stratum. By surveying SU's in the order selected, the survey can be terminated when an adequate population estimate has been attained and a simple random sample of SU's is ensured.

TABLE 1

TEN THOUSAND RANDOM DIGITS

	00–04	05–09	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49
00	88758	66605	33843	43623	62774	25517	09560	41880	85126	60755
01	35661	42832	16240	77410	20686	26656	59698	86241	13152	49187
02	26335	03771	46115	88133	40721	06787	95962	60841	91788	86386
03	60826	74718	56527	29508	91975	13695	25215	72237	06337	73439
04	95044	99896	13763	31764	93970	60987	14692	71039	34165	21297
05	83746	47694	06143	42741	38338	97694	69300	99864	19641	15083
06	27998	42562	63402	10056	81668	48744	08400	83124	19896	18805
07	82685	32323	74625	14510	85927	28017	80588	14756	54937	76379
08	18386	13862	10988	04197	18770	72757	71418	81133	69503	44037
09	21717	13141	22707	68165	58440	19187	08421	23872	03036	34208
10	18446	83052	31842	08634	11887	86070	08464	20565	74390	36541
11	66027	75177	47398	66423	70160	16232	67343	36205	50036	59411
12	51420	96779	54309	87456	78967	79638	68869	49062	02196	55109
13	27045	62626	73159	91149	96509	44204	92237	29969	49315	11804
14	13094	17725	14103	00067	68843	63565	93578	24756	10814	15185
15	92382	62518	17752	53163	63852	44840	02592	88572	03107	90169
16	16215	50809	49326	77232	90155	69955	93892	70445	00906	57002
17	09342	14528	64727	71403	84156	34083	35613	35670	10549	07468
18	38148	79001	03509	79424	39625	73315	18811	86230	99682	82896
19	23689	19997	72382	15247	80205	58090	43804	94548	82693	22799
20	25407	37726	73099	51057	68733	75768	77991	72641	95386	70138
21	25349	69456	19693	85568	93876	18661	69018	10332	83137	88257
22	02322	77491	56095	03055	37738	18216	81781	32245	84081	18436
23	15072	33261	99219	43307	39239	79712	94753	41450	30944	53912
24	27002	31036	85278	74547	84809	36252	09373	69471	15606	77209
25	66181	83316	40386	54316	29505	86032	34563	93204	72973	90760
26	09779	01822	45537	13128	51128	82703	75350	25179	86104	40638
27	10791	07706	87481	26107	24857	27805	42710	63471	08804	23455
28	74833	55767	31312	76611	67389	04691	39687	13596	88730	86850
29	17583	24038	83701	28570	63561	00098	60784	76098	84217	34997
30	45601	46977	39325	09286	41133	34031	94867	11849	75171	57682
31	60683	33112	65995	64203	18070	65437	13624	90896	80945	71987
32	29956	81169	18877	15296	94368	16317	34239	03643	66081	12242
33	91713	84235	75296	69875	82414	05197	66596	13083	46278	73498
34	85704	86588	82837	67822	95963	83021	90732	32661	64751	83903
35	17921	26111	35373	86494	48266	01888	65735	05315	79328	13367
36	13929	71341	80488	89827	48277	07229	71953	16128	65074	28782
37	03248	18880	21667	01311	61806	80201	47889	83052	31029	06023
38	50583	17972	12690	00452	93766	16414	01212	27964	02766	28786
39	10636	46975	09449	45986	34672	46916	63881	83117	53947	95218
40	43896	41278	42205	10425	66560	59967	90139	73563	29875	79033
41	76714	80963	74907	16890	15492	27489	06067	22287	19760	13056
42	22393	46719	02083	62428	45177	57562	49243	31748	64278	05731
43	70942	92042	22776	47761	13503	16037	30875	80754	47491	96012
44	92011	60326	86346	26738	01983	04186	41388	03848	78354	14964
45	66456	00126	45685	67607	70796	04889	98128	13599	93710	23974
46	96292	44348	20898	02227	76512	53185	03057	61375	10760	26889
47	19680	07146	53951	10935	23333	76233	13706	20502	60405	09745
48	67347	51442	24536	60151	05498	64678	87569	65066	17790	55413
49	95888	59255	06898	99137	50871	81265	42223	83303	48694	81953

TABLE 1 (Continued)

TEN THOUSAND RANDOM DIGITS

	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–99
00	70896	44520	64720	49898	78088	76740	47460	83150	78905	59870
01	56809	42909	25853	47624	29486	14196	75841	00393	42390	24847
02	66109	84775	07515	49949	61482	91836	48126	80778	21302	24975
03	18071	36263	14053	52526	44347	04923	68100	57805	19521	15345
04	98732	15120	91754	12657	74675	78500	01247	49719	47635	55514
05	36075	83967	22268	77971	31169	68584	21336	72541	66959	39708
06	04110	45061	78062	18911	27855	09419	56459	00695	70323	04538
07	75658	58509	24479	10202	13150	95946	55087	38398	18718	95561
08	87403	19142	27208	35149	34889	27003	14181	44813	17784	41036
09	00005	52142	65021	64438	69610	12154	98422	65320	79996	01935
10	43674	47103	48614	70823	78252	82403	93424	05236	54588	27757
11	68597	68874	35567	98463	99671	05634	81533	47406	17228	44455
12	91874	70208	06308	40719	02772	69589	79936	07514	44950	35190
13	73854	19470	53014	29375	62256	77488	74388	53949	49607	19816
14	65926	34117	55344	68155	38099	56009	03513	05926	35584	42328
15	40005	35246	49440	40295	44390	83043	26090	80201	02934	49260
16	46686	29890	14821	69783	34733	11803	64845	32065	14527	38702
17	02717	61518	39583	72863	50707	96115	07416	05041	36756	61065
18	17048	22281	35573	28944	96889	51823	57268	03866	27658	91950
19	75304	53248	42151	93928	17343	88322	28683	11252	10355	65175
20	97844	62947	62230	30500	92816	85232	27222	91701	11057	83257
21	07611	71163	82212	20653	21499	51496	40715	78952	33029	64207
22	47744	04603	44522	62783	39347	72310	41460	31052	40814	94297
23	54293	43576	88116	67416	34908	15238	40561	73940	56850	31078
24	67556	93979	73363	00300	11217	74405	18937	79000	68834	48307
25	86581	73041	95809	73986	49408	53316	90841	73808	53421	82315
26	28020	86282	83365	76600	11261	74354	20968	60770	12141	09539
27	42578	32471	37840	30872	75074	79027	57813	62831	54715	26693
28	47290	15997	86163	10571	81911	92124	92971	80860	41012	58666
29	24856	63911	13221	77028	06573	33667	30732	47280	12926	67276
30	16352	24836	60799	76281	83402	44709	78930	82969	84468	36910
31	89060	79852	97854	28324	39638	86936	06702	74304	39873	19496
32	07637	30412	04921	26471	09605	07355	20466	49793	40539	21077
33	37711	47786	37468	31963	16908	50283	80884	08252	72655	58926
34	82994	53232	58202	73318	62471	49650	15888	73370	98748	69181
35	31722	67288	12110	04776	15168	68862	92347	90789	66961	04162
36	93819	78050	19364	38037	25706	90879	05215	00260	14426	88207
37	65557	24496	04713	23688	26623	41356	47049	60676	72236	01214
38	88001	91382	05129	36041	10257	55558	89979	58061	28957	10701
39	96648	70303	18191	62404	26558	92804	15415	02865	52449	78509
40	04118	51573	59356	02426	35010	37104	98316	44602	96478	08433
41	19317	27753	39431	26996	04465	69695	61374	06317	42225	62025
42	37182	91221	17307	68507	85725	81898	22588	22241	80337	89033
43	82990	03607	29560	60413	59743	75000	03806	13741	79671	25416
44	97294	21991	11217	98087	79124	52275	31088	32085	23089	21498
45	86771	69504	13345	42544	59616	07867	78717	82840	74669	21515
46	26046	55559	12200	95106	56496	76662	44880	89457	84209	01332
47	39689	05999	92290	79024	70271	93352	90272	94495	26842	54477
48	83265	89573	01437	43786	52986	49041	17952	35035	88985	84671
49	15128	35791	11296	45319	06330	82027	90808	54351	43091	30387

