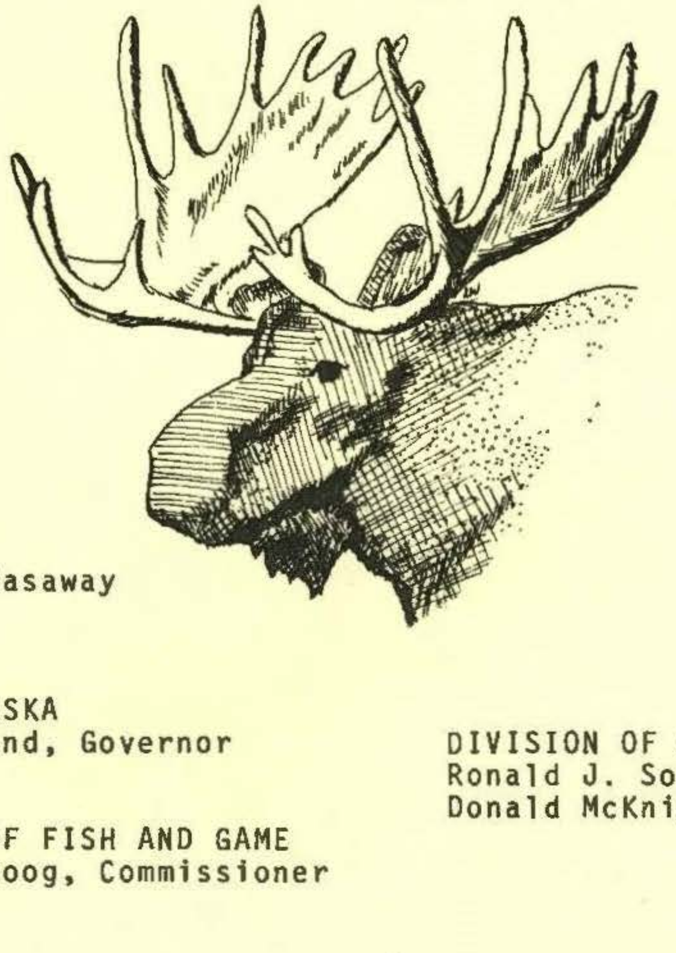
ALASKA DEPARTMENT OF FISH AND GAME

JUNEAU, ALASKA

INTERIOR MOOSE STUDIES



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FINAL REPORT

Federal Aid in Wildlife Restoration
W-21-1, Jobs No. 1.17R, 1.18R, 1.19R, 1.26R and 1.28R

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JOB PROGRESS AND FINAL REPORTS (RESEARCH)

State:	Alaska		
Cooperators:	William C. Gasaway, Stephen D. DuBois, and Samuel J. Harbo		
Project No.:	W-21-1	Project Title:	Big Game Investigations
Job No.:	1.17R	Job Title:	Development of Sampling Procedures for Censusing Moose
Job No.:	1.18R	Job Title:	Determination of Sightability of Moose During Aerial Census
Job No.:	1.19R	Job Title:	Standardization of Moose Census Techniques in Alaska

Period Covered: July 1, 1979 through June 30, 1980

SUMMARY

This study was designed to estimate sightability of moose during aerial transect surveys flown in May and June and to identify biases in the survey method which affect sex and age composition estimates. Sightability was estimated from the percentage of marked moose observed during aerial surveys. Sources of bias in the survey method were identified by comparing data on habitat use, activity, and aggregation size from radio-collared moose to moose observed during aerial transect surveys. Radio-collared moose were assumed to be representative of the population. An estimated 35 and 25 percent, respectively, of the moose were seen during aerial surveys in May and June.

Newborn calves which accompanied collared cows were missed approximately 10 percent of the time once the cow was located during aerial surveys. The sightability of all moose during aerial transect surveys was significantly less for moose utilizing vegetation with tall canopies than for moose using low canopies. Differences in habitat selected by bulls and cows were documented and resulted in bulls being more visible during transect surveys. Consequently, bulls tend to be overrepresented in transect survey data. Moose that were lying down were unlikely to be seen during transect surveys. Some sex and age classes tend to aggregate more resulting in their greater sightability; therefore, cow/yearling pairs

were overrepresented while cow/calf pairs were underrepresented in the survey data. Consequently, there was an overestimation of yearling recruitment and overwinter survival during May surveys and an underestimation of initial calf production during June. Moose typically seen during aerial transects were aggregated and in low vegetation.

CONTENTS

BACKGROUND

Intensive management of Alaska's moose *(Alces alces)* populations is required now more than ever. Human demands on the moose resource increase annually while in much of Alaska moose populations decline. Ecological impact studies assessing effects of industrial development on moose populations are becoming increasingly important, as are studies to monitor moose populations which are rapidly changing in size due to a multitude of factors, e.g. natural and artificial habitat alteration, high levels of harvest by sportsmen, predation, nutrition, pathogens, extension of range, etc. However, a major hindrance to management and research efforts is the inability to accurately estimate numbers of moose and their sex and age composition. No completely satisfactory census method has been devised for moose (Timmermann 1974). Accurate estimates of population numbers and representative sex and age composition data are extremely difficult to obtain because of the behavior of moose and the type of forested habitat they prefer.

Transect surveys are most commonly employed to determine the sex and age composition of Alaskan moose populations. They are also occasionally used to census or estimate numbers of moose. The transect method basically involves flying parallel lines at prescribed altitudes and counting moose seen in prescribed transect widths (Banfield et al. 1955). Two basic problems exist in using the transect census method:

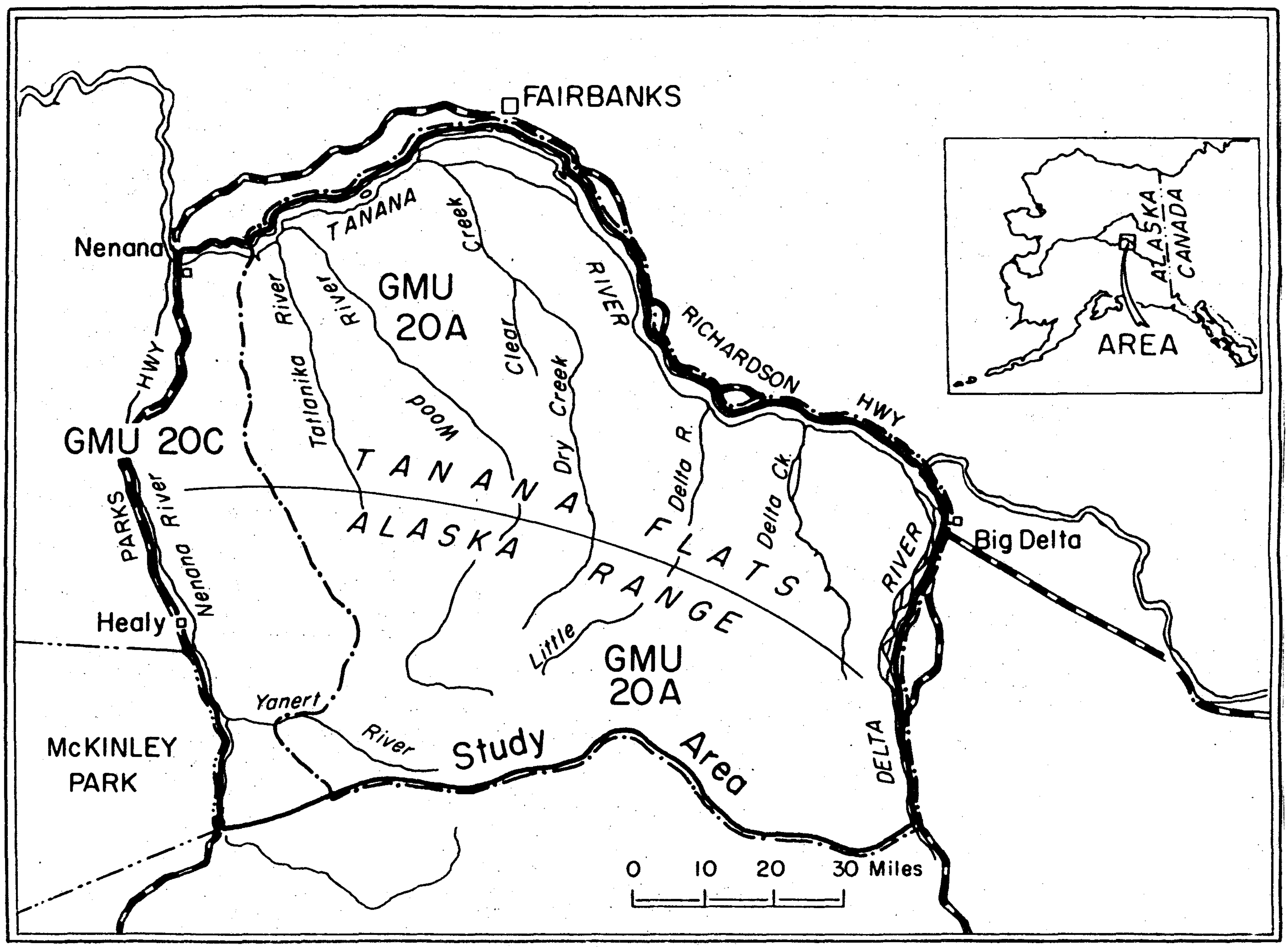

Fig. 1. The study area in interior Alaska.

1) determining the width of sample transects is difficult; and 2) the number of moose not seen is unknown and highly variable.

This study was undertaken to identify and evaluate biases of this method when used to estimate moose population size and sex and age composition during May and June.

OBJECTIVES

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

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

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

STUDY AREA

The study area in Interior Alaska (Fig. 1) includes the lowlands of the Tanana Flats 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)* forests and includes shrub-dominated seres following wildfires (LeResche et al. 1974). 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 ridge tops and higher elevations. Spruce, aspen *(Populus tremuloides)*, and birch *(Betula papyrifera)* are characteristic of lower elevations.

METHODS

The influence of habitat selection, activity, and other variables affecting moose sightability was compared between uncollared (UC) moose observed during aerial transect surveys and radio-collared (RC) moose that were relocated and which served as control animals representative of the moose herd in the study area.

Sightability and Behavior of Moose Seen on Aerial Transect Surveys

The Alaska Department of Fish and Game conducted pre- and postcalving composition surveys in the study area. Parallel aerial transects were flown in a Piper Super Cub PA-18 or Helio Courier at 70 ± 5 mph (113 km/hr), 300 ± 100 ft above the ground (91m) and at approximately 0.5 to 0.75 mi (0.8 to 1.2km) intervals. Although pilots and observers were not consistent between surveys, all pilots and observers were experienced. Both pilot and observer searched for moose a distance on each side of the transect equal to approximately one-half the transect interval. When a moose was seen the pilot would deviate from the transect, make a low pass over the animal to identify sex, age, activity, habitat selected, and aggregation size, and circle to search for other moose. The transect was resumed again near the departure point.

