Abundance, Sex/Age Composition and Seasonal Distribution of Moose in the Northern Richardson Mountains

Annual Progress Report

C.M.M. Smits

June 1989

Yukon
Renewable Resources

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ABSTRACT

The results of the second year of a continuing population study of moose in the northern Richardson Mountains are presented. During aerial drainage surveys in April 1988, November 1988, and March 1989 totals of 443 ± 218 (SE), 336 ± 99 (SE), and 264 ± 62 (SE) adult moose were estimated to be present in the study area. The extended population estimates including calves amount to 526, 392, and 315, respectively. During the April 1988 survey 84.3% of moose observed (N=140) were adults (≥ 22 months) and 15.7% were short yearlings (10 months). Cows (≥ 30 months), bulls (≥ 30 months), yearlings (18 months) and calves (6 months) made up 39.0%, 36.2%, 10.5%, and 14.3%, respectively, of observed moose (N=287) during the November 1988 survey. Bull/cow, calf/cow and yearling/cow ratios were 93:100, 37:100, and 27:100, respectively. The twinning rate was 20.6%. During the March 1989 survey bulls (≥ 22 months), cows (≥ 22 months), calves (10 months) comprised 37.7%, 34.2%, and 18.4% of observed moose (N=265). Bull/cow and calf/cow ratios were 108:100 and 41:100, respectively. The twinning rate was 16.2%.

The mean yearly adult mortality rate derived from radio-collared moose (N=26) was 16.3% - 16.8% during October 1987 - March 1989. Calf mortality derived from calves with radio-collared cows was calculated at 0.18 - 0.36 from October 1987 - April 1989, and at 0.47 - 0.53 from May 1988 - March 1989. This estimate may underestimate mortality as some neonatal mortality may have gone undetected as a result of infrequent monitoring flights. Calf mortality rates derived from calf/cow ratios in November 1988 and March 1989 indicate that virtually no calf mortality occurred during this period.

It was not possible to determine population trend from abundance estimates due to low levels of precision in surveys performed previous to March 1989. Instead inferences were made from recruitment figures and adult mortality rates. Yearling recruitment as derived from short-yearling counts during late winter appeared constant between the 1987, 1988 and 1989 late winter surveys (16.0%, 15.7%, and 16.2%,

respectively). Adult mortality derived from radio-collared animals during October 1987 - March 1989 was similar (16.3% - 16.8%). Since this rate is expected to overestimate adult mortality, it would appear more likely that the moose population remained stable or increased slightly than that it decreased during the period of study.

Distinct seasonal movements were observed among radio-collared moose. There was a trend for moose to move towards the south and lower elevations as winter progressed. This trend appeared to be reversed during spring. Moose radio-collared on the North Slope moved longer distances (up to 100 km) between summer and winter range than any other radio-collared moose. Moose captured on the South Slope generally were associated with that region throughout the year, while moose captured on the North Slope (during summer) generally moved to the South Slope for the winter. Moose were most often associated with shrub vegetation during the April, November 1988, and March 1989 surveys, particularly during November. During both late winter surveys shrub vegetation > 2m was used more frequently than shrub vegetation < 2m compared to the fall survey when no observations were made in the latter vegetation type. Moose were most often associated with tree vegetation during late winter than during fall surveys, and more so with mixed coniferous/deciduous vegetation than with vegetation dominated mainly by either deciduous or coniferous trees. Radio-collared moose were most often associated with shrub vegetation during all four seasons. Use of shrub vegetation < 2m increased during summer while use of shrub vegetation > 2m decreased concurrently. Association with tree vegetation was similar to that observed during surveys in the same periods. During summer moose were more frequently associated with tree vegetation than during fall, but less so than during spring or winter.

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). This 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. These characteristics 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.

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 to determine the sustainable harvest levels and to delineate key habitat of moose in the northern Richardson Mountains and adjacent coastal plain.

This report presents progress from April 1988 to March 1989. Activities during this period include:

1) surveys in April 1988 and March 1989,
2) a sex/age composition count in November 1988,
3) aerial monitoring (nine flights during the period reported),
4) radio-collaring of an additional six moose.

Since the study is ongoing, final and more extensive analyses will be done upon completion of the study.

STUDY AREA

The study area 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^{0}C, whereas those in the summer are slighly above 3^{0}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 (Vaccinium uliginosum), bog cranberry (V. vitis-idaea), common crowberry (Empetrum nigrum), Labrador tea (Ledum palustre), cloudberry, (Rubus chamaemorus) and mosses.

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.

METHODS

Abundance

Information of abundance was collected through aerial surveys during April 1988 and March 1989. The surveys were done when the ground of moose habitat in the study area was covered by snow. Moose habitat was assumed to be indicated by tree and shrub vegetation protruding above the snow, practically all of which occurs in relatively narrow valley bottoms (Watson et al., 1973; Walton-Rankin, 1977). The surveys were therefore essentially drainage surveys (Martin and Garner, 1985).

The April 1988 survey was 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 habitats units or those with a relatively dense vegetation, more transects were flown to minimize avoiding animals. Survey routes were similar to those previously used (Smits, 1988). 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 and group size was recorded. A group was defined as all moose within a maximum of approximately 50 m of one another. Notes were also made of the habitat unit moose were associated with (see Habitat Use). 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 Index method to the radio-collared sample of adult moose in the study area (Blower et al., 1981). The ratio of observed radio collars (m) to observed adult moose

(n) was equated to the ratio of radio collars known to be available for observation (M) to the estimated total (N). The equation m/n=M/N was solved for N. The standard error was calculated from the equation SE = $((M^2 n(n-m))/m^3)^{1/2}$, as described in Blower et al. (1981). Estimates were made only for adults and therefore are the only class for which standard errors 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 Index.

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 (Smits, 1988). 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 (Smits, 1988). 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 calculation of the estimate of the total number of moose present in the study area and its standard error 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 April 1988 and March 1989 surveys, sex and age composition was determined from an aerial drainage survey in November 1988, covering the standardized survey route. The procedures of this survey were similar to the April 1988 survey 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.

Mortality

Adult mortality rates were calculated from the known mortality of radio-collared moose by means of animal periods as described by Gasaway et al. (1983). The exact date that mortalities occurred could not be ascertained. The method was therefore adapted to give a range of mortality rates by incorporating both a first and last date that mortalities might have taken place. Given the potential for radio failure only radio-collared moose known to be dead (from carcass observation) were used in the calculations. 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 survey) and cows $\geq$ 22 months (late winter surveys); yearling/cow ratios were based on estimates of cows $\geq$ 30 months (fall survey).

Capture and immobilization

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 (Palmer Chemical and Equipment Co., Douglasville, GA, U.S.A.) and a combination of 5 ml Etorphine hydrochloride (M 99) and 2 ml Xylazine hydrochloride (Rompun). The moose were fitted with radio transmitters attached to collars (Telonics Inc., Mesa, Arizona, U.S.A.). The transmitters pulsed initially at approximately 60 beats.minute^{-1} (slow mode) and when ceased for 6 hours the pulse rate tripled (fast or mortality mode). An outside incisor was pulled for aging (Sergeant and Pimlott, 1959), a tuft of hair was plucked from the right or left shoulder for analysis of trace elements (Franzmann et al., 1975), and a sample of fecal pellets was collected from the rectum for food habits analysis. 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 May, June, August, September, November 1988, February, March, 1989. 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 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.

Habitat use

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 < 2 m, shrub vegetation > 2 m, coniferous forest, deciduous forest, mixed coniferous/deciduous forest).A vegetation map delineating moose habitat is currently being prepared from Satellite imagery (thematic mapper)(G. Nassiopoulos, in prep.). Once completed, surface area of the various habitat units will be calculated enabling: 1) analyses evaluating preference/avoidance of habitat units, 2) calculations of seasonal moose densities.

Harvest

Harvest information of moose is being collected from Mackenzie Delta communities through the IFA Harvest Management Program (Fabijan, in prep.).

RESULTS

Abundance and Sex/Age composition

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).

