Status and Seasonal Distribution of Moose in the Northern Richardson Mountains

C.M.M. Smits
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STATUS AND SEASONAL DISTRIBUTION OF MOOSE

IN THE NORTHERN RICHARDSON MOUNTAINS

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ABSTRACT

Presented are the results of a study into the abundance, seasonal movement patterns, and habitat use of moose (Alces alces) in the northern Richardson Mountains and adjacent Yukon Coastal Plain. Aerial surveys covering the whole study area were completed in March/April and October 1987, April and November 1988, and March 1989. All surveys prior to 1989 were fixed-wing surveys for the purpose of determining sex/age composition and seasonal distribution. The March 1989 survey yielded, additionally, a precise estimate of moose abundance in the study area: 237 adults (>1 yr.) ± 28 (95% CI). The extended population estimate including calves amounted to 283. Twenty-six adult moose were radio-collared (20 in October 1987: 14 females, six males; six in July 1988: four females, two males) across the study area and aerially monitored through July 1990 to determine mortality rates, seasonal movements and habitat use. The range of annual mortality (95% CI) was 8.7%-17.4% and 15.8%-21.1% for the periods June 1988 - July 1989 and July 1989 - July 1990, respectively. Although estimates of calf recruitment in March 1989 overlap with the adult mortality rate estimated for the period June 1988-July 1989 it is thought to be more likely for the population to have increased during the period June 1988 - July 1989. Mean group size of moose was lowest in July (1.3) and highest in December (4.4). Seasonal movement patterns were strikingly different between moose spending the summer on the North Slope ('North Slope moose') and those summering on the South Slope ('South Slope moose'). North Slope moose exhibited maximum distances between summer and winter locations averaging 97.3 km, significantly different from South Slope moose (30.3 km). Total home range area of adult males was not different from adult females. Average home range area of combined adult male and adult female moose was 1,142.0 km^2. Mean home range area of 'North Slope moose' (2,285.2 km^2) differed from 'South Slope moose' ($\bar{X}$=197.6 km^2). Moose habitat constituted 609.0 km^2 (6.5%) of the study area with a March 1989 density of 0.46 $moose.km^{-2}$ of moose habitat. Of nine radio-collared moose summering on the North Slope, only one remained there year-round. A quantitative estimate of seasonal distribution was derived from the distribution of radio-collared animals relative to the numbers and distribution of moose observed during the March 1989 survey. It appeared that 160 moose were present on the North Slope during the summer of 1988. Sixty-nine percent of these wintered on the South Slope within the study area. The remaining 173 moose wintering on the South Slope appeared to be year-round residents. During late winter, 88% of the estimated moose 'sub'-population resides in the Yukon, and 12% in the Northwest Territories. Observations of moose in groups with one or more radio-collared moose, pooled by season among years, were non-randomly associated with vegetation types during all seasons. Moose were most often associated with shrub vegetation in all seasons (range 50.7%-94.3%). Association with other vegetation types ranged from 0%-13.0% for coniferous vegetation, from 0.8%-2.9% for deciduous vegetation, and from 4.8%-33.3% for mixed coniferous/deciduous vegetation. Significant positive linear relationships were found between moose numbers and total moose habitat, by drainage and between moose numbers and shrub vegetation availability, by drainage. Moose were non-randomly associated with elevational classes during all seasons. During spring most animals were concentrated between 1,000-2,499ft. The most frequently used elevation was 1,000-1,499ft. Summer observations were more evenly distributed over the available elevations. Relative to spring, this constituted a shift toward lower (<1,000ft) elevations. In fall moose were concentrated between 1,500-2,999ft, with almost half of all observations between 2,000-2,499ft. During winter moose were relatively evenly distributed over the 1,000-2,499ft elevations. Moose groups were seasonally aggregated although less aggregated in April 1988 than in either April 1987, or March 1989. Similarly, moose groups were more aggregated in fall than they were in late winter/spring. The clumped distribution of moose combined with the narrowness of habitat patches makes the moose population vulnerable to hunting and disturbance. Because current estimates of 'North Slope moose' are crude and this 'sub'-population is difficult to survey, conservative harvest rates of 3%, bull only, or 5 bulls annually, are proposed. For the South Slope portion of the study area an annual harvest rate of 6% or ten moose, either sex, is proposed. Proportional with the distribution of moose observed during March 1989 nine of these should be harvested in Yukon and one from the Northwest Territories.

INTRODUCTION

Little is known of the biology of moose (Alces alces) on the Yukon North Slope. Most observations of moose in the area were made in the early 1970's in conjunction with caribou studies addressing the impact of a proposed pipeline route (Watson et al. 1973; Doll et al. 1974; Jakimchuk et al. 1974; Ruttan, 1974; Walton-Rankin 1977; Wooley 1976). As a result, these observations have been inconsistently collected and are insufficient as baseline information to manage moose. The available information suggests that these moose constitute a unique population; striking features appear to be their migratory behaviour and their dependence on often widely dispersed habitat patches. Such characteristics would make this moose population vulnerable to hunting and disturbance.

Up to the present, moose in the area have occurred under relatively pristine conditions, however various sources of potentially negative impact are anticipated for the future. They include: 1) habitat degradation and displacement by road development supporting exploration and development of hydrocarbon resources in the Beaufort Sea, 2) increased harvest levels facilitated by these roads, and, 3) the establishment of an outfitting industry.

Because the Yukon Fish and Wildlife Branch lacks the necessary information about moose populations in the area to accurately assess the ultimate impacts from these increasing resource demands, it is unable to dispute or condone specific demands or provide recommendations to regulate and minimize negative impacts on moose populations or habitat.

The eastern part of the Yukon North Slope is likely to be the first area to become exposed to these impacts. The Yukon Fish and Wildlife Branch, in support of the Wildlife Management Advisory Council (North Slope), therefore embarked on a study with the following objectives:

1. To determine abundance of moose in the study area.
2. To delineate seasonal movement patterns and location, timing, and duration of seasonal use of habitat units.
3. To estimate sustainable harvest levels.

STUDY AREA

The study area (9,367 km^2) includes the northern Richardson Mountains and adjacent Yukon Coastal Plain (Fig. 1). The southern extension of the study area includes the northern slopes of Mt. Millen. To the west, the area extends as far as the headwaters of the western tributaries of the upper Bell River, and the Blow River excluding its western tributaries. The Mackenzie River Delta forms the eastern and northern boundary.

The following description is derived from Wiken et al. (1981). The northern Richardson Mountains are angular mountains eroded from the folds of cretaceous sandstones. Much of the landscape is composed of colluvium-covered slopes and valley bottoms covered with fluvial sediments. The northern part of the Richardson Mountains has substantially less relief, forming a transition between the high, angular mountains to the south and the relatively low and flat Yukon Coastal Plain. The Yukon Coastal Plain consists of rolling deposits of moraine interspersed with nearly flat areas of lacustrine materials.

The climate of the area is subarctic continental. The mean daily temperatures in the winter are commonly below -20°C, whereas those in the summer are slightly above 3°C. Precipitation at all times of the year is light; total annual accumulation is often under 13 cm.

Alpine vegetation is widespread in the Richardson Mountains; upper slopes are largely bare of vegetation. Middle and lower portions of slopes have open stands of white spruce (Picea glauca) in the northern and eastern part, or white spruce along with white birch (Betula papyrifera) in the southern part. White spruce lines the river and stream borders in the southern part of the study area; along many of the streams common species include balsam poplar (Populus balsamifera), and willow shrubs (Salix spp.). In the northern part, river and stream bottoms are typified by thickets or scattered individuals of willow shrub. Vegetation of river and stream terraces is highly variable across the study area, depending upon surface materials, but common species are willow shrub and shrub birch (Betula glandulosa), along with white spruce, alder (Alnus crispa), alpine blueberry (Vaccininum uliginosum), bog cranberry (V. vitis-idaea), common crowberry (Empetrum nigrum), Labrador tea (Ledum palustre), cloudberry (Rubus chamaemorus), and mosses.

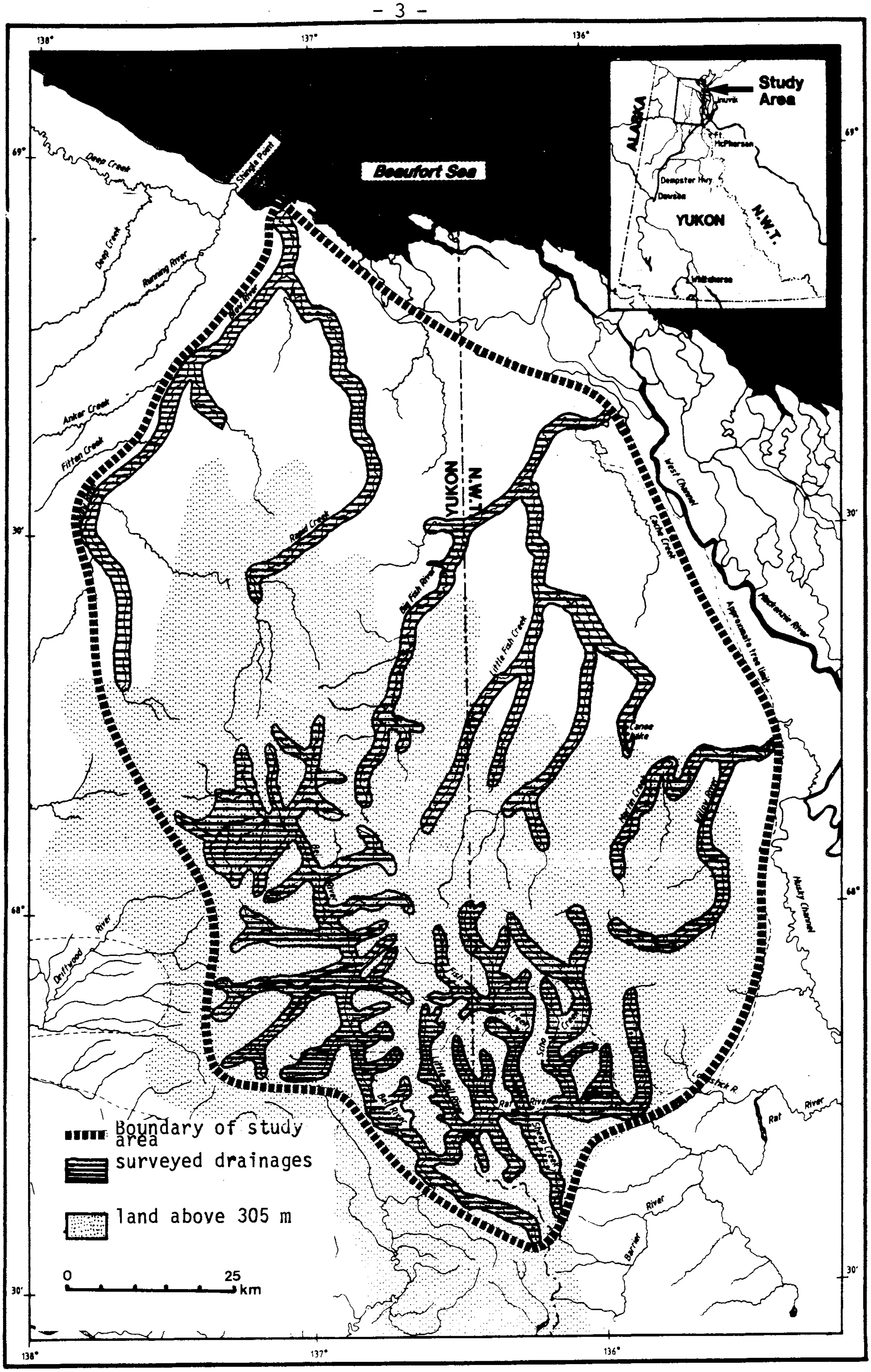

Fig. 1. Location of the study area.

The vegetation of the Yukon Coastal Plain is predominantly tussock and trailing heath tundra composed of sheated cottongrass (Eriophorum vaginatum), along with Labrador tea, bog cranberry, and dwarf birch (Betula nana). Other trailing shrubs such as Alpine blueberry, crowberry, Arctic heather (Cassiope tetragona) and common bog-rosemary (Andromeda polifolia) are widespread, while mosses, particularly Sphagnum sp., are locally abundant.

Moose habitat is generally less extensive and productive in the area draining towards the Beaufort Sea and adjacent Mackenzie Delta, i.e. the North Slope as compared to the area draining towards the Porcupine and Rat Rivers, i.e. the South Slope.

As part of this study, moose habitat was delineated from Thematic Mapper Imagery and black and white airphotos (appendix A). Moose habitat was assumed to be indicated by tree and shrub vegetation protruding above the snow. This assumption was confirmed during the study from cumulative observations of moose during aerial surveys and monitoring flights.

METHODS

Abundance

Information of abundance was collected through aerial surveys during March-April 1987, April 1988, and March 1989. The surveys were conducted when the ground was snow covered. Practically all moose habitat occurs in relatively narrow valley bottoms (Watson et al., 1973; Walton-Rankin, 1977). The surveys were therefore essentially drainage surveys (Fig. 1) (Martin and Garner, 1985).

The March-April 1987 and April 1988 surveys were flown with a Piper PA-18 Super Cub at 60-120 m above ground level at an indicated airspeed of approximately 112 km/hr.$^{-1}$. Valley bottoms with relatively open moose habitat narrower than 800 m were covered with two adjacent transects (one flying up, the other flying down the valley). In wider habitat units, or those with a relatively dense vegetation, more transects were flown to minimize avoiding animals.

The observer in the rear seat watched one side while the pilot watched the other side and the front. The locations of moose were plotted on a 1:250,000 topographical map. Moose were classified as adult or short yearling on the

+basis of body size, and group size was recorded. A group was defined as all moose within approximately 50 m of one another. Notes were also made of the habitat unit moose were associated with (see Habitat Use). During the April 1988 survey, an estimate of visibility bias was derived from the proportion of radio-collared moose present in the study area observed during the survey. All moose observed were checked for presence of a radio collar. Immediately following the survey, the study area was aerially monitored for radio-collared moose. Radio-collared animals were located no later than one day after completion of the survey and it is assumed that no radio-collared animals moved out of, or into, the study area during this time. The total number of moose estimated to be in the area was calculated by applying the Lincoln-Petersen method (Chapman 1951) to the radio-collared sample of adult moose in the study area as follows:

$$\hat{N} = \frac{(n_a + 1)(n_b + 1)}{(m_b + 1)} - 1,$$

where, $\hat{N}$ is the estimate of total population size,

n_a is the number of radio-collared moose present in the study area,

n_b is the total number of moose observed during the survey,

m_b is the number of radio-collared moose observed during the survey.

The estimated variance of $\hat{N}$ (Seber 1982:60) is defined as:

$$\hat{Var}\ (\hat{N}) = \frac{(n_a + 1)(n_b + 1)(n_a - m_b)(n_b - m_b)}{(m_b + 1)^2\ (m_b + 2)}$$

with a 95% confidence interval constructed as:

$$\hat{N} \pm 1.96\ \hat{Var}\ (\hat{N})^{\frac{1}{2}}$$

Estimates were made only for adults and, therefore, adults are the only class for which a confidence interval could be calculated. Estimates of numbers of yearlings and calves were derived by applying their observed ratios to adults from surveys to the number of adults as calculated from the Lincoln-Petersen method.

Confidence intervals for calf or short-yearling proportions were calculated following Spiegel (1961:158)'s method for sampling without replacement from a population of finite size:

$$P \pm z_c \sqrt{\frac{pq}{N}} \sqrt{\frac{N_p - N}{N_p - 1}},$$

where, P is the calf or short-yearling proportion in the population,

z_c is the normal deviate,

p is the calf or short-yearling proportion in the observed sample,

q1 is (1-p),

N_p is the total estimated number of moose in the population

N is the number of moose in the observed sample.

The March 1989 survey was flown with a Bell 206B Jet Ranger helicopter at 30-60 m above ground level at an indicated air speed of 95-160 km/hr^{-1}. Valley bottoms with extensive stands of coniferous forest cover were flown following transects approximately at right angles to the main valley. This method differed from the approach used during previous surveys (by Super Cub) of the study area. The latter method involved flying up the valley covering moose habitat on one side of the drainage and subsequently flying down the valley on the other side. The helicopter caused substantially more disturbance than previous fixed-wing surveys and great errors might have resulted by causing moose to move to the unsurveyed side of the valley. With the procedure used, observed moose were still disturbed, however as transects across the narrow (usually < 1 km) valley bottoms were relatively short these moose could be kept track of. Survey routes were similar to those previously used. Two observers sat in the rear of the helicopter, one on each side. A navigator in the front, as well as the pilot, acted also as observers. The locations of moose were plotted on a 1:250,000 topographical map. Moose were classified as adult (>22 months) female or male by the presence or absence of a vulva patch (Mitchell, 1970) or antler pedicles, as short yearling (10 months), or as unclassified adult. Group size was recorded and notes were made of the habitat unit moose were associated with. Visibility bias was also estimated from the proportion of radio-collared moose observed during the survey. Unlike the procedure followed during the April 1988 survey, the identity of radio-collared animals observed was determined immediately upon locating them by turning on the receiver. The receiver was only briefly turned on to identify radio-collared moose observed and this minimized possible biases caused by increased search effort for additional radio-collared moose heard nearby. The calculations of the estimate of the total number of adult moose present in the study area, its confidence interval, and the extended estimate of the total number of adult and calf moose was identical to the one used for the April 1988 survey.

A survey to determine sex and age composition was carried out in November 1988 (see below). Although not specifically designed to determine abundance (the procedures, however, were similar to those used during late winter surveys), survey conditions were better during this survey than during the April 1988 survey. For comparative purposes, therefore, the results of this survey are also reported with respect to abundance.

Sex and age composition

In addition to information of sex/age composition collected during the March-April 1987, April 1988, and March 1989 surveys, sex and age composition was determined from aerial drainage surveys in October 1987 and November 1988, covering the standardized survey route. The procedures of this survey were similar to the March-April 1987 and April 1988 surveys with the exception that moose were classified as adult ($\geq$30 months) male, female, yearling male (18 months)(based on antler characteristics, Dubois *et al*., 1981) and calf. The proportion of all yearlings in the sample population was subsequently calculated by doubling the proportion of yearling males observed, assuming even sex ratio at birth and no difference in calf mortality between males and females. Since yearling females are likely mistaken for adult females, the proportion of adult females was similarly corrected by subtracting the observed number of yearling males from the total number of adult females.

Capture and immobilization

Following the October 1987 survey, 20 moose were captured and fitted with radio collars. Fourteen adult female and six adult male moose were immobilized from a Bell 206B Jet Ranger helicopter using a Cap-Chur dart rifle (Palmer Chemical and Equipment Co., Douglasville, GA, USA) and a combination of carfentanil and Xylazine. The moose were fitted with radio transmitters attached to collars

(Telonics Inc., Mesa, Arizona). The transmitters pulsed initially at approximately 60 beats/minute (slow mode) and when movement ceased for 6 hours, the pulse rate tripled (fast or mortality mode). An outside incisor was pulled for aging (Sergeant and Pimlott 1959). Female moose were palpated via the rectum for pregnancy diagnosis. Blood samples were collected to determine serum progesterone levels providing another means of pregnancy diagnosis. After handling, a mixture of Nalaxone and Diprenorphine hydrochloride (M50-50) was administered as an antagonist.

An additional six moose were captured on the North Slope during July 1988. Four adult cows and two adult bulls were located and immobilized from a Bell 206B Jet Ranger helicopter using a Cap-Chur dart rifle and a combination of 5 ml Etorphine hydrochloride (M 99) and 2 ml Xylazine hydrochloride (Rompun). The moose were fitted with radio transmitters similar to the ones used in October 1987. After handling, 7 ml Diprenorphine hydrochloride (M 50-50) was administered as an antagonist.