Antlers served as the criterion for sex identification. Moose were classified as calf, yearling, or adult. Body size, pelage color, and muzzle shape were used to distinguish yearlings from adults. Activity of moose was recorded as lying or standing. Habitat type used by moose was classified as aquatic, herbaceous, low shrub, tall shrub, deciduous forest, or conifer forest. A more detailed discussion of habitat classifications will be given in the methods used for RC moose and in the analysis of habitat data. Aggregation size was based on a subjective judgment by the observer and generally included moose whose behavior influenced each other and that were visible to each other.

To determine the sightability of cow moose during spring-summer transect surveys, 58 cow moose were captured in the study area between 8-14 May 1975. Animals were darted from a helicopter and immobilized with Anectine (Succinylcholine chloride, Burroughs Wellcome & Co., Research Triangle Park, NC). Moose were fitted with yellow canvas visual collars measuring 6 inches (15.2cm) wide and 42 inches (106.7cm) long (Denver Tent Co., Denver, CO). Each collar was individually identifiable with 5-inch (12.7cm) black numbers. Yellow-collared moose were then recorded during all subsequent ADF&G composition surveys in the study area. Sightability of moose during a survey was defined as the percentage of yellow-collared moose observed.

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

In addition to routine composition surveys, 18 repetitive surveys were also flown in a portion of the study area (Fig. 2) from 4-11 June 1976 and 20-21 June 1977 to determine the variability found in moose survey data. During 1976, consecutive surveys of approximately 2 hours duration were flown every 4 hours from 0630 to 2040 hours on 4 different days. In 1977 two consecutive surveys were flown at 0330 and 0630 hours on 2 different days. The same pilot and observer were used on all repetitive surveys.

Estimation of Normal Moose Behavior and Identification of Bias

Observations of RC moose were used to describe normal behavior of moose. Forty-nine moose were radio-collared during 1976, 1978, and 1979. Moose were darted from a helicopter with a 10cc dart containing M-99 (Etorphine hydrochloride, D-M Pharmaceuticals, Inc., Rockfield, MD) and Rompun (Xylazine hydrochloride, Chemagro Division of Bay Chemical Corp., Kansas City, MO). Immobilized moose were fitted with radio collars produced by AVM Instrument Co., Champaign, IL and Telonics, Mesa, AZ. A representative cross-section of the adult moose population was radio-collared including bulls, cows with calves, and cows without calves. Radio-collared moose were routinely relocated from fixed-wing aircraft from one to three times per month. During each relocation the following data were recorded: sex, initial activity, habitat type used, habitat available, aggregation size, and time of day.

Analysis of Habitat Use Data

The classification used to describe habitat types available to moose included aquatic (A), herbaceous (H), low shrub (LS) (shrubs up to approximately 6 feet in height), tall shrub (TS) (shrubs from approximately 6 to 12 feet in height), deciduous forest (D), spruce forest (S), sparse spruce forest (SS), and larch (L). Habitat types were generally pooled into the following four categories for data analysis: aquatic-herbaceous (AH), LS, TS, and the forest types of deciduous-spruce-sparse spruce-larch (DS).

A vegetative type map of the study area prepared by Coady (ADF&G files, unpubl. data) was used as a basis for statistical analysis of habitat use patterns. Observed habitat use by moose was compared to expected use in order to determine selection, rejection, or random use of habitat types.

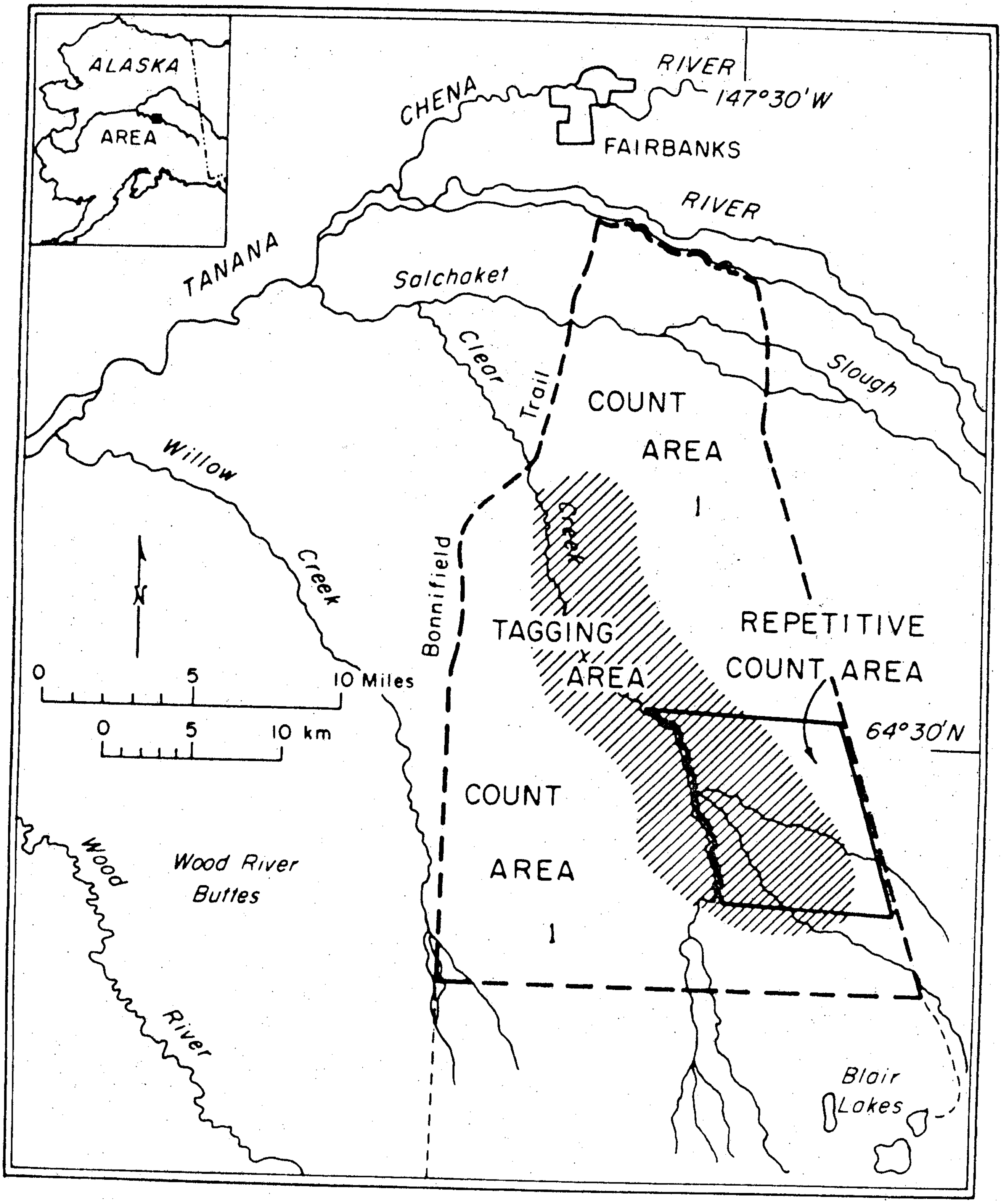

Fig. 2. Repetitive count area on the Tanana Flats, Alaska.

Preliminary analysis of the habitat selection data for each group of moose except cows with calves was performed by analyzing the information independently for May and June. June was further subdivided into 1-15 June and 16-30 June for cow/calf data. Chi-square "goodness-of-fit" tests were performed to compare observed to expected habitat selection for each segment of the population (i.e. cows without calves). If significant differences were present ($P < 0.05$ or $P < 0.01$), family confidence coefficient limits (FCC) were calculated for those habitat types meeting the requirements of the test (Neu et al. 1974). A nonsignificant FCC ($P > 0.05$) denoted random selection of that particular habitat type, whereas significance ($P < 0.05$) confirmed selection or rejection, depending on the confidence limits established. Due to inadequate sample sizes, it was frequently impossible to calculate a FCC for a particular habitat type or for all moose in a segment of the population. Then the difference between the proportion of moose observed in a habitat type was compared on a nonstatistical basis to the proportion of moose expected in that habitat. Additional analysis of these data may require alteration of the procedure in order to compensate for small samples of some data sets.

If sample sizes were inadequate to calculate a chi-square "goodness-of-fit" for any month, a 2 x k contingency table was calculated to compare May and June data. Nonsignificance ($P > 0.05$) warranted lumping between months. Selection, rejection, or random use of habitats was then determined.

Habitat selection data for RC moose was then compared with 2 x k contingency tables to test for differences in habitat selection between segments of the moose population (i.e. cows without calves vs. cows with calves). In some cases, May and June data were pooled when sample sizes were inadequate for any one month. Nonsignificance ($P > 0.05$) indicated that data could be pooled between segments of the population or between months.

Habitat selection data recorded for UC moose during May transect surveys had AH and LS recorded as one category, and June data had AH and LS recorded as A and H-LS. Therefore, habitat selection data for RC moose were arranged to allow a direct comparison to UC moose data. A 2 x k contingency table was used to compare data sets, and significance of $P < 0.05$ resulted in rejection of the null hypothesis. The null hypothesis was that no difference existed between habitat use by RC moose and UC moose seen on transect surveys. Rejection of the null hypothesis resulted from a significant difference in the habitat types in which RC and UC moose were observed. This difference resulted from variable difficulty in seeing UC moose in varying habitat types and indicated bias was present in the transect survey methods.

Analysis of Activity Data

Activity of RC and UC moose was analyzed to allow a comparison between the percentage of moose standing and lying in each data set. No statistical tests have been performed to date.

Analysis of Aggregation Data

Mean aggregation size for RC moose during May was calculated for cows with yearlings, cows without yearlings, and bulls. A cow/yearling pair was always counted as an aggregation of two moose because the body size of a yearling makes it nearly equal to an adult in sightability. Mean aggregation size for cow/yearling groups include all aggregations containing at least one cow/yearling pair. Therefore, a lone cow with a cow/yearling pair is counted as an aggregation of three moose. Mean aggregation size for cows without yearlings was calculated for any aggregation containing a lone cow (aggregation size = 1) or a cow without yearling plus any other moose. Mean aggregation size for bulls was calculated for any aggregation containing a lone bull or a bull with any other moose. An aggregation containing a cow/yearling pair, a cow without a yearling, and a bull would be tallied as an aggregation of four moose. This aggregation would be counted once in the cow/yearling tally, once in the cow without yearling tally, and once in the bull tally in order to determine mean aggregation size for any aggregation containing each of these moose.