Table 1 (Continued)

Ten Thousand Random Digits

	00–04	05–09	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49
50	54441	64681	93190	00993	62130	44484	46293	60717	50239	76319
51	08573	52937	84274	95106	89117	65849	41356	65549	78787	50442
52	81067	68052	14270	19718	88499	63303	13533	91882	51136	60828
53	39737	58891	75278	98046	52284	40164	72442	77824	72900	14886
54	34958	76090	08827	61623	31114	86952	83645	91786	29633	78294
55	61417	72424	92626	71952	69709	81259	58472	43409	84454	88648
56	99187	14149	57474	32268	85424	90378	34682	47606	89295	02420
57	13130	13064	36485	48133	35319	05720	76317	70953	50823	06793
58	65563	11831	82402	46929	91446	72037	17205	89600	59084	55718
59	28737	49502	06060	52100	43704	50839	22538	56768	83467	19313
60	50353	74022	59767	49927	45882	74099	18758	57510	58560	07050
61	65208	96466	29917	22862	69972	35178	32911	08172	06277	62795
62	21323	38148	26696	81741	25131	20087	67452	19670	35898	50636
63	67875	29831	59330	46570	69768	36671	01031	95995	68417	68665
64	82631	26260	86554	31881	70512	37899	38851	40568	54284	24056
65	91989	39633	59039	12526	37730	68848	71399	28513	69018	10289
66	12950	31418	93425	69756	34036	55097	97241	92480	49745	42461
67	00328	27427	95474	97217	05034	26676	49629	13594	50525	13485
68	63986	16698	82804	04524	39919	32381	67488	05223	89537	59490
69	55775	75005	57912	20977	35722	51931	89565	77579	93085	06467
70	24761	56877	56357	78809	40748	69727	56652	12462	40528	75269
71	43820	80926	26795	57553	28319	25376	51795	26123	51102	89853
72	66669	02880	02987	33615	54206	20013	75872	88678	17726	60640
73	49944	66725	19779	50416	42800	71733	82052	28504	15593	51799
74	71003	87598	61296	95019	21568	86134	66096	65403	47166	78638
75	52715	04593	69484	93411	38046	13000	04293	60830	03914	75357
76	21998	31729	89963	11573	49442	69467	40265	56066	36024	25705
77	58970	96827	18377	31564	23555	86338	79250	43168	96929	97732
78	67592	59149	42554	42719	13553	48560	81167	10747	92552	19867
79	18298	18429	09357	96436	11237	88039	81020	00428	75731	37779
80	88420	28841	42628	84647	59024	52032	31251	72017	43875	48320
81	07627	88424	23381	29680	14027	75905	27037	22113	77873	78711
82	37917	93581	04979	21041	95252	62450	05937	81670	44894	47262
83	14783	95119	68464	08726	74818	91700	05961	23554	74649	50540
84	05378	32640	64562	15303	13168	23189	88198	63617	58566	56047
85	19640	96709	22047	07825	40583	99500	39989	96593	32254	37158
86	20514	11081	51131	56469	33947	77703	35679	45774	06776	67062
87	96763	56249	81243	62416	84451	14696	38195	70435	45948	67690
88	49439	61075	31558	59740	52759	55323	95226	01385	20158	54054
89	16294	50548	71317	32168	86071	47314	65393	56367	46910	51269
90	31381	94301	79273	32843	05862	36211	93960	00671	67631	23952
91	98032	87203	03227	66021	99666	98368	39222	36056	81992	20121
92	40700	31826	94774	11366	81391	33602	69608	84119	93204	26825
93	68692	66849	29366	77540	14978	06508	10824	65416	23629	63029
94	19047	10784	19607	20296	31804	72984	60060	50353	23260	58909
95	82867	69266	50733	62630	00956	61500	89913	30049	82321	62367
96	26528	28928	52600	72997	80943	04084	86662	90025	14360	64867
97	51166	00607	49962	30724	81707	14548	25844	47336	57492	02207
98	97245	15440	55182	15368	85136	98869	33712	95152	50973	98658
99	54998	88830	95639	45104	72676	28220	82576	57381	34438	24565

Source: Prepared by Fred Gruenberger, Numerical Analysis Laboratory, University of Wisconsin, Madison, Wis., 1952.

Table 1 (Continued)

Ten Thousand Random Digits

	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–99
50	58649	85086	16502	97541	76611	94229	34987	86718	87208	05426
51	97306	52449	55596	66739	36525	97563	29469	31235	79276	10831
52	09942	79344	78160	11015	55777	22047	57615	15717	86239	36578
53	83842	28631	74893	47911	92170	38181	30416	54860	44120	73031
54	73778	30395	20163	76111	13712	33449	99224	18206	51418	70006
55	88381	56550	47467	59663	61117	39716	32927	06168	06217	45477
56	31044	21404	15968	21357	30772	81482	38807	67231	84283	63552
57	00909	63837	91328	81106	11740	50193	86806	21931	18054	49601
58	69882	37028	41732	37425	80832	03320	20690	32653	90145	03029
59	26059	78324	22501	73825	16927	31545	15695	74216	98372	28547
60	38573	98078	38982	33078	93524	45606	53463	20391	81637	37269
61	70624	00063	81455	16924	12848	23801	55481	78978	26795	10553
62	49806	23976	05640	29804	38988	25024	76951	02341	63219	75864
63	05461	67523	48316	14613	08541	35231	38312	14969	67279	50502
64	76582	62153	53801	51219	30424	32599	49099	83959	68408	20147
65	16660	80470	75062	75588	24384	27874	20018	11428	32265	07692
66	60166	42424	97470	88451	81270	80070	72959	26220	59939	31127
67	28953	03272	31460	41691	57736	72052	22762	96323	27616	53123
68	47536	86439	95210	96386	38704	15484	07426	70675	06888	81203
69	73457	26657	36983	72410	30244	97711	25652	09373	66218	64077
70	11190	66193	66287	09116	48140	37669	02932	50799	17255	06181
71	57062	78964	44455	14036	36098	40773	11688	33150	07459	36127
72	99624	67254	67302	18991	97687	54099	94884	42283	63258	50651
73	97521	83669	85968	16135	30133	51312	17831	75016	80278	68953
74	40273	04838	13661	64757	17461	78085	60094	27010	80945	66439
75	57260	06176	49963	29760	69546	61336	39429	41985	18572	98128
76	03451	47098	63495	71227	79304	29753	99131	18419	71791	81515
77	62331	20492	15393	84270	24396	32962	21632	92965	38670	44923
78	32290	51079	06512	38806	93327	80086	19088	59887	98416	24918
79	28014	80428	92853	31333	32648	16734	43418	90124	15086	48444
80	18950	16091	29543	65817	07002	73115	94115	20271	50250	25061
81	17403	69503	01866	13049	07263	13039	83844	80143	39048	62654
82	27999	50489	66613	21843	71746	65868	16208	46781	93402	12323
83	87076	53174	12165	84495	47947	60706	64034	31635	65169	93070
84	89044	45974	14524	46906	26052	51851	84197	61694	57429	63395
85	98048	64400	24705	75711	36232	57624	41424	77366	52790	84705
86	09345	12956	49770	80311	32319	48238	16952	92088	51222	82865
87	07086	77628	76195	47584	62411	40397	71857	54823	26536	56792
88	93128	25657	46872	11206	06831	87944	97914	64670	45760	34353
89	85137	70964	29947	27795	25547	37682	96105	26848	09389	64326
90	32798	39024	13814	98546	46585	84108	74603	94812	73968	68766
91	62496	26371	89880	52078	47781	95260	83464	65942	91761	53727
92	62707	81825	40987	97656	89714	52177	23778	07482	91678	40128
93	05500	28982	86124	19554	80818	94935	61924	31828	79369	23507
94	79476	31445	59498	85132	24582	26024	24002	63718	79164	43556
95	10653	29954	97568	91541	33139	84525	72271	02546	64818	14381
96	30524	06495	00886	40666	68574	49574	19705	16429	90981	08103
97	69050	22019	74066	14500	14506	06423	38332	34191	82663	85323
98	27908	78802	63446	07674	98871	63831	72449	42705	26513	19883
99	64520	16618	47409	19574	78136	46047	01277	79146	95759	36781