Aerial monitoring

Aerial searches for radio-collared moose were made in December 1987, January, February, March, April, May, June, August, September, November 1988, February, March, May, July, September, November 1989, and in March and July 1990. Aircraft used included Cessna-170, Cessna-185, Piper PA-18 Super Cub, Cessna-300, Cessna-206, Piper PA-12, Bell 206B Jet Ranger. With the exception of the monitoring flight in February (by Cessna-300), attempts were made during all flights to make visual contact with radio-collared animals. The February 1989 flight was used to locate some radio-collared animals not found on some previous monitoring flights. Radio-collared moose heard on this flight were located very imprecisely and these were therefore not used in home range analyses. Once observed, group size was recorded and notes were made of the vegetation type moose were associated with. Moose were classified as adult female or male by the absence or presence of antlers, as calves, or as unclassified adults.

Mortality

Annual adult mortality rates were calculated from the known mortality of radio-collared moose using Kaplan-Meier survival analysis (Pollock et al. 1989). Only radio-collared moose known to be dead (from carcass observation) were used in the calculations. Bounds to the survival distribution were obtained by allowing censoring (e.g. losing contact with animals) to take two very extreme forms. A lower bound was obtained by assuming that every censored observation was really a death and an upper bound by assuming that every censored observation was not a death and that the animal survived to the end of the study. Differences in survival functions between years were tested using the log-rank test (Pollock et al. 1989). Natural calf mortality was estimated from aerial surveys during fall and late winter in the form of calf/cow and yearling/cow ratios. Calf/cow ratios were based on estimates of cows $\geq$30 months (fall surveys) and cows $\geq$22 months (late winter surveys); yearling/cow ratios were based on estimates of cows $\geq$30 months (fall surveys).

Home Range

Locations of moose obtained during aerial monitoring flights were plotted on 1:250,000 topographical maps. Home range areas, as defined by Burt (1943), were estimated with program HOMERANGE (Ackerman et al. 1989). Program HOMERANGE provides home range estimates based on several different methods. I selected the minimum convex polygon method (Hayne 1949). Sample size (the no. locations used to depict a home range) has been shown to have a nonlinear, positive relationship to estimate home-range size (Cranford 1977, Bekoff and Mech 1984) if based on nonstatistical measures such as the minimum convex polygon. The effect of sample size on estimated home-range size was analyzed for combined home ranges using the REG procedure of SAS (SAS Institute Inc, 1985). Only home ranges estimated from at least the minimum number of locations necessary to cause a loss of significance in the relationship between sample size and home range size were used in male-female comparisons. Differences between home range sizes were evaluated with the Mann-Whitney U test.

Habitat use

Vegetation type selection

Association of moose with specified habitat types was described during surveys and monitoring flights. Habitat types were described by the dominant vegetation within an area extending approximately 100 m around observed groups of moose (e.g. shrub vegetation, coniferous forest, deciduous forest, mixed coniferous/deciduous forest). Surface area of vegetation types was calculated from a vegetation map delineating moose habitat in the study area (Appendix B) in order to:

1. evaluate seasonal preference or avoidance by moose of vegetation types (following Neu et al. 1974). For this analysis cow-calf groups were treated as single observations as calves are assumed to not utilize habitat independently of their mother.
2. to calculate moose density (number of moose estimated from aerial surveys per total available moose habitat).

In this report, we use the Chi-square technique to analyze utilization-availability under the restrictions proposed by Cochran (1954), i.e., that no expected frequency should be less than 1.0 and that no more than 20% of the expected frequencies should be less than 5.0. Habitat use differences between seasons were evaluated using Chi-square heterogeneity testing (Zar 1984:50).

Spatial and elevational distribution

The spatial distribution of groups of moose observed during aerial surveys was tested for conformity to a random distribution using the distance to nearest neighbour method (Clark and Evans 1954). The mean of the distances between each group and its nearest neighbour is computed, as is the mean to be expected if dispersion were random. The ratio (R) of the observed mean distance to the expected mean distance serves as the measure of departure from randomness. In a random distribution, R equals 1. Under conditions of maximum aggregation, R equals 0, while under conditions of maximum spacing R equals 2.1491. The significance of the difference between the means of observed and random dispersion patterns is obtained from the standard variate of the normal curve (c). The c values 1.96 and 2.58 represent respectively the 5% and the 1%

levels of significance. Differences in R between surveys were evaluated using procedures outlined by Clark and Evans (1954:452) and the ANOVA (Tukey's studentized range test) procedure of SAS (SAS Institute Inc., 1985). The elevational distribution of individual moose observed during monitoring flights was compared with the elevational distribution of 1014 randomly generated points across the study area using the techniques described by Marcum and Loftsgaarden (1980) and Neu et al. (1974). Cow-calf groups were treated as single observations for this analysis. Differences in elevational distribution between seasons were evaluated using Chi-square heterogeneity testing (Zar 1984:50).

RESULTS

Abundance and Sex/Age Composition

Aerial surveys covering the whole study area were performed during March/April 1987, October 1987, April 1988, November 1988, and March 1989 (Table 1).

Table 1. Numbers and sex/age composition of moose observed during surveys in the northern Richardson Mountains.

Sex/age Composition[a]	March/April 1987		October 1987		April 1988		November 1988		March 1989	
	n[b]	%	n[b]	%	n[b]	%	n[b]	%	n[b]	%
Bulls			46	43.8			104	36.2	100	37.7
Cows		84.0	35	33.3			112	39.0	91	34.3
Yearlings			6	5.7			30	10.5		
Unclass. Adults	152				118	84.3			31	11.7
Calves	29	16.0 ($\pm$2.8)[c]	18	17.1 ($\pm$2.9)[c]	22	15.7($\pm$3.7)[c]	41	14.3($\pm$1.8)[c]	43	16.2($\pm$1.0)[c]
TOTAL	181		105		140		287		265	
Bulls/100 cows			132				93		108	
Yearlings/100 cows			17				27			
Calves/100 cows			51[d]				37[d]		41[d]	
Twinning rate		11.5		20.0		22.2		20.6		16.2

[a] bulls, cows: ≥30 months (November survey), ≥22 months (March survey); yearlings: 18 months (November survey); calves: ~10 months (March, April surveys), ~6 (November survey); unclass. adults: ≥22 months (March, April surveys).

[b] number of moose in category observed (yearlings and adult females corrected as outlined in methods).

[c] 95% confidence interval; values for total population size used in variance calculations is 283 for late-winter surveys, and 383 for fall surveys.

[d] assuming a male:female ratio of unclassified adults identical to the one observed among identified moose; note that fall calf:cow ratios exclude yearlings, unlike late-winter ratios.

Radio-collared animals were present in the study area during the latter three surveys and an estimate of observability was obtained using the proportion of observed radio-collared animals. The only survey yielding an estimate of total adult moose with an acceptable level of precision was the March 1989 survey (Table 2). The extended population estimate including calves and using the calf proportion among observed moose amounted to 283. A more detailed description of the surveys including survey conditions and moose distribution by drainage is provided in Appendix A (Survey Results, Tables 3, 4, 5, 6).

Table 2. Estimated abundance of moose in the study area as determined from aerial surveys.

Survey Period	95% Confidence Interval for Total Number of Adult Moose (CI%)	Total Number of Moose[a]
April 1988	380 ± 247 (65.0%)	451
November 1988	328 ± 87 (26.5%)	383
March 1989	237 ± 28 (11.8%)	283

a corrected for observed calf proportions.

Survival of radio-collared moose

Capture and immobilization

Twenty moose (14 adult females and 6 adult males) were captured across the study area and fitted with radio-collars during October 19-22, 1987 (Tables 7 and 8, Appendix A). An attempt was made to distribute moose captures over the whole study area. However, inclement weather prevented captures in the northwestern portion of the study area. Eleven (79%) of the cow moose immobilized were accompanied by calves, three of which had twin calves. These calf/cow ratios and twinning rates should not be taken to be representative of the population as a whole. Whenever two or more females were encountered in a group, females with twin calves were selected over females with single calves. This capture process of selecting against cows without calves would also cause an age-bias in the capture sample. Reproductive rates of yearling cows and old cows are lower than those of middle-aged cows (Pimlott 1959; Markgren 1969; Blood 1974) and middle-aged cows would thus tend to be captured in disproportionately higher numbers. In eleven (79%) of the female moose, eight of which were accompanied by calves, pregnancy was confirmed by rectal palpation. This figure should be considered a minimum estimate as foetuses can usually be detected by this method after only approximately two weeks (G. Glover, pers. commun.)

During July 18-20, 1988, six additional moose (four adult females and two adult males) were captured across the North Slope portion of the study area and fitted with radio-collars (Tables 7 and 8, Appendix A). An attempt was made to capture some animals in drainages in the eastern part of the North Slope (i.e. Willow River, Martin Creek) however, no moose were observed there. Two (50%) of the cow moose captured were accompanied by calves, one of which had twins.

Mortality

Adult Mortality

Seven (35%)(six females, one male) out of 20 adult moose radio-collared in October 1987 were confirmed to have died by July 1990 (Table 9; Appendix A). With the exception of one moose not heard since March 1989, all other moose radio-collared in October 1987 were confirmed alive in July 1989. One (17%)(male) out of six moose radio-collared in July 1988 was confirmed to have died by July 1990. It appeared to have died during the period September-November 1989.

When combined mortalities are grouped by period, six (75%) out of eight mortalities occurred during October-April and two (25%) during May-September.

Table 10 gives Kaplan-Meier survival estimates of radio-collared moose for the periods June 1988-July 1989 and July 1989-July 1990. Survival functions were similar between the two annual periods (Table 11). Annual mortality range was 8.7%-17.4% for June 1988-July 1989 and 15.8%-21.1% for July 1989-July 1990.

Table 10. Kaplan-Meier survival estimates for moose radio-collared in the study area October 1987, July 1988. Upper and lower bounds for the survival function have been presented. The upper bound has been obtained by assuming that every censored observation was not a death and the animals survived to the end of the study and the lower bound by assuming that every censored observation was really a death.

Period	Number at Risk	Number Deaths	Number Censored	Number New Added	Survival	Lower 95% CL* of Survival	Upper 95% CL** of Survival	Annual Mortality
June 1988 - July 1989	23	2(4)	2(0)	6	0.9130(0.8261)	0.6853	1.0231	0.0870(0.1739)
July 1989 - July 1990	19	3(4)	1(0)	0	0.8421(0.7895)	0.6266	0.9926	0.1579(0.2105)

* Lower 95% confidence limit of lower bound

** Upper 95% confidence limit of upper bound

Table 11. Log-rank test calculations comparing the four possible scenarios of survival distribution of radio-collared moose in the study area, between June 1988 - July 1989 and July 1989 - July 1990, modified to allow for the staggered entry of new animals into the study. Survival scenarios are those of Table 10.

June 1988 - July 1989		July 1989 - July 1990		Total					
No. at risk	No. deaths	No. at risk	No. deaths	No. at risk	No. deaths	E(d)*	var(d)**	χ^2***	p****
23	2	19	4	42	6	2.714	1.305	1.2673	0.25<p<0.50
23	2	19	3	42	5	2.262	1.118	0.4872	0.25<p<0.50
23	4	19	3	42	7	3.167	1.480	0.0188	0.75<p<0.90
23	4	19	4	42	8	3.619	1.643	0.0884	0.75<p<0.90

*E(d) Expected value for the number of deaths(d) in period July 1989 - July 1990.

**var(d) Variance of (d)

***χ^2 Approximate Chi-square test statistic with 1 degree of freedom.

****p Probability that year-to-year comparisons in survival are different.

Juvenile Mortality

Mortality information of calves of radio-collared cows is of a fragmented nature because it was often impossible to make observations of cow-calf groups during monitoring flights (Table 12, Appendix A). Of eleven cows with calves (14 calves) radio-collared in October 1987, visual contact was made with six (55%) during the following March or April monitoring flights. All eight calves associated with these six radio-collared cows were still present in March or April 1988 and one additional calf associated with a radio-collared cow in October 1987 which was not found during either March or April may have been alive as well (it was still alive in February 1988). Two radio-collared cows had lost their calves (n=2) by December. Of the remaining two cows with calves (n=3), the cows died during the winter and the fate of their calves is not known. The minimum mortality rate, therefore, would have been 0.18, however, if the calves (n=3) associated with cows that died during the winter also died, then the mortality rate might have been as high as 0.36. The latter cows died before March 5 and between February 6 and April 17. The status of their calves after capture was never ascertained.

Seven calves were confirmed present with cows in March 1989, indicating a mortality rate of 0.47-0.53 (7 or 8 out of 15) during the period May 1988-March 1989. Of seven calves assumed to have died during May 1988-March 1989, two appeared to have died by September, two more by November, and the remaining three between November and March. These mortality rates may well be higher since some neonatal calf mortality may have gone undetected as a result of infrequent monitoring flights.

Of 13 cows alive in May or July 1989, five were confirmed to have calves (n=6), two were observed without calves, and six were not observed during this period. Four of the latter six were observed later that year (either September or November) three of which were then without a calf, one with a single calf. Only three cows observed with calves during May-November 1989 were observed in March 1990 and were then without calves. The fate of the other calves is not known. This very small sample size suggests a calf mortality rate of 1.00.

An index of calf mortality between fall and late-winter surveys was obtained by comparing calf percentages (Table 1). Late-winter calf percentages were corrected for the adult mortality rates assumed for the fall to late-winter periods as determined from radio-collared animals. For the period October 1987-April 1988, a mean monthly mortality rate of 1.3 was used, assumed from the mean annual rate (15.8) between June 1988-July 1989 and July 1989-July 1990. For the period November 1988-March 1989, a mean monthly mortality rate of 1.1 was assumed from the mean annual rate (13.1) between July 1989 and July 1990. A comparison of the calf percentage from October 1987 (17.1) with the adjusted calf percentage of April 1988 (14.5) suggests a calf mortality rate of 0.15 during this period. Between November 1988 and March 1989, on the other hand, a comparison of these rates (14.3 and 15.5, respectively) would suggest a proportional increase of calves in the study area.

Movements, home range and habitat use

Group Size

Differences in observed mean group sizes per month were determined for radio-collared adult moose from December 1987 to July 1990 (Fig. 2). There were no differences among years; therefore, all years were pooled. Similarly, there were no differences in mean group sizes between moose observed during aerial surveys and groups associated with one or more radio-collared moose during radio-tracking flights conducted in the same month. Mean group size was lowest in July, then began increasing and reached a high in December,

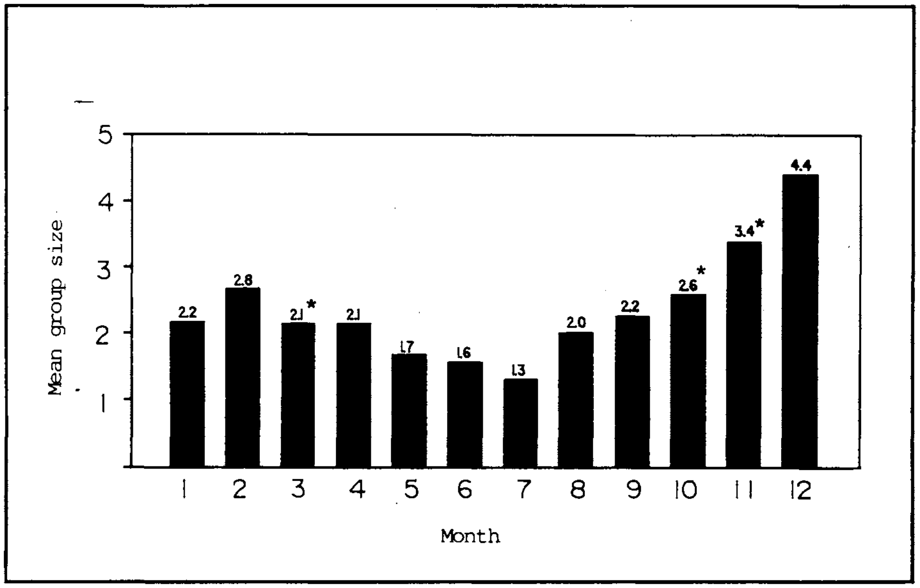

Figure 2. Mean group size containing one or more radio-collared moose by month of observation in the study area (* combined survey/radio-monitoring data).

reflecting rutting and post-rutting concentrations. After December mean group sizes declined until August.

Movement patterns

There was a striking difference in movement pattern between moose that spend the summer on the North Slope and those summering on the South Slope (Figures 3a-3q, Appendix A). Moose summering on the North Slope would typically make extensive movements to winter ranges to the south. Maximum distances between summer and winter locations averaged 97.3 km (±28.1, S.D.; range 60.0-138.0) for moose summering on the North Slope (moose summering on the North Slope as well as on the South Slope were excluded from this analysis). Maximum distances between seasonal locations (30.3 km, ± 6.8 S.D.; range 20.0-40.5) for moose summering on the South Slope were different from those summering on the North Slope ($p<0.001$). Of nine moose summering consistently on the North Slope, only one appeared to have remained there year-round.

From the seasonal distribution of radio-collared moose a quantitative, albeit crude, estimate can be otained of seasonal distribution of moose between the North Slope and the South Slope and between the study area and adjacent areas. A comparison of the ratio (1:20) of radio-collared moose (n=1) to observed moose (corrected for visibility bias) (n=20) during the March 1989 survey with the number of radio-collared moose located during summer (8) suggests that as many as, or more than, 160 moose may have been present on the North Slope during the summer of 1988. Of eight radio-collared moose summering on the North Slope, five consistently wintered on the South Slope within the study area, two on the South Slope outside of the study area, and one wintered one year inside, one year outside the study area, both years on the South Slope. Therefore, on average 69% of radio-collared moose summering on the North Slope wintered on the South Slope within the study area. The remaining 31% wintered outside of the study area. Therefore, it is assumed that 110 moose (69% of 160) summering on the North Slope, winter on the South Slope portion of the study area. The remaining 173 moose (283 from the March 1989 survey, minus 110) were year-round residents on the South Slope portion of the study area. From the March 1989 survey, it appears that 88% (n=234) of the study area "sub" population resided in Yukon, the remaining 12% (n=31) in the Northwest Territories during late winter.

Home range

Regression of home range area on number of locations for 21 total home ranges showed that over the range of sample sizes considered, the regression coefficient did not differ significantly (p=0.31) from zero (Fig. 4). Thus the

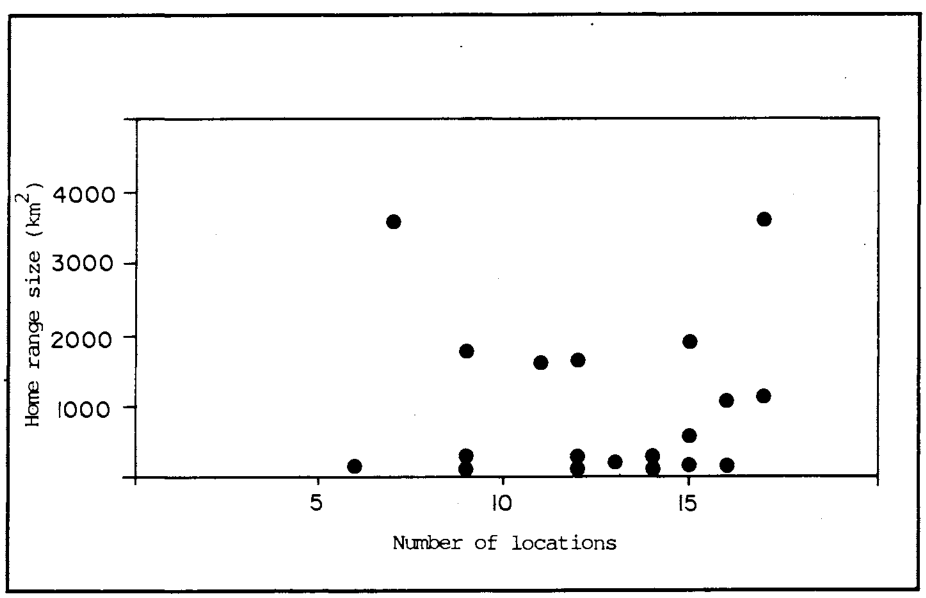

Figure 4. Home range size plotted against the number of locations for 21 individual moose in the study area. Only home ranges estimated from a minimum of six locations were used in the analysis (Y=2319.16 - 94.36X, R^2=0.05, p=0.31).

relationship of home range size to number of locations did not appear significant above the cut-off point of 5 locations which I used. Total home range area of adult males averaged 1,106.8 km^2 ($\pm$1,371.8, S.D.; range 39.0-3,934.5) not different ($p=0.68$) from adult females ($\bar{X}$=1,185.2 km^2 $\pm$1,433.9, S.D.; range 83.5-3847.5) . Average home range area of combined adult male and adult female moose was 1,142.0 (±1,445.6, S.D., range 39.0-3,934.5). Home ranges of moose summering on the North Slope averaged 2,285.2 km^2 ($\pm$1,480.7 S.D.; range 43.0-3,934.5), and were different ($p<0.003$) from moose summering on the South Slope ($\bar{x}$=197.6 km^2, $\pm$282.6 S.D.; range 39.0-163.0)(moose summering on the North Slope as well as on the South Slope were excluded from this analysis).