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

Sex/Age Composition*	April, 1988		November, 1988		March, 1989	
	n**	%	n**	%	n**	%
Bulls			104	36.2	100	37.7
Cows			112	39.0	91	34.3
Yearlings			30	10.5		
Unclass.Adults	118	84.3			31	11.7
Calves	22	15.7	41	14.3	43	16.2
Bulls/100 Cows			93		108	
Yearlings/100 Cows			27			
Calves/100 Cows			37		40.6***	
Twinning rate		(22.2)		(20.6)		(16.2)

* bulls, cows: ≥ 30 months (November survey), ≥ 22 months (March survey); yearlings: 18 months (November survey); Calves: ≈ 10 months (March, April surveys), ≈ 6 months (November survey); Unclass.Adults: ≥ 22 months (March, April surveys).

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

*** assuming a male:female ratio of unclassified adults identical to the one observed among identified moose.

Most animals (121 or 86%) were observed in South Slope drainages, while 19 (14%) animals were observed on the North Slope (Table 2). 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 443 ± 218(SE)(Table 3). The extended population estimate including calves and using the calf proportion among observed moose amounts to 526.

Table 2. Distribution of moose observed across the study area in an aerial survey in the northern Richardson Mountains 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 ($\geq$ 22 months).

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 4). 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

Table 3. Estimated abundance of moose in the study area as determined from aerial surveys.

Survey Period	Total number of adult moose ($\pm$ SE)	Total number of moose[a]
April 1988	443 ($\pm$ 218)	526
November 1988	336 ($\pm$ 99)	392
March 1989	264 ($\pm$ 62)	315

a corrected for observed calf proportions.

Table 4. Distribution of moose observed across the study area in an aerial survey in the northern Richardson Mountains during November, 1988.

Drainage	No. Adult Males*	No. Adult Females*	No.Yearling Males*	Calves	Total
South Slope:					
Bell River	70	83	12	28	193
Fish Creek	9	10	1	3	23
Little Bell R.	3	8	-	3	14
Rat River	3	10	-	3	16
Scho Creek	5	7	1	-	13
Unnamed Cks. S. 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 (≥ 30 months), adult females (≥ 18 months), yearling males (18 months).

of adult moose in the study area is therefore 336 ± 99 (SE) (Table 3). The extended population estimate including calves and using the calf proportion among observed moose amounts to 392.

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 South Slope (Table 5). 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 264 ± 62 (SE)(Table 2). The extended population estimate including calves and using the calf proportion among observed moose amounts to 315.

Table 5. Distribution of moose observed across the study area in an aerial survey in the northern Richardson Mountains during March, 1989.

Drainage	No. Adult Males*	No. Adult Females*	No. Calves	No.Unclass. Adults*	Total
South Slope:					
Bell River	75	67	33	4	179
Little Bell R.	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

* Adults (≥ 22 months).

Approximately as many adult (≥ 22 months) males as adult 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 adults (11.7% of all moose observed) animals were not classified to sex (Table 1).

Mortality

Adult mortality

Four (20%) out of 20 adult moose radio-collared were confirmed to have died by March 1989 (Table 6). All of these were females. The periods during which they appear to have died are: October - December 1987, October 1987 - March 1988, February - March 1988, June - September 1988.

With the exception of one moose not heard since February 1989, all moose radio-collared in October 1987 were confirmed alive in March 1989. Five (83%) of six moose radio-collared in July 1988, were confirmed alive in

Table 6. **Mortality status* of radio-collared adult moose in the northern Richardson Mountains during October 1987 - March 1989.**

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

*** +, confirmed alive**
blank, status unknown
(Note that moose #'s 21-27 were collared during July 1989).

March 1989. The adult mortality rate calculated according to Gasaway et al. (1983) and adapted as outlined is therefore 16.3 - 16.8% per year.

Juvenile mortality

Mortality information of calves of radio-collared cows is of a fragmented nature since it was often impossible to make observations of cow-calf groups during monitoring flights (Table 7). 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

Table 7. Mortality status* of calves accompanied by radio-collared cows in the northern Richardson Mountains, during October 1987 - March 1989.

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

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

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 cow 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 those cows that died during the winter would have died also, 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.

Of eleven cows alive in May or June 1988, seven were confirmed to have calves (N=7), three were observed without calves in either May or June, and one was not observed during this period. The latter moose was first observed again in September and was then without a calf. Four additional cows were radio-collared in July 1988, two of which appeared to have calves (N=3). The three cows not seen with calves in May or June were observed with calves (N=5) the following November or March. One cow died before September and the fate of her calf is not known. Seven calves were confirmed present with cows in March, 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.

Calf-cow ratios were similar in both the November 1988 (37:100) and March 1989 (41:100) surveys. Corrected for a 5-month adult mortality rate of 6.9% (assuming a mean monthly adult mortality rate similar to that calculated from 17 months radio-collar information) the calf mortality rate during November-March amounts to ≈0 (37-38)/37).

Seasonal Distribution

Capture and Immobilization

Six moose (four adult females and two adult males) were captured across the North Slope portion of the study area and fitted with radio collars, during July 1988 (Tables 8 and 9). 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.

Aerial Monitoring

In 1988, monitoring flights were made on March 5, April 16-18, May 26 - 27, June 14, 29-30, August 14, September 15-16 and November 4-7, and in 1989 on February 4 and March 8-13. Frequent occurrences of localized ice fog and low clouds precluded the monitoring of all moose during each flight. Moose captured in the northern part of the study area appeared to make more extensive seasonal movements than moose captured in the south (Figs. 2a-2q). There was a trend for moose to move towards the

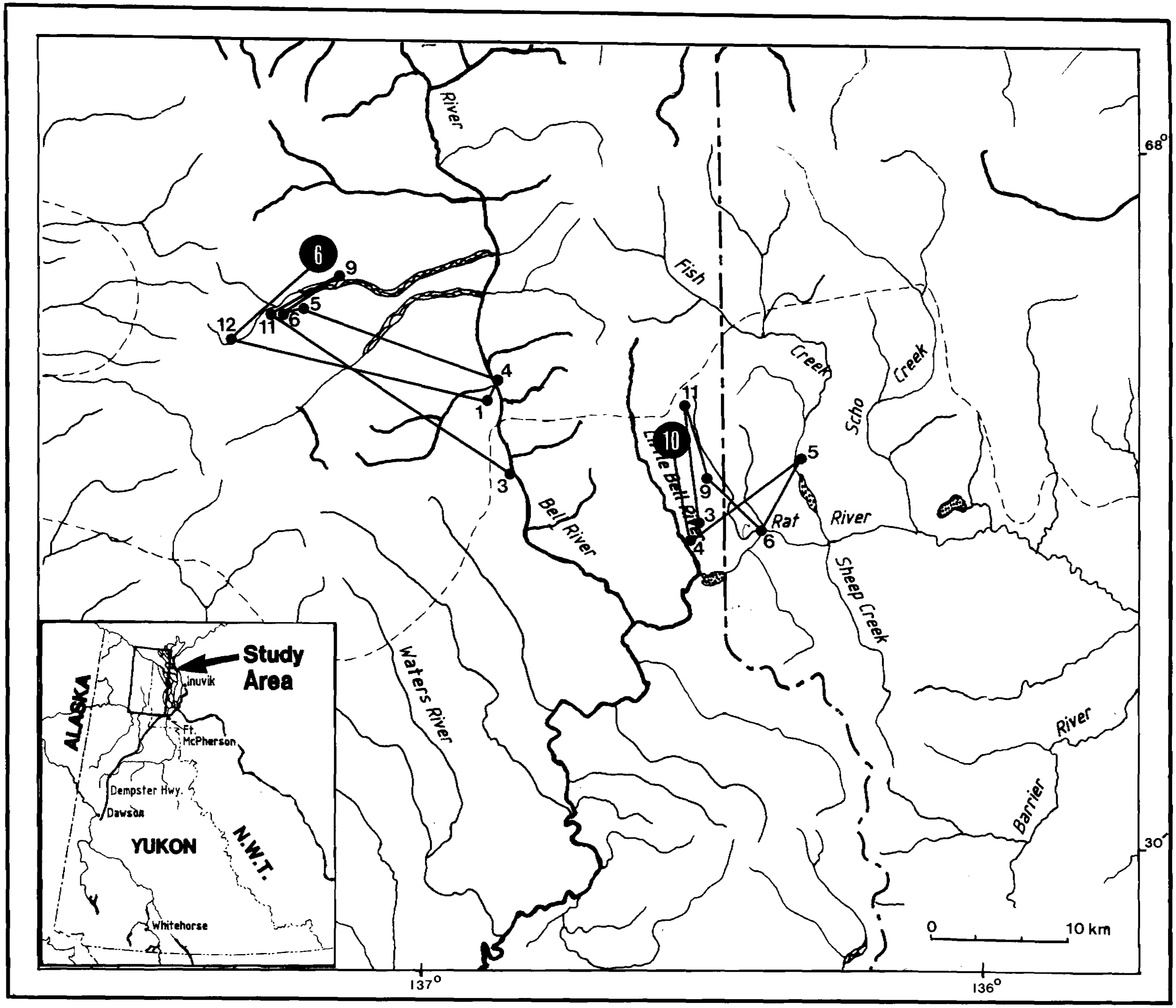

Fig. 2a. Locations (•) of radio-collared female moose as determined from monitoring flights; ● - capture location (number is moose ID #); 1, ..., 12 - Jan., ..., Dec. Both animals were radio-collared in October 1987.