The frequency of aggregation for RC moose defines the proportion of time moose were in groups of two or greater. The frequency of aggregation of bulls, for example, is the number of relocations when RC bulls were aggregated with any other moose divided by the total number of RC bull relocations. Frequency of aggregation for cows with yearlings is always 100 percent because the aggregation size always equals two moose.

In June the presence of a newborn calf did not contribute substantially to the probability of spotting a cow/calf pair during transect surveys. Therefore, a cow/calf pair during June was considered as an aggregation of one moose for sightability purposes. All other parameters for June aggregation data were calculated similar to those for May data.

Mean aggregation size and frequency of aggregation for UC moose seen on transect surveys during May and June were calculated for comparison to the aggregation parameters of RC moose. Mean aggregation size for UC moose was calculated identically as for RC moose. However, the calculation of frequency of aggregation for UC moose was altered because individually identifiable moose were not available for analysis. Therefore, frequency of aggregation for bulls, for example, was calculated by dividing the number of bulls in aggregations by the total number of bulls observed.

RESULTS

Sightability of Moose during Aerial Transect Surveys

A relatively small percentage of the total moose herd was seen during spring and summer aerial surveys based on observations of yellow-collared moose. Mean sightability of yellow-collared moose during May before leaves developed and during June after leaves developed was 36 and 24 percent, respectively (Table 1). These sightability estimates were only approximate because the exact number of collared moose in the surveyed area could not be determined. For example, we considered there were 58 collared moose in the survey area shortly after collaring in May 1975. By June 1975 some animals may have moved out of the area, although surveys in adjacent areas suggested that no significant emigration had occurred. The following year there was no way to firmly establish the number of yellow-collared moose returning, so we estimated the number of moose in the following manner. In spring 1976 moose were assumed to have returned to the tagging area, since moose in this portion of Alaska exhibit very traditional movement patterns (Gasaway et al. in press). We assumed that the number of moose not returning was equal to the number dying. Thus, with an assumed annual mortality rate of 10 percent, about 52 moose may have been in the survey area in 1976. In spite of the crude manner of establishing the number of collared moose in 1976, the derived value was considered sufficiently accurate to demonstrate the approximate sightability of moose.

The accuracy of cow/calf ratios obtained in this manner is dependent, in part, on the ability of the pilot and observer to locate the calf after the dam is spotted. The secretive nature of young calves makes them very difficult to locate during aerial surveys (Rausch and Bratlie 1965, Stringham 1974). Hence, omission of calves likely will further depress estimates of the actual cow/calf ratio. In the present study 89 repeat observations of collared cow moose with calves between late May and early July demonstrated that calves were overlooked an estimated minimum of 7 percent and a maximum of 11 percent of the time. The best estimate of the true value probably is near the maximum, since these data contain two biases which reduce the estimated error. First, observers may have unknowingly searched harder for calves of collared animals and, second, a miss occurring on the first of the series of observations of a cow could not be detected. However, the latter bias was considered negligible since most counts were conducted after the peak of calving and after that time first observations included calves if calves were seen in any subsequent observation. Therefore, a reasonable estimate of the number of moose

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

Month and Year of Survey	Estimated Number of Collared Moose in Count Area	Sightability (% of collared moose seen)
May 1975	58	31
May 1975	55	33
May 1976	52	44
Mean and SD for May surveys		36(4)
June 1975	58	16
June 1975	58	31
June 1976	52	23
June 1976 (repetitive counts)	15	33
Mean and SD for June surveys		24(5)

calves overlooked during aerial surveys may be approximately 10 percent. Rausch's (1962) estimate of calves missed during aerial surveys based on the physical appearance and behavior of cows was greater (14%). However, this difference was probably attributable to differences in methodology and intensity of search.

The most likely cause reason for overlooking a calf during June was the distance, up to a quarter of a mile, which may separate calves from cows (Rausch and Bratlie 1965). Stringham (1974) observed the maximum cow/calf separation up to 2 weeks postpartum to be 100 yards; however, separation was usually less than 10 yards. Cow/calf separation commonly occurred when the cow entered large openings or deep water (Stringham 1974, LeResche 1966, Altmann 1963).

Effects of Habitat Use On Sightability of Moose

The environmental variable with the most profound influence on moose sightability may be the habitat. As the height and density of vegetation increase, sightability decreases during aerial transect surveys. Therefore, an understanding of habitat use is necessary to define the habitat-related problems that are encountered during moose censuses and surveys.

Representative habitat use by moose was estimated from 435 relocations of 29 individual RC moose from 2 May-30 June 1977-1979. The habitat use patterns of cows with calves differed significantly from random use ($P < 0.01$) during May through June, and use patterns changed significantly from May to late June ($P < 0.01$). Two habitat types, AH and TS, were preferred by cows with calves, and the selection of each increased steadily from May to June (Table 2). Forest types (DS) were selected during May but used randomly during June. Low shrub was consistently rejected based on the proportion of its occurrence in the study area. Habitat types were recombined into low canopies (AH, LS, TS) and tall canopies (DS) to assist in the evaluation of the influence of habitat selection on sightability of moose during aerial surveys. Cows with calves selected tall canopies 40 percent of the time during May but only 19 percent during June.

Habitat use by cows without calves differed significantly ($P < 0.01$) from random use during May and June and the pattern of habitat use was similar ($P > 0.05$) to that of cows with calves (Table 2). During May 30 percent of the cows without calves were located in tall canopies, compared to 16 percent found there in June.

Relocations of cows with yearlings occurred primarily during May due to the dissolution of the cow/yearling bond by June. Habitat use data did not differ ($P > 0.05$) between May and

Table 2. Habitat selection by radio-collared moose during May and June 1977-1979 on the Tanana Flats, Alaska.

Type of Moose	Time Period	Habitat Type	Proportion of each Habitat Available	No. Moose Observed in Habitat	No. Moose Expected in Habitat	Index of Habitat Selection or Rejection[1]
Cows with calves	May	AH	0.054	5	2.1	+2.4
		LS	0.732	14	27.8	--2.0
		TS	0.045	4	1.7	+2.4
		DS	0.168	15	6.4	++2.3
	1-15 June	AH	0.054	15	4.2	+3.6
		LS	0.732	30	56.3	-1.9
		TS	0.045	17	3.5	+4.9
		DS	0.168	15	12.9	+1.1
	16-30 June	AH	0.054	20	4.1	++4.9
		LS	0.732	21	55.6	--2.6
		TS	0.045	21	3.4	++6.2
		DS	0.168	14	12.8	+1.1
	1-30 June	AH	0.054	35	8.3	++4.2
		LS	0.732	51	112.0	--2.2
		TS	0.045	38	6.9	++5.5
		DS	0.168	29	25.7	++1.1
Cows without calves	May	AH	0.054	8	4.3	+1.9
		LS	0.732	26	56.7	--2.2
		TS	0.045	22	3.5	++6.3
		DS	0.168	24	11.8	++2.0
	June	AH	0.054	9	2.8	+3.2
		LS	0.732	23	37.3	-1.6
		TS	0.045	11	2.3	+4.8
		DS	0.168	8	8.6	-1.1
Cows with yearlings	May and June	AH	0.054	9	3.1	+2.9
		LS	0.732	15	42.5	+2.8
		TS	0.045	16	2.6	+6.2
		DS	0.168	18	9.7	+1.9
Bulls	May and June	AH	0.054	18	3.0	+6.0
		LS	0.732	23	40.3	-1.8
		TS	0.045	11	2.5	+4.4
		DS	0.168	3	9.2	-3.1

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[1] ++ or -- indicates statistically significant selection or rejection of habitat based on confidence interval of 95% family confidence coefficient. + or - indicates nonstatistical selection or rejection of habitat where sample size was small. Values are the ratio of number of moose observed to moose expected.

June so these data were pooled to increase sample size. Habitat use patterns of cows with yearlings during May-June varied significantly ($P < 0.01$) from random use and were similar ($P > 0.05$) to habitat selection by both cows with calves and cows without calves during May (Table 2). Cows with yearlings were seen in tall canopies 35 percent of the time in May and 22 percent of the time in June.

There was no difference in habitat use by bull moose ($P > 0.05$) between May and June and therefore these data were pooled. Habitat use by bulls during May-June was significantly disproportionate ($P < 0.01$) to habitat availability. The habitat selection pattern by bulls differed significantly from all cows (with and without offspring) ($P < 0.05$) during May but not during June. Bulls made much more extensive use of AH than cows and used it 6 times more than expected (Table 2). Bulls were the only segment of the moose population to show rejection of DS. Occurrence of bulls in a tall canopy was unusual, and they were only found there 11 percent of the time in May and 3 percent of the time in June.

Cow moose with and without yearlings observed on aerial transect surveys during May composition counts were not representative of the population. Habitat use of UC cows seen on aerial transect surveys differed significantly ($P < 0.01$) from that of RC cows with yearlings and cows without yearlings. Tall shrub and DS were effective visual barriers substantially reducing the sightability of cows during aerial surveys. Only 27 percent of the UC cows were observed in TS or DS habitats, compared to 58 percent of the RC cows (Table 3).

Habitat types in which UC bulls were observed during transect surveys did not vary significantly from habitat selected by RC bulls ($P > 0.05$). Most RC bulls and UC bulls were recorded in AH-LS (Table 4). Habitat selection patterns of bulls made them highly visible during May transect surveys.

Habitat selection of all RC moose (cows with and without calves and bulls) was similar during June; therefore, all RC moose were pooled for the comparison to UC moose. During aerial surveys in June UC moose were seen in significantly different ($P < 0.01$) habitat types than RC moose indicating bias in the survey method. Radio-collared moose commonly used TS and DS while UC moose were seen almost exclusively in A, H, and LS habitats (Table 5).

Effects of Activity On Sightability of Moose

Activity of moose influence the probability of their being seen during a survey, with lying moose being the most difficult to see. This is particularly important during the snow-free period of the year. Therefore, an understanding

Table 3. Habitat use by radio-collared (RC) cows with and without yearlings relocated during May 1977-1979 compared to habitat in which uncollared (UC) cows with and without yearlings were seen during aerial transect surveys, Tanana Flats, Alaska.