Habitat Use

Vegetation type distribution

The distribution of vegetation types in the study area was derived from satellite imagery and black and white aerial photography (Table 13) (see Appendix B for methods). Moose habitat constituted 609.9 km^2 of the study

Table 13. Area distribution of vegetation types across the study area, by drainage.

	Area Distribution (km^2)				
Drainage	Shrub	Coniferous	Deciduous	Mixed Coniferous/Deciduous	Total
South Slope:					
Bell River	123.0	52.0	7.3	0.9	183.2
Little Bell River	59.0	7.9	--	--	66.9
Fish Creek	19.7	15.7	--	--	35.4
Scho Creek	18.6	24.9	--	--	43.5
Creeks E. of Scho Creek	27.6	1.3	4.0	1.6	34.5
McDougall Pass area	13.0	9.4	9.5	--	31.9
Creek S. of Summit Lake	11.5	2.5	3.6	--	17.6
Subtotal	272.4	113.7	24.4	2.5	413.0
North Slope:					
Blow River	67.0	--	--	--	67.0
Rapid/Cache Creek	35.1	--	--	--	35.1
Big Fish River	29.3	--	6.0	9.6	44.9
Martin Creek/Willow River and Area	10.8	21.6	3.0	14.5	49.9
Subtotal	142.2	21.6	9.0	24.1	196.9
Total	414.6	135.3	33.4	26.6	609.9

area, 413.0 km^2 (67.7%) of which occurs on the South Slope, and 196.9 km^2 (32.3%) on the North Slope. Shrub vegetation (dominated by willow, dwarf birch, and alder) constituted the main vegetation type (68.0% of the area) followed by coniferous vegetation (dominated by white spruce)(22.2%), deciduous vegetation (dominated by balsam poplar)(5.5%), and mixed coniferous/deciduous vegetation (dominated by white spruce and balsam poplar)(4.4%).

Vegetation type selection

Moose were non-randomly associated with vegetation types during all aerial surveys. Similarly, when observations of radio-collared moose and those associated with these were pooled by season between years, moose were non-randomly associated with vegetation types during all seasons. Association of moose with vegetation types was different between October 1987 and November 1988 surveys (x^2=9.40, df3, p<0.025)(Table 14) with the difference most

Table 14. Distribution of association with vegetation types of moose observed during aerial surveys of the study area, March 1987 - March 1989.

Vegetation Type	Total Surface Area (km^2)	Observed Number of Moose by Survey Period				
		March/April 1987	October 1987	April 1988	November 1988	March 1989
Shrub	414.50	84$^{N.S.}$	73$^+$	74$^{N.S.}$	233$^+$	120$^-$
Coniferous	135.21	44$^+$	3$^-$	6$^-$	1$^-$	31$^-$
Deciduous	33.28	1$^-$	0$^-$	3$^{N.S.}$	1$^-$	2$^-$
Coniferous/ Deciduous	26.59	7$^{N.S.}$	0$^-$	34$^+$	11$^{N.S.}$	87$^+$
Total	609.58	136	76	117	246	240

N.S. Not significantly different from random association.
\+ Associated significantly more frequently than expected.
\- Associated significantly less frequently than expected.

pronounced in the use of coniferous (used more frequently in 1987) and mixed coniferous/deciduous vegetation (used more frequently in 1988). The shrub vegetation type was selected while coniferous and deciduous vegetation were avoided. Moose were non-randomly associated with coniferous/deciduous vegetation in November 1988 but avoided this type in October 1987. For both fall surveys moose were associated almost exclusively with shrub vegetation (94.7%-96.1% of all observations), and very infrequently with coniferous (0%-4.0%), deciduous (0.4%-4.0%), and mixed coniferous/deciduous (0%-4.5%) vegetation.

Vegetation use observed during late-winter surveys (Table 14) was different between years (x^2=278.15, df6, P<0.001) with the annual differences most pronounced in the relative use of coniferous and mixed coniferous/deciduous vegetation. For all the late winter surveys moose were associated most frequently with shrub vegetation (range 50%-61.8%), least with deciduous vegetation (0.7%-2.6%) and intermediate with coniferous (5.1%-32.4%) and mixed coniferous/deciduous (5.2%-36.3%) vegetation.

Seasonal comparisons in vegetation use were made for moose in groups with one or more radio-collared animals located during monitoring flights. Observations were pooled between years for the seasons spring, summer, fall, and winter. The pattern of vegetation use was different between seasons (heterogeneity x^2=114.20, df9, p<0.001). None of the vegetation types categories were consistently selected, avoided, or randomly used by moose during all seasons (Table 15). Moose avoided the shrub type during spring, selected it during summer and fall, and used it randomly during winter. The coniferous type was avoided during summer, fall, and winter, and used randomly during spring. The deciduous type was avoided during fall and winter and used randomly during

Table 15. Seasonal distribution of association with vegetation types of moose in groups with radio-collared animals located in the study area, December 1987 - July 1990 (data pooled between years).

Vegetation Type	Total Surface Area (km^2)	Season			
		Spring	Summer	Fall	Winter
Shrub	414.50	35^-	82^+	99^+	$82^{N.S.}$
Coniferous	135.21	$9^{N.S.}$	9^-	0^-	13^-
Deciduous	33.28	$2^{N.S.}$	$2^{N.S.}$	1^-	1^-
Coniferous/ Deciduous	26.59	23^-	$7^{N.S.}$	$5^{N.S.}$	22^+
Total	609.58	69	100	105	118

N.S. Not significantly different from random association.
\+ Associated significantly more frequently than expected.
\- Associated significantly less frequently than expected.

spring and summer. The mixed coniferous/deciduous type was selected during winter and spring and used randomly during summer and fall.

Moose were most often associated with shrub vegetation in all seasons (range: 50.7% - 94.3%). Association with other vegetation types ranged from 0%-13.0% for coniferous vegetation, from 0.8%-2.9% for deciduous vegetation, and from 4.8%-33.3% for mixed coniferous/deciduous vegetation.

Table 16 gives the distribution of moose numbers observed during the March 1989 survey (the most intensive survey during the course of study). Moose densities

Table 16. Abundance of moose relative to habitat availability as determined from an aerial survey in the study area during March 1989.

Drainage	Number of Moose	Available Habitat (km^2)	Moose Density ($moose/km^2$ habitat)
South Slope*:			
Bell River	179	183.2	0.98
Little Bell River	28	66.9	0.42
Fish Creek	11	35.4	0.31
Scho Creek	16	43.5	0.37
McDougall Pass area	4	31.9	0.13
North Slope*:			
Fish River	10	44.9	0.22
Rapid Creek/Cache Creek	7	35.1	0.20
Blow River	2	67.0	0.03

* Mean moose density of South Slope drainages (0.44) is significantly greater than that of North Slope drainages (0.15) ($t=3.22$, $df=7$, $p<0.02$).

were higher on the South Slope than on the North Slope. Moose numbers by drainage were regressed on the availability of vegetation categories within these drainages. There were significant positive linear relationships between moose numbers and total moose habitat, and between moose numbers and shrub vegetation availability (Figures 5 and 6). The number of moose estimated during the March 1989 survey (n=283) yield a density of 0.46 $moose.km^{-2}$ of moose habitat in the study area.

Elevational distribution

Moose in groups with radio-collared animals located during monitoring flights were non-randomly associated with elevational classes during all seasons (Table 17).

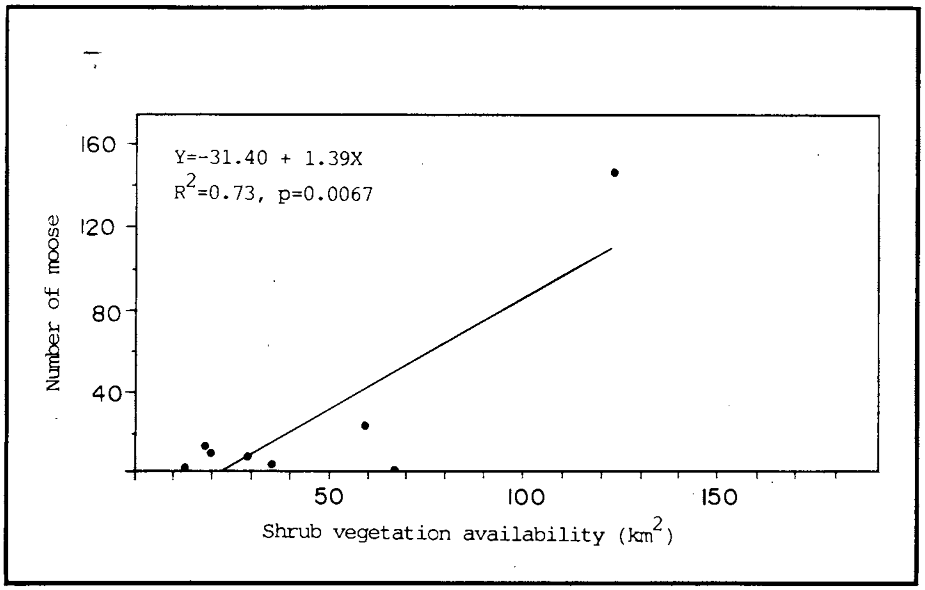

Figure 5. Shrub vegetation availability by drainage plotted against number of moose observed during an aerial survey of the study area during March 1989.

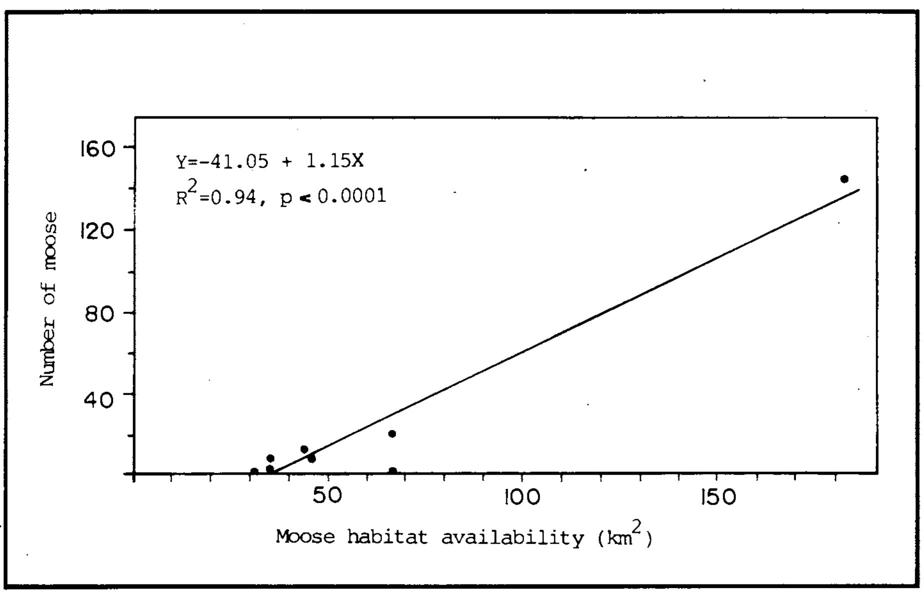

Figure 6. Availability of total moose habitat by drainage plotted against number of moose observed during an aerial survey of the study area during March 1989.

Table 17. Distribution of association with elevational classes of radio-collared moose located in the study area during combined seasons between December 1987 and July 1990.

Elevational Class (feet)	Availability of Elevational Class[a]	Season			
		Spring	Summer	Fall	Winter
0- 499	150	2^-	24^+	0^-	0^-
500- 999	191	4^-	8^-	0^-	1^-
1,000-1,499	186	29^+	$17^{N.S.}$	$4^{N.S.}$	30^+
1,500-1,999	130	$15^{N.S.}$	$13^{N.S.}$	$7^{N.S.}$	31^+
2,000-2,499	152	$16^{N.S.}$	$13^{N.S.}$	20^+	$24^{N.S.}$
2,500-2,999	102	$3^{N.S.}$	$6^{N.S.}$	$7^{N.S.}$	$8^{N.S.}$
3,000-3,499	64	1^-	1^-	$3^{N.S.}$	0^-
3,500-4,499	39	0^-	$1^{N.S.}$	$0^{N.S.}$	0^-
Total	1014	70	83	41	94

a Expressed as number of randomly generated points across study area to fall within elevational class (total number of points: 1,014).
N.S. Not significantly different from random association.
\+ Associated significantly more frequently than expected.
\- Associated significantly less frequently than expected.

During spring, moose selected the 1,000-1,499 ft. elevation, were randomly associated with the 1,500-2,999 ft. elevations, and avoided the 0-999 ft. and the 3,000-4,499 ft. elevations. During summer, the lowest elevations (0-499 ft.) were selected while other elevations were either avoided (500-999, 3,000-3,499) or randomly used (all classes between 1,000-2,999 ft., and 3,500-4,499). During fall, the 2,000-2,499 ft. elevation was selected while other elevations were either avoided (0-999 ft., 3,500-4,499 ft.) or used randomly (1000-1,999 ft., 2,500-3,499 ft.) During winter, the 1,000-1,999 ft. elevations were selected, the 2,000-2,999 ft. elevations used randomly, and all other elevational classes avoided. Elevational distributions were different between seasons (heterogeneity Chi-square = 138.10, df 24, $p<0.001$).

During spring most (85.7%) of all observations were concentrated between 1,000 ft.-2,499 ft. Summer observations were more evenly distributed over the available elevations. Compared to spring this constituted a shift towards lower (<1,000 ft.) elevations. Fall observations were concentrated between 1,500 ft.-2,999 ft., with almost half (48.8%) of all observations between 2,000 ft.-2,499 ft. During winter 90.4% of all observations were relatively evenly distributed over the 1,000 ft.-2,499 ft. elevations.

Spatial distribution

During all surveys, moose groups were more aggregated than they would have been under random conditions (Table 18). In some seasons, moose groups were more aggregated than in others (Table 19). Moose groups were less aggregated in April 1988 than in either April 1987 or March 1989. Similarly, moose groups were more aggregated in October 1987 than they were in either April 1987 or March 1989.

Table 18. Distribution and dispersion of groups of moose observed during aerial surveys of the study area.*

PERIOD	NUMBER OF GROUPS OBSERVED	GROUPS/km^2	r_A	r_E	R	C	P
March/April 1987	85	0.0091	2.38	5.25	0.45	9.66	<0.01
October 1987	41	0.0044	3.12	7.54	0.41	7.18	<0.01
April 1988	67	0.0072	4.66	5.91	0.79	3.31	<0.01
November 1988	93	0.0099	2.82	5.02	0.56	8.07	<0.01
March 1989	106	0.0111	2.28	4.70	0.49	10.12	<0.01

* r_A The mean of the series of distances to nearest neighbor.

r_E The mean distance to nearest neighbor expected in an infinitely large random distribution of the same density.

R Equals r_A / r_E

C The standardized variate of the normal curve.

P The level of significance (P) is that for the difference between the distribution and a random one of the same overall density. Computation from Clark and Evans (1954).

Table 19. Evaluation of the difference in degree of spacing of groups of moose between survey periods.

Period	M	S.D.	N
April 1987	0.0052	0.0042	85
October 1987	0.0101	0.0125	41
April 1988	0.0094	0.0121	67
November 1988	0.0059	0.0112	93
March 1989	0.0046	0.0056	106

M The mean of the meausure of the degree to which the observed distribution departs from random expectation with respect to the distance to nearest neighbor. Each value of distance to nearest neighbor multiplied by a factor $2\sqrt{p/N}$, where p is the density of the observed distribution expressed as the number of individuals per unit of area, N is the number of measurements of distance taken in the observed population.

S.D. Standard deviation of M

N Number of measurments of distance taken in the observed population.

* Values connected by brackets are significantly different at the P=0.95 level (Tukey's studentized range text).

Discussion

Population Status

Given the low levels of precision in surveys performed previous to March 1989, it is not possible to evaluate population trend during the period of study based on abundance estimates alone. However, inferences can be made from juvenile and adult mortality as derived from sex/age composition and radio-collar information. Yearling recruitment, as evidenced from late-winter calf percentages, appeared constant between March/April 1987, April 1988 and March 1989 at 16.0%, 15.7% and 16.2%, respectively. There are errors inherent in determining mortality rates from the relatively small sample of radio-collared animals and the estimated mean annual adult mortality rates of 13.1 for June 1988 - July 1989 and 18.5 for July 1989 - July 1990 should only be taken as a rather crude measurement. Nevertheless, I feel it is likely that these figures overestimate adult mortality since, 1) capture-related etiology is common as a result of immobilization with carfentanil (Glover and Larsen 1988) and, 2) one-year to three-year old moose, which are reported to suffer relatively low mortality (Wolfe, 1977), are underrepresented in the radio-collared sample of adult moose. The only year from which both calf recruitment and adult mortality rates are available is the period June 1988 - July 1989. Calf recruitment in March 1989 amounted to 16.2% (15.2-17.2, 95% CI) and the adult mortality rate during that period was 13.1%(8.7%-17.4%, 95% CI). Although the confidence intervals overlap, in view of the above considerations I consider it more likely that the moose population increased slightly during the period June 1988 - July 1989 (assuming no net emigration or immigration).

The observed adult mortality rates fall within the 10-20% range typical of populations subject to heavy predation pressure (Peterson 1977; Hauge and Keith 1981; Messier and Crete 1985). I suspect that the relatively low calf recruitment rates observed in March 1989 were not a function of low productivity of the population but rather of a low calf survival (assuming natality rates consistent with observed pregnancy rates). Twelve out of 14 cows radio-collared in October 1987 were pregnant (excluding one which was observed with twins in November 1988), indicating a pregnancy rate $\geq$ 0.86. Information from radio-collared cow-calf groups suggests there may have been a mortality rate of 0.53 of calves during May/June 1988 - March 1989. However, no calf mortality was apparent between November 1988 and March 1989 as indicated by calf/cow ratios observed during surveys and the relatively low calf recruitment rate in March 1989 is therefore more likely a result of early calf mortality. Calf mortality is therefore likely to have taken place before November 1988. The limited amount of information from radio-collared cows also suggests that most mortality took place before November. Similarly, calves appeared to have suffered a relatively low mortality (15%) during October 1987 - April 1988 as evidenced from a comparison of calf percentages observed during surveys. In other moose populations where both bears (Ursus arctos and U. americanus) and wolves (Canis lupus) occur, most calf losses due to these predators take place during the summer months (Hauge and Keith 1981; Ballard et al. 1981, 1988; Larsen et al. 1987; Boertje et al. 1988). The observed high rates of calf mortality would be typical of moose populations subject to heavy predation (Hauge and Keith 1981; Gasaway et al. 1983; Messier and Crete 1985; Larsen et al. 1987.

Movements and Home Range

The distribution of group size throughout the year is similar to other studies, indicating that moose aggregations were highest in late fall and early winter (LeResche 1974, Peek et al. 1974, Ballard et al. 1991). Largest group sizes occur during the rut and following the rut (until December).