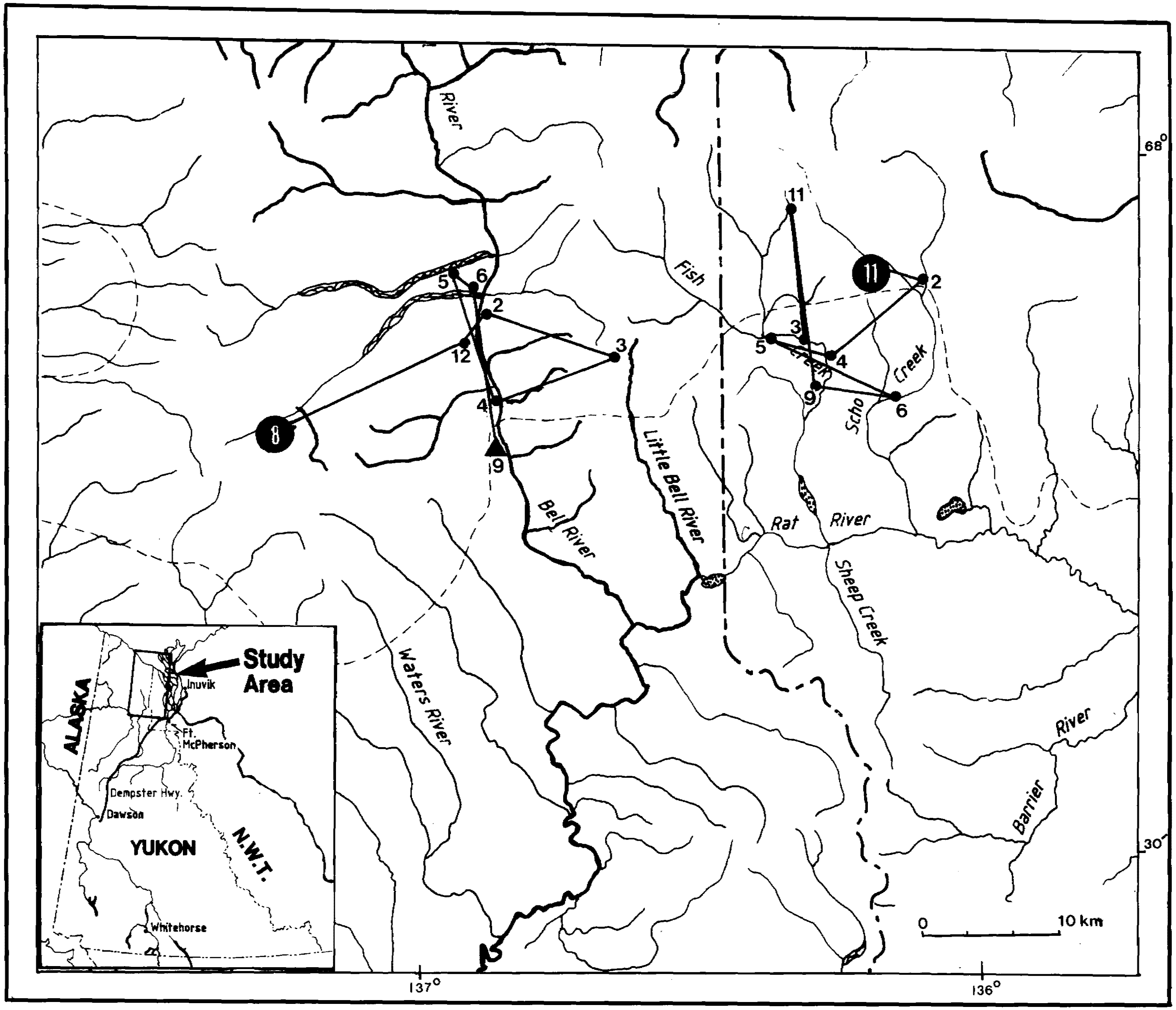

Fig. 2b. Locations (•) of radio-collared female moose as determined from monitoring flights; ● - capture location (number is moose ID #); ▲ - mortality location. 1, ..., 12 - Jan., ..., Dec. Both animals were radio-collared in October 1987.

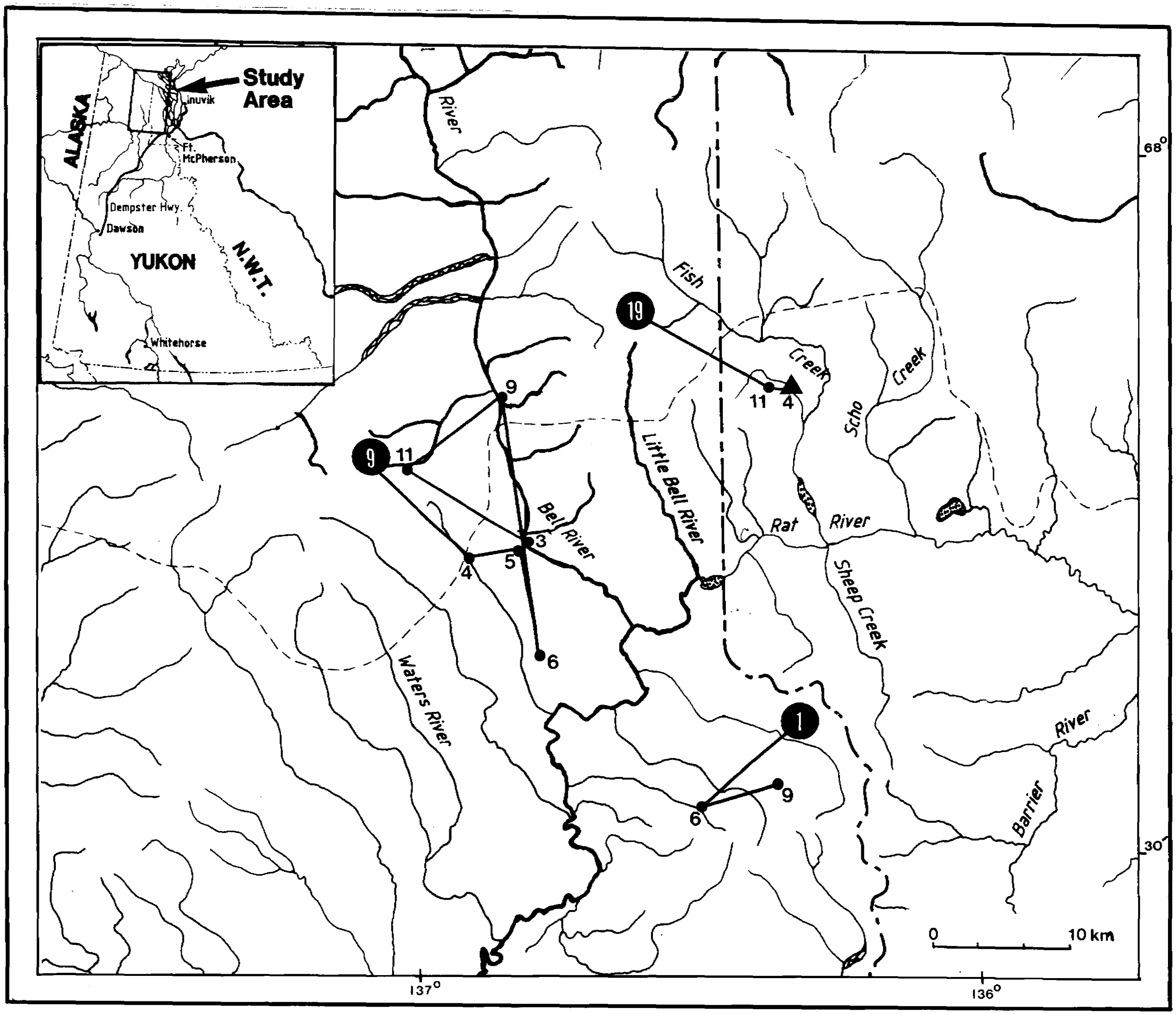

Fig. 2c. Locations (•) of radio-collared female moose as determined from monitoring flights; ● - capture location (number is moose ID #); ▲ - mortality location. 1, ..., 12 - Jan., ..., Dec. All three animals were radio-collared in October 1987.