Habitat	Moose	No. Moose Observed	Percent of Total
AH-LS	RC	58	42
	UC	343	73
TS	RC	38	28
	UC	71	15
DS	RC	42	30
	UC	58	12

Table 4. Habitat use by radio-collared (RC) bulls during May 1977-1979 compared to habitat in which uncollared (UC) bulls seen during aerial transect surveys, Tanana Flats, Alaska.

Habitat	Moose	No. Moose Observed	Percent of Total
AH-LS	RC	41	75
	UC	97	82
TS	RC	11	20
	UC	14	12
DS	RC	3	6
	UC	8	7

Table 5. Habitat use by all radio-collared (RC) moose during June 1977-1979 compared to habitat in which all uncollared (UC) moose were seen during aerial transect surveys, Tanana Flats, Alaska.

Habitat	Moose	No. Moose Observed	Percent of Total
A	RC	16	6
	UC	59	20
H-LS	RC	143	55
	UC	210	71
TS	RC	60	23
	UC	22	8
DS	RC	40	15
	UC	3	1

of activity of moose will assist in identifying survey method biases.

RC moose were standing during 60 and 56 percent of the relocations in May and June, respectively (Table 6). Activity of moose recorded during transect surveys in May and June varied substantially from the activity of RC moose with 91 and 88 percent, respectively, of all moose standing. The difference between activity of RC moose and moose seen on transect surveys is probably greater than indicated by these data because the method used to collect activity data for RC moose was biased by disturbance from the aircraft. Several passes with the aircraft in the general area of the moose were often required to see the moose, particularly if the moose was located in tall vegetation. Lying moose that were not seen during the first pass with the aircraft had an opportunity to stand up before being seen on subsequent passes. Situations resulting in questionable moose activity were recorded as unknown activity; however, an unknown number of lying moose surely stood up due to disturbance and were subsequently recorded as standing moose.

Effects of Aggregation Size On Sightability of Moose

The largest mean aggregations of RC moose were recorded for cow/yearling pairs with a mean aggregation size of 2.1 moose (Table 7). Cows with newborn calves were the most solitary segment of the moose population and had the smallest aggregations. During June, cow/calf pairs were aggregated with other adult moose for only 0.6 percent of the relocations. Adult cows without offspring and bulls had intermediate mean aggregation sizes and frequencies of aggregation during May and June.

Moose located on transect surveys were aggregated more frequently than RC moose during both May and June and were generally spotted in larger aggregations (Table 7). The largest mean aggregation sizes recorded during transect surveys consisted of cow/yearling pairs, while cows with newborn calves comprised the smallest mean aggregations.

The majority (88%) of RC moose aggregations of two or more moose were characterized by synchronous activity among the aggregation members (Table 8) and most moose displaying synchronous activity were standing (60%). Synchronous activity was also frequently observed among aggregations of moose located during transect surveys (Table 9). Aggregations of these moose had a level of synchronous activity (92%) similar to RC moose, but had a much larger proportion of aggregations with all moose standing. The high percentage of aggregations with synchronous activity indicates that activity of individual moose within an aggregation influenced, and was influenced by, other moose in the aggregation. The result of this social facilitation on activity

Table 6. Activity of radio-collared (RC) moose compared to uncollared (UC) moose observed during transect surveys on the Tanana Flats, Alaska. Values in parentheses are sample sizes.

Date	Moose	RC Moose		NRC Moose	
		% Standing	% Lying	% Standing	% Lying
May	cow w/o yrlg	58(60)	42(43)	72(24)	28(2)
	cow w/ yrlg	58(30)	42(22)	84(16)	16(3)
	bull	65(31)	35(17)	100(13)	0(0)
	all	60(121)	40(82)	91(53)	9(5)
June	cow w/o calf	63(44)	37(26)	92(134)	8(11)
	cow w/ calf	51(83)	49(81)	91(105)	9(11)
	bull	62(48)	38(30)	83(172)	17(36)
	all	56(175)	44(137)	88(411)	12(58)

Table 7. Mean aggregation size and frequency of aggregating by radio-collared (RC) moose compared to uncollared (UC) moose observed during aerial transect surveys on the Tanana Flats, Alaska. Values in parentheses are sample sizes.

	May				June			
	RC Moose		UC Moose		RC Moose		UC Moose	
	$\bar{x}$ agg size	Percent aggregated	$\bar{x}$ agg size	Percent aggregated	$\bar{x}$ agg size	Percent aggregated	$\bar{x}$ agg size	Percent aggregated
Cow w/yrlg	2.1 (109)	100.0	2.9 (96)	100.0	-	-	-	-
Cow w/calf	-	-	-	-	1.0 (170)	0.6	1.1 (220)	7.5
Cow	1.1 (132)	10.4	1.6 (410)	54.5	1.1 (78)	4.1	1.4 (305)	31.5
Bull	1.1 (60)	9.4	2.0 (218)	61.8	1.4 (109)	25.0	1.4 (337)	39.0

Table 8. Activity of radio-collared moose and their aggregation members during May and June on the Tanana Flats, Alaska. Sample sizes are in parentheses.

Agg. Size	All Lying	Number Standing					Total Agg.	Total Moose
		1	2	3	4	5		
1	48 (227)	52 (243)					470	470
2	31 (32)	13 (13)	56 (58)				103	206
3	11 (1)			89 (8)			9	27
4				25 (1)	75 (3)		4	16
5						100 (1)	1	5
Total							587	724

Table 9. Activity within aggregations of uncollared moose seen during May and June aerial transect surveys on the Tanana Flats, Alaska. Sample sizes are in parentheses.

Agg. Size	All lying	Number Standing										Total Agg.	Total Moose
		1	2	3	4	5	6	7	8	9	10		
2	6 (11)	7 (12)	87 (159)									182	364
3	2 (1)	6 (3)	4 (2)	89 (47)								53	159
4	4 (1)	4 (1)	11 (3)	4 (1)	78 (27)							27	108
5					10 (1)	90 (9)						10	50
6							100 (2)					2	12
7								100 (1)				1	7
8									100 (1)			1	8
9												0	0
10											100 (1)	1	10
Totals												277	718

was to increase the time that aggregated moose spent standing. This effect of increased activity in aggregations can easily be seen when lone moose (excluding cows with newborn calves) were compared with aggregated RC moose. Only 52 percent of lone moose were standing while 66 percent of the aggregated moose were standing and 74 percent of moose in aggregations were associated with at least one standing moose. Therefore, moose in aggregations can be seen more readily than lone moose on aerial surveys due to a generally higher level of increase in activity.

DISCUSSION

This study demonstrated that a low percentage of moose were observed during aerial transect surveys and that sex and age composition information calculated from these data were not representative of the population. Some factors responsible for bias in the survey method were sex and reproductive status of the moose, their activity, habitat selection, and aggregation behavior.

Habitat selection had a major influence on sightability of moose. Moose in low, open habitat types were most highly visible on transect survey. Sightability decreased rapidly as vegetation height increased and tall canopies became effective visual barriers. Therefore, moose selecting taller canopies were poorly represented in the sample.

Habitat selection by different segments of the moose population resulted in varying sightability during aerial transect surveys and resulted in biases which significantly alter sex and age ratio data. For example, May data recorded for RC cow/yearling pairs and cows without yearlings demonstrated different habitat selection from that by RC bulls because cows selected a higher proportion (30%) of forest habitats than RC bulls (6%). This differential habitat selection resulted in an overestimation of bulls relative to cows. During June, no significant differential habitat selection was documented between RC cows and bulls. Therefore, sex and age ratios calculated from June survey data should be more representative of the population.

Activity of moose had a significant influence on sightability during aerial transect surveys. Lying moose were poorly represented on transect surveys and comprised only about 10 percent of the moose that were recorded, whereas 43 percent of the RC moose were lying when relocated. Therefore, a lying moose was likely to be missed during aerial surveys. No significant differential activity patterns were recorded between segments of the RC moose population; however, activity may affect sex and age composition estimates through the interaction between activity and aggregation. This will be investigated further.

Aggregation size alters sightability of moose during aerial transect surveys. As aggregations become larger, the probability increased of seeing at least one moose within an aggregation. This resulted in overrepresentation of large aggregations of moose on transect surveys. Large aggregations were easily seen and once the most visible moose was observed from the transect a low pass was made over the animal to facilitate sex and age classification and to search for other moose. Therefore, sightability of a moose in an aggregation was not only related to its habitat use and activity, but also to the activity and habitat chosen by other aggregation members.

Surveys conducted during May were designed to estimate the overwinter survival of calves (yearling recruitment). The largest aggregations during May were cow/yearling pairs, averaging about twice the size of those for cows without offspring. Aggregation size was an important determinant of sightability for all cows during May because their activity patterns and habitat use were similar. Therefore, cow/yearling pairs will be overrepresented relative to cows without offspring largely due to the influence of aggregation size. Estimates of recruitment and overwinter survival of calves will be inflated because of this bias.

The principal purpose of June surveys was to estimate initial calf production. However, representative calf/cow ratios were not obtained due primarily to the tendency for cows with calves to remain solitary, which reduced their relative sightability. Additional calves were also missed after the cow was spotted. Both of these factors resulted in an underestimation of calf/cow ratios. In the study area calf/cow ratios during June have been unrealistically low even when the population has been increasing. Therefore, we suggest that aerial transect surveys during June are of little value to wildlife managers in this area.

Moose seen on transect surveys during May or June were typically standing in a low habitat type and were commonly aggregated. Bulls and cow/yearling pairs most often fit these characteristics, hence, their proportion in the moose population will generally be overestimated from aerial transect survey data.

RECOMMENDATIONS

1. Complete analysis of data and prepare a final report on Job 1.19R.

2. Accurate estimates of initial calf production cannot be obtained from aerial transect surveys; therefore, they should be discontinued in Interior Alaska.

3. Biologists should recognize that yearling recruitment and overwinter calf survival estimates are overestimated from aerial transect surveys during May.

ACKNOWLEDGMENTS

We thank Oliver Burris, Dale Haggstrom, Mel Buchholtz, Larry Jennings, and Jim Raymond for assistance during the study, and John Coady and Don McKnight for reviewing the manuscript.