2. Some SU's which were selected for surveying may be skipped because of localized bad flying weather or poor snow. Simply replace this SU with the next one on the list from the same stratum which is in an area with suitable weather conditions.

V. Survey Methods and Search Effort

A. Search effort will average approximately 4-5 min/mi^2 for each SU. At this rate, it will be possible to survey approximately one SU per hour plus the flight time required between SU's.

1. The minimum acceptable time is 4 min/mi^2. This search intensity is greater than used on routine aerial composition surveys (Table 2) and requires flight lines at 0.25 mi intervals.

a. Most moose are seen during surveys with 4-5 min/mi^2 search effort during early winter in most moose habitat of Interior Alaska (Table 3, Fig. 10).

b. A high sightability of moose must be maintained during the survey. The best way to assure a high sightability is to maintain a high search intensity to compensate for day-to-day variations in survey conditions and variations in survey conditions between SU's.

Table 2. Time searched per square mile during composition surveys conducted between 1974 and 1980 in Alaska.

Game Management Unit	Mean min per mi sq (Range)		
	Flats	Hills	Mtn. Foothills
20A	1.4(1-1.9)	-	1.9(1.5-2.2)
20B	-	2.1(1.5-3.0)	-
13	0.8	-	1.6 (1.2-2.0)

[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.

Table 3. 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)

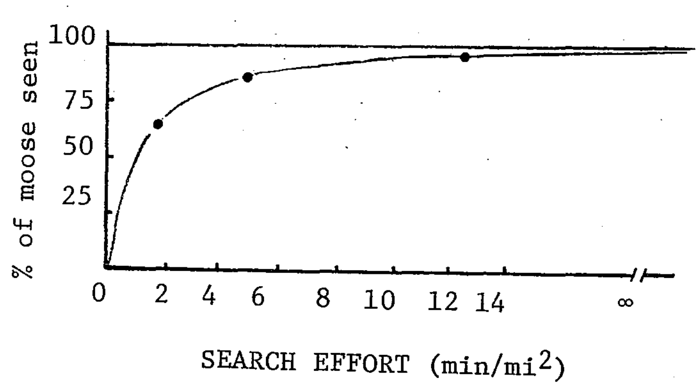


Fig. 10. Sightability of moose during aerial surveys.

2. The appropriate search time for a SU can be calculated by estimating its area in mi^2 from the map and multiplying by 4.5 min/mi^2.

   a. Practice will be required in gauging your flight pattern so as to complete the SU survey in the appropriate time. However, in order to maintain a high sightability of moose, it is better to over search than under search. Practice should occur prior to the survey, and both pilot and observer should be familiar with the technique.

3. The search pattern flown varies with the topography.

   a. Flat land: parallel transects are flown at 0.25 mi intervals.

      1) Transects should be short. Choose a compass heading that is perpendicular to the long axis of the SU.

      2) Short transects allow you and the pilot to stay oriented, i.e., not miss areas or overlap too much.

      3) Estimate the number of transects that should be made during the search, i.e., 4x the length of the SU in miles. Make sure no fewer are flown (Fig. 11).

         a) Predrawing transects on the map before the survey can be helpful in monitoring your progress while in the SU.

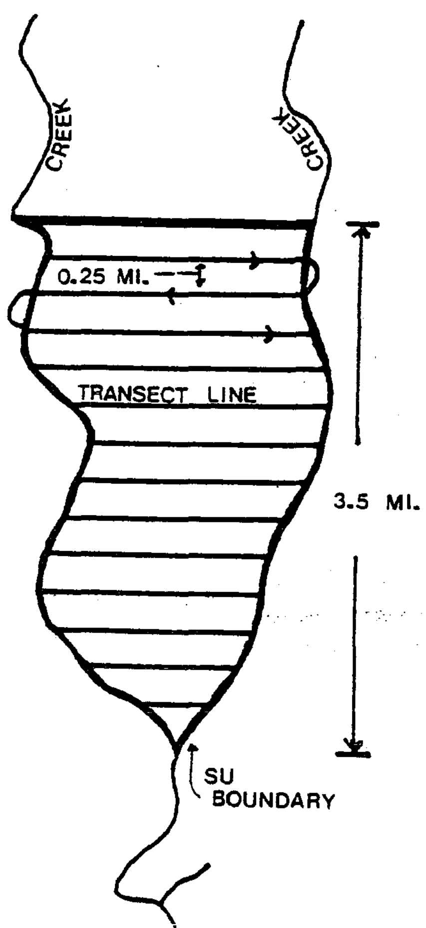


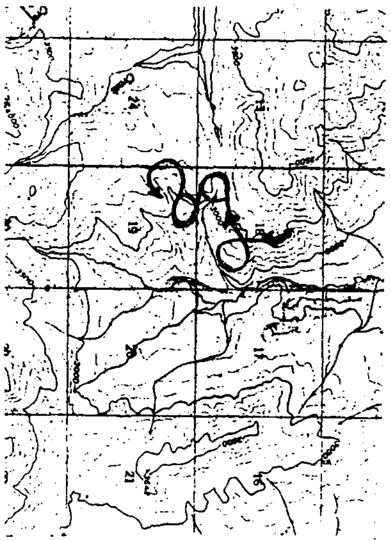
Fig. 11. Flight pattern for sample units in flat terrain.

4) Mark the approximate location of the transect on the map while turning between transects.

5) Mark the location of moose on the map while between transects if time permits.

b. Hills and mountains: the flight path generally follows topographic features and consists of contour routes, circles, and flights along ridges and creeks.

1) Circles are very effective at the heads of valleys and at the ends of ridges (Fig. 12).



igure 12. Circling flight attern in heads of valleys nd ends of ridges.

2) Concentrate search effort out of one side of the plane. This reduces the chance of overlooking a portion of the SU. Generally the down slope side of the plane is preferred (Fig. 13). However, there are many occasions when viewing from the upslope side will be more practical and effective. For example, very steep slopes and the ends of gently rounded ridges are best viewed from the upslope side of the aircraft.