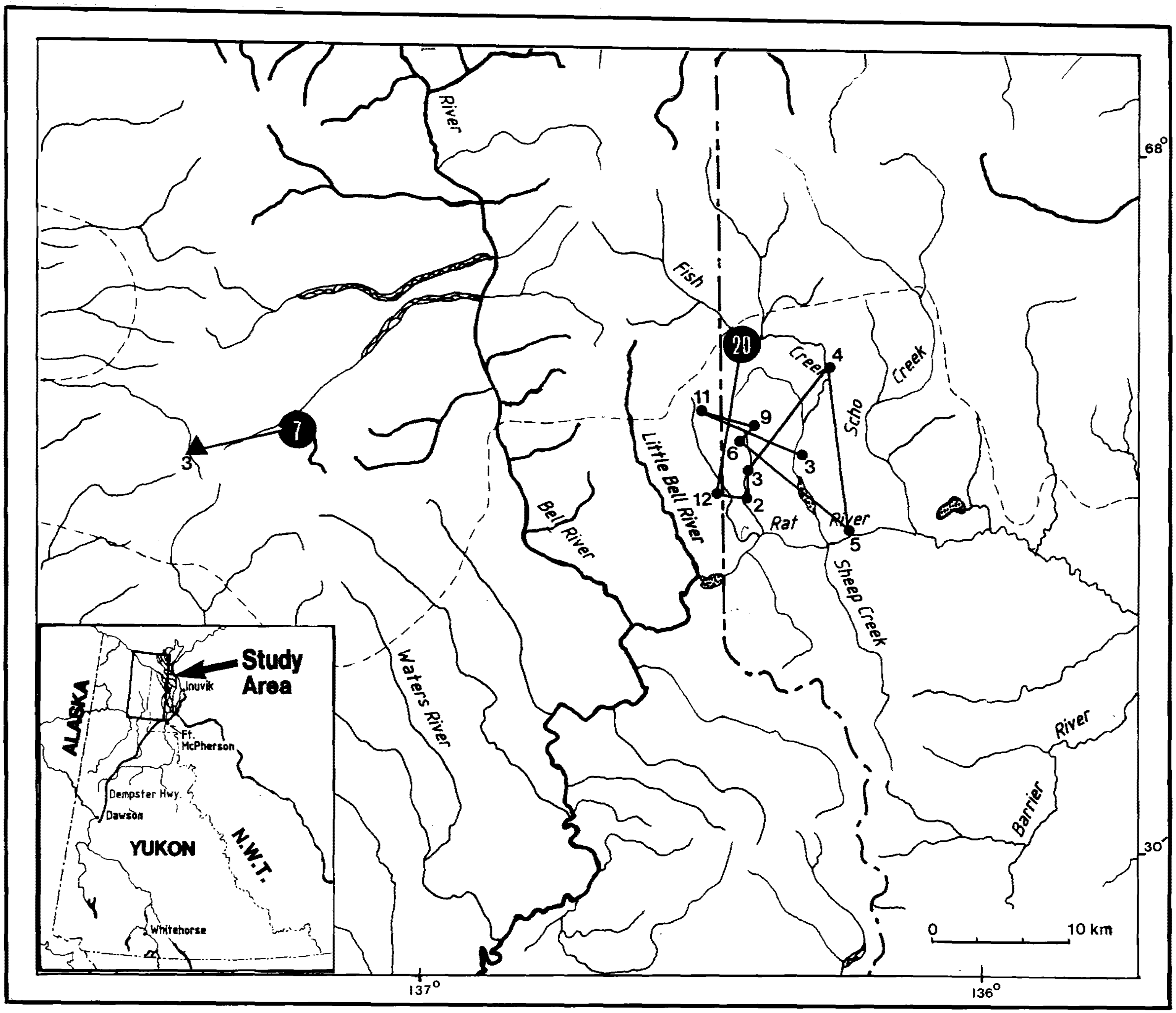

Fig. 2d. Locations (•) of radio-collared female moose as determined from monitoring flights; ● - capture location (number is moose ID #); ▲ - mortality location. 1, ..., 12 - Jan., ..., Dec. Both animals were radio-collared in October 1987.

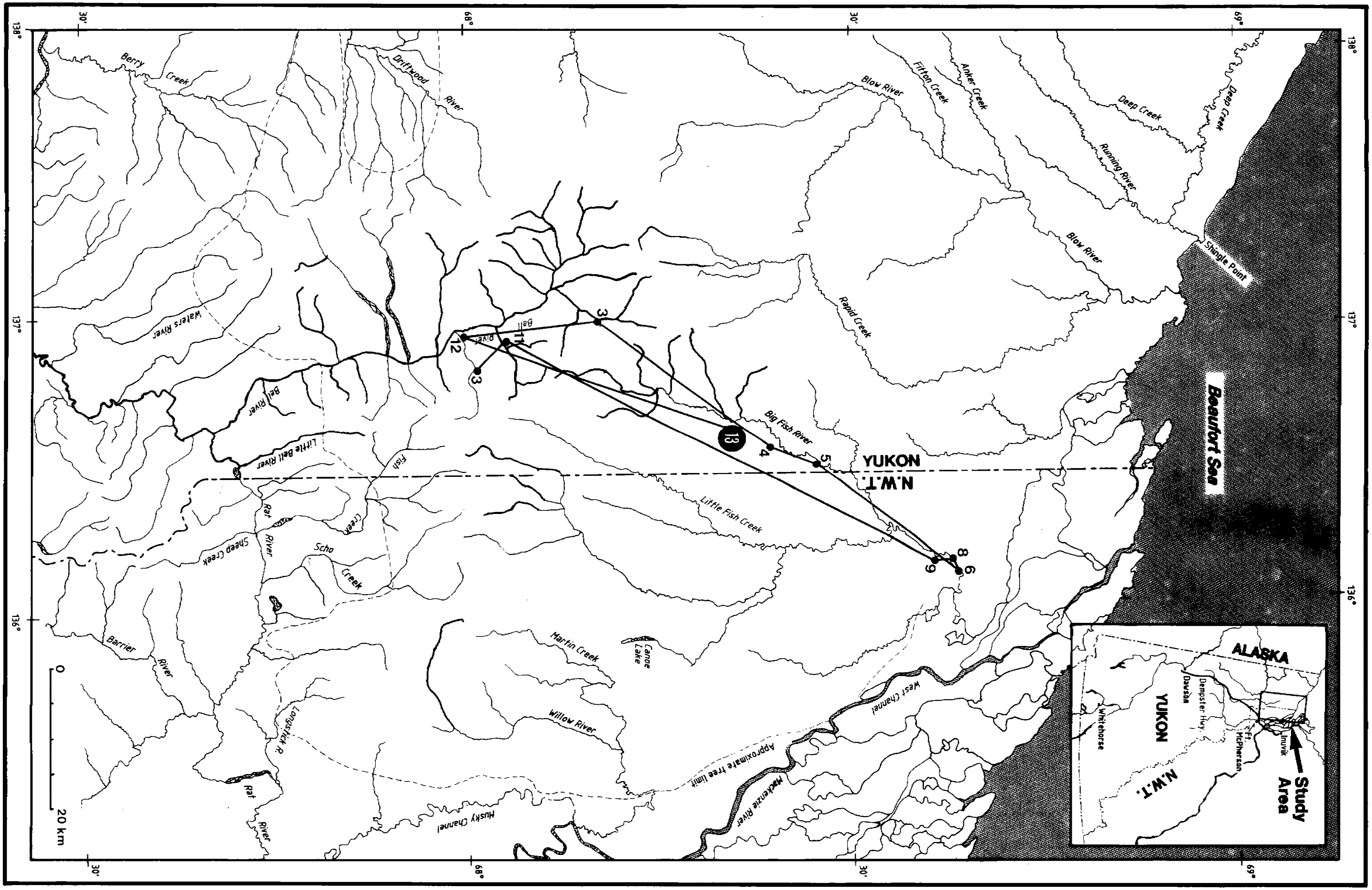

Fig. 2e. Locations (•) of a radio-collared female moose as determined from monitoring flights; ⬤ - capture location (number is moose ID #); 1, ..., 12 - Jan., ..., Dec. The animal was radio-collared in October 1987.