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JOB PROGRESS REPORT (RESEARCH)

State:	Alaska		
Cooperators:	William C. Gasaway, Stephen D. DuBois, and Karen L. Brink		
Project No.:	W-21-1	Project Title:	Big Game Investigations
Job No.:	1.26R	Job Title:	Sightability and Movements of Juvenile Moose
Period Covered:	July 1, 1979 through June 30, 1980		

SUMMARY

Dispersal of 1- to 3-year-old moose from a low density, but rapidly growing, moose population was investigated. Radio collars were placed on 17 offspring of previously radio-collared adult cows. Comparison of home ranges of independent offspring and their respective dams indicates a close spacial relationship between home ranges. No long distance dispersal resulting in the formation of a home range separate from that of the dam's was observed. Winter home ranges of offspring tended to deviate more from that of their dams' than did summer home ranges. Thus, this moose population demonstrated a very slow rate of dispersal. For managers this conclusion has important consequences: 1) newly created habitat will not be rapidly located and occupied by dispersing moose; 2) locally overhunted areas will be repopulated primarily by offspring of moose surviving in the area; and 3) since declining moose populations adjacent to low density populations derive few new members by immigration, each population must be managed with respect to its individual potential growth rates.

CONTENTS

BACKGROUND

Results of work accomplished under that portion of Job 1.26R dealing with the movements of subadult moose *(Alces alces)* were recently summarized and presented as a preliminary report at the 16th North American Moose Conference and Workshop, April 1980. Because the manuscript, "Dispersal of subadult moose from a low density population in Interior Alaska," by William Gasaway, Stephen DuBois, and Karen Brink, will not be available in the printed proceedings for approximately 1 year, it is presented here as the Progress Report for this job. Preliminary results of the sightability of juvenile moose are included in the sightability study (Job 1.18R) under this same cover.

Dispersal of Subadult Moose From a Low Density Population in Interior Alaska

The extent of dispersal from a moose 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 (Likhachav 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 adults demonstrate toward their home ranges minimizes the role of adult moose 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 these studies. Dispersal from a moose population that was clearly at low density relative to carrying capacity was found only by Mercer and Kitchen (1968).

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

This study was designed to investigate the frequency, direction, and distance of dispersal, and 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^2 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^2 by 1975 as a result of severe winter weather, malnutrition, high harvest by hunters, and high rates of predation by wolves *(Canis lupus)* (Bishop and Rausch 1974; Gasaway et al. 1978). 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^2 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 the extent to which offspring adopt movement patterns different from those of the dam.

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

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

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

STUDY AREA

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 includes 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)* which grade into extensive stands of black spruce *(Picea mariana)* on saturated and 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 ridge tops and higher elevations. Spruce, aspen, and birch are characteristic of lower elevations.

METHODS

Forty-four adult moose were immobilized with a mixture of M99 (Etorphine hydrochloride, D-M Pharmaceuticals, Inc., Rockfield, MD) and Rompun (Xylazine hydrochloride, Chemagro Division of Bay Chemical Corp., Kansas City, MO), and radio-collared (AVM Instrument Co., Champaign, IL) during August and October 1976 (Gasaway et al. 1978). A representative cross-section of the adult moose population was radio-collared including bulls, cows with calves, and cows without calves. The moose were radio-collared in conjunction with a project designed to determine the sightability of moose during aerial surveys. Although the sightability project was not designed as a moose movement study, radio-collared moose were routinely relocated from fixed-wing aircraft during sightability work. Periods of most frequent relocations included October-March 1976-78 and May-June 1977-78. Moose were generally relocated one to three times per month during these periods, and an attempt was made to relocate moose at least once per month during all other times of the year. However, longer gaps between relocations were common.

At the onset of the dispersal study in May 1978, six yearlings and one 2-year-old offspring of radio-collared dams were immobilized with a mixture of 5 mg M99 and 200 mg Rompun and fitted with radio collars prior to separation of

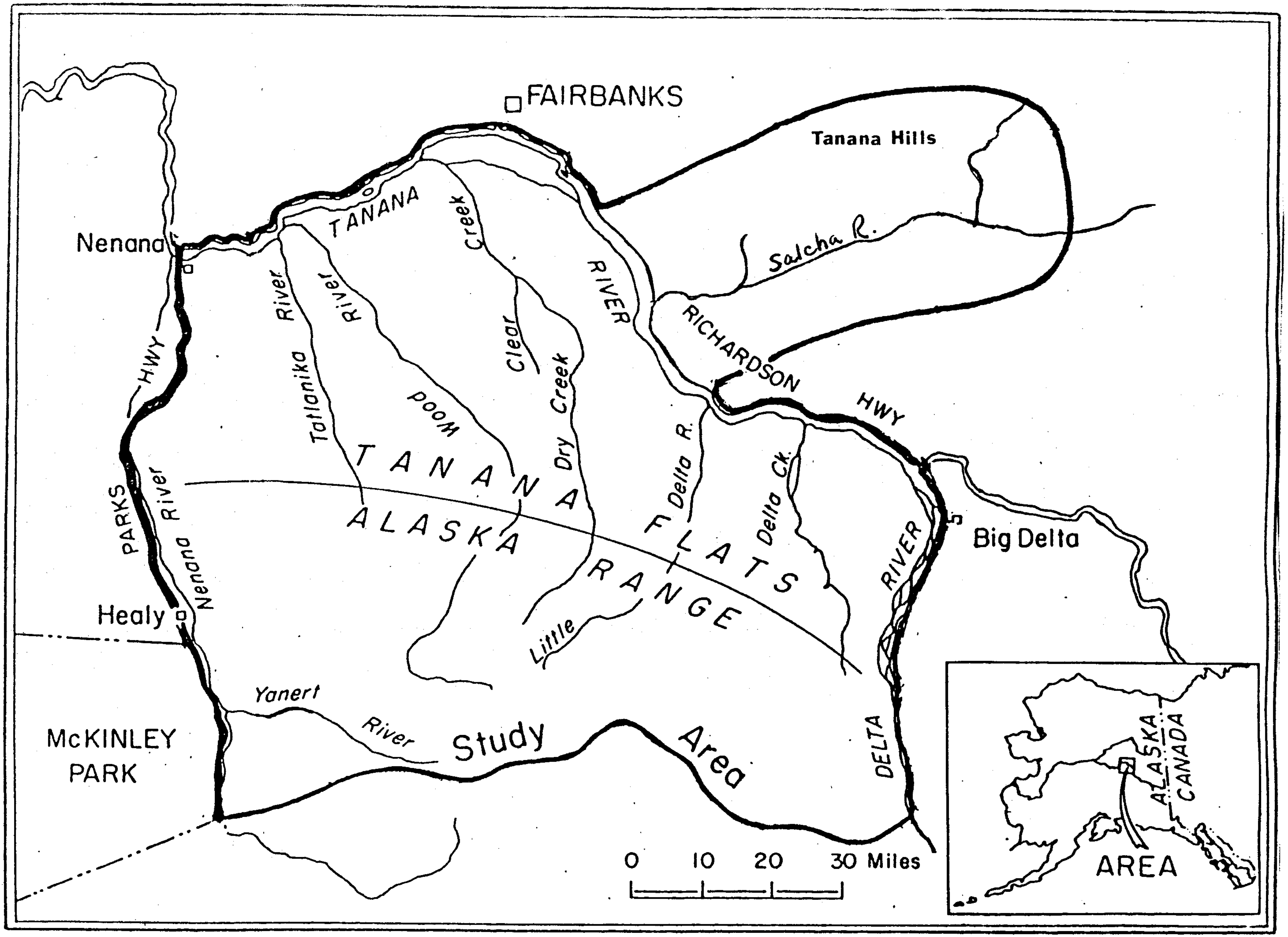

Fig. 1. The study area in Interior Alaska.

the dam/offspring bond. An accumulation of 19-21 months of movement data was available on the cows at that time and 12-24 months of movement data were available on the offspring during the time they accompanied their dams. We also radio-collared an adult cow that had previously been radio-tracked from October 1974 to July 1975 (Coady 1976); in addition, her yearling offspring was radio-collared. All radio-collared dams and their radio-collared offspring were relocated approximately once per month. More frequent relocations occurred during winter. All relocation points were plotted on 1:63,360 topographic maps.

From 9-16 May 1979 we replaced the radio collars (Telonics, Mesa, AZ) on 11 adult cows that had been radio-collared in 1976 in order to maintain continuity of data on these individuals. Ten yearlings of previously radio-collared cows were also radio-collared, along with four previously uncollared adult cows.

For purposes of this preliminary study, we defined dispersal as the spatial separation of the home range of the independent offspring from 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 experienced while associated with its dam to lengthy distances if the offspring moves to a new home range. Minimum year-round home ranges were drawn for radio-collared moose by connecting outside relocation points to generate a concave polygon of home range area (A, Fig. 2). Concave polygons were used because relocating moose on a monthly basis prohibited us from precisely defining the home range of individual moose. Also, during periods of more frequent relocation, occasionally moose were noted to make sporadic forays of short duration, in which individuals left and then returned to a central region of activity. If these forays were enclosed within a convex polygon, a substantial increase in the home range would result (B, Fig. 2). A concave polygon, however, better describes the area where moose were actually recorded. Seasonal polygons were calculated for both summer (May-August) and winter (September-April) home ranges of dams and their offspring.

Relocations of moose were too infrequent to define migration routes for migratory moose. Therefore, arbitrary migration routes were created by drawing a straight line between the last relocation point prior to migration and the first relocation point after migration.

To quantify dispersal of radio-collared offspring, we measured several parameters based on the relationship of relocation sites of the independent offspring to the home range occupied by the offspring while accompanying its dam. This latter home range will be referred to as the dam's home range hereafter. These measurements included: (1) the

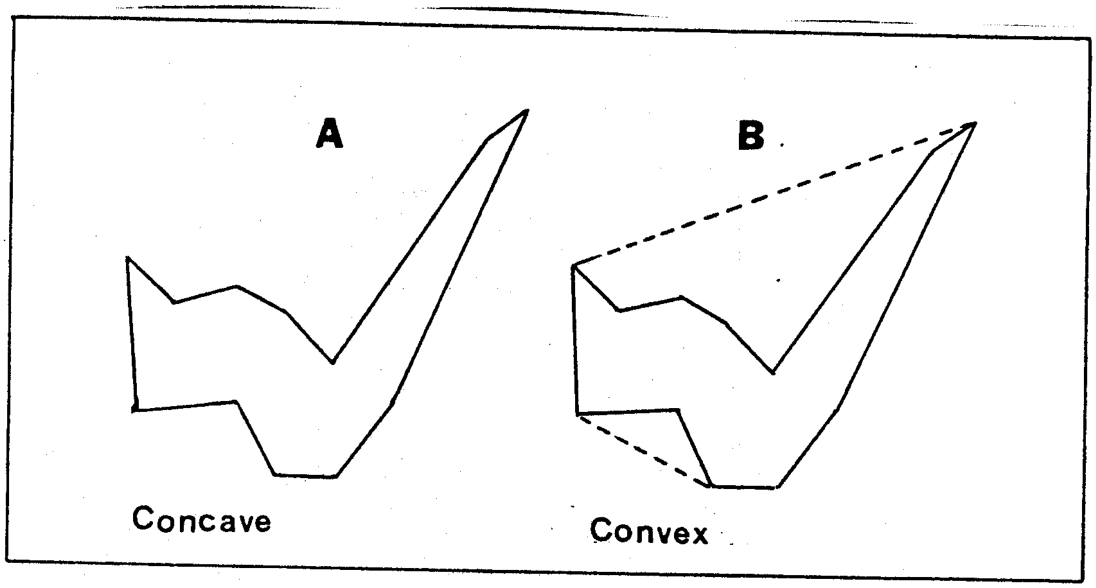

Fig. 2. Concave polygons (A) were used to make estimates of minimum home range size of moose. Convex polygons (B) enclose large areas where the moose were not observed.

length of year-round home range. This was the greatest linear distance between the two most widely separated relocation points (A, Fig. 3); (2) spatial separation between the year-round home range of dams and their offspring. This was determined by measuring the linear distance from each relocation point of the offspring to the closest portion of the home range of the dam (B, Fig. 3) including migratory routes (C, Fig. 3); relocation points of the offspring that were enclosed by the dam's home range were given a distance of 0 km (D, Fig. 3); and (3) spatial separation of seasonal home ranges. This was determined by measuring the linear distance from each relocation point of the offspring (including points during migration) to the closest point on the appropriate seasonal polygon of the cow (E, Fig. 3).