This study demonstrated migratory and sedentary moose phenotypes, e.g. moose that migrate from winter ranges on the South Slope to summer ranges on the North Slope, and moose that stay year-round on the South Slope. Although some South Slope moose appear to use different portions of their year-long range between winter and summer, this seasonality is far more pronounced in moose that summer on the North Slope. According to LeResche (1974), North Slope moose should be classified as migratory and South Slope moose as sedentary. The high degree of traditionality in seasonal home range use agrees with what has been found in other studies (Van Ballenberghe 1977; Cederlund et al. 1987; Sweanor and Sandegren 1988, 1989). Maximum distances between seasonal locations for moose summering on the North Slope are greater than those reported for many other studies (Mytton and Keith 1981, Doerr 1983, Lynch and Morgantini 1984, Cederlund and Okarma 1988, Courtois and Crete 1988, Ballard et al. 1991). Even longer seasonal migrations have been reported for the Northwest Territories by Barry (1961). Only some of the moose wintering on the South Slope make the reported long-range movements to summer range on the North Slope. This suggests that summer range on the South Slope is somehow limiting moose population levels. The absence of moose in winter in arctic tundra areas like the Yukon North Slope has been attributed to the combination of high wind speeds, deep snow, and limited food (Kelsall 1972). The first two factors exist within moose habitat on the Yukon North Slope. A more favourable microclimate exists in the middle reaches of the Big Fish River where the deeply incised valley affords protection from winds. The presence of moose in that area during winter supports Kelsall's contention.

A minor portion of the home ranges consists of usable habitat and comparisons with other studies have to take this into account. The large size of these home ranges relative to other studies (Hauge and Keith 1981, Mytton and Keith 1981, Doerr 1983, Cederlund and Okarma 1988) therefore reflects the patchiness of moose habitat and the resulting need of these moose to cover great areas to fullfill their seasonal resource needs.

Distribution of moose on the North Slope in summer appears skewed toward the western portion of the study area as observed during the helicopter survey in July and is generally consistent with the distribution of moose habitat. A notable exception is the Willow River which appeared to have excellent moose habitat but no moose were observed during the July helicopter search (nor were any moose observed in this valley during fall and late winter surveys).

Moose radio-collared in the western part of the study area generally moved out of the study area during winter, whereas all but one of the moose radio-collared in the eastern part of the study area stayed within the study area year-round. As a result, moose abundance in the study area was probably lowest during winter, highest during summer, and intermediate during spring and fall.

Habitat Use

The trend to use high elevations during fall and descend to lower elevations during winter conforms to other studies in mountaineous terrain in Alaska (Ballard et al. 1991, Modafferi 1991) and Yukon (Larsen et al. unpubl.). This seasonal elevational distribution pattern is thought to be a function of availability of forage plants, height of browse and differences in phenology between plant species and areas (Hjeljord et al. 1990). In other studies in Alaska and Yukon where summer distributions of moose have been reported, moose used elevations in summer intermediate between those used during fall and winter. The use of the very lowest elevations in summer found in this study reflects the distribution of moose across the lowlands of the North Slope, a habitat type very similar in vegetation cover to higher elevations further south.

Shrub vegetation is used most frequently in summer, least in spring and intermediate in fall and winter. During summer and fall shrub is almost used to the exclusion of other vegetation types. During winter and spring the coniferous and mixed coniferous/deciduous vegetation types are also relatively frequently used vegetation types. Much of the shrub vegetation is Willow (Salix spp.), an important food source in northern North American moose ranges (Peek 1974, Risenhoover 1989, Van Ballenberghe et al. 1989). The increased use of treed habitats during winter and spring likely reflects the trade-off between the need for cover and food. The variation in vegetation community association observed between late winter surveys may, at least in part, be an artifact of differing survey intensities.

The clumped distribution of moose observed during surveys reflects the distribution of moose habitat. The latter occurs in narrow (<5 km.) strips in valley bottoms. This phenomenon, as well as the predominant association with shrub vegetation makes the moose population vulnerable to hunting and disturbance. In similar, but much more accessible, moose habitat on Alaska's North Slope, the moose population has recently suffered a decline, partly, if not wholly, due to hunting (Mauer, 1989).

The linear relationship between habitat availability (both total habitat and shrub vegetation) and moose abundance attests to the importance of habitat as a factor in determining moose abundance. The relationships reported here are of a preliminary nature and should be further explored. Ultimately they will become useful in predictive models of habitat capability to sustain moose in Yukon's northern region.

The density of moose reported here is substantially higher than areas further south in Yukon where wolf and bear populations are lightly exploited. With the exception of the Teslin and Rose Lake survey areas where densities of 0.42 moose.km^{-2} and 0.27 moose.km^{-2}, respectively, have been reported (Larsen et al. 1989), the density reported in this study (0.46 moose.km^{-2}) was at least twice as high as those estimated for all other survey areas in Yukon (Larsen et al. 1989, Ward and Larsen, 1990) and is more similar to densities in western Alaska (Gasaway et al. in prep.) where wolf and bear populations were reduced. It seems therefore that moose density in the northern Richardson Mountains does not fit the general Low Density Equilibrium model provided in Gasaway et al. (in prep.) for systems with lightly exploited predator (wolves, bears) and prey (moose) systems. Wolf and bear populations are thought to occur at densities as would occur under pristine conditions on the moose winter ranges of the northern Richardson Mountains (B. Hayes, B. Smith, pers. commun., respectively). Human exploitation of moose is thought to be insignificant (Aklavik Hunters and Trappers Committee, pers. commun.) but is more difficult to evaluate in areas where human access is less restricted, for example many of the moose survey areas further south. One major difference with other pristine areas is the frequent influx of large segments of the Porcupine Caribou Herd during much of the fall, winter, spring, and occasionally during summer seasons (Russell, et al. in prep.). In a recent study (Hayes and Bear, in prep.) it has been shown that wolves resident in the Richardson Mountains switch to prey on caribou when available. Given the frequency with which Porcupine caribou winter in the Richardson Mountains (13 winters out of the last 18, Russell et al. in prep.) the potentially associated reduced levels of predation on moose could conceivably have substantial positive effects on moose population levels. The situation in the northern Richardson Mountains therefore appears to better fit the wolf-bear-multiprey system where moose are a minor prey and can become moderately abundant (Crete 1987, Bergerud and Snider 1988). This has been reported (Gasaway et al., in prep.) to occur primarily in the southern portion of the moose's range and possibly in mountainous western Canada where other ungulate species are more important to wolves. Examples are Algonquin Provincial Park, Ontario (400-700 moose/1,000 km^2, Wilton 1987) and Riding Mountain National Park, Manitoba (800 moose/1,000 km^2, Carbyn 1983). Habitat type, availability, (as shown in this study) and productivity would appear to be important factors in predictive moose abundance models as well.

Management Implications

Individual moose captured at each site exhibited 'subpopulation'-specific movement patterns. Moose captured on the North Slope in summer or fall generally wintered on the South Slope, whereas moose captured on the South Slope at that time generally stayed there year-round. This has implications for the management of North Slope moose. Given the extremely low visibility of moose on the North Slope in summer (pers. observ.), obtaining even a crude estimate of moose abundance (e.g. by capture/recapture) would be expensive and in light of the apparent low numbers of moose likely harvestable, very cost-ineffective. As a result, the effects on population levels of any management prescription involving harvest of North Slope moose cannot be readily evaluated from summer surveys. In other words, management of North Slope moose cannot be done effectively as an adaptive learning process (Walters 1986) and suffers the inherent risk of overharvest that may go unnoticed until a precipitous decline has set in. One possible way to verify the effects of a harvest prescription would be to monitor the trend in numbers of moose wintering on the North Slope using these as an index of summer abundance. However, only about 10% of the moose summering on the North Slope stay there year-round making this index a rather crude one. In view of this and the crude estimate of moose summering on the North Slope (160) a conservative quota should be established to harvest moose in summer on the North Slope.

What level of harvest can be sustained by the northern Richardson Mountains moose (sub)population? Gasaway _et al._ (in prep.) have presented an approximate sustainable yield curve from empirical data from 22 populations at varying densities. Although the relationship has limitations, Gasaway _et al._ believe the yield curve to be useful in a first approximation of sustained yields from low- and moderate-density moose populations in Alaska and Yukon. Using this curve gives a predicted sustained yield of 6% for moose in the study area. The pattern of seasonal distribution exhibited by both 'North Slope' moose and 'South Slope' moose however should be reflected in the harvest rates for the North Slope and South Slope. First of all, the number of moose summering on the North Slope needs to be known (160). Then one has to take into account the proportion of this number wintering on the South Slope within the study area (69% or 110 moose). Moose summering on the North Slope may be harvested on the North Slope during summer or on the South Slope during the remainder of the year. Some of these moose stay on the North Slope during winter and these may be harvested at that time as well. In view of the abovementioned considerations North Slope moose should be harvested conservatively and I propose that harvest rates do not exceed 3% and are bull-only. This would amount to an annual harvest of 5 bulls. For the South Slope I propose a harvest rate of 6% (either sex) for moose resident in the area year-round and 0% for moose that summer on the North Slope. An estimated 110 moose summering on the North Slope winter on the South Slope portion of the study area while 173 moose are year-round residents on the South Slope portion of the study area in winter. The annual harvest rate for the South Slope should therefore not exceed 6% of 173 or 10 moose. As 88% of the estimated late winter population during the March 1989 survey occurred in Yukon and 12% in Northwest Territories, a proportional division of the annual harvest of moose on the South Slope would amount to 9 moose for the Yukon and 1 moose for the Northwest Territories. Population trend surveys should be carried out from time to time. The frequency of these surveys should be a function of the levels of moose harvest relative to the estimated sustainable yield. In order to allow for a better comparison with the March 1989 survey, they should be done during late winter. An additional advantage of a late winter survey is that an index of calf recruitment can be obtained.

A consequence of the large home ranges and small total area of moose habitat in the study area is that individual moose use a relatively large proportion of available moose habitat. Hence disturbance of local habitat patches may impact a relatively large segment of the moose population. Furthermore, the shape of habitat patches (e.g. narrow strips of vegetation) increases the impact of disturbance from features like roads that tend to follow drainages. Moose have been shown to avoid areas of human disturbance (Ferguson and Keith 1982). The potential negative impact of human disturbance in the northern Richardson Mountains is further exacerbated by the openness of the vegetation moose are generally associated with. The above should be taken into account when reviewing land use applications involving moose habitat in the northern Richardson Mountains.

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A P P E N D I X

APPENDIX A:

SURVEY RESULTS AND MISCELLANEOUS INFORMATION

March/April 1987 Survey

An aerial survey covering the whole study area was performed between March 12 and April 20, 1987. Snow cover was continuous across all moose habitat (depth in Bell River valley was measured at 75 cm) and observability was considered to be good. A total of 181 moose were observed of which 152 (84.0%) were adults (Table 1). Moose were observed in the valleys of the Bell River, Fish Creek, Scho Creek, Little Bell River, Big Fish River, Sheep Creek and Rat River. The area with the greatest number of moose was the Bell River (Table 2). On several occasions when flying over a previously surveyed drainage, moose not observed before (as indicated by the distance from the nearest moose located previously or the total number observed between the two flights) were sighted, suggesting that not all moose present in the study area may have been counted. The observed number of moose is therefore less than the actual number of moose.

October 1987 Survey

During the October survey inclement weather prevented surveying in the Blow River valley and its tributary creeks. In the remainder of the study area moose were observed in the same drainages as late winter. Snow depth was only 5-10 cm, with many snowfree areas in valley bottoms at lower elevations, and observability was poor locally. It was therefore felt that many more moose may have been present than those observed. A total of 105 moose were classified as to sex and age class (Table 1). Adult males ($\geq$30 months) were the largest single cohort making up 44% of all moose observed compared to 33% adult females ($\geq$30 months). The few yearlings observed represented 6%, while calves comprised 17% of all moose observed. Calf survival appeared good while yearling recruitment seemed low, with 51 calves/100 cows and 17 yearlings/100 cows, respectively. The twinning rate was 20% (3 sets of twins among 15 calf-cow groups).

April 1988 Survey

An aerial survey covering the whole study area was performed during April 16-19, 1988. Snow depth in the southwestern part of the study area was approximately 30 cm with substantially less snow in the remaining area. Many track networks of caribou occurred throughout the study area and observability was generally considered poor. A total of 140 moose were observed, of which 118 (84.3%) were adults (Table 1). Most animals (121 or 86%) were observed in South Slope drainages, while 19 (14%) animals were observed on the North Slope (Table 3). Of 15 radio-collared moose known to be present in the study area, 4 (27%) were observed during the survey. The estimate for the total number of adult moose in the study area is therefore 380 ± 247 (95% CI)(Table 4). The extended population estimate including calves and using the calf proportion among observed moose amounts to 451.

November 1988 Survey

This survey was carried out during November 4-6, 1988. Snow cover was continuous across the study area and amounted to approximately 20 cm. Observability was considered good. A total of 287 moose were observed of which 246 (85.7%) were adults. Most of these (263, or 92%) were observed on the South Slope, while 24 (8%) occurred on the North Slope (Table 5). Of 15 radio-collared moose known to be present in the study area, 11 (73%) were observed during the survey. The estimate for the total number of adult moose in the study area is therefore 328 ± 87 (95% CI)(Table 4). The extended population estimate including calves and using the calf proportion among observed moose amounts to 383. Approximately as many adult (≥30 months) bulls and adult cows were observed (36.2% and 39.0% of all moose observed, respectively). The number of yearlings (18 months) observed represented 10.5%, while calves comprised 14.3% of all moose observed. Calf survival and yearling recruitment seemed low, with 37 calves/100 cows and 27 yearlings/100 cows, respectively. The twinning rate was 20.6% (7 sets of twins among 34 calf-cow groups) Table 1).

March 1989 Survey

A helicopter survey covering the whole study area was completed during March 7-10, 1989. Snow cover was continuous across the study area. Snow depth amounted to approximately 30 cm on the South Slope, and somewhat less on the North Slope. Observability was considered good. A total of 265 moose were observed, of which 222 (83.8%) were adults. Most of these (246 or 93%) occurred on the South Slope, while 19 (7%) were observed on the North Slope

(Table 6). Of 15 radio-collared moose known to be present in the study area 14 (93%) were observed during the survey. The estimate for the total number of moose in the study area is therefore 237 ± 28 (95% CI)(Table 4). The extended population estimate including calves and using the calf proportion among observed moose amounts to 283.

Approximately as many adults (≥ 22 months) males as females were observed (100 or 42.7%, and 91 or 38.9% of all animals identified, respectively). Forty-three (16.2%) calves were identified, while 31 adult (11.7% of all moose observed) animals were not classified to sex (Table 1).

Table 3. Distribution of moose observed across the study area in an aerial survey during March - April, 1987.

Drainage	Number of Adults*	Number of Calves	Total
Bell River	100	18	118
Little Bell River	13	2	15
Big Fish River	9	3	12
Fish Creek	9	2	11
Scho Creek	6	2	8
Rat River	2	1	3
Barrier River	2	-	2
Sheep Creek	1	-	1
Several unnamed creeks south of Summit Lake combined	10	1	11
Total	152	29	181

*Adults (22 months).

Table 4. Distribution of moose observed across the study area in an aerial survey during April, 1988.

Drainage	Number of Adults*	Number of Calves	Total
South Slope:			
Bell River	88	15	103
Fish Creek	5	1	6
Scho Creek	3	1	4
Unnamed Cks. East of Horn Lake	3	1	4
Unnamed Cks. South of Summit Lake	4	0	4
North Slope:			
Cache Creek	1	0	1
Fish River	10	3	13
Rapid River	3	1	4
Purkiss Creek	1	0	1
Total	118	22	140

*Adults (22 months).

Table 5. Distribution of moose observed across the study area in an aerial survey during November, 1988.

Drainage	Number of Males*	Number of Females*	Number of Males*	Calves	Total
South Slope:					
Bell River	70	83	12	28	193
Fish Creek	9	10	1	3	23
Little Bell River	3	8	-	3	14
Rat River	3	10	-	3	16
Scho Creek	5	7	1	-	13
Unnamed Cks. South of Summit Lake	3	1	-	-	4
North Slope:					
Fish River	10	7	1	4	22
Blow River	1	1	-	-	2
Total	104	127	15	41	287

* Adult males ($\geq$30 months), adult females ($\geq$18 months), yearling males (18 months).

Table 6. Distribution of moose observed across the study area in an aerial survey during March, 1989.

Drainage	Number of Males*	Number of Females*	Number of Calves	Number Unclass. Adults*	Total
South Slope:					
Bell River	75	67	33	4	179
Little Bell River	1	4	5	18	28
Fish Creek	7	4	-	-	11
Scho Creek	9	4	2	1	16
Rat River	3	1	-	-	4
North Slope:					
Fish River	3	4	1	2	10
Rapid Creek	-	5	-	-	5
Cache Creek	2	-	-	-	2
Blow River	-	1	1	-	2
Total	100	91	43	31	265

* Adult ($\geq$22 months).

Table 7. Radio transmitter information and location of moose captured in the northern Richardson Mountains, during October 1987 and July 1988.

Moose ID#	Date of Capture	Sex	Number of Calves	Age	Radio Frequency (MHz)	Transmitter Serial No.	Capture Location (UTM)	General Location
1	Oct. 19, 1987	F	-	5	152.178	18065	MK4399	South of Summit Lake
2	Oct. 19, 1987	M	-	5	151.508	14873	MK4298	South of Summit Lake
3	Oct. 19, 1987	F	2	6	150.642	14853	ML4830	Fish Creek
4	Oct. 19, 1987	M	-	3	153.751	21372	ML1235	Bell River
5	Oct. 19, 1987	M	-	9	153.820	14837	ML0936	Bell River
6	Oct. 19, 1987	F	-	7	153.770	21374	ML0935	Bell River
7	Oct. 19, 1987	F	1	14	150.892	14861	ML0624	Bell River
8	Oct. 21, 1987	F	1	5	153.730	18063	ML0725	Bell River
9	Oct. 21, 1987	F	1	-	150.061	14827	ML1321	Bell River
10	Oct. 21, 1987	F	1	4	150.588	18029	ML3519	Little Bell River
11	Oct. 21, 1987	F	2	7	153.832	14840	ML5234	Scho Creek
12	Oct. 21, 1987	M	-	-	152.450	21689	ML2978	Big Fish River
13	Oct. 21, 1987	F	1	-	152.100	18058	ML3383	Big Fish River
14	Oct. 22, 1987	M	-	-	153.861	14848	ML3382	Big Fish River
15	Oct. 22, 1987	M	-	4	152.901	21690	ML2555	Bell River
16	Oct. 22, 1987	F	1	3	151.781	18046	ML1062	Bell River
17	Oct. 22, 1987	F	1	9	153.890	18034	ML0955	Bell River
18	Oct. 22, 1987	F	2	7	153.807	14830	ML0755	Bell River
19	Oct. 22, 1987	F	1	13	153.739	18071	ML3133	Vunta Creek
20	Oct. 22, 1987	F	-	-	153.650	R CAR04/87	ML4028	Fish Creek
21	July 18, 1988	F	1	4	152.742	-	ML5688	Tribuatary of Cache Creek
22	July 19, 1988	M	-	3	150.135	-	MM1338	Blow River
23	July 19, 1988	F	-	?	150.290	-	MM1944	Blow River
24	July 19, 1988	M	-	3(4)	152.472	-	MM2324	Rapid Creek
26	July 20, 1988	F	2	5-6	150.450	-	ML1335	Blow River
27	July 20, 1988	F	-	6	152.752	-	ML1538	Blow River

Table 8. Body measurements* of moose captured in the northern Richardson Mountains during October 1987 and July 1988.