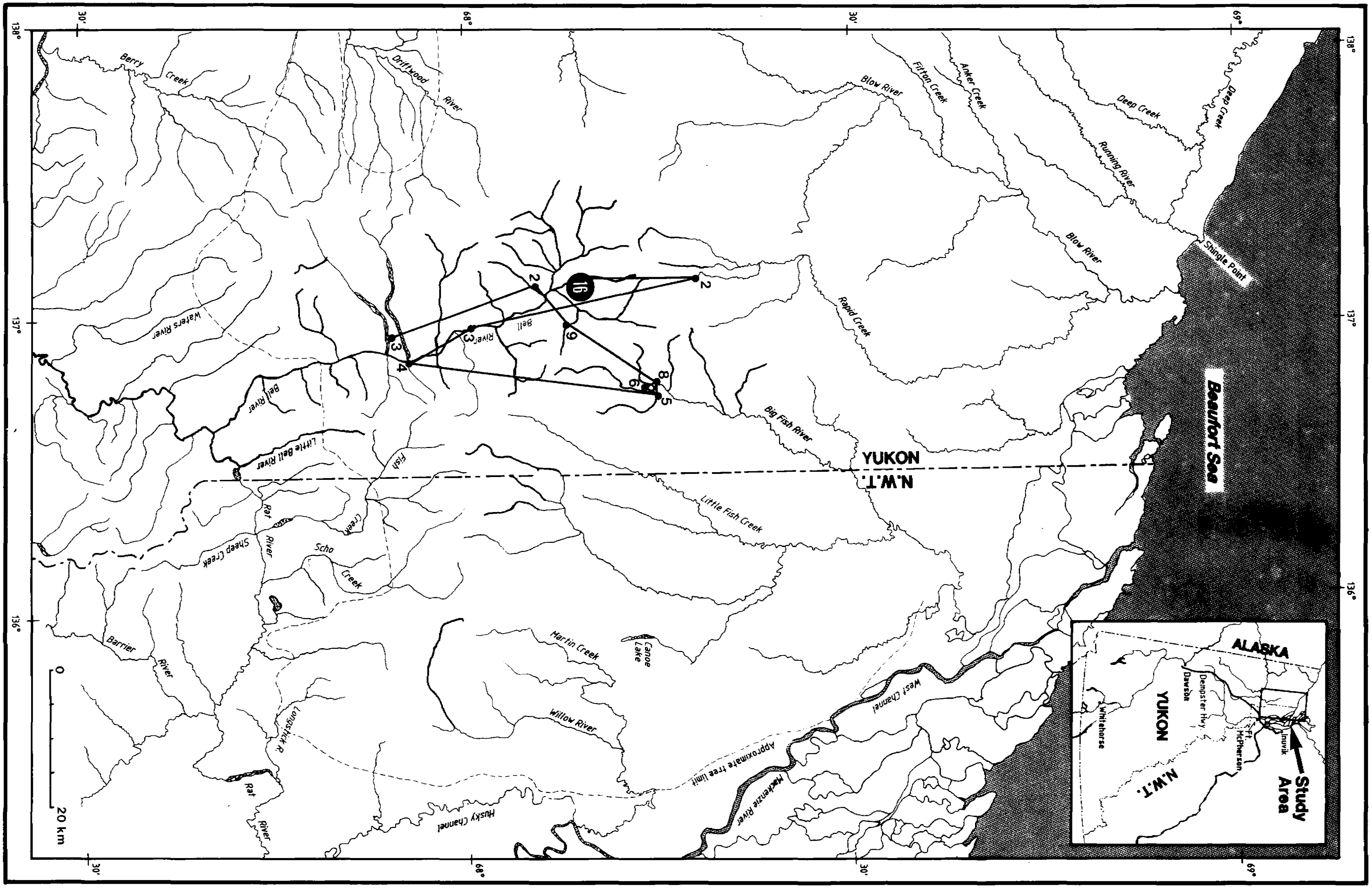

Fig. 2f. Locations (•) of a radio-collared female moose as determined from monitoring flights; ⬤ - capture location (number is moose ID #); 1, ..., 12 - Jan., ..., Dec. The animal was radio-collared in October 1987.

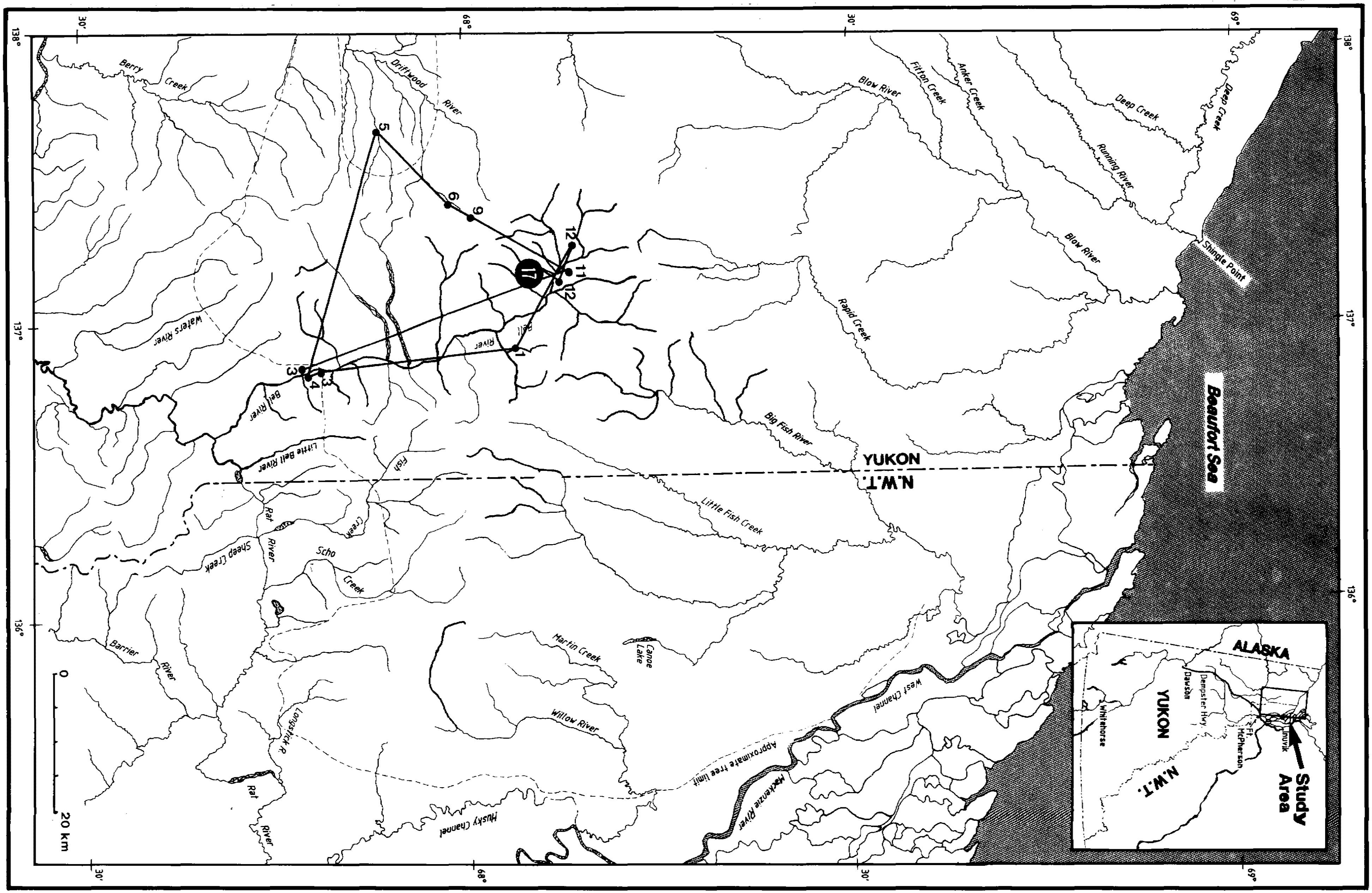

Fig. 2g. Locations (•) of a radio-collared female moose as determined from monitoring flights; ● - capture location (number is moose ID #); 1, ..., 12 - Jan., ..., Dec. The animal was radio-collared in October 1987.