Student's t-test was used to detect significant differences between mean values ($P < 0.05$). In testing for significant differences of paired observations, i.e. dam versus the offspring or the same individuals between years, a paired Student's t-test was used (Simpson et al. 1960).

RESULTS

Two-year-old offspring did not differ significantly from yearling offspring in distances from their respective dam's home range (Table 1). In addition, of five 2- and 3-year-old moose that were followed since their births, there was no significant difference between their first and second year of independence in spacial separation from their respective dam's home range (Table 2, Fig. 4). Therefore, we pooled all offspring into a single subadult category for investigating dispersal.

Based on relocations, subadult moose were separated by an average of 3.1 km from their dams' year-round home range; the mean greatest distance which offspring were separated from the dam's range was 9.5 km (Table 1). In all but 1 case, a portion of the subadult's home range overlapped that of its dam. A mean dispersal of approximately 3 km is a relatively short distance when compared with the lengths and areas of home ranges which were observed. The total length of home ranges for all subadults and adults averaged about 40 km with a maximum of 90 km (Table 3). The mean home range area of 5 dams and their offspring collared in May 1978 was 60 km^2 with a range of approximately 25-110 km^2. It should be pointed out that the distances calculated for dispersal are maximum values since the concave polygons used to describe a home range tend to maximize separation between offspring and dam. During their first year of independence male and female offspring did not differ significantly in mean relocation distances from their dams' year-round home ranges. Figs. 4 and 5 illustrate the juxtaposition of home ranges of dams and their offspring and show the mean distance of the offspring from the dam's year-round home range.

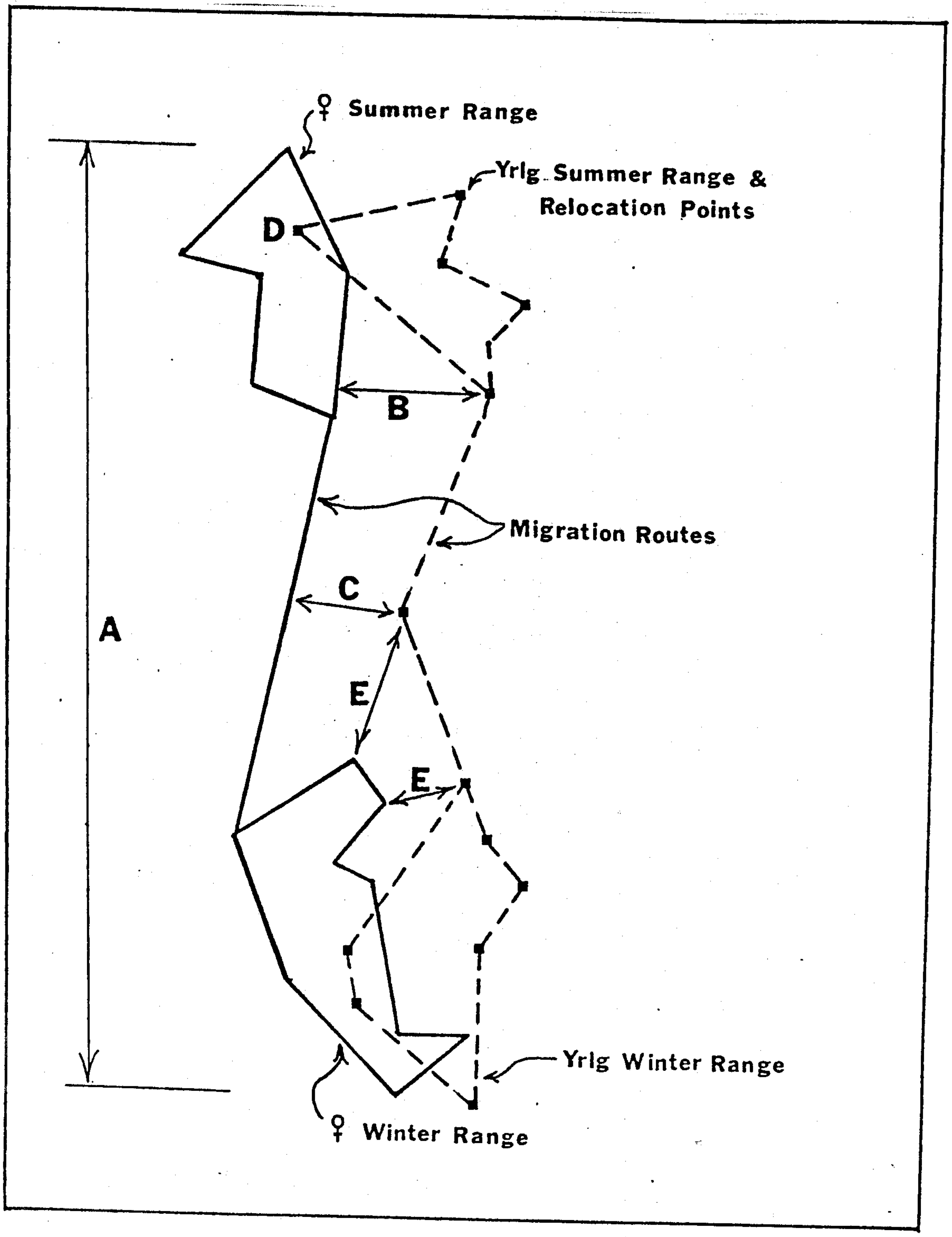

Fig. 3. Examples of measurements used to quantify the spatial relationship between the dam's home range and relocation points of the offspring. "A" is greatest length of year-round home range. "B" is the minimum linear distance from a relocation point to any home range polygon of the dam, or migration route "C." Relocation points within the dam's home range "D" received 0.0 km distance separation. "E" is the minimum linear distance of a seasonal relocation point of the offspring to the dam's appropriate seasonal polygon.

Table 1. Mean straight line distances separating relocations of offspring from year-round home range of their dams. Distances are reported in km. Standard deviation and range are in parentheses.

Age of Offspring n	Mean of Mean Separation	Mean of Minimum Separation	Mean of Maximum Separation
Yearling n=15	3.4a[1] (4.7,0.0-18.7)	0.0a (0.0,0.0-0.0)	9.7a (9.3,0.0-38.9)
2 year old n=5	2.7a (2.4,0.2-5.6)	0.2a (0.2,0.0-0.5)	8.8a (4.2,1.6-12.1)
3 year old n=1	0.8	0.0	9.3
All Combined n=21	3.1 (4.0,0.0-38.9)	0.0 (0.2,0.0-0.5)	9.5 (8.0,0.0-38.9)

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[1] Means followed by similar letters in columns indicate no significant difference ($P > 0.05$) between yearlings and 2 year olds.

Table 2. Comparison of straight line distances separating locations of offspring from their dam's year-round home range during their first and second year of independence from their dam. Distances are reported in km. Standard deviation and range are in parentheses.

No. of Offspring	Mean of All Observations		Mean Maximum Deviation	
	1st year	2nd year	1st year	2nd year
5	2.1a[1] (1.6,1.0-4.7)	2.7a (2.3,0.2-5.6)	9.2b (4.0,3.7-13.2)	8.7b (4.2,1.6-12.1)

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[1] Similar letters following paired means for first and second years indicate no significant difference ($P > 0.05$) between means.