Moose ID#	Sex	Preg-nant	Age	Total Length	Tail Length	Body Circumference	Foreleg Length	Hindleg Length	Shoulder Height	Neck Girth Min	Neck Girth Max	Antler Spread	Palm Width Lft.	Palm Width Rght.	P L
1	F	Yes	5	293	7	200	62	86	-	89	96	-	-	-	
2	M	-	5	313	8	203	68	86	206	113	130	-	23.5	22.0	7
3	F	Yes	6	307	8	198	57	84	190	86	107	-	-	-	
4	M	-	3	297	8	203	86	87	-	100	115	-	9.0	13.8	5
5	M	-	9	282	6	205	61	-	-	113	123	-	32.5	31.5	8
6	F	Yes	7	297	6	-	63	87	198	82	92	-	-	-	
7	F	Yes	14	295	8	192	64	82	193	76	88	-	-	-	
8	F	Yes	5	287	7	-	61	85	192	82	93	-	-	-	
9	F	Yes	-	299	9	-	65	87	200	86	103	-	-	-	
10	F	Yes	4	310	9	-	63	-	-	72	84	-	-	-	
11	F	Yes	7	299	9	-	-	-	-	73	88	-	-	-	
12	M	-	-	288	7	-	68	85	210	-	-	146	33.0	33.6	8
13	F	?	-	-	-	-	69	87	-	-	-	-	-	-	
14	M	-	-	307	5	-	-	-	-	108	125	150	33.5	34.0	7
15	M	-	4	286	10	-	66	88	203	-	-	132	26.0	27.0	7
16	F	Yes	3	276	9	-	61	84	191	79	84	-	-	-	
17	F	No	9	299	7	-	63	85	204	82	91	-	-	-	
18	F	No	7	304	8	-	61	85	-	87	97	-	-	-	
19	F	Yes	13	285	7	183	61	89	171	76	94	-	-	-	
20	F	Yes	-	278	7	-	61	85	192	83	99	-	-	-	
21	F	N/A	4	284	13	182	-	83	191	74	87	-	-	-	
22	M	N/A	3	278	10	173	-	83	183	72	82	79	16.0	27.0	3
23	F	N/A	-	-	-	-	-	-	-	-	-	-	-	-	
24	M	N/A	7	-	-	-	-	-	-	-	-	131	24.0	25.0	6
25	M	N/A	3(4)	246	7	-	62	79	-	-	-	69	7.0	8.0	2
26	F	N/A	5-6	289	9	-	-	-	-	76	92	-	-	-	
27	F	N/A	6	266	10	179	66	84	193	72	91	-	-	-	

* all length measurements are in cm.

NOTE: many measurements unavailable due to position moose were in during capture.

Table 9. Mortality status* of radio-collared adult moose in the northern Richardson Mountains during October 1987 to July 1990.

	1987	1988									1989						1990	
Moose ID#	Dec	Jan	Feb	Mar	Apr	May	Jun	Aug	Sep	Nov	Feb	Mar	May	Jul	Sep	Nov	Mar	Jul
1							+		+		+			+	+		MORT.	---
2					+	+			+	+	+	+	+	+	+	+	+	+
3	MORT.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
4	+	+			+	+	+		+	+	+	+	+	+	+	+	+	+
5	+	+			+	+	+		+	+	+	+	+	+	+	MORT.	---	---
6	+	+			+	+	+		+	+	+	+	+		+	+	+	+
7				MORT.	---	---	---	---	---	---	---	---	---	---	---	---	---	---
8	+		+		+	+	+		MORT.	---	---	---	---	---	---	---	---	---
9					+	+	+		+	+	+	+	+	+	+	+	+	+
10					+	+	+		+	+	+	+	+	+	+	+	+	+
11			+		+	+	+		+	+	+	+	+	+	+	+	+	+
12	+			+	+	+	+	+	+	+	+	+	+	+	+		+	+
13	+			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
14	+	+		+	+	+	+	+	+		+	+						
15	+			+	+	+			+	+	+	+	+	+	+	+	+	+
16			+	+	+	+	+	+(?)	+	+	+	+	+	+	+	+	+	+
17	+	+		+	+		+		+	+	+	+	+	+	+		+	+
18	+		+	+	+					+	+	+	+		+		+	+
19			+		MORT.	---	---	---	---	---	---	---	---	---	---	---	---	---
20	+		+	+	+	+	+		+	+	+	+	MORT.	---	---	---	---	---
21	---	---	---	---	---	---	---	+	+	+	+	+	+	+	+	+	+	+
22	---	---	---	---	---	---	---	+	+	+	+	+	+	+	+	MORT.	---	---
23	---	---	---	---	---	---	---	+			+	+	+	+	+	+	+	+
24	---	---	---	---	---	---	---				+	+	+	+	+	+	+	+
26	---	---	---	---	---	---	---	+			+	+	+	+	+	+	+	
27	---	---	---	---	---	---	---				+							

* +, confirmed alive
blank, status unknown

(Note that moose #'s 21-27 were collared during July 1988)

Table 12. Mortality status* of calves accompanied by radio-collared cows in the northern Richardson Mountains, during October 1987 - July 1990.

		1987	1988								1989					1990	
Moose ID#	Number of Calves at capture	Dec	Feb	Mar	Apr	May	Jun	Aug	Sep	Nov	Mar	May	Jul	Sep	Nov	Mar	Jul
1	-	?	?	?	?	?	?	?	-	?	?	?	?	-	?	Mort.	---
3	2	Mort.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6	-	-	?	?	?	1	1	?	-	-	-	?	?	?	1	-	?
7	1	-	?	Mort.	---	---	---	---	---	---	---	---	---	---	---	---	---
8	1	1	1	-	?	1	?	?	Mort.	---	---	---	---	---	---	---	---
9	1	?	?	?	1	-	-	?	-	-	1	?	?	?	-	-	-
10	1	?	?	?	1	-	1	?	-	1	-	?	-	?	1	?	-
11	2	?	2	?	2	2yrl.	1	?	-	-	-	?	?	-	-	?	?
13	1	1	?	1	?	-	2	?	2	-	1	1	?	2	2	-	-
16	1	?	1	1	?	-	1	?	?	1	-	1	?	-	-	-	?
17	1	-	?	-	?	-	-	?	-	-	-	-	1	-	?	?	1
18	2	2	2	?	2	?	-	?	?	2	2	2	?	?	?	?	2
19	1	?	?	?	Mort.	---	---	---	---	---	---	---	---	---	---	---	---
20	-	-	-	-	-	-	1	?	-	-	-	Mort.	---	---	---	---	---
21	1							1	1	-	-	?	?	?	?	?	1
23	-							?	?	?	2	?	-	?	?	-	?
26	2							?	?	?	1	1	-	?	?	?	?
27	-							?	?	?	?	?	?	?	?	?	?

* - no calf observed.
? status of calf unknown (cow not located or calf not observed).

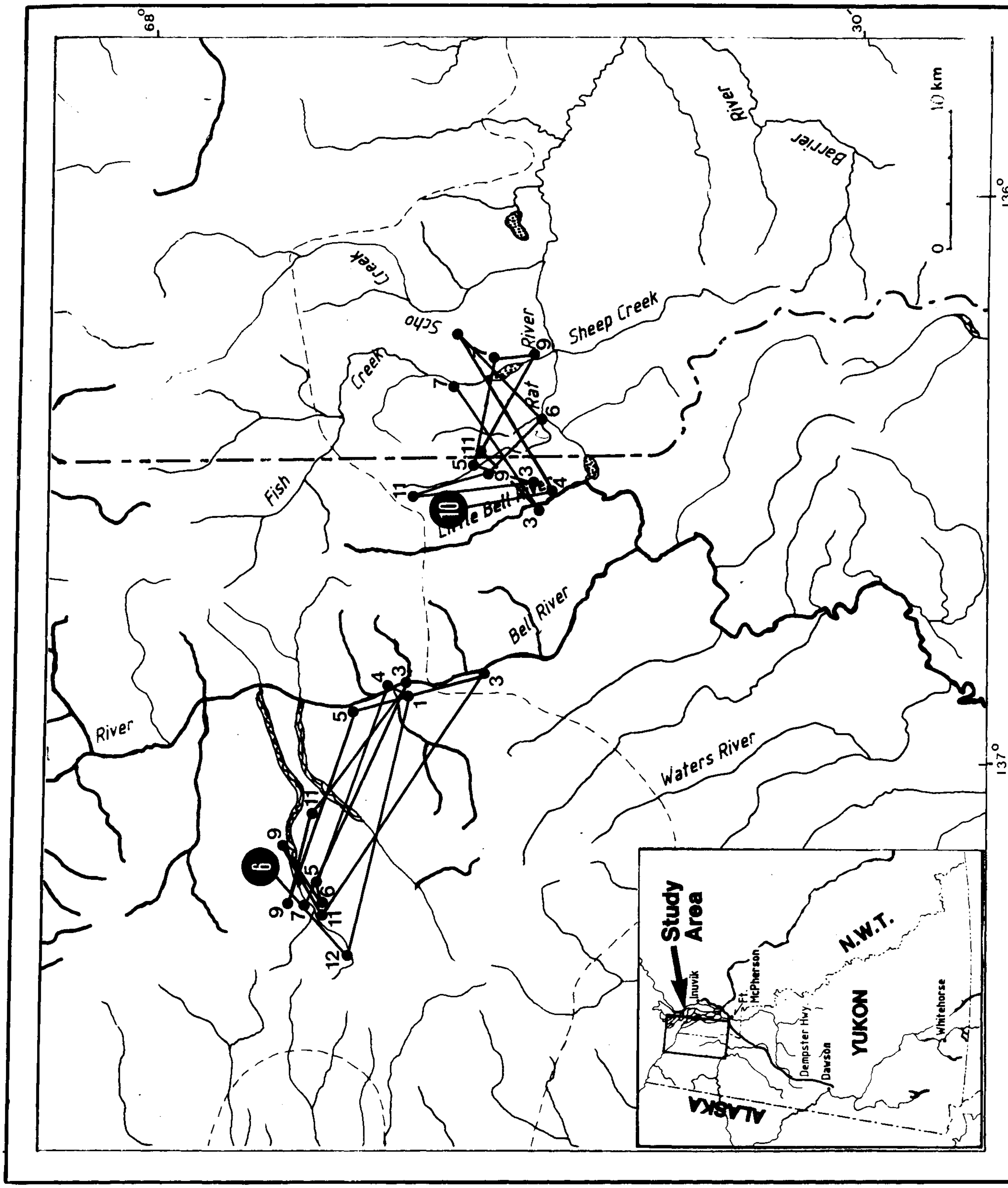

Figure 3a. Locations (●) of radio-collared female moose as determined from monitoring flights; ⬤- capture location (number is moose ID #); 1 through 12: January through December. Both animals were radio-collared in October 1987.

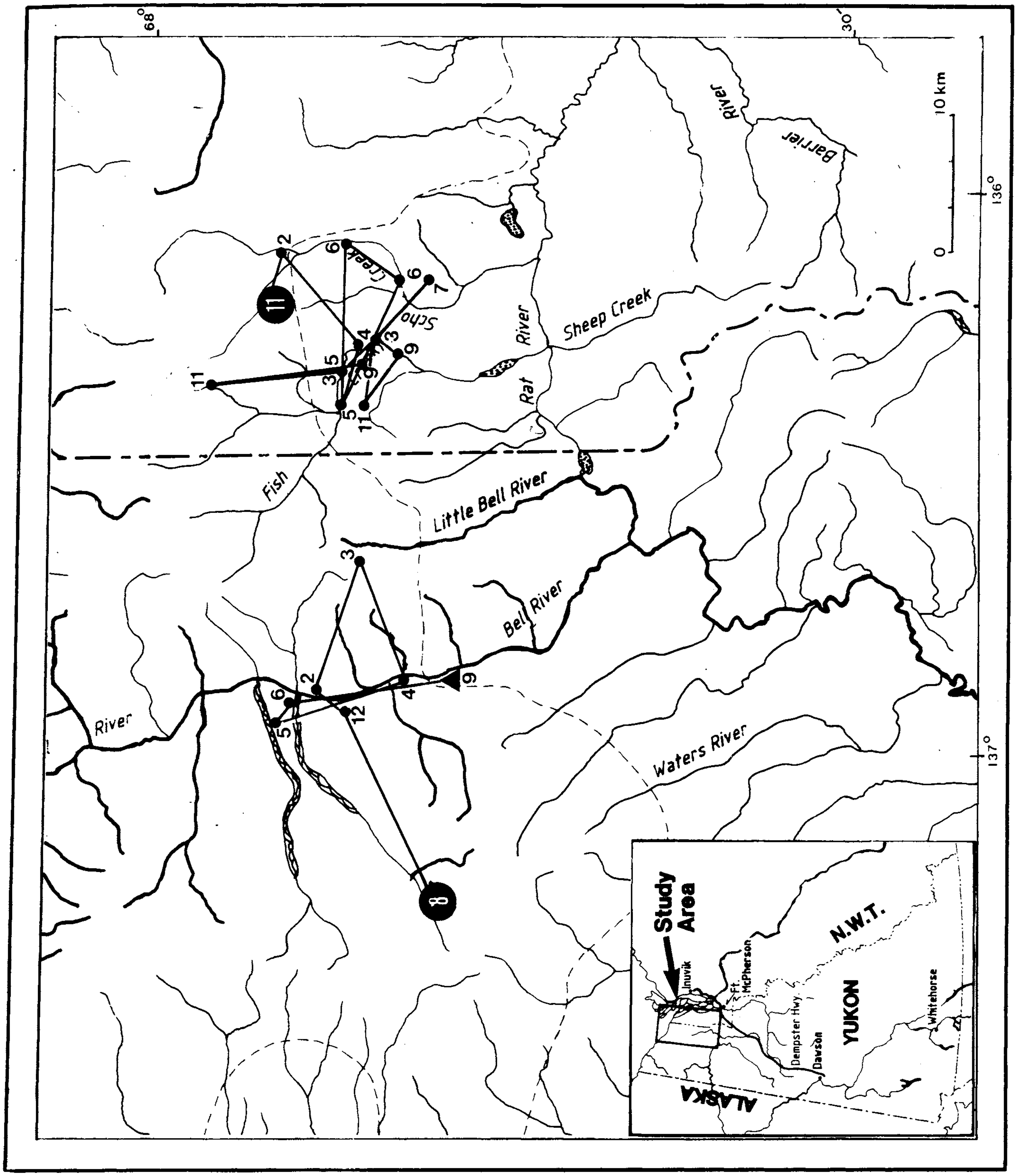

Figure 3b. Locations (●) of radio-collared female moose as determined from monitoring flights; ⬤- capture location (number is moose ID #); ▲- mortality location. 1 through 12: January through December. Both animals were radio-collared in October 1987.

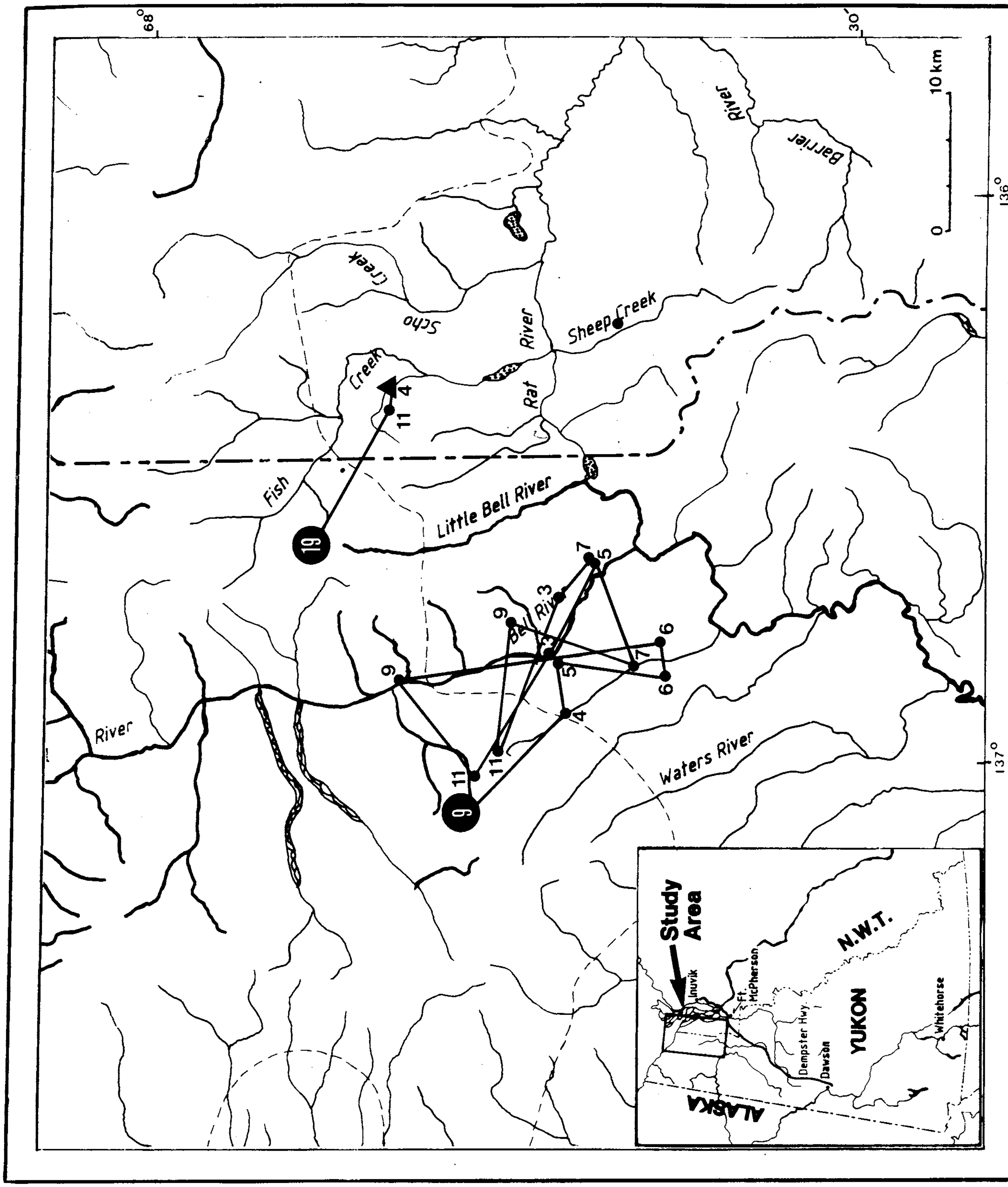

Figure 3c. Locations (●) of radio-collared female moose as determined from monitoring flights; ⬤- capture location (number is moose ID #); ▲- mortality location. 1 through 12: January through December. All three animals were radio-collared in October 1987.

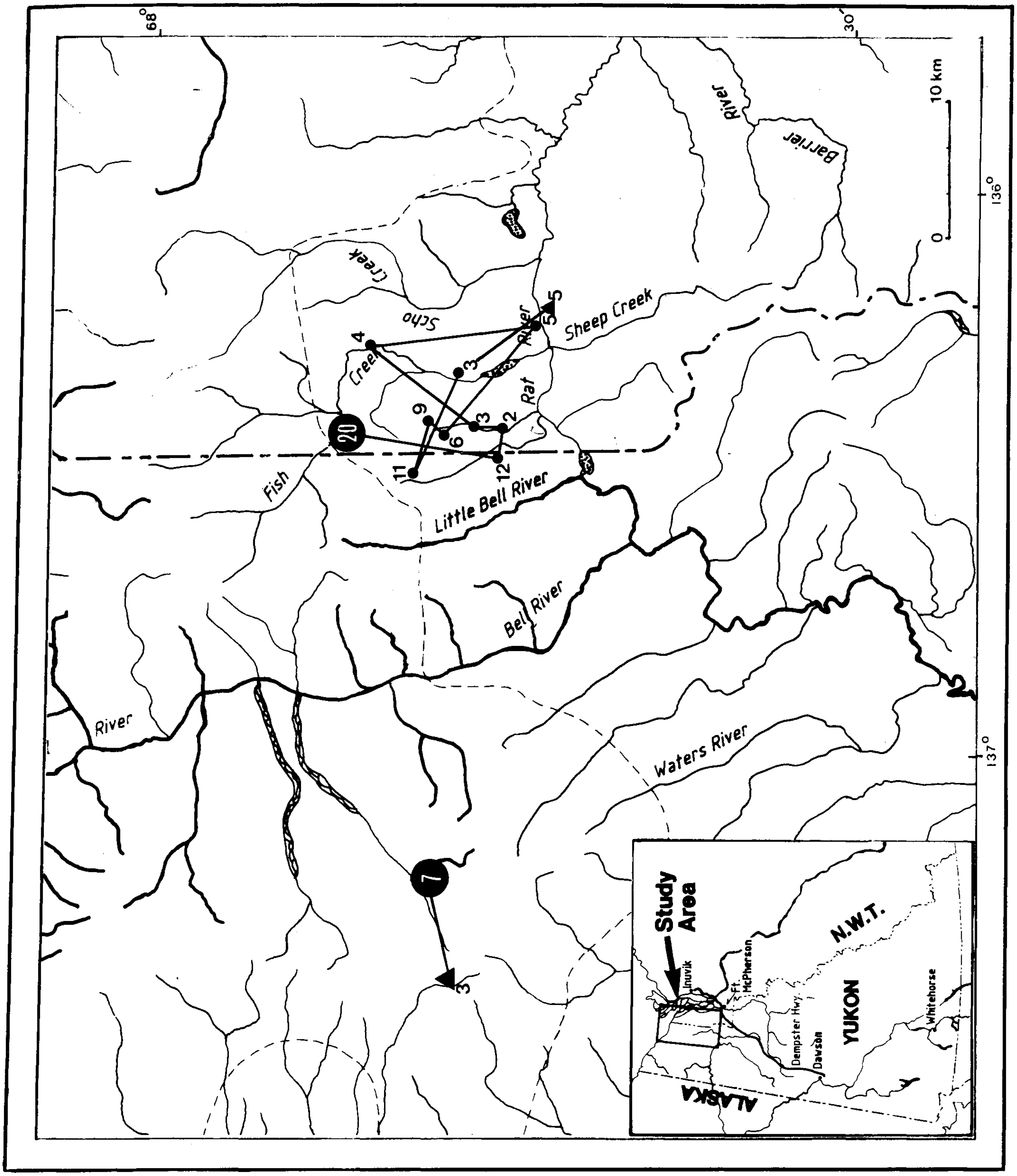

Figure 3d. Locations (●) of radio-collared female moose as determined from monitoring flights; ⬤- capture location (number is moose ID #); ▲- mortality location. 1 through 12: January through December. Both animals were radio-collared in October 1987.