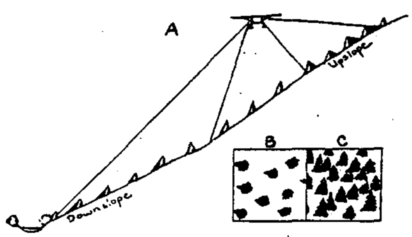


Fig. 13. (A) Amount of hidden ground and perspective of terrain obtained by viewing upslope and downslope during a contour flight; (B) Observer's view downslope illustrating top aspect of trees; and (C) Observer's view upslope illustrating side aspect of trees.

3) The interval between flight lines is approximately 0.25 mi.

c. The pilot's first responsibility is to fly the appropriate search pattern and keep the plane oriented with respect to SU boundaries. But also expect pilots to help look for moose when they can.

VI. Estimating Sightability of Moose with Approximately 4 min/mi^2 Aerial Search Effort

A. Sightability is defined as the percentage of moose seen during an aerial survey.

B. Sightability of moose must be estimated so that the total number of moose present in the survey area can be estimated. Upon completion of the 4 min/mi^2 search of a SU, a search effort of approximately 12 min/mi^2 is repeated in some of the SU's to estimate the total number of moose present. We assume 97 percent of all moose are seen during the intensive search.

1. The sightability correction factor (SCF) is estimated only from those SU's having the two levels of search.

$$\text{SCF} = \frac{\text{\# moose seen during the intensive search}}{\text{\# moose seen during low search effort}} \times 1.03$$

a. The value 1.03 in the above formula is the correction for the 3 percent of the moose that were estimated to have been missed during the intensive search.

b. The SCF will be greater than 1.0 since more moose will be seen with the intensive search.

c. The corrected total moose estimated to be present in the survey area is calculated as follows:

corrected estimate of number of moose = SCF x (estimated no. moose seen during 4 min/mi^2 search effort)

d. This SCF is also used to adjust the confidence interval (CI) of the final population estimate for the survey area. Details for adjusting the CI will be discussed later.

2. Experimental data demonstrate that the number of moose seen on high intensity searches during early winter is a good estimator of the true number of moose present in Interior Alaska.

   a. 97 percent of radio-collared moose were seen with an intensive search effort of approximately 12 min/mi^2 (Table 3).

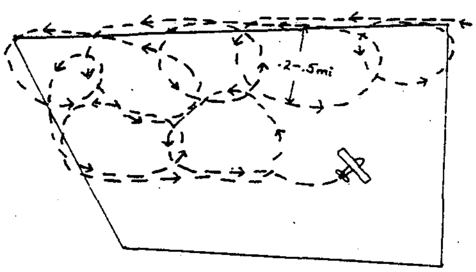
   b. When applying this finding to other areas, habitat selection and social behavior of moose are assumed to be similar. If moose differ significantly in a way that reduces their sightability from those in the experimental area, this assumption cannot be applied. Experimental work with radio-collared moose in many areas would be needed to verify this assumption; however, in the meantime we have incorporated a correction component of 1.03 in the SCF for early winter surveys only.

3. The high intensity search of approximately 12 min/mi^2 uses a different flight pattern than the lower intensity search.

   a. Flat land: a series of continuous slightly overlapping circles or ovals should be flown (Fig. 14).

      1) The pilot is responsible for ensuring <u>all</u> surface area has been viewed.

      2) The radii of circles should be 0.2-0.3 mi. As vegetational canopy height and density increase, the turning radius should decrease.



igure 14.
light pattern (top view) used during intensive search of lat terrain illustrating the elongated, overlapping parallel ircling pattern to ensure complete coverage of a quadrat.

3) Observations are made from the low wing side.

b. Hills and mountains: Fly close contours and make frequent circles. This search pattern is similar to that used for the SU except contours are closer and circling is more frequent.

4. Selection of high intensity search plots.

a. Approximately 20 plots should be intensively searched.

b. Plots are located within SU's from the high and medium density strata only.

1) Select a random sample of 20 SU's from those previously selected for the survey.

2) Divide each of these 20 sample units into approximately four quarters and randomly select one quarter from each SU. The plot to be intensively searched should be located in this quarter.

3) Area of plots should be approximately 2 mi^2 so as not to take more than 0.5 hours to search.

4) The exact plot boundaries will be identified from the air immediately prior to searching the SU. Upon completion of the search at an intensity of approximately 4 min/mi^2, the plot is intensively searched at 12 min/mi^2.

5) Moose observed in the SU's must be mapped accurately with reference to the plot boundaries during the low and high intensity searches.

6) Do not search the plot with different effort during the low intensity search than you normally would use for the low intensity.

7) Do not inform the pilot of the location of the plot until it is time for the high intensity search.

5. The SCF should be calculated on a daily basis and maintained at a mean value of no greater than 1.18 during early winter surveys.

   a. Increase the initial search effort in future SU's to increase sightability.

   b. SCF of 1.06 has been achieved in Alaska although the financial expense required to produce a very low SCF may be prohibitive in many areas.

VII. Recording Observations on the Moose Survey Form (Forms 1 and 2)

A. Routine information includes the following:

1. Sample unit number
2. Date
3. Start and stop time of the sample unit survey
4. Page
5. Location
6. Weather

B. Additional information includes:

1. Habitat description

   a. The dominant habitat within the SU should be classified as one of two major types, with further subdivisions under each general category as follows:

FORM 1

MOOSE SURVEY FORM FOR POPULATION ESTIMATION

SAMPLE UNIT No.________ Date________ Start Time________ Stop Time________ Page___of___

Location: map ________ Pilot/Observer________

Location description________

Habitat description________

Weather:________

SNOW Age: Fresh____ Moderate____ Old____

Cover: Complete____ Some low veg showing____ Distracting amounts of bare ground showing____ Snow on trees and shrubs____

Estimated Sample Unit Area ______ mi^2

Measured Sample Unit Area ______ mi^2

Type of Survey: / / 4-5 mim/mi^2 / / Intensive

Time of Search: ____ 4-5 min/mi^2 ____ Intensive

Remarks________

	Agg. No.	BULLS/activ. vrlg	med	lge	COWS/activ. W/O calf	W/1 calf	W/2 calf		UNIDENT	Total Moose	HABITAT
	1										H LS TS D SS S L
	2										H LS TS D SS S L
	3										H LS TS D SS S L
	4										H LS TS D SS S L
	5										H LS TS D SS S L
	6										H LS TS D SS S L
	7										H LS TS D SS S L
	8										H LS TS D SS S L
	9										H LS TS D SS S L
	10										H LS TS D SS S L
	11										H LS TS D SS S L
	12										H LS TS D SS S L

Total Moose=

FORM 2

MOOSE SURVEY FORM FOR POPULATION ESTIMATION

SAMPLE UNIT No. 352 Date 11/16/78 Start Time 1031 Stop Time 1143 Page 1 of 1

Location: map Fairbanks A-1 Pilot/Observer Haggland / DuBois

Location description South Bank Tanana R

Habitat description low shrub dominated - Burn

Weather: Clear, +30°F, 8 mph wind

SNOW Age: Fresh___ Moderate ✓ Old___

Cover: Complete ✓ Some low veg showing___ Distracting amounts of bare ground showing___ Snow on trees and shrubs___