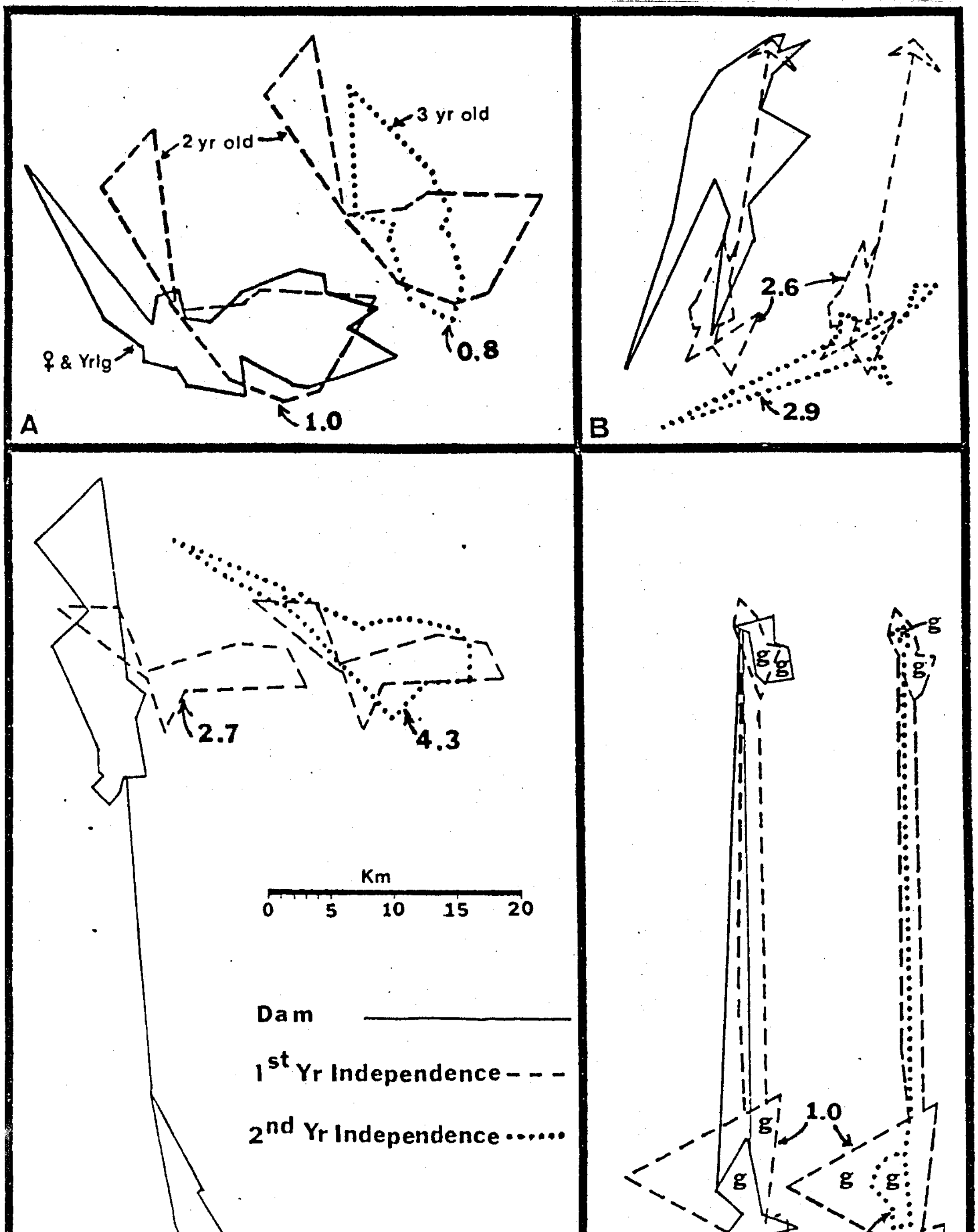

Fig. 4. Examples of minimum home ranges of independent offspring in relation to its dam's home range. Numerical values indicate mean distance of all observed locations of the offspring from its dam's year-round home range. Home range polygons which are difficult to separate from migration routes are indicated by "g." To avoid congestion on the figure, home ranges for the second year of independence are offset and referenced to home ranges of the first year of independence.

Table 3. Comparison of maximum year-round home range length between dams and their offspring. Distances are maximum straight line measurements in km between the two most distant points. Standard deviation and range are in parentheses.

n	Dam	Offspring
Yearlings n=15	43.8a1 (20.0,14.8-72.7)	38.3a2 (20.8,13.7-90.1)
2 year old n=5	51.0a (19.1,30.2-72.7)	34.4a (12.2,24.8-47.9)
3 year old n=1	33.8	20.4
All Combined n=21	45.0a (19.1,14.8-72.7)	36.5a (18.7,13.7-90.1)

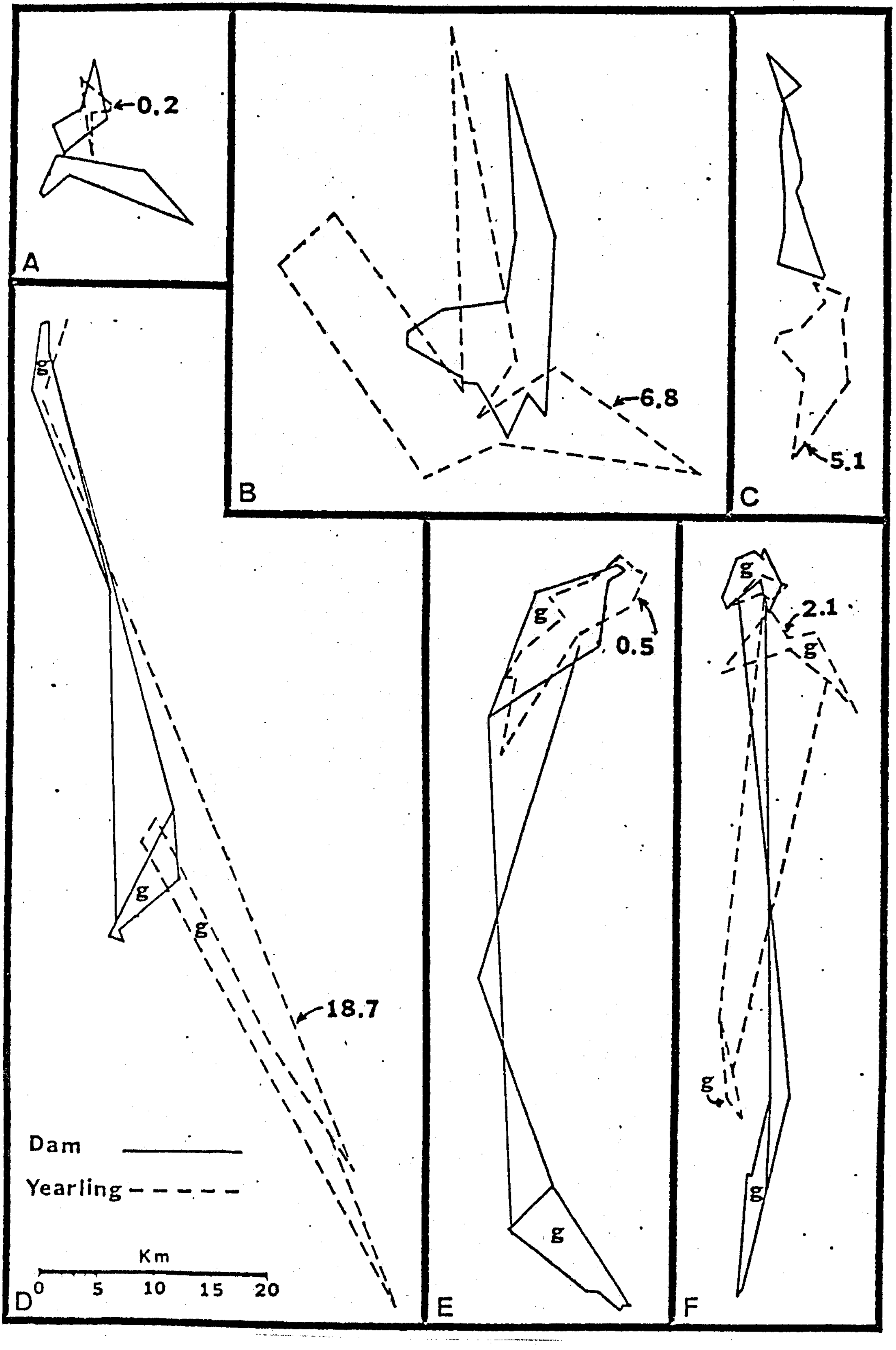

Fig. 5. Minimum home range estimates of independent yearling moose relative to its dam's home range. Numerical values indicate mean distance of all observed locations of the offspring from it's dam's year-round home range. Home range polygons which are difficult to separate from migration routes are indicated by "g."

These figures assist in visualizing the spatial relationships used to quantify subadult dispersal.

The mean maximum year-round length of yearling home ranges did not differ significantly from that of 2-year-old moose (Table 3). The mean maximum length of year-round home ranges for dams was not significantly different from that of their yearling or 2-year-old offspring (Table 3). Therefore, yearling and 2-year-old moose did not exhibit greater home range lengths than their dams.

Although dam and offspring year-round home ranges were separated by a relatively short mean distance (3.4km), seasonal home ranges were often separated by considerable distances (Table 4). During winter the distance subadults were separated from the winter range of their dams averaged 9.3 km, with a mean maximum distance of 18.2 km (Table 4). The distances separating dam and subadult home ranges during summer were significantly shorter than during winter (Table 4).

Differences between seasonal and year-round spatial separation measurements (Tables 1 and 4) resulted from a combination of differences in chronology of migration for the dam and offspring and the dispersal of offspring from the dam's home range. When the timing of long migrations differs, a large seasonal separation can develop even though little separation in year-round home ranges exists. For example, Fig. 4C illustrates an extreme case in which the offspring of a migratory female became a resident on the dam's summer range. Year-round home ranges were in close proximity, while winter ranges differed substantially. Dispersal of offspring from the home range of the dam also contributed to the seasonal separation shown in Table 4, particularly during winter when the greatest dispersal occurred. Therefore, seasonal home range differences, as calculated in the present study, represent a general time-specific spatial relationship of two moose and should not be thought of strictly as a measure of dispersal.

Several individual case histories will be used to describe the variation in movement of subadults in relation to the home range of their dams' during the period the offspring accompanied the cow.

1. The longest mean dispersal recorded on a year-round basis was 18.7 km between male yearling 7751 and his dam 7712 (Fig. 5D). Although 7751 overlapped the home range of his dam at times, he ranged up to 55.2 km away from his dam's range during the summer and 38.9 km away during the winter.

2. An offspring of cow 6915 was radio-collared in each of 2 successive years. Male yearling 7730 was radio-collared in May 1978 and male yearling 7753 (Fig. 5E) was

Table 4. Straight Line Distances Separating Locations of Offspring From the Seasonal Home Range of Their Dams. Distances Are Reported in km. Standard Deviation and Range Are in Parentheses.

Age of Offspring n	Summer (May-Aug)			Winter (Sept-Apr)		
	Mean of Mean Separation	Mean of Minimum Separation	Mean of Maximum Separation	Mean of Mean Separation	Mean of Minimum Separation	Mean of Maximum Separation
Yearling n=15	3.2a[1] (4.7,0.0-19.0)	0.0a (1.1,0.0-0.3)	10.6a* (15.3,0.0-33.6)	9.7a (12.2,0.0-48.3)	3.4a (10.0,0.0-38.9)	20.1a* (17.1,0.0-54.4)
2 year old n=5	2.9a (3.4,1.1-8.8)	0.2a (0.3,0.0-0.6)	11.7a (13.0,2.3-34.4)	10.6a (14.0,0.5-34.3)	2.7a (3.5,0.0-7.4)	15.3a (16.3,1.3-40.9)
3 year old n=1	3.7	0.5	9.3	0.5	0.0	2.9
All Combined n=21	3.2* (4.2,0.0-19.0)	0.2 (0.2,0.0-0.6)	10.8 (14.0,0.0-21.4)	9.3* (12.2,0.0-48.3)	3.1 (8.5,0.0-38.8)	18.2 (16.6,0.0-33.8)

[1] Means followed by similar letters in columns indicate no significant difference ($P > 0.05$) between yearlings and 2 year olds.