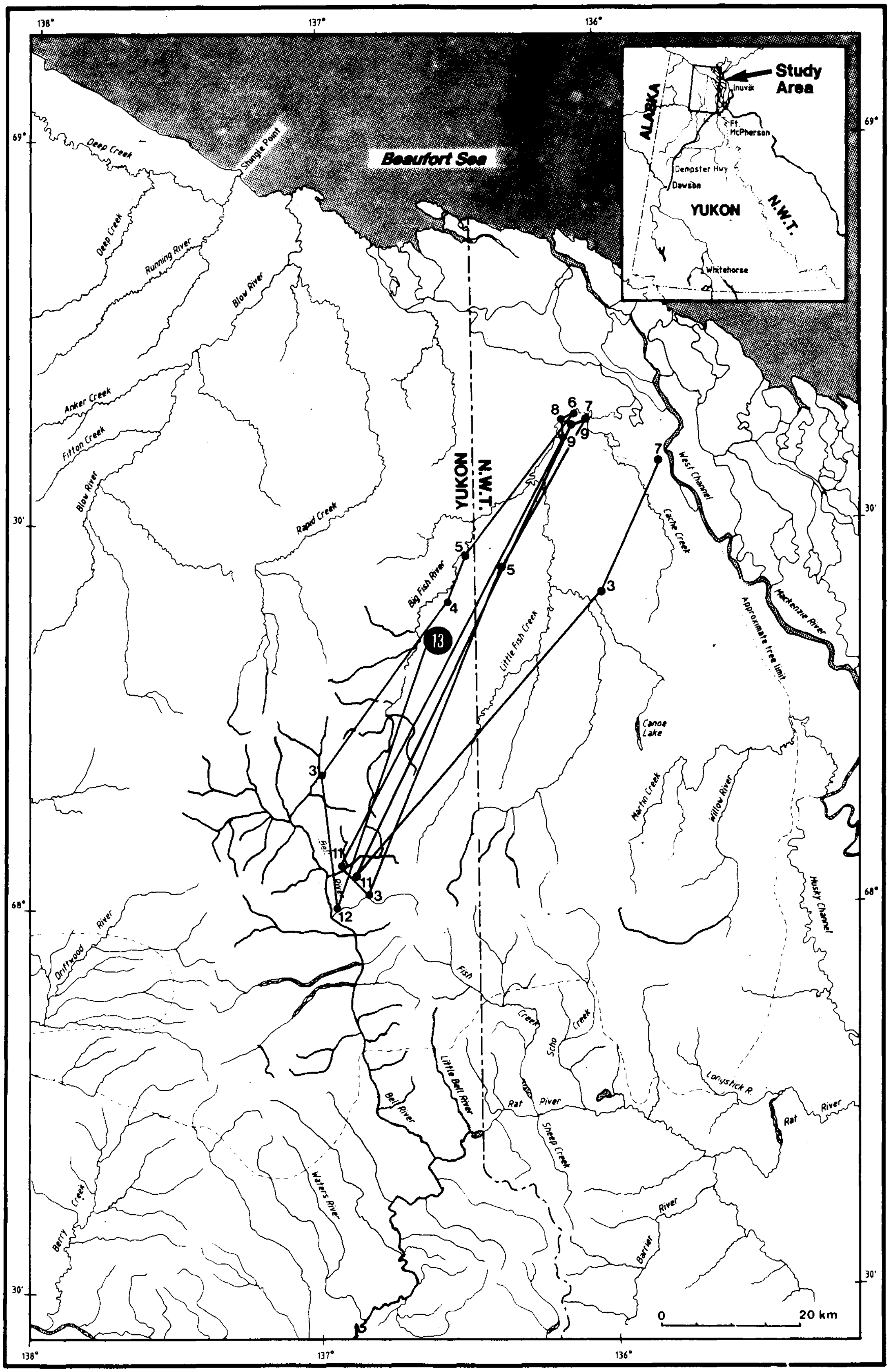

Figure 3e. Locations (●) of radio-collared female moose as determined from monitoring flights; ⬤- capture location (number is moose ID #); 1 through 12: January through December. The animal was radio-collared in October 1987.

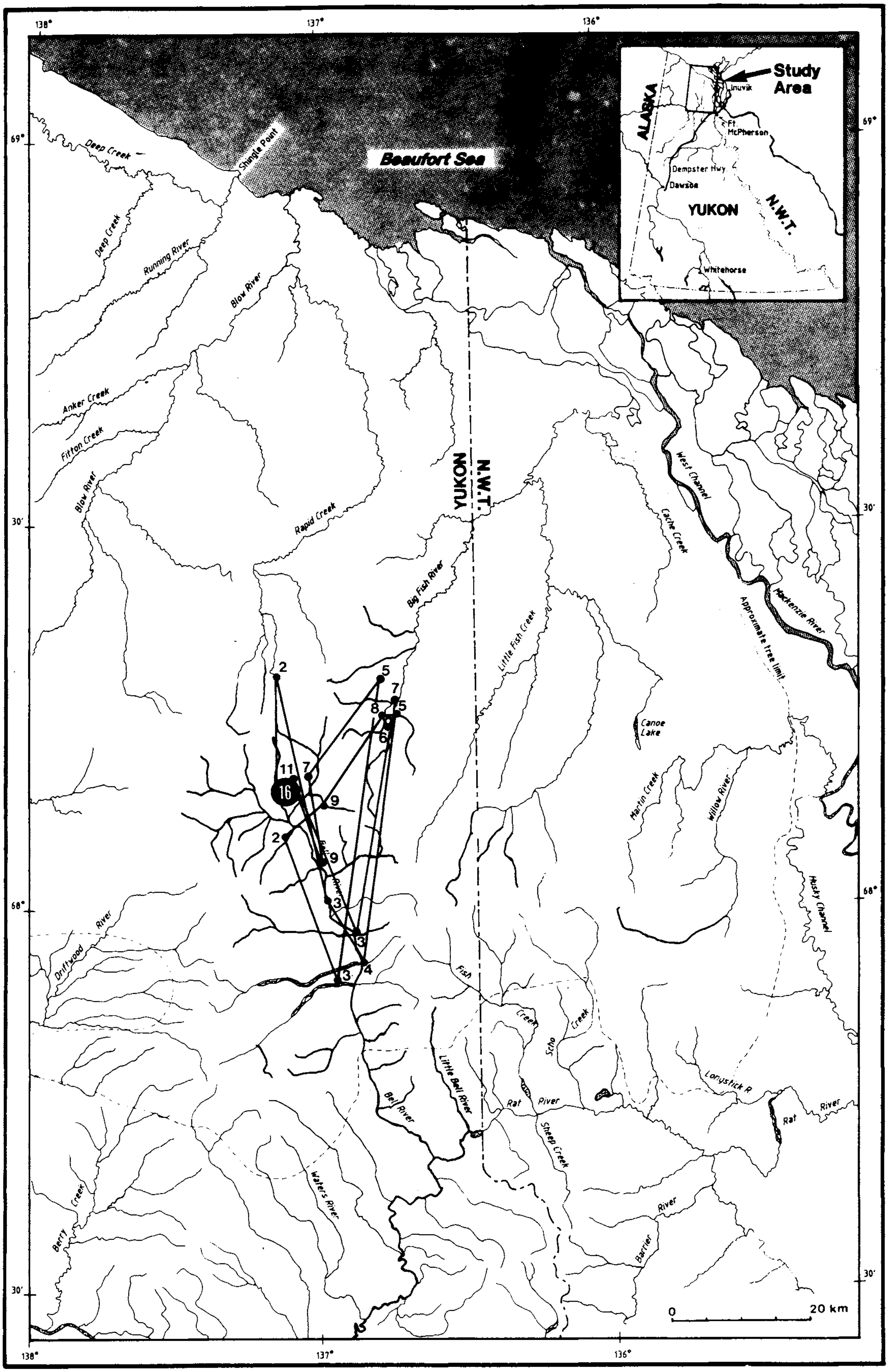

Figure 3f. Locations (●) of radio-collared female moose as determined from monitoring flights; ⬤ - capture location (number is moose ID #); 1 through 12: January through December. The animal was radio-collared in October 1987.

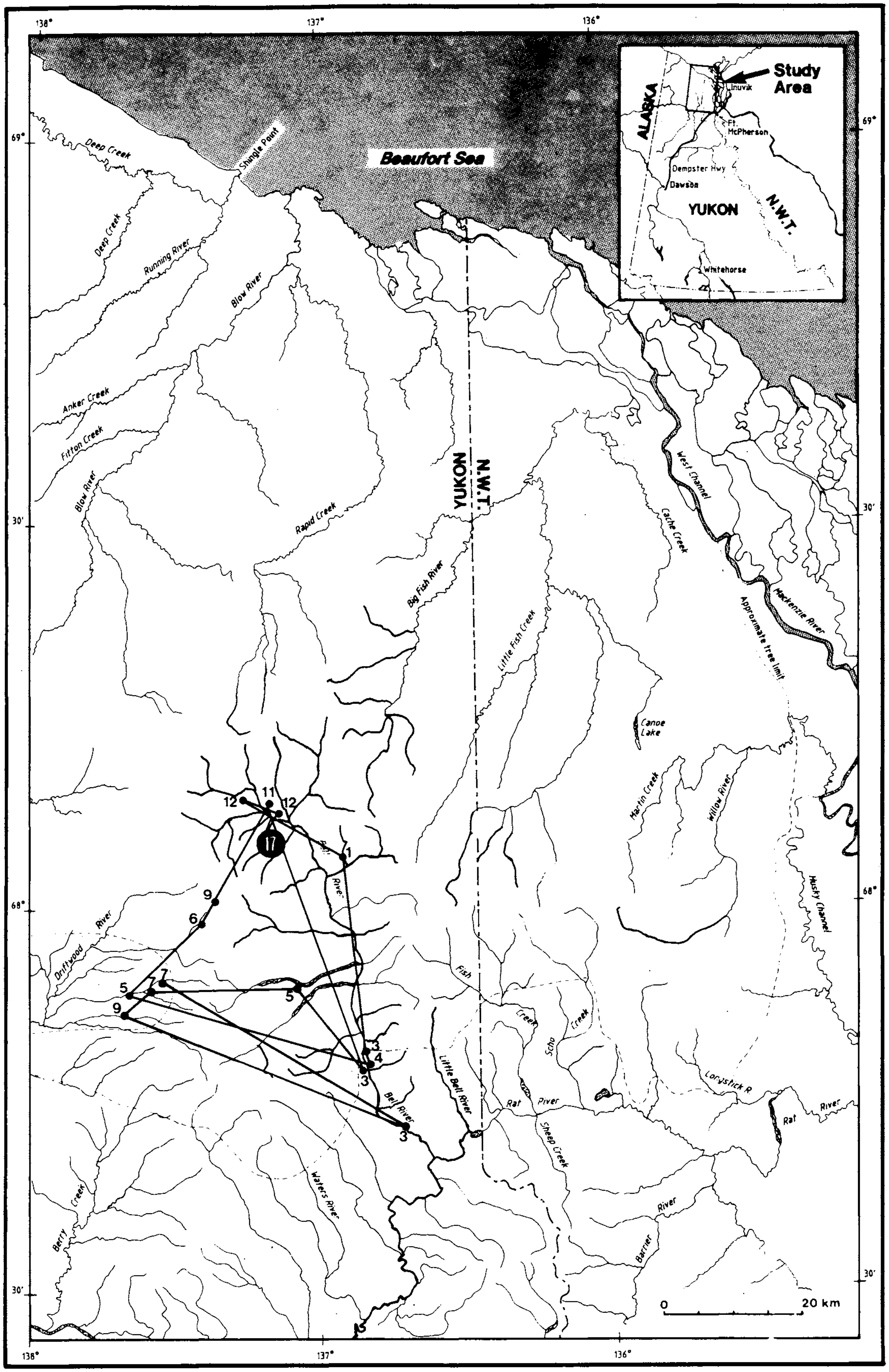

Figure 3g. Locations (●) of radio-collared female moose as determined from monitoring flights; ●- capture location (number is moose ID #); 1 through 12: January through December. The animal was radio-collared in October 1987.

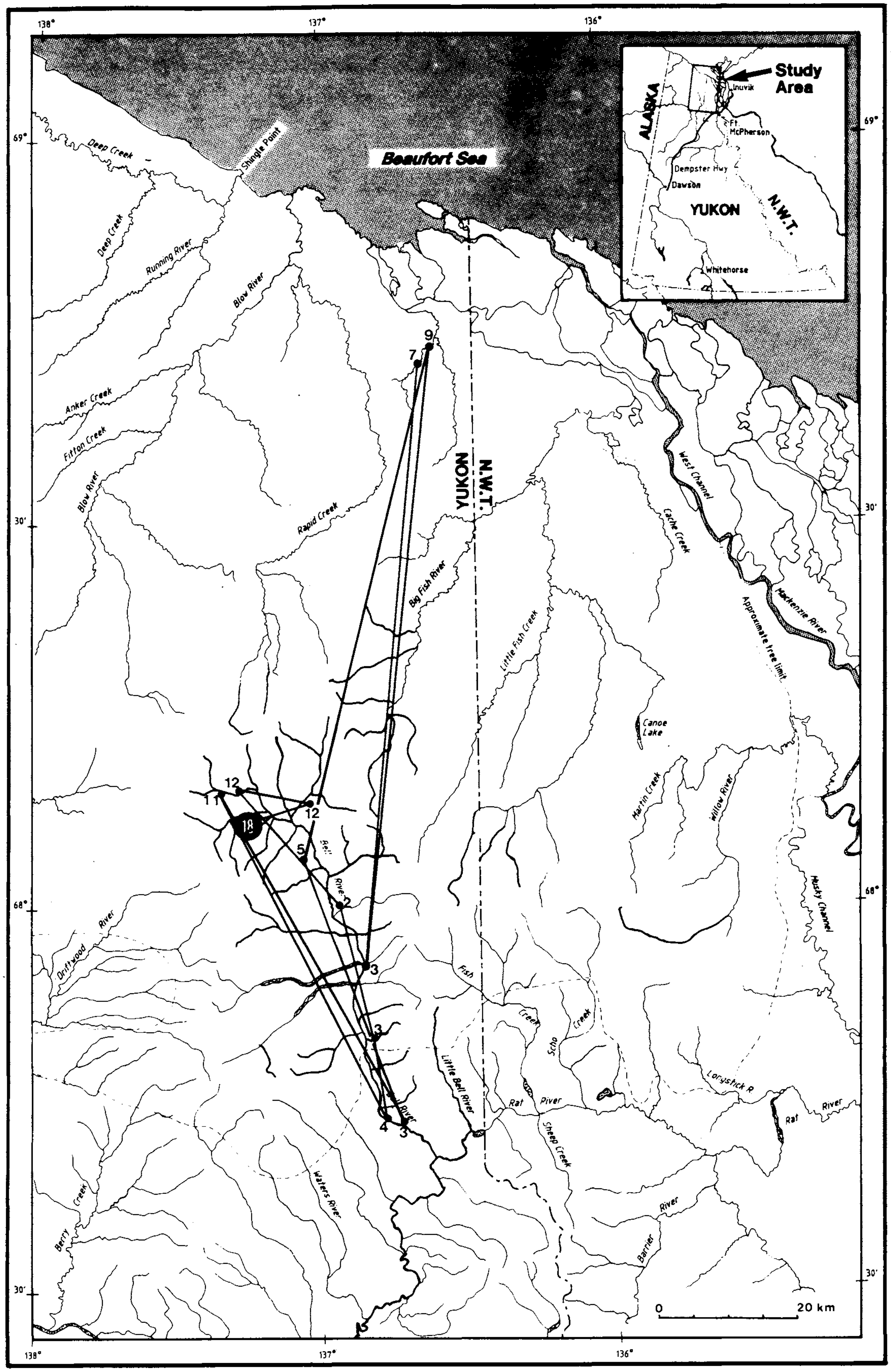

Figure 3h. Locations (●) of radio-collared female moose as determined from monitoring flights; ⬤- capture location (number is moose ID #); 1 through 12: January through December. The animal was radio-collared in October 1987.

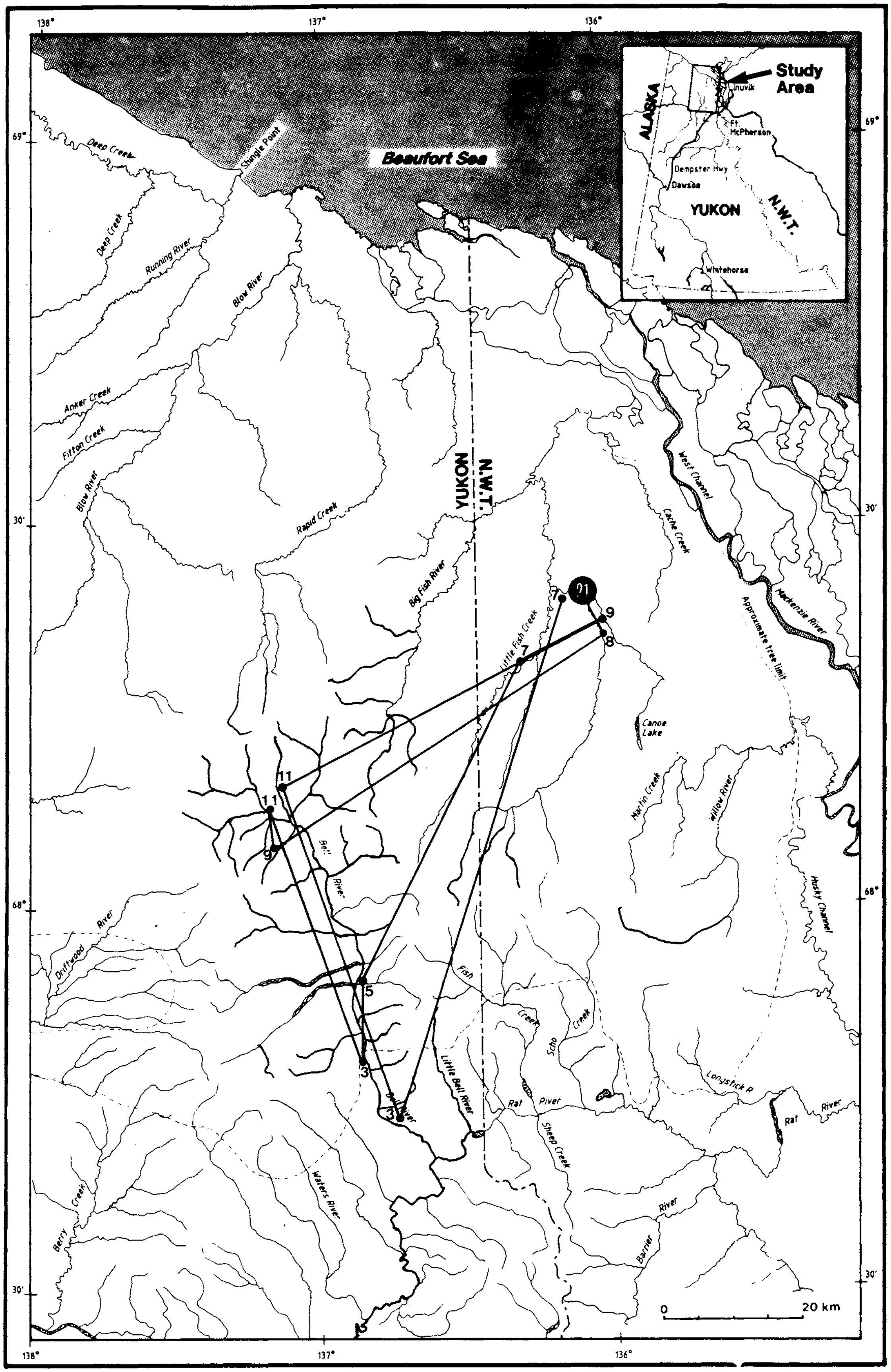

Figure 3i. Locations (●) of radio-collared female moose as determined from monitoring flights; ●- capture location (number is moose ID #); 1 through 12: January through December. The animal was radio-collared in July 1988.