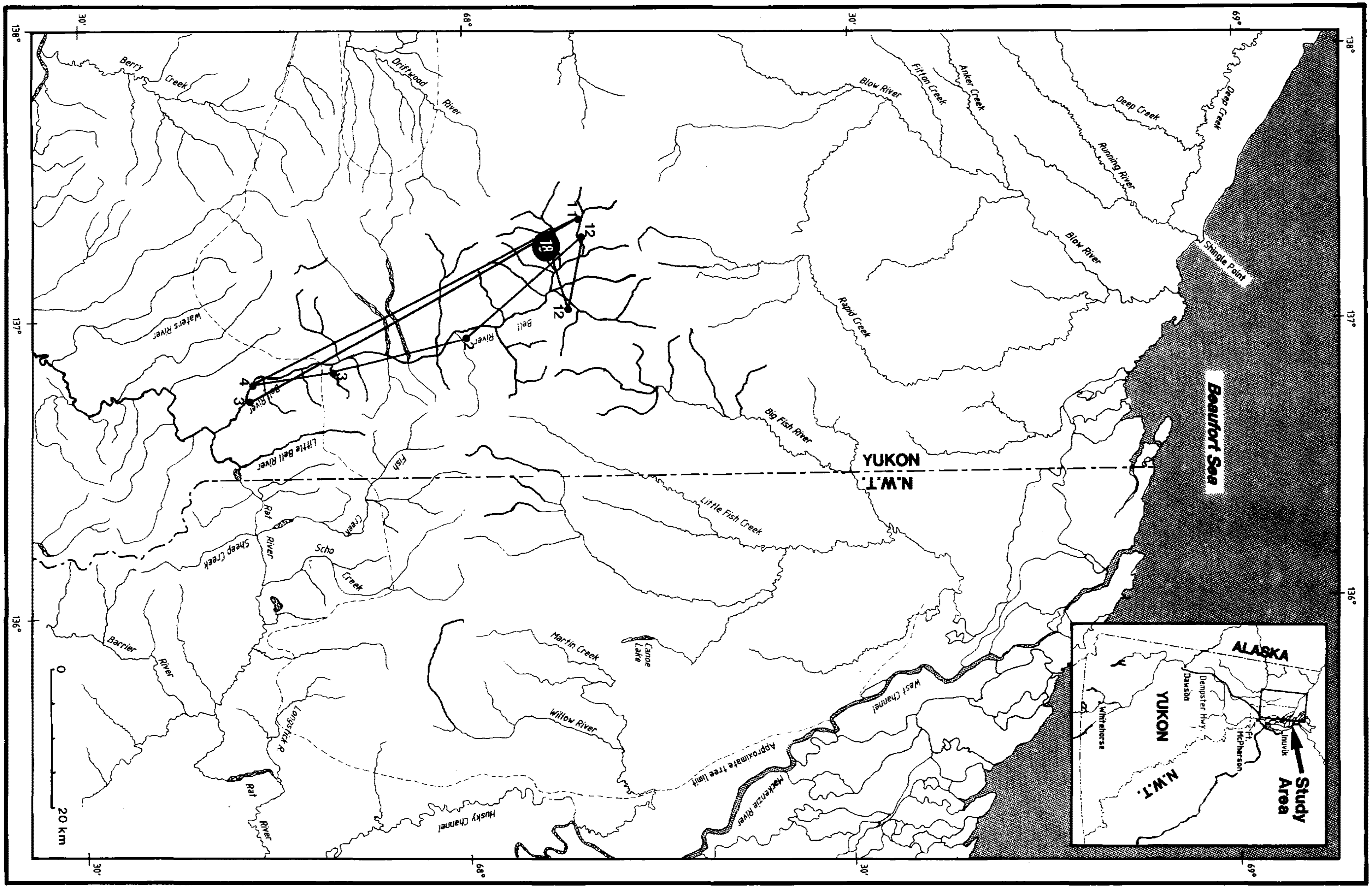

Fig. 2h. Locations (•) of a radio-collared female moose as determined from monitoring flights; ⬤ - capture location (number is moose ID #); 1, ..., 12 - Jan., ..., Dec. The animal was radio-collared in October 1987.

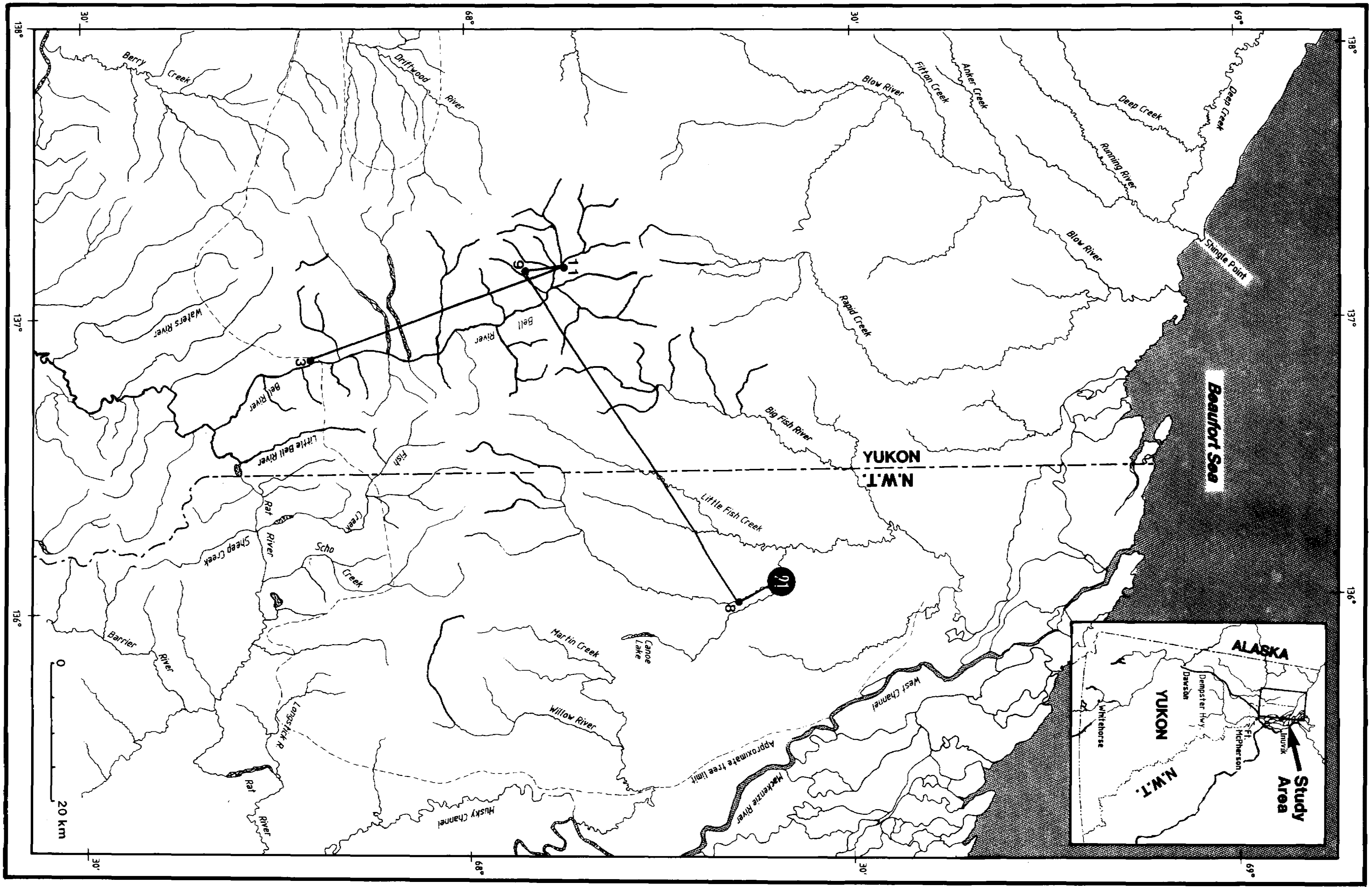

Fig. 2i. Locations (•) of a radio-collared female moose as determined from monitoring flights; ● - capture location (number is moose ID #); 1, ..., 12 - Jan., ..., Dec. The animal was radio-collared in July 1988.