[2] * indicates a significant difference ($P < 0.05$) between comparable means in rows for summer and winter periods.

radio-collared in May 1979. The greatest mean seasonal separation we recorded was between 6915 and 7753. During the summer 7753 dispersed an average of only 0.5 km from the dam's home range. However, 7753 did not migrate to the traditional winter range of 6915 and had a mean separation of 48.3 km during the winter. At the time of writing (March 1980), 7753 had remained on the dam's summer range for about 5 months after the dam traditionally migrated and may well reside there the remainder of the winter. A year earlier yearling 7730 also exhibited movement patterns similar to those of 7753 and lagged behind the dam's migration by 3-4 months. However, 7730 eventually migrated to the vicinity of the dam's winter home range in January-February of that year.

3. Male yearling 7758 was the most mobile yearling monitored (Fig. 5B). Although 7758 has not shown significant linear dispersal in any one direction of travel, he moved an average of 17.4 linear km between monthly relocation points and was rarely relocated within his dam's home range. However, year-round 7758 had only dispersed a mean of 6.8 km from his dam's home range because he often travels back and forth through the home range of dam 7742.

4. The most sedentary offspring monitored was male yearling 7759 (Fig. 5A). Yearling 7759 was one of twin yearlings produced by dam 7713. We succeeded in radio-collaring both 7759 and its male twin 7756. Yearling 7759 dispersed a mean of only 0.2 km from the dam's year-round home range. The maximum distance 7759 was separated from the dam's home range was 0.5 km. Unfortunately, the transmitter on 7756 failed after one relocation within the dam's home range. We visually relocated 7756, 5.5 months later, approximately 250 m from 7759, and both yearlings were within 7713's home range at that time. Thus, both offspring appeared to remain very close to their dam's home range.

5. Adult cow 7704 and female yearling 7760 are the only pair not exhibiting overlapping of home ranges (Fig. 5C). However, yearling 7760 dispersed a mean of only 5.1 km on a year-round basis and was separated from the dam's home range a maximum of 15.0 km.

DISCUSSION

Dispersal by subadult moose in the study area was characterized by relatively short movement away from their dams' home range. Home ranges of subadults were generally established in close proximity to the dam with some overlap between dam and offspring ranges. Long distance emigration resulting in the formation of a home range entirely separate from that of their dams was not observed.

Some dispersal of subadult moose from the home range of their dams seems inevitable because offspring rarely retain persistent social bonds with their dams after 1 year of age. Only when family groups are maintained, as in mountain sheep *(Ovis dalli)* (Geist 1971) or elephants *(Loxodonta africana)* (Douglas-Hamilton and Douglas-Hamilton 1975), and only if fidelity to the annual home range is strong, would home ranges of the dam and offspring coincide completely. Even in those species which maintain family units, one sex usually leaves the family unit upon reaching puberty and establishes a separate home range (Geist 1971, Douglas-Hamilton and Douglas-Hamilton 1975). Considering the definition we used for dispersal and the absence of persistent maternal/filial bonds in moose, we expected to observe dispersal. The question to be addressed was what was the relative magnitude of dispersal in this particular moose population and its demographic significance to this and adjacent moose populations.

We were unable to compare much of our data with those of other investigators because no other studies were found that evaluated dispersal of subadult moose relative to the home range of their dams. However, data presented by Houston (1968), Roussel et al. (1975), and Lynch (1976) suggested that greater dispersal of subadults occurred than was observed in the present study. In each of the above studies moose were marked in what we interpreted to be high density moose populations relative to the carrying capacity of the range. However, we admit this interpretation may be incorrect.

The low density moose population in the present study would probably be slow to locate and exploit newly created, high quality seral habitat. This is in contrast to the rapid reoccupation of a burn by moose in Minnesota where moose densities increased approximately five-fold in two growing seasons following a wildfire (Peek 1974a). At that time moose had generally reached peak densities for recorded history in northeast Minnesota (Peek et al. 1976) and were probably near carrying capacity in the area adjacent to the burn (surmised from Peek 1974a).

Wildfire is the primary ecological factor creating extensive areas of seral moose habitat in Interior Alaska. The first moose to reoccupy burns in our study area will probably be offspring of moose with home ranges adjacent to the burn, or adults partially, or totally, displaced by the effects of the wildfire and adopting new home ranges adjacent to the burn. The strong fidelity of adult moose to home ranges which we and others (Coady 1976, VanBallenberghe 1978) observed indicated that few adults, not living next to a burn or migrating through it, would ever encounter new burns and be faced with the choice of maintaining traditional home ranges or utilizing new habitat.

There probably is minimal environmental and social pressure to disperse into newly created, vacant habitat from low density populations as compared to high density moose populations such as those studied by Houston (1968) or Peek (1974a). Howard (1960) suggested that environmentally induced dispersal should move offspring only far enough to locate more favorable habitat or reduce social stress. Houston (1968) observed agonistic behavior by adult moose towards yearlings and suggested that it was the incentive which resulted in yearlings dispersing from high to low density areas. Therefore, when moose density is high more moose should disperse farther and those which disperse in the direction of a burn, for example, may readily occupy it. Those dispersing moose not encountering the high quality habitat will presumably occupy marginal habitat where moose density is low and agonistic behavior is reduced (Houston 1968).

Wildlife and habitat managers should not expect rapid, short-term increases in moose density as a result of habitat improvement programs in Interior Alaska where moose densities are low relative to carrying capacity. However, this does not discount the present value of habitat improvement programs through controlled wildfires. Wildfires are necessary for the long-term maintenance of high moose densities, and in some areas of Interior Alaska where habitat quality is low wildfire must precede other management actions which could lead to increased potential growth of moose populations.

Moose populations which have been locally reduced by hunting or predation and which are adjacent to other low density moose populations should receive relatively few dispersing moose for reasons similar to those discussed for the reoccupation of burned sites. If immigration does not contribute substantially to restocking depleted range, then the offspring of surviving adults must be the primary stock for repopulating these areas (Goddard 1970). Even in relatively high density moose populations where dispersal of subadults was documented (Lynch 1976), no dispersal into heavily hunted and locally depleted areas was observed. Moose managers should, therefore, think of each low density moose population as a separate entity and manage it with respect to its unique demographic parameters.

RECOMMENDATIONS

Combine monitoring the movements of subadult moose and their dams to determine the magnitude of dispersal by subadults.

ACKNOWLEDGMENTS

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JOB FINAL REPORT (RESEARCH)

State: Alaska

Cooperators: William C. Gasaway, Nancy Tankersly, Arthur Flynn, and Albert W. Franzmann

Project No.: W-21-1 Project Title: Big Game Investigations

Job No.: 1.28R Job Title: Moose Mineral Lick Studies

Period Covered: July 1, 1979 through June 30, 1980

SUMMARY

Nancy Tankersly is continuing field studies and will complete writing the results for a Master's Thesis by January 1981. Laboratory analysis of approximately 125 lick samples has not been completed to date.

BACKGROUND

It has long been observed that ungulates throughout the world seek out minerals from sources other than food (Cowan and Brink 1949, Heimer 1973). Most commonly these sites are licks characterized by wet, muddy areas fed by a ground water source. However, recently moose *(Alces alces)* have been reported to actively select aquatic microplants as a primary nonbrowse mineral source in Ontario and on Isle Royale (Botkin et al. 1973, Jordan et al. 1973). These authors stress the role of sodium as a possible limiting factor for moose. Other studies have suggested single elements as limiting factors to ungulates (Hanson and Jones 1976, Best et al. 1977); however, in some situations several macro- and/or microelements are likely to be sought from licks and aquatic plants, as suggested by Cowan and Brink (1949) and Chamberlin et al. (1977). Mineral licks are possibly of great importance to Alaskan moose as has been shown for moose in Alberta, Ontario, and Isle Royale; however, information is limited on the use of licks by Alaskan moose. Studies in Alberta (Best et al. 1977) indicate moose annually make significant deviations to visit licks during migrations from winter to summer range. These visits appear to last only a few days. Gerry Lynch (pers. comm.) concluded from his studies that most moose in Alberta have a lick within their home range. Therefore, the distribution and abundance of moose may be somewhat dependent on access to licks. Hence, land use policies should consider the preservation of mineral licks, and, possibly, the frequently used sources of aquatic plants in Alaska if studies demonstrate moose reliance on these mineral sources (Franzmann et al. 1975). The success of moose management programs in certain areas of the state could be dependent upon the long-term maintenance of such critical habitats.

Moose licks and aquatic feeding sites are vulnerable to destruction by man due to their general lowland nature and overlap with man's use of the land (Franzmann et al. 1975). Road construction and agricultural and industrial development may not only limit, or exclude, moose from traditional licks but may also change the flow pattern of ground and surface water in some areas. This could limit availability of aquatic plants in areas where they replace mineral licks.

The need for adequate mineral sources for moose in Alaska has been clearly demonstrated in studies by Flynn and Franzmann (1974) and Flynn et al. (1977) where copper deficiencies were identified in Kenai moose. If moose mineral sources are not permanently maintained, deficiencies may develop which would complicate our already difficult task of managing moose populations.

OBJECTIVES

To determine the abundance of mineral licks and aquatic feeding sites in Alaska and time and magnitude of their use by moose; to determine the chemical nature and required elements in mineral licks; to determine the relative importance of mineral sources to moose and to define their management implication.

METHODS

Presently, 18 licks are known to exist in Interior Alaska and two on the Kenai Peninsula. Three licks in McKinley Park occur within the two areas of greatest summer moose density. Several licks on Eielson AFB are spread along the base of a ridge for approximately 1 mile. These licks are near existing roads, making them readily available for study. Efforts were made to locate and sample other moose mineral licks throughout Alaska.

Observations at licks were conducted periodically during the snow-free season to determine the time and magnitude of lick use. Lick samples were collected throughout the state and will be analyzed for micro- and macroelements. Samples will be analyzed for the following minerals required by ungulates: Ca, P, K, Na, Cl, Mg, S, I, Fe, Cu, Mn, Se, Co, Zn, Mo, Cr, Sn, V, Ni, and Si, and elements toxic to ruminants: Pb, Cd, As, and Hg.

RESULTS

The field work in this cooperative study was carried out by Nancy Tankersly, graduate student at the University of Alaska. Results of her research will provide the basis for a Master's Thesis and should be available by January 1981.

The ADF&G provided funds for the analysis of mineral lick samples from licks sampled by Nancy Tankersly. Approximately 125 samples were collected during the year and sent to Arthur Flynn for analyses. The analyses of lick samples have not been completed as yet; therefore, results will be reported in Ms. Tankersly's thesis.

RECOMMENDATIONS

1. Analyze data collected and report the results.

2. Sample additional mineral licks.

3. Make recommendations on management of land in the vicinity of mineral licks used by moose.

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