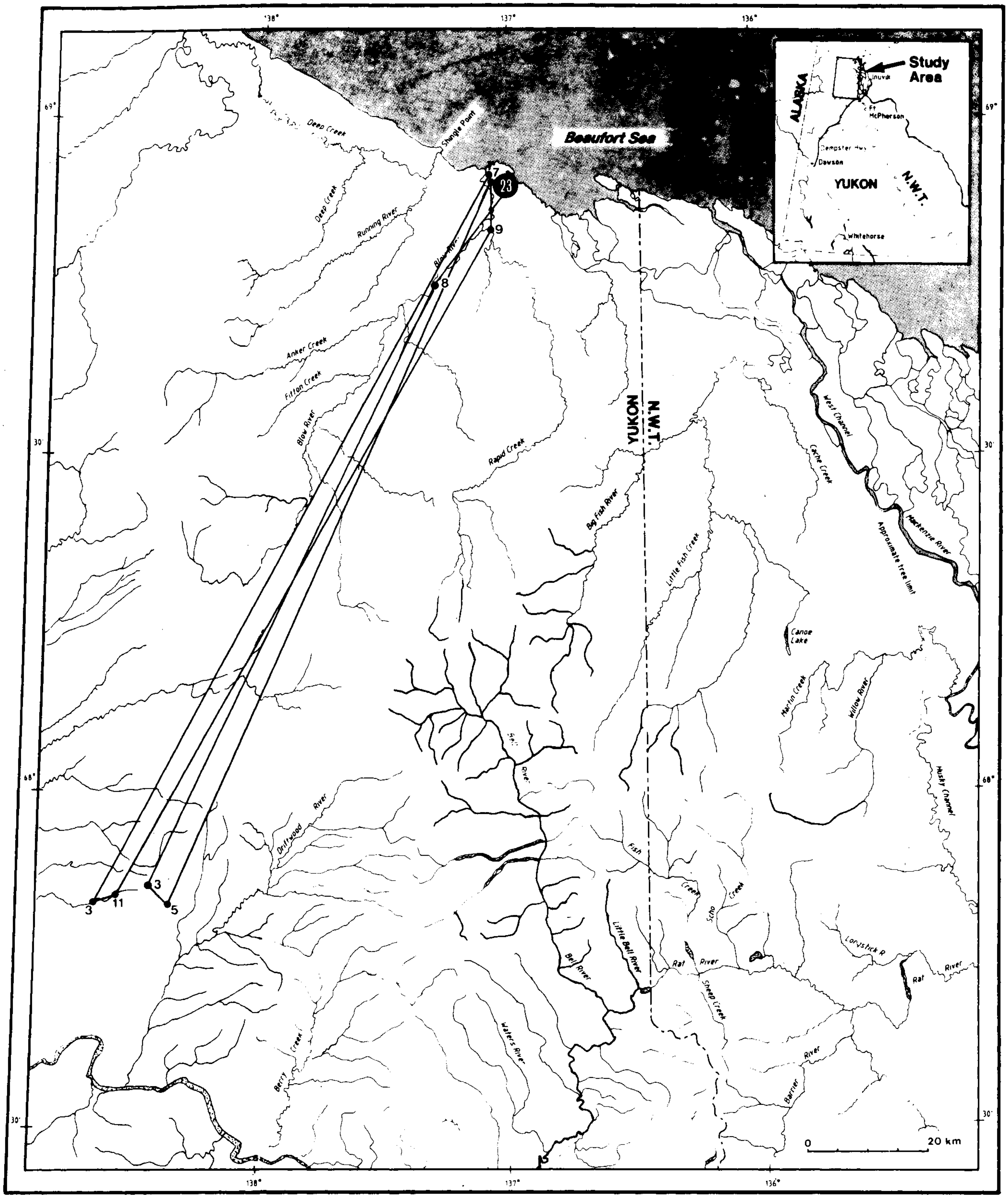

Figure 3j. Locations (●) of radio-collared female moose as determined from monitoring flights; ⬤- capture location (number is moose ID #); 1 through 12: January through December. The animal was radio-collared in July 1987.

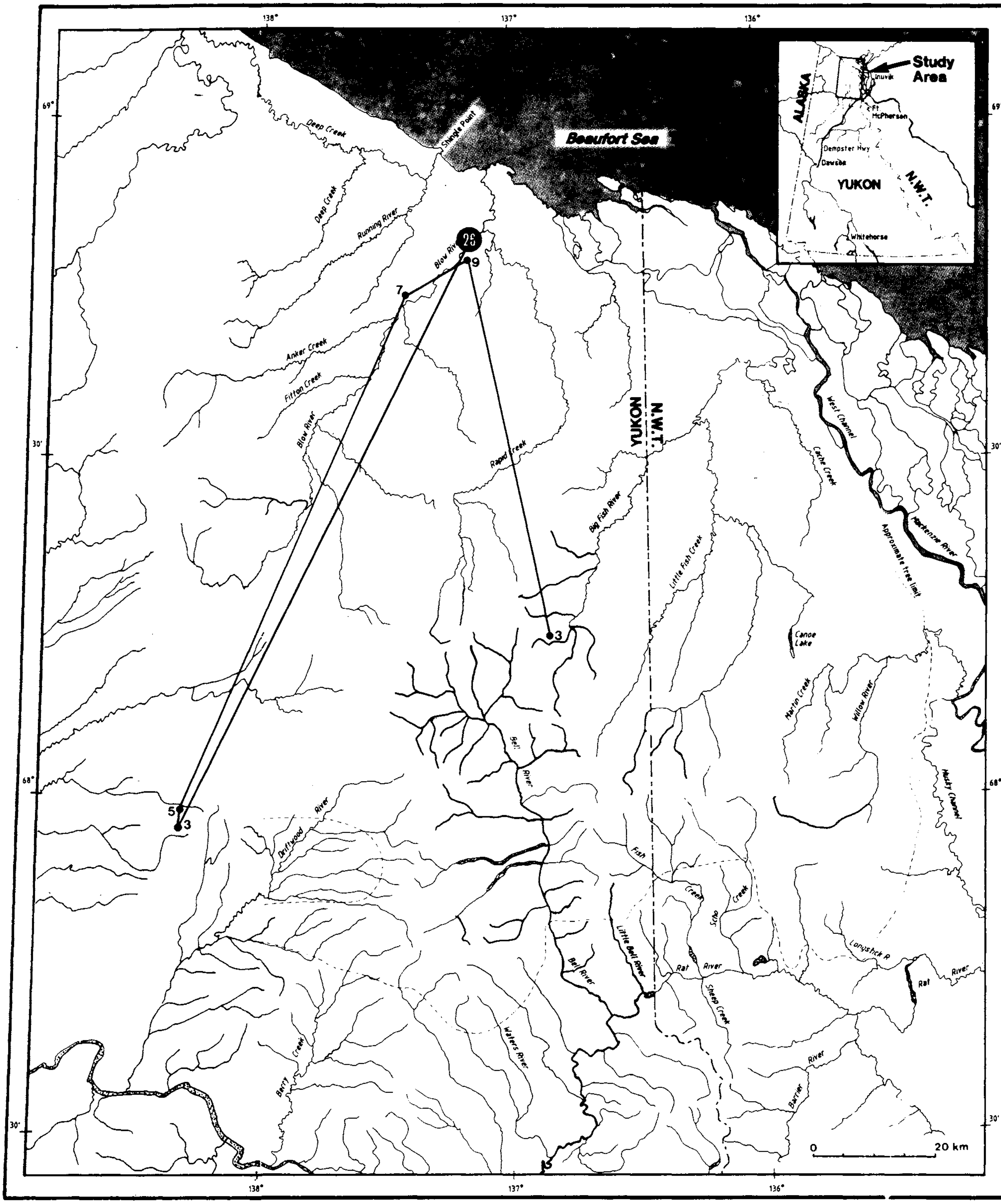

Figure 3k. Locations (●) of radio-collared female moose as determined from monitoring flights; ●- capture location (number is moose ID #); 1 through 12: January through December. The animal was radio-collared in July 1987.

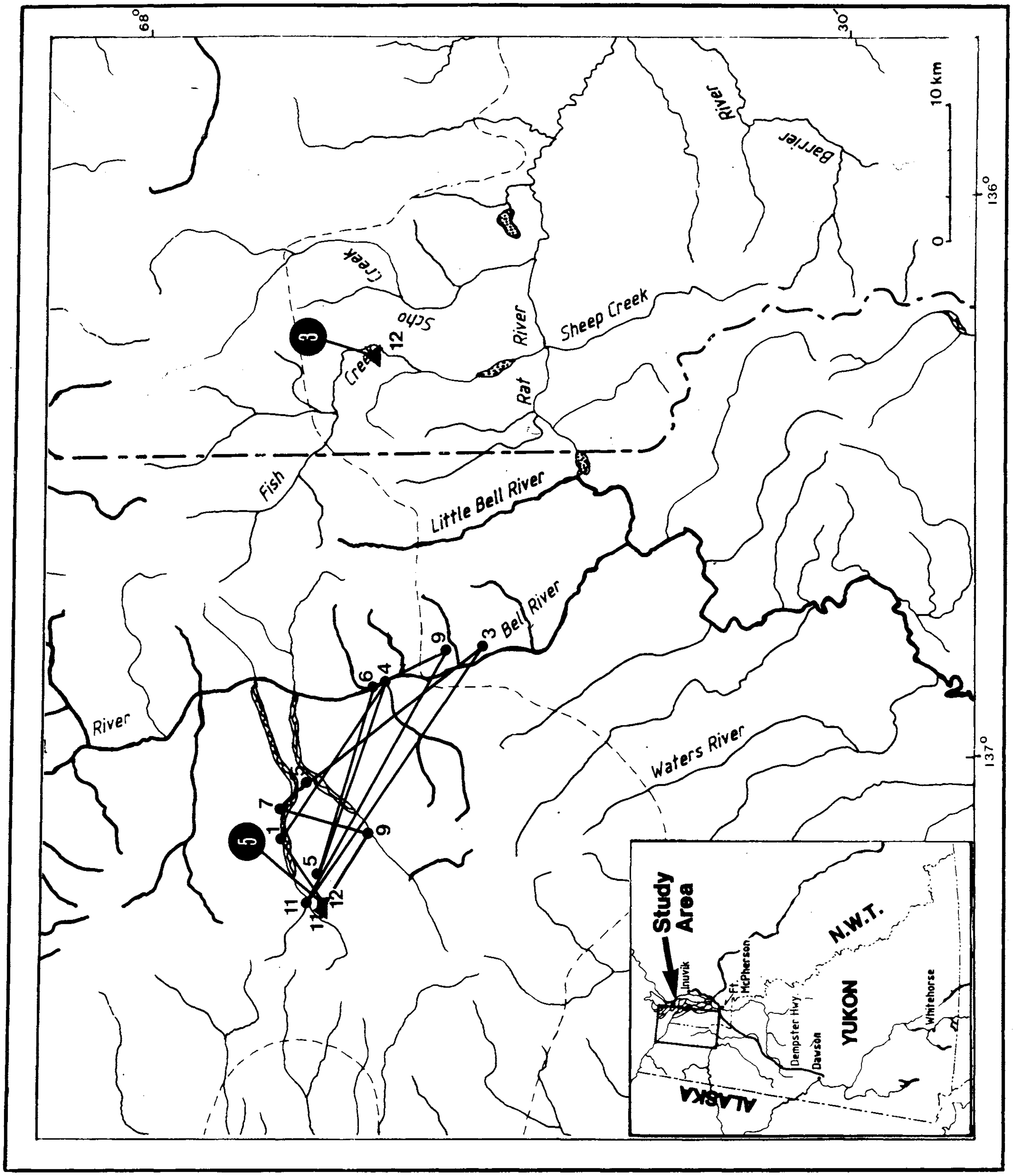

Figure 31. Locations (●) of radio-collared female moose (#3 is female, #5 is male) as determined from monitoring flights; ●- capture location (number is moose ID #); ▲- mortality location. 1 through 12: January through December. Both animals were radio-collared in October 1987.

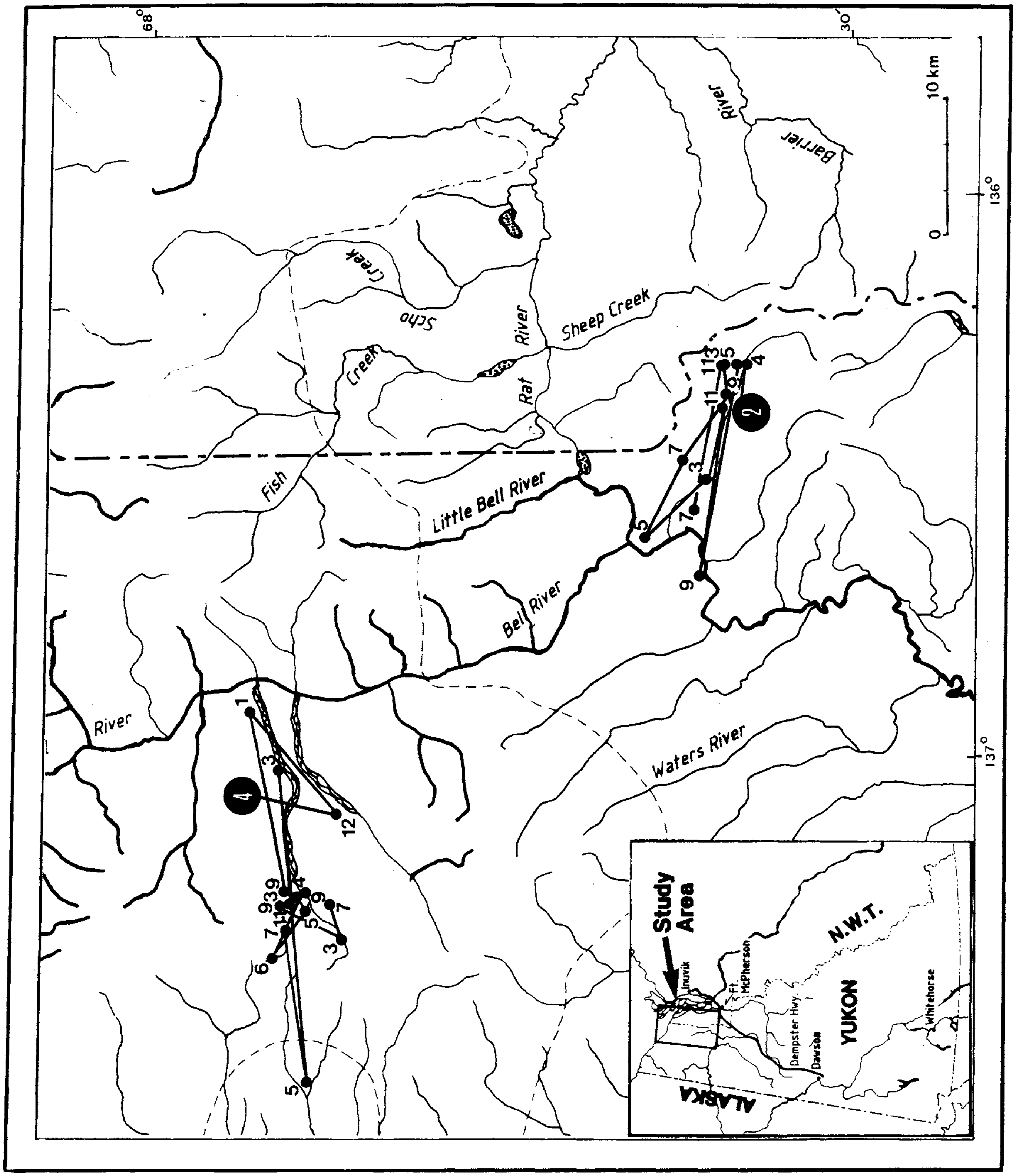

Figure 3m. Locations (●) of radio-collared male moose as determined from monitoring flights; ⬤- capture location (number is moose ID #); 1 through 12: January through December. Both animals were radio-collared in October 1987.

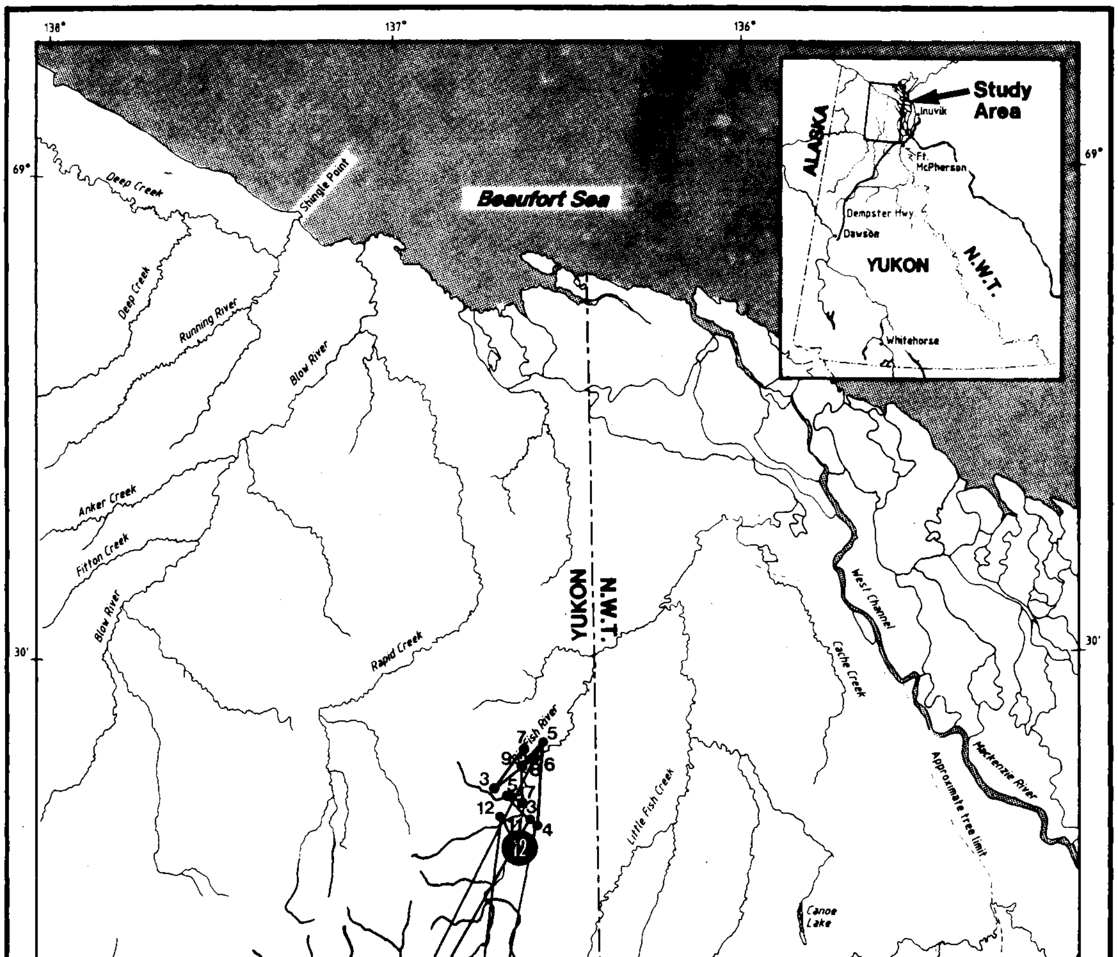

Figure 3n. Locations (●) of radio-collared male moose as determined from monitoring flights; ●- capture location (number is moose ID #); 1 through 12: January through December. The animals was radio-collared in October 1987.