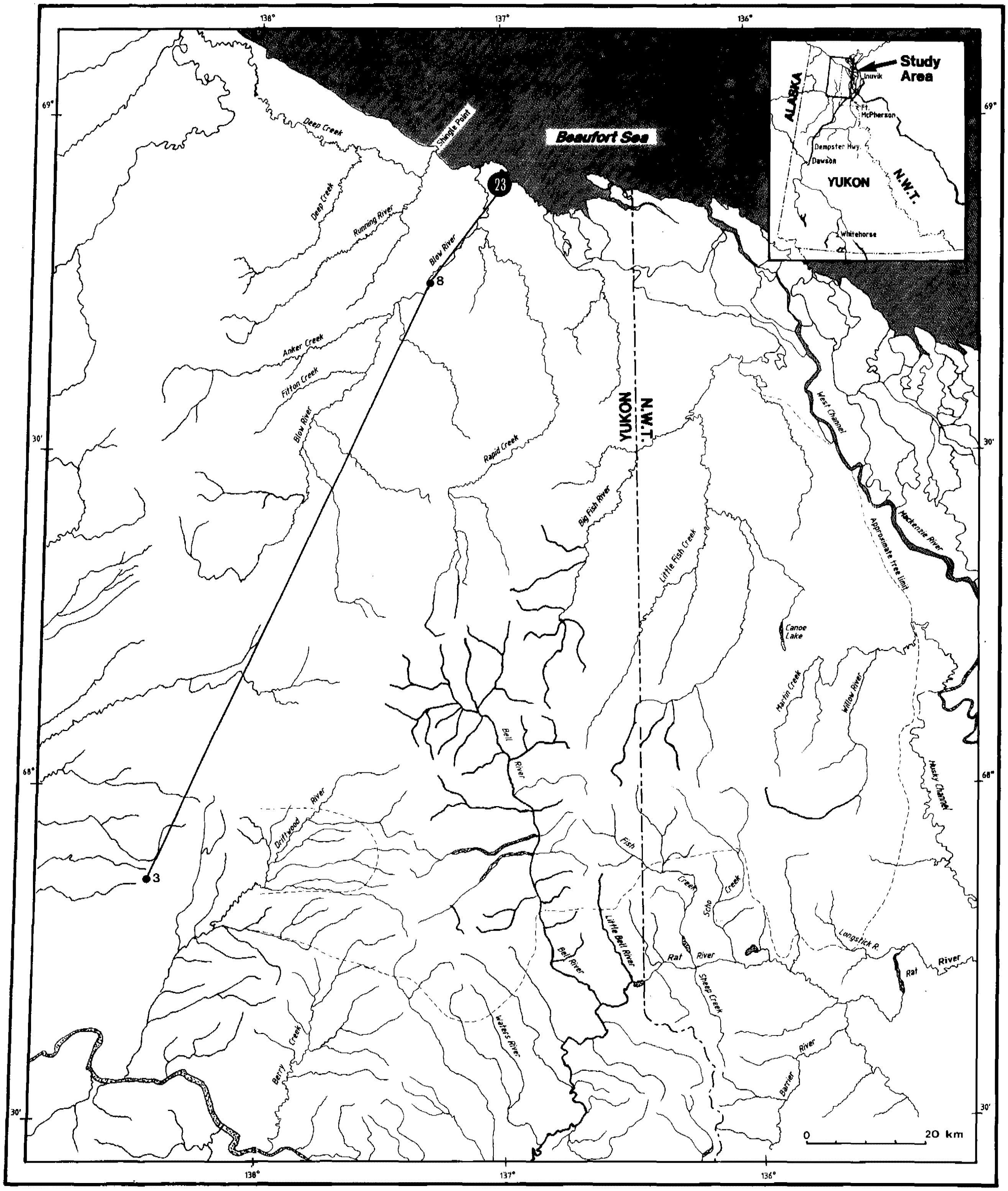

Fig. 2j. Locations (•) of a radio-collared female moose as determined from monitoring flights; ● - capture location (number is moose ID #); 1, ..., 12 - Jan., ..., Dec. The animal was radio-collared in July 1987.

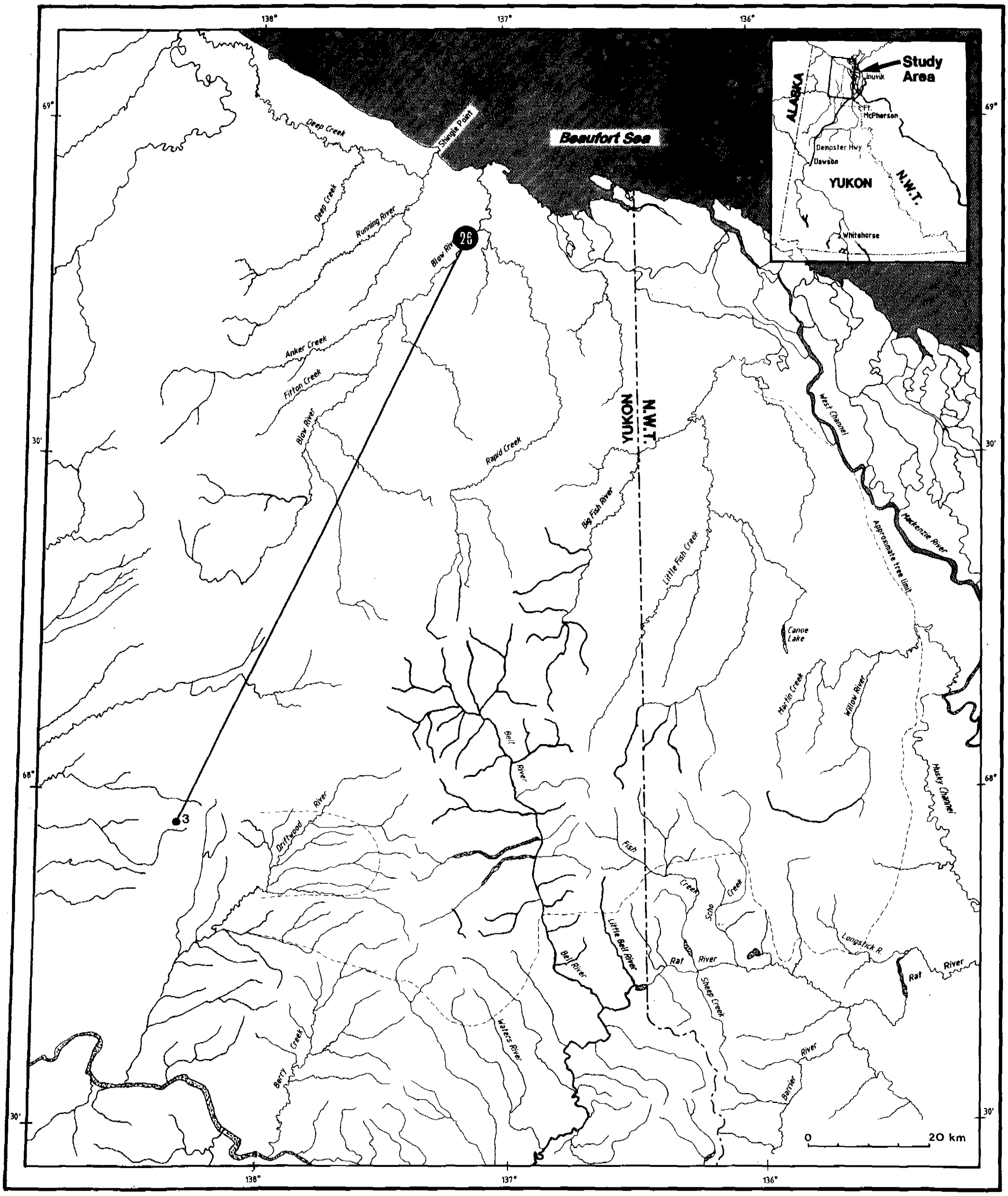

Fig. 2k. Locations (•) of a radio-collared female moose as determined from monitoring flights; ⬤ - capture location (number is moose ID #); 1, ..., 12 - Jan., ..., Dec. The animal was radio-collared in July 1987.