Estimated Sample Unit Area ______ mi^2

Measured Sample Unit Area ______ mi^2

Type of Survey: ✓ 4-5 mim/mi^2 11 Intensive

Time of Search: 72 4-5 min/mi^2 ___ Intensive

Remarks ______________________

Agg. No.	BULLS/activ. yrlg	BULLS/activ. med	BULLS/activ. lge	COWS/activ. W/O calf	COWS/activ. W/1 calf	COWS/activ. W/2 calf		UNIDENT	Total Moose	HABITAT
1				3/L					3	H LS TS D SS S L
2					1/L				2	H LS TS D SS S L
3					1/L				2	H LS TS D SS S L
4					1/L				2	H LS TS D SS S L
5						1/S			3	H LS TS D SS S L
6	1/L								1	H LS TS D SS S L
7				1/S					1	H LS TS D SS S L
8					1/L				2	H LS TS D SS S L
9					1/L				2	H LS TS D SS S L
10						1/L			3	H LS TS D SS S L
11	EXAMPLE									H LS TS D SS S L
12										H LS TS D SS S L

Total Moose= 21

1) shrub-dominated

a) recent burn

b) subalpine

2) forest-shrub mixture

a) shrub-dominated forest (greater than 50% shrub)

b) deciduous-dominated forest (greater than 50% forest)

c) spruce-dominated forest

2. Snow conditions

a. Snow conditions have a profound influence on moose sightability (Table 4). Snow conditions should be classified based on the following subjective components.

1) age of the snow

a) fresh

b) moderate

c) old

2) snow cover

a) complete

b) some low vegetation showing

c) distracting amounts of bare ground or herbaceous vegetation showing

d) fresh snow on trees and shrubs

3) a combination of snow cover and age can be used to rank the quality of snow conditions in each sample unit as good, moderate, or poor (Table 5).

Table 4. The influence of activity, habitat selected by moose, and search intensity on the sightability of moose during aerial surveys under good, moderate, and poor snow conditions.

	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.

Table 5. 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

a) We do not recommend surveys be conducted when snow conditions are ranked as poor.

3. Habitat use by moose can be evaluated during this survey.

a. Any habitat classification system familiar to the observers will work.

b. We use the following habitat categories in our work:

1) herbaceous

2) low shrub--shrubs up to 6 feet in height

3) tall shrub--shrubs greater than 6 feet in height

4) deciduous forest

5) sparse spruce forest

6) spruce forest

7) larch forest

c. The survey form has a check list of these habitat types for each aggregation of observed moose. An X can be placed over the habitat used, and habitats available can be circled (Form 2).

5. Moose spotted during SU surveys should be recorded by aggregations.

6. The activity of moose on the initial sighting can be recorded as lying or standing by putting a S or L below the number of moose seen (Form 2).

VIII. Calculation of the Moose Population Estimate and Confidence Interval

A. The calculated population estimate is the number of moose that could have been seen if the entire survey area had been searched at approximately 4-5 min/mi^2. This calculation results in an underestimation of the number of moose present in the survey area because some moose were missed during the survey. The SCF will be incorporated in the population estimate later to correct for those moose not seen.

B. The population estimate and its variance is obtained by estimating the number of moose and variance for each stratum and then summing all strata estimates to arrive at the total for the survey area. Formulas are presented in this section that show how to calculate estimates for only one stratum. The next section combines estimates for strata into estimates for the entire survey area.

1. The following symbols are used in the calculation of each individual stratum population estimate and variance.

A = total surface area (square miles) in a particular stratum

y_i = number of moose in the i^{th} SU

x_i = number of square miles in the i^{th} SU

$\bar{x}$ = mean size of all SU's surveyed in a particular stratum

n = number of SU's selected in a particular stratum

N = total number of SU's in a particular stratum

$\hat{T}$ = total population estimate for a particular stratum

a. Prior to performing any calculations, determine the total area per stratum (A) and the number of square miles in each SU (x_i) that was surveyed.

1) Solve for A by adding the areas of all SU within each stratum.

2) The area of each SU (x_i) can be easily estimated in the field by counting the 1 mile square sections on the map.

3) The area of each SU (x_i) should be determined with a polar compensating planimeter before final calculations are made.

a) This task is simplified by tracing the perimeter of each SU onto a piece of tracing paper rather than attempting to operate the planimeter directly on the map.

2. The following calculations will be performed for each stratum:

a. The density of moose for each stratum (r) is the number of moose per square mile.

$$r = \frac{\text{total no. of moose observed in all SU's that were surveyed}}{\text{total surface area of all SU's (mi}^2\text{) that were surveyed}} = \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} x_i}$$

b. The population estimate for each stratum.

T = density of moose X total surface area of the stratum

<u>or</u>

$$\hat{T} = r \cdot A$$

c. Variance $\{V(\hat{T})\}$ for the stratum population estimate.

$$V(\hat{T}) = A^2 \cdot \left[\frac{1}{\bar{x}^2} \cdot \frac{s_q^2}{n} \left(1 - \frac{n}{N}\right)\right]$$

1) $1 - \frac{n}{N}$ = Finite Population Correction Factor

a) One advantage of using a simple random sample versus other sampling types (i.e., sampling proportional to size of SU's) is that a finite population correction factor can be incorporated into the calculations. The finite population correction factor reduces the variance of the estimate as the number of SU's surveyed increases.

2) In order to solve for $V(\hat{T})$ it is first necessary to solve for s_q^2 as follows:

$$s_q^2 = \frac{\Sigma \begin{matrix}\text{No. of moose}\\ \text{in each SU}\end{matrix}^2 - 2r \cdot \Sigma \begin{matrix}\text{Surface area}\\ \text{of each SU}\end{matrix} \times \begin{matrix}\text{No. moose in the}\\ \text{corresponding SU}\end{matrix} + r^2 \cdot \Sigma \begin{matrix}\text{Surface area}\\ \text{of each SU}\end{matrix}^2}{n - 1}$$

OR

$$s_q^2 = \frac{\sum_{i=1}^{n} y_i^2 - 2r \cdot \sum_{i=1}^{n} x_i\, y_i + r^2 \sum_{i=1}^{n} x_i^2}{n-1}$$

The value of s_q^2 can then be inserted into the variance formula to solve for V(T).

C. The population estimate $(\hat{T}_t)$ uncorrected for sightability and the variance of the population estimate $\{V(\hat{T}_t)\}$ for the entire survey area are determined by summing estimates for individual strata.

1. Total population estimate = Σ strata population estimates

$$\hat{T}_t = \hat{T}_h + \hat{T}_m + \hat{T}_\ell = (r_h \cdot A_h) + (r_m \cdot A_m) + (r_\ell \cdot A_\ell)$$

where h = high density stratum, m = medium, and ℓ = low

2. Variance of the population estimate = Σ variance of the strata population estimates

$$V(\hat{T}_t) = V(\hat{T}_h) + V(\hat{T}_m) + V(\hat{T}_\ell) = [A^2_h \cdot V(r_h)] + [A^2_m \cdot V(r_m)] + [A^2_\ell \cdot V(r_\ell)]$$

D. Calculation of the confidence interval (CI) for the population estimate of the survey area.

1. An estimate of the number of moose is useful to the biologist; 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, a range of values or interval in which the true value is likely to lie can be described. This interval is the confidence interval, and the specification of such an interval is as important in moose population estimation as the estimation of the number of moose (Simpson, G. G., A. Roe, and R. C. Lewontin. 1960. Quantitative Zoology. Harcourt, Brace and Co., NY. 440pp.)

   a. A CI gives you a known probability that the true number of moose lies within that interval. The known probability is the α level used in calculating the CI. Unfortunately, as the CI 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.

b. It is solely up to the wildlife biologist to choose the level of confidence for each case. Ideally, a narrow CI with a high probability of containing the true number of animals is desired, such as a 95 percent CI which is $\pm$ 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.

c. We recommend striving for precision equal to or greater than a 90 percent CI which has outer limits of $\pm$ 20 percent of the population estimate.