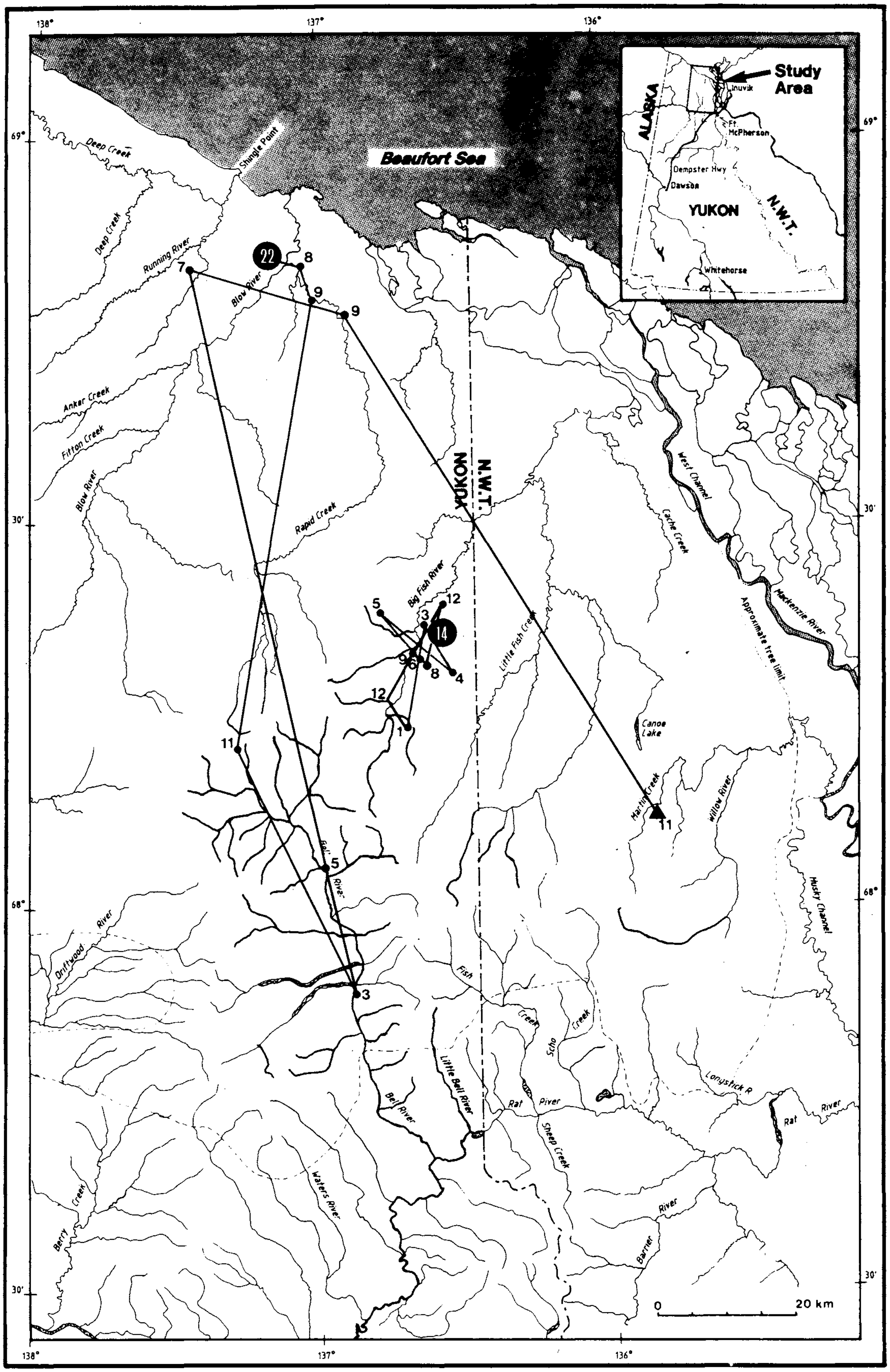

Figure 3o. Locations (●) of radio-collared male moose as determined from monitoring flights; ●- capture location (number is moose ID #); ▲- mortality location; 1 through 12: January through December. Moose #14 and #22 were radio-collared in October 1987 and July 1988, respectively.

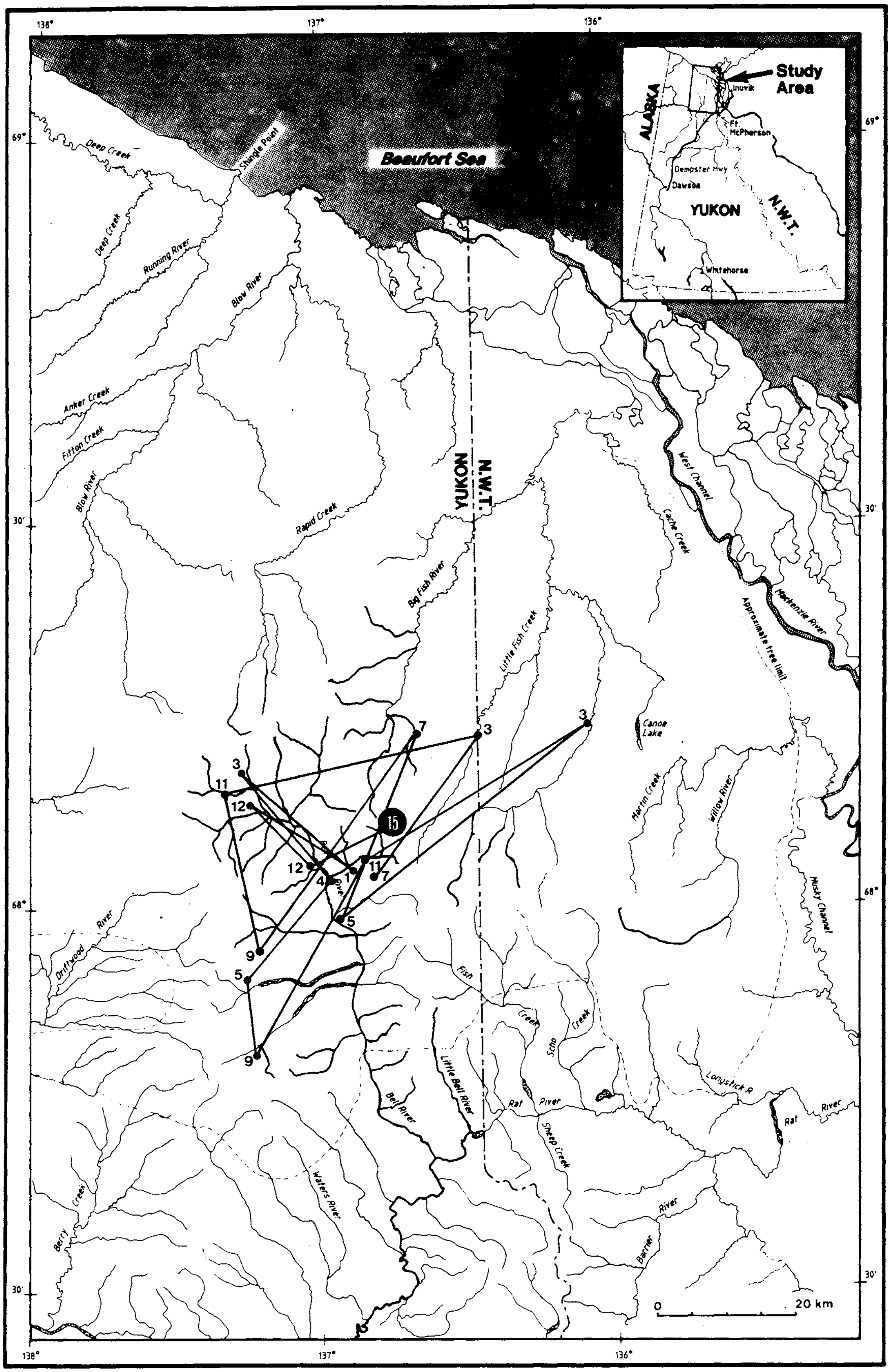

Figure 3p. Locations (●) of radio-collared male moose as determined from monitoring flights; ● - capture location (number is moose ID #); 1 through 12: January through December. The animal was radio-collared in October 1987.

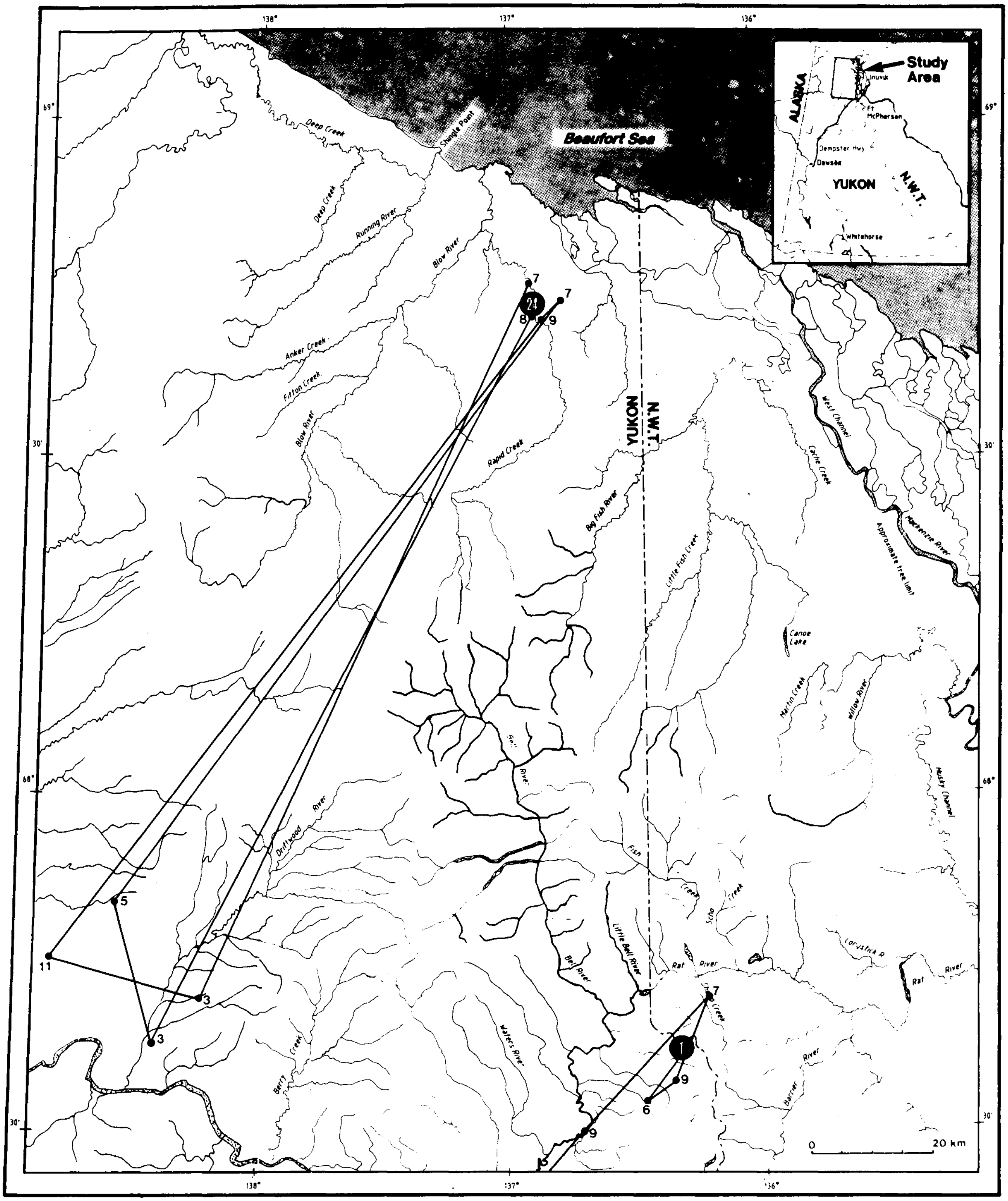

Figure 3q. Locations (●) of a radio-collared (#24 is male, #1 is female) moose as determined from monitoring flights; ●- capture location (number is moose ID #); 1 through 12: January through December. Moose #1 was radio-collared in October 1987, moose #24 in July 1988. Moose #1 was last located in March 1990 (mortality), 50 km SW from its September 1989 location.

APPENDIX B:

MOOSE HABITAT TYPES OF THE NORTHERN RICHARDSON MOUNTAINS AS DETERMINED FROM THEMATIC MAPPER IMAGERY AND BLACK AND WHITE AIRPHOTOS

G. Nassiopoulas[1] and C. Smits

Studies of moose in the Yukon Coastal Plain/Northern Richardson Mountains area have revealed a number of unique habitat use patterns. Moose in this area tend to be migratory in nature, moving between pockets of acceptable habitat (this report). These areas tend to be restricted mainly to valley bottoms. The study area is characterized by two distinctive valley types. In the south-west portion, in the area including the Bell and Little Bell Rivers and Fish Creek, the valleys are deep and incised, and dominated by high mountain ranges. These mountains form the northern extent of the Richardson Mountains. They are rugged and have not suffered extensive glaciation. As one proceeds further north and east however, the terrain is dominated by rolling tundra. Here the trees are limited to valley bottoms and side slopes. The trees do not grow above the tops of the valley walls due to severe climatic conditions. Trees only seem to grow in these valleys to a latitude of 68° 15'N. This would include the Rat River, Willow Creek, and the mid-portions of Little Fish Creek. The headwaters of Little Fish Creek are devoid of trees likely due to elevation and exposure (i.e. to the south), and the lower valleys (to the north) likely due to exposure. Moose are restricted to well defined areas and since a significant relationship between the extent of these areas and moose abundance has been determined, it would be possible to estimate population numbers over large geographic areas if one could determine the total area of vegetation types constituting moose habitat. The intent of this study was to map out the the extent of available tree cover as well as usable willow/alder communities within the study area. This task was complicated by the lack of airphoto coverage for much of the area. As a result, new techniques were employed to realize the results. The community types delineated are outlined on the enclosed legend (Figure 1).

Since airphoto coverage was old and incomplete, satellite imagery was used as the interpreted medium. Thematic mapper (TM) transparencies at an original

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1 Parks, Resources and Regional Planning Branch, Yukon Department of Renewable Resources, Whitehorse.

scale of 1:500,000 were projected at a scale of 1:100,000 with the aid of a Procom 2 imaging device onto a basemap of similar scale. The communities were subsequently hand drawn onto the basemap. Band combinations were 5.3.4. This combination provided the best distinction between coniferous and deciduous communities if the imagery was captured in mid to late July in this region. Imagery captured after this date did not differentiate well between true heath/forb tundra and shrub communities, making mapping difficult along the north slope. This factor was not as critical in the mountainous areas of the south-west, where conifers occur predominantly in river valleys. The maps were then verified for accuracy of polygon size, shape, and community type with 1:50,000 B/W airphotos where available (airphoto coverage was available from the western portion of the study area east to 135° 56' longitude).

Proceeding the mapping itself, the senior author conducted a 5-hour overview flight of the study area in order to observe and verify the vegetation types found there. A second flight was performed in July of 1990 to evaluate the accuracy of the maps. The senior author was not present on this flight and verification was performed by the junior author.

The preliminary flight in July of 1989 revealed some interesting features in vegetation patterns in the study area. In drainages like the Rat River and Willow Creek, the vegetation was a complex mosaic of white spruce, balsam poplar, alder, and willow. North facing slopes were denominated by deciduous rather than coniferous species as in more southerly regions, and south exposures were dominated by conifers. Previous studies reported aspen as a major species. These were actually balsam poplar. In many instances, alder and willows took on tree like proportions, often exceeding 5-6 meters. For the most part, trees in the study area rarely exceeded 10m, although some attained heights of 13m. Only in limited areas in the Bell River, Little Bell, and Fish Creek valley bottoms did trees exceed 10m and densities above 15-20% ground cover. Healthy stands are also found in the Rat and Willow Creek drainages.

In the Coastal Plain physiographic unit, upland exposed areas were dominated by tussock tundra and prostrate shrub communities. Alder communities were very prevalent and in many areas dominated willow and shrub birch. In many areas, alder was the only shrub species present right up into the alpine. Trees only grew in the water-carved valleys where protection from exposure allowed for the establishment and maintenance of trees. The tops of the trees almost never exceeded the tops of the valley walls. Despite the potential for these valleys being cold air sinks in the winter, exposure to cold winds and desiccation may be a more important factor to tree survival. In addition, although not tested, frost may not be as close to the surface in the valleys where incident radiation and less dense vegetation may allow thawing of frost close to the surface. This would make it possible for trees to establish. It is also likely that persistent winds in the tundra region makes conditions too harsh for trees to establish and survive.

By contrast, in the south-west areas (Richardsons), vegetation patterns more closely emulate patterns found in the central Yukon. The Bell, Fish and Little Bell Rivers have extensive braided channel development due to meandering rivers and flooding. Willows, alders, and some balsam poplars dominate active river channels, with white spruce dominating more stable sites. Black spruce was not present. Trees were rarely found above 2,500' (762m). The interface between trees and high elevation shrublands was well defined in steep slopes, while trees were found in low densities (>1% cover) in high elevation shrublands where slope did not exceed 10% - 20%.

As a result of this diversity of habitat, treed areas were mapped as one of three categories. They include spruce cover $\geq$ 10%, cover <10% but > 1%, and spruce cover $\leq$ 1%. For the most part, spruce stands > 10% cover were restricted to valley bottoms and north-facing slopes below 2,000'. In all but a few cases, treed communities were found adjacent to shrub communities, presumably making them valuable to moose.

The Bell River valley had the best spruce stands found in the study area, both in terms of density and volume. This area had a mosaic of spruce-willow (willow > 2m) communities, interspersed with non-vegetated gravel bars. This mosaic of spruce-willow communities should constitute the best moose habitat in the area and in fact, in the overview flight in July 1989, six moose were incidentally observed in a 15 mile stretch of valley bottom, while only one moose was observed in other vegetation types.

The use of satellite transparencies proved to be an effective method of conducting vegetation surveys. Despite limitations in resolution, and hence detail of plant types, generalized community mapping was plausible. Accuracy in delineating the boundaries of vegetation communities was approximately 85%. Spruce-dominated polygons could be mapped accurately to 90-95% (based on post-mapping field inspections using b+w air photos). Polar communities are harder to delineate, but this could be accomplished with more accurate, detailed ground observations. Tall willow communities were differentiated from medium/low height shrublands by their location along stream banks or elevations and different spectral patterns on the imagery.

Prostrate shrub communities, lichen/moose/forb types and non-vegetated types are also easily discernible.

The intent of this exercise was primarily to map key winter moose habitat, i.e. spruce dominated strands and to use a planimeter to measure its total area. For that purpose, the use of satellite imagery proved to be accurate and inexpensive when compared to conventional airphoto interpretation alone. The combination of the two mediums provides an extremely accurate product, that is more cost effective than airphotos or computer driven analyses alone.