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

2. CI = Total population estimate ± $(t_{\alpha,v})\sqrt{\text{variance of the total population estimate}}$

$$CI = \hat{T}_t \pm t_{\alpha,v}\sqrt{V(\hat{T}_t)},$$ where t is the Student's t value for a specified probability

a. Table 6 lists Student's t probabilities for confidence intervals used for determining $t_{(\alpha,v)}$

b. The degrees of freedom (v) are calculated as follows:

$$v = \frac{[V(\hat{T}_t)]^2}{\frac{[V(\hat{T}_h)]^2}{n_h-1} + \frac{[V(\hat{T}_m)]^2}{n_m-1} + \frac{[V(\hat{T}_\ell)]^2}{n_\ell-1}}$$

where n_h, n_m, and n_ℓ are the number of sample units flown in the high, medium, and low strata, respectively.

c. α is the probability level.

3. Evaluation of the CI for the total population estimate of the survey area (or, how precise was the population estimate).

a. $$\frac{\left(\text{total population estimate}\right) - \left(\text{lower end of CI}\right)}{\text{Total population estimate}} = \text{\% of population estimate}$$

$$\frac{\hat{T}_t - CI_L}{\hat{T}_t} = \text{\% of population estimate}$$

TABLE 6. Cumulative Student's t distribution. The body of the table contains values of Student's t; n is the number of degrees of freedom.

Probabilities for confidence intervals

n	.9	.95
1	6.314	12.706
2	2.920	4.303
3	2.353	3.182
4	2.132	2.776
5	2.015	2.571
6	1.943	2.447
7	1.895	2.365
8	1.860	2.306
9	1.833	2.262
10	1.812	2.228
11	1.796	2.201
12	1.782	2.179
13	1.771	2.160
14	1.761	2.145
15	1.753	2.131
16	1.746	2.120
17	1.740	2.110
18	1.734	2.101
19	1.729	2.093
20	1.725	2.086
21	1.721	2.080
22	1.717	2.074
23	1.714	2.069
24	1.711	2.064
25	1.708	2.060
26	1.706	2.056
27	1.703	2.052
28	1.701	2.048
29	1.699	2.045
30	1.697	2.042
40	1.684	2.021
60	1.671	2.000
120	1.658	1.980
∞	1.645	1.960

IX. Sample Calculations of a Population Estimate

A. The following data were collected during a 1978 survey of the Tanana Flats, Alaska.

Table 7. Moose survey data for the Tanana Flats, November 1978.

	Stratum					
	Low		Medium		High	
Sample Unit	Moose (no.) (y)	Area (mi^2) (x)	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
Total Area Per Stratum (A)		1144.0		1388.0		294.0
Total SU possible Per Stratum (N)		74.0		93.0		19.0

B. Population estimate and variance for low density stratum

1. Ratio estimator of moose density

$$r_\ell = \frac{17 \text{ moose observed in low density SU's}}{125.1 \text{ mi}^2 \text{ surveyed in low density stratum}}$$

$$r_\ell = 0.136 \text{ moose/mi}^2 \text{ in the low density stratum}$$

2. Population estimate

$$\hat{T}_\ell = (0.136 \text{ moose/mi}^2)\ (1144 \text{ mi}^2 \text{ in low density stratum})$$

$$\hat{T}_\ell = 156 \text{ moose in low density stratum}$$

3. Variance of the population estimate, $V(\hat{T}_\ell)$

First solve for s_q^2 in the variance formula

$$s_q^2 = \frac{[(7)^2 + (4)^2 + (0)^2 + (4)^2 + (2)^2] - \{2(0.136) \times [(7x22.1) + (4x35.0) + (0x20.1) + (4x29.6) + (2x18.3)]\} + \{(0.136)^2 \times [(22.1)^2 + (35.0)^2 + (20.1)^2 + (29.6)^2 + (18.3)^2]\}}{5-1}$$

$$s_q^2 = \frac{85 - 122.318 + 59.912}{4}$$

$s_q^2 = 5.649$, use this value to solve for $V(\hat{T}_\ell)$

$$V(\hat{T}_\ell) = (1144)^2 \left[\frac{1}{(25.020)^2} \times \frac{5.649}{5}\left(1 - \frac{5}{74}\right)\right]$$

$$V(\hat{T}_\ell) = (1144)^2\ [0.002 \times 1.130\ (0.932)]$$

$$V(\hat{T}_\ell) = (1144)^2\ [0.002]$$

note: $V(r) = 0.002$

$$V(\hat{T}_\ell) = 2617$$

note: The variance may differ somewhat depending on the number of significant digits used in rounding; however, this will not cause significant errors in the calculations.

C. Population estimate and variance for the medium density stratum

1. $r_m = 0.379$ moose/mi^2
2. $\hat{T}_m = 526$ moose
3. $V(\hat{T}_m) = 7706$
   a. $s_q^2 = 11.236$

D. Population estimate and variance for the high density stratum

1. $r_h = 1.462$ moose/mi^2
2. $\hat{T}_h = 430$ moose

3. $V(\hat{T}_h) = 1556$

   a. $s_q^2 = 26.197$

E. Total population estimate and variance for the Tanana Flats survey area (uncorrected for sightability)

1. $\hat{T}_t = 156 + 526 + 430$

   $\hat{T}_t = 1112$ total moose

2. $V(\hat{T}_t) = 2617 + 7706 + 1556$

   $V(\hat{T}_t) = 11{,}879$

F. Calculation of the CI for the total population estimate of the survey area.

1. $CI = 1112 \pm 1.746 \sqrt{11{,}879}$

   $CI = 1112 \pm 190$

2. The total population estimate is between 922 and 1302 moose (still uncorrected for sightability)

G. Evaluation of the CI for the total population estimate of the Tanana Flats survey area.

1. $\dfrac{1112 - 922}{1112} = 17\%$ of the population estimate

H. Sightability correction of total population estimate and variance.

1. Correction of the estimate for sightability was discussed in Section VI and is calculated at this point. Simply multiply the SCF times the population estimate and the CI.

X. Hewlett-Packard 97 Moose Survey Program will make all Calculations for the Population Estimate

A. The following description is a step-by-step procedure for calculating the survey area population estimate and variance, with the HP 97 calculator.

1. Put HP 97 on "Run" and "Man" and turn "On."
2. Load program card number 1 on side 1 and push A.
3. Load program card number 2 on side 1 and side 2, then push A.
   a. The display will read "10.0" and indicates that the HP 97 is ready for step 4.
4. Enter total surface area (A) of the first stratum and push R/S.
5. Enter the total number of possible SU's (N) in the first stratum and push R/S.
6. Enter the number of moose observed in the first SU surveyed (y) for the stratum and push R/S.
7. Enter the number of square miles in the first SU surveyed (x) for the stratum and push R/S.
   a. Display will read the number of SU's entered as each set of y and x data is entered.
8. Repeat step 6 and 7 until y and x have been entered for all SU's surveyed in the first stratum (HP 97 will handle a maximum of x = 50 per stratum).
9. Push B and HP 97 prints the following parameters of the first stratum.
   a. r
   b. $\hat{T}$

c. $V(r)$

d. $V(\hat{T})$

10. Display will read "10" and indicates that the HP 97 is ready for steps 4-9 again for the next stratum.

    a. Repeat steps 4-9 for each stratum.

    b. The program will handle a total of 5 strata in this procedure.

11. When the data have been entered for all strata, push C and the HP 97 will print the following:

    a. $\hat{T}_t$

    b. $V(\hat{T}_t)$

    c. v

12. The display now reads "20." This is an indication to select either the 90 or 95 percent confidence level. Enter either 90 or 95 and push R/S. The HP 97 prints the following:

    a. 90 or 95

    b. $t_{\alpha,v}$

       1) The program will calculate ± values when $v \geqq 4$.

    c. CI - upper end

    d. CI - lower end

    e. CI as a % of the population estimate

13. The display now reads "30." Enter the ratio of number of moose seen during high intensity searches of SU's divided by number of moose seen during low intensity searches of SU's and push R/S (assume 1.15 for this example).

14. Enter the correction factor for percentage of moose missed during high intensity searches of SU's and push R/S.
    a. Use a correction factor of 1.03 for October-November surveys.
    b. Use a correction factor of 1.09 for February, March, and April surveys.
    c. HP 97 prints the following parameters:
        1) Corrected $\hat{T}_t$
        2) Corrected CI - upper end
        3) Corrected CI - lower end
15. HP 97 displays "40" to indicate that the program is finished.
    a. To recycle the program, simply push A and return to step 4.

B. The results of the HP 97 may vary from calculations performed by hand on a desk calculator. However, these variations will only produce small changes in the total population estimates (approx. 2-4 moose/1000 moose in the final estimate).
    1. These discrepancies are due to the rounding difference that may occur between hand calculations and the HP 97 program.
        a. The HP 97 performs all calculations with numbers carried 10 decimal places and exponents through 2 digits even though the display may indicate only 2 decimal places.

C. The following is a sample HP 97 population estimation program using the data in Table 8.

Table 8. Sample print out from HP 97 population estimation program.

LOW	A	1144.0	***
	N	74.	***
	y	7.	***
	$\bar{x}$	22.1	***
		4.	***
		35.0	***
		0.	***
		20.1	***
		4.	***
		29.6	***
		2.	***
		18.3	***
	r	0.136	***
	$\hat{T}$	155.	***
	$V(r)$	0.0019	***
	$V(\hat{T})$	2363.	***
MEDIUM		1388.0	***
		93.	***
		3.	***
		8.2	***
		13.	***
		14.3	***
		4.	***
		12.1	***
		0.	***
		14.4	***
		6.	***
		9.6	***
		11.	***
		27.7	***
		5.	***
		16.4	***
		5.	***
		16.2	***
		6.	***
		21.1	***
		4.	***
		10.4	***
		0.379	***
		526.	***
		0.0044	***
		8462.	***

HIGH		294.0	***
		19.	***
		21.	***
		13.6	***
		27.	***
		20.6	***
		2.	***
		6.2	***
		15.	***
		10.8	***
		25.	***
		16.0	***
		24.	***
		10.8	***
		1.462	***
		430.	***
		0.0177	***
		1534.	***
	$\hat{T}_t$	1111.	***
	$V(\hat{T}_t)$	12359.	***
	ν	16.	***
	C.I.	90.	***
	t	1.746	***
	CI-up	1305.	***
	CI-low	917.	***
	%	17.5	***
	SCF	1.15	***
		1.03	***
CORRECTED	$\hat{T}_t$	1316.	***
	CI-up	1546.	***
	CI-low	1086.	***

XI. Optimum Allocation of Search Effort (or how to get the most accurate population estimate for your dollar)

A. Optimum allocation of search effort is the process of distributing the available survey time in the most efficient manner to produce the best possible population estimates.

1. Optimum allocation of search effort involves monitoring the variance of each stratum as the survey progresses, and adjusting the number of SU's to be surveyed to produce the smallest variance in each stratum.

2. Discussion of optimum allocation was delayed until this point because it is advantageous to first understand how to calculate the population estimate. However, optimum allocation must be considered much earlier in the survey process, and the allocation of SU's is continually revised during the survey.

B. Adjustment of the sampling effort among strata is accomplished by calculating strata variances as soon as at least 3-5 SU's have been surveyed in each stratum. Strata with the largest variances will receive a higher proportion of the remaining sampling effort.

1. Use the HP 97 to calculate variances.

a. For example, a survey is being conducted on the Tanana Flats and economics dictate that a maximum of 50 SU's can be surveyed. After 2 days of flying, the first 21 SU's to be surveyed produced the following strata variances:

1)

Density	No. SU's Surveyed	Stratum Variance
High	6	1556
Medium	10	7706
Low	5	2617

2) By calculating the variance for each stratum based on the first 21 SU's, it is apparent that the largest variance is produced from the medium density stratum.

3) At this point, the biologist has 29 SU's remaining to produce the best possible population estimate.

4) Even though the medium density stratum has received over 50 percent of the first 21 SU's, it is apparent that the greatest variation in moose density occurs there. Therefore, even greater sampling effort must be directed into that stratum in an attempt to reduce its variance.

C. The process of reapportioning sampling effort is influenced by the rate that the survey is progressing and the variation in observed moose density within strata. But, in order to maintain optimum allocation of sampling effort, the variance within strata should be calculated as frequently as deemed necessary (usually daily).

XII. Precision of the Population Estimate

A. No estimate of numbers of moose will be absolutely accurate. Several sources of error exist which always cause a discrepancy between the estimated and the true number of moose.

1. Sampling error

   a. If the entire area were searched, there would be no need for sample units and no sampling error would exist. However, we are conducting surveys in areas too large for total count procedures.

   b. The mean density of moose found in the area sampled will always differ slightly from the true density, but it will approach the true density as the number of sample units increases.

2. Error in sightability estimate

   a. We see less than 100 percent of the moose; therefore, a sightability correction factor must be estimated. The estimated SCF is not exact.

3. Errors in calculations

   a. The area of each stratum cannot be measured exactly, thus an error of several percent could result from this source alone.

B. How accurate is the estimate? Since you can never know the true density of number of moose, you cannot directly evaluate the quality of the estimates.

   1. However, a probability that the true value is within a certain range of the estimated value can be assigned. This is the CI.

      a) As the CI decreases at a particular probability, you have reason to develop increasing confidence in the accuracy of the estimate.

C. Ways to improve accuracy

1. Choose a SU area which minimizes variation between SU.
2. Stratify accurately.
3. Maintain a search effort which provides a high sightability.
4. Spend the effort to make a good estimate of sightability of moose.
5. Practice survey procedures prior to the survey.
6. Fly when the weather and snow conditions are acceptable to reduce variation in sightability of moose.

XIII. Experience and Currency of Pilots and Observers

A. All personnel piloting or observing should be trained in the methods to ensure consistency among survey teams.

1. Biologists and pilots should practice methods prior to the survey, so proper search effort and search pattern can be used from the first SU counted. Locating boundaries of SU's requires a little practice. The pilot is primarily responsible for maintaining the flight path within the SU while searching. The pilot must be able to read 1:63,360 scale maps on a very detailed basis.
2. Pilots should be fully briefed on reasons for the survey, overall methods, type of search pattern to be flown, expected results of the survey, and the importance of their participation in achieving a precise population estimate.

Free flowing communication should start prior to flying and continue during the survey. Pilot and observer should discuss the search pattern and flying techniques early in the survey, so an effective team is built. Observers are often reluctant to tell the pilot to alter the flight pattern, and similarly, pilots are often unsure of what is expected of them because of poor directions from the observer. Teamwork is built by communications--so talk!

3. Periodic breaks during the day will help reduce fatigue and maintain good counting efficiency. Take a short break every 2 hours or so if possible. A good survey requires that you are mentally sharp during the search of SU's. Use the flight time between SU's to relax in the plane (pilot should not relax too much).

4. The aircraft choice is a two-place plane with tandem seating.

XIV. Cost of Surveys

A. The labor and financial expenditures required to make a population estimate are substantially greater than conducting composition surveys in comparable areas.

B. Financial expenditures for a population estimate can be subdivided into fixed and variable costs.

   1. Fixed costs are expenses that will be incurred regardless of the location of the survey area.

      a. Purchase of materials such as topographic maps, acetate, and miscellaneous supplies are fixed.

b. Aircraft charter costs that are fixed consist of flight time actually spent within the survey area itself and include:

1) Stratification flight time

2) Flight time required to search SU's and fly intensive searches within SU's

3) Flight time between SU's within a census area.

2. Variable costs are those expenses that are dependent on the accessibility of the survey area.

a. Aircraft flight time required to fly between the airport and the survey area can be quite large.

1) For example, the survey area may be located 30-45 min flying time from the airport and 20-60 min may be required to traverse a large survey area. Therefore, an hour or more of flight is needed to simply get to some SU's.

b. Food and lodging expenses are also quite variable for the survey crews. If survey crews are able to return to their own homes each day, expenses are considerably less than when they are lodged in commercial facilities.

c. Variable expenses can be 25 to 50 percent of the cost and must be given serious consideration.

3. An example is given for labor and aircraft flight times during a survey in a 5,000 mi^2 area which had 333 SU's averaging 15 mi^2. Assume that the SU's are searched at 4.0 min/mi^2, and 20 intensive searches are flown at 12 min/mi^2 for 2.0 mi^2 areas.

a. Fixed aircraft charter times total 134 hr.

1) Stratification was calculated at the rate of 650 mi^2 stratified per aircraft per 6 hr day and total 46 hr.

2) Surveying SU's, intensive searches, and travel time between SU's totals 88 hr.

b. Fixed labor expenditures total 224 hr of effort

1) Presurvey preparation (purchasing supplies, preparing maps, and drawing SU's) requires 21 hr.

2) Stratification (flight time within the survey area, transferring data to the survey area map, and preparation for flying) requires 60 hr.

3) Surveying SU's (flight time within the survey area, preparation for sampling, selecting SU's to be surveyed, and calculating optimum allocation of search effort) require 88 hr.

4) Data analyses (measuring areas of SU's and calculating population estimates) require 25 hr.

C. Small survey areas (300-700 mi^2) require a proportionally larger total area to be surveyed than large survey areas.

1. A small survey area may have only 25-50 total SU's that are subdivided into several strata.

a. To have an acceptable variance, it may be necessary to sample most if not all SU's in a stratum. This is especially true for the high and medium density strata.

2. As the size of a survey area decreases, the financial and labor expenditures per mi^2 increase, but the total cost decreases.

   a. Only 20-25 percent of a large survey area may have to be sampled versus 50-90 percent of a small area to produce a population estimate of comparable precision.

3. Moose abundance and distribution in a small survey area will play an important part in determining the proportion of the survey area to be sampled.

   a. If moose density is high and a large proportion of the area is stratified as high or medium density, 75-80 percent of the total survey area may have to be sampled.

   b. If moose density is low and there is a large area stratified as low density, then perhaps only 50 percent of the survey area may have to be sampled.

   c. If moose distribution is very uniform and the survey area is subdivided into only 1-2 stratum, then a smaller proportion of the total area will have to be sampled than if three strata are used.

4. Survey areas smaller than approximately $300mi^2$ can generally be surveyed in their entirety, thereby saving the expense of stratification.

XV. Materials List for Moose Population Estimation Surveys

<u>Mapping supplies</u>

topographic maps (5-7 sets)

lead pencils

colored pencils

grease pencils (3 colors, 3 each)

large erasers (4)

scissors (3 pair)

large felt tip markers (2)

transparent colored markers (3)

clear tape (6-8 rolls)

masking tape (1 roll)

heavy gauge acetate at least 40 in. wide (enough to cover maps of the survey area)

expandable file folders to store maps and data sheet (6)

<u>Flying supplies</u>

clipboards

lead pencils

topographic maps of SU's

data sheets

watch

intercom and headsets

spare batteries for intercom

survival gear

foam pad to sit on

"Preparation H" (in case you forget the foam pad) (use of trade name does not imply government endorsement of commercial products)

air sickness pills

sunglasses

yellow glasses

ear plugs

Data calculation supplies

Hewlett-Packard 97 and population estimation program

extra batteries and paper for HP 97

instruction manual for HP 97

polar compensating planimeter

pad of writing paper

extra battery-powered calculator that can perform the required calculations

Other

notebook to store all forms, calculations, and notes

XVI. Calculation of Unbiased Sex and Age Ratios from Moose Observed During a Population Estimation Survey.

A. Sex and age ratios are calculated for each stratum based on the number of moose observed during 4 min/mi^2 searches of the SU's.

1. For example, the following data were collected during a November 1980 census of Count Area 7 and 14 in GMU 13.

Stratum	Type of Moose	No. Moose Observed During 4 min/mi^2 Searches (%)	Sex-Age Ratios by Stratum
High	♂	35 (9.9)	14 ♂/100 ♀
	♀	254 (72.0)	25 ca/100 ♀
	ca	64 (18.1)	
Medium	♂	19 (8.8)	13 ♂/100 ♀
	♀	146 (67.3)	36 ca/100 ♀
	ca	52 (24.0)	
Low	♂	14 (8.1)	13 ♂/100 ♀
	♀	111 (64.5)	42 ca/100 ♀
	ca	47 (27.3)	

B. Next calculate the number of bulls, cows, and calves in each stratum based on the stratum population estimate from the HP-97 program. The estimated number of moose is uncorrected for sightability.

Stratum	Percentage of Population	X	Estimated Population	=	Estimated Number
High	9.9 ♂		954		94 ♂
	72.0 ♀				687 ♀
	18.1 ca				173 ca
Medium	8.8 ♂		655		58 ♂
	67.3 ♀				441 ♀
	24.0 ca				157 ca
Low	8.1 ♂		375		30 ♂
	64.5 ♀				242 ♀
	27.3 ca				102 ca

C. Now the SCF is applied to the estimated number of moose for each stratum as follows:

Stratum	Uncorrected No. of Moose	X	SCF	=	Corrected No. of Moose
High	94 ♂		1.06		100 ♂
	687 ♀		1.06		728 ♀
	173 ca		1.06		183 ca

Medium	58 ♂	1.06	61 ♂
	441 ♀	1.06	467 ♀
	157 ca	1.06	166 ca
Low	30 ♂	1.06	32 ♂
	242 ♀	1.06	257 ♀
	102 ca	1.06	108 ca
TOTALS			193 ♂
			1,452 ♀
			457 ca

D. In order to compute the unbiased sex and age ratios for the entire survey area, calculate the appropriate ratios based on the corrected number of bulls, cows, and calves as follows:

Corrected No. of Moose	Sex-Age Ratios
193 ♂	13 ♂/100 ♀
1,452 ♀	31 ca/100 ♀
457 ca	