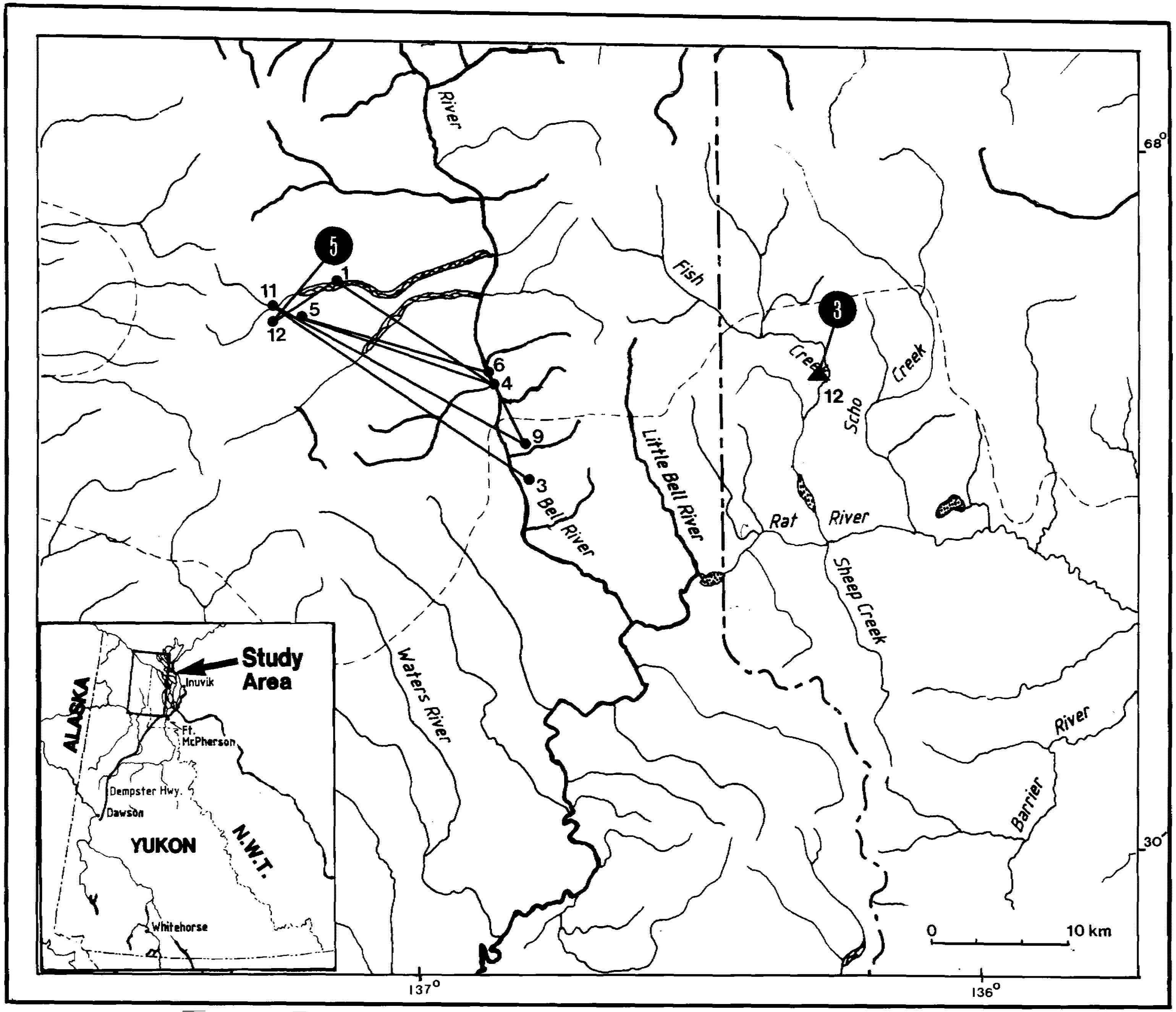

Fig. 21. Locations (•) of radio-collared moose (#3 is female, #5 is male) as determined from monitoring flights; ● - capture location (number is moose ID #); ▲ - mortality location. 1, ..., 12 - Jan., ..., Dec. Both animals were radio-collared in October 1987.

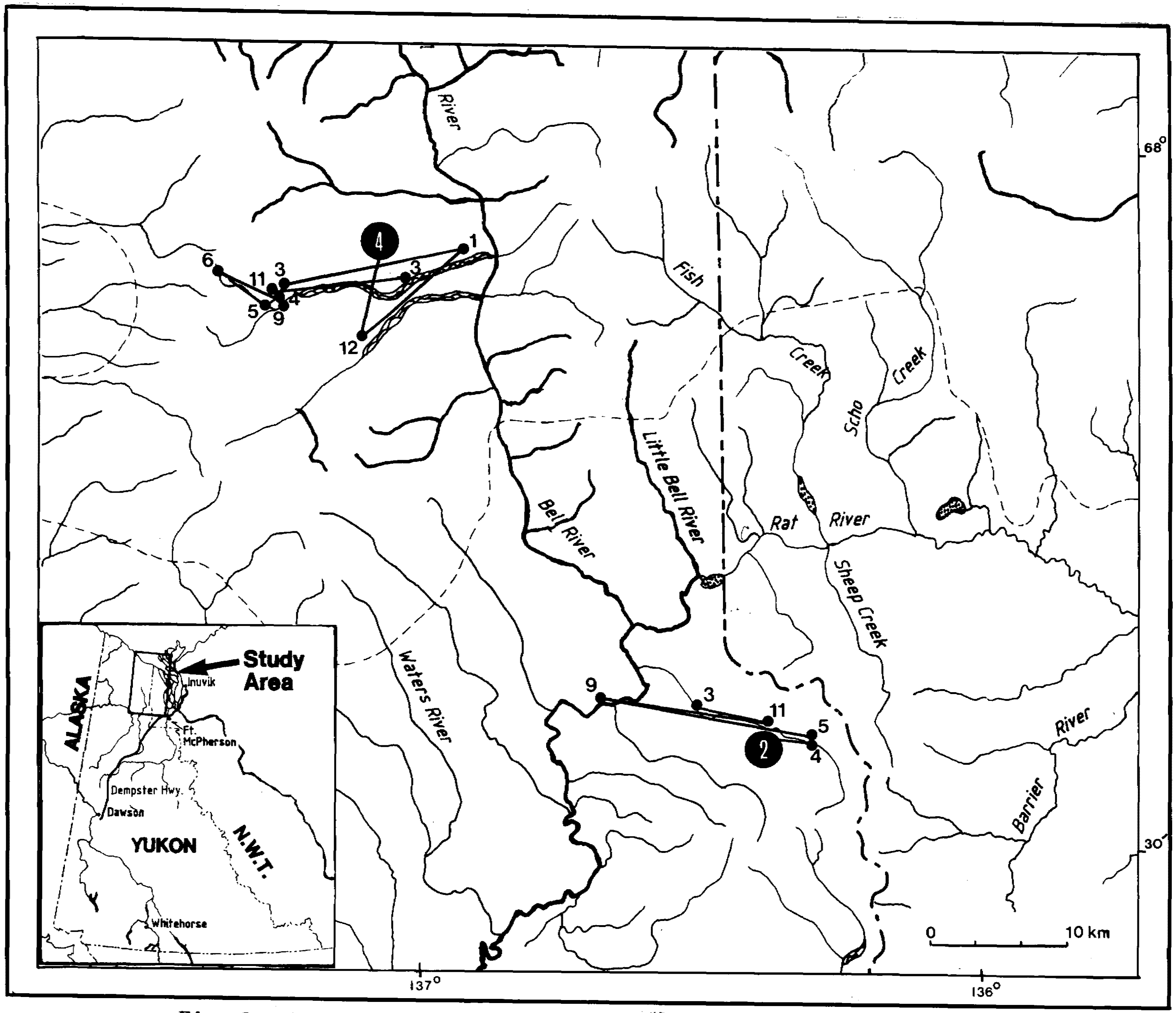

Fig. 2m. Locations (•) of radio-collared male moose as determined from monitoring flights; ● - capture location (number is moose ID #); 1, ..., 12 - Jan., ..., Dec. Both animals were radio-collared in October 1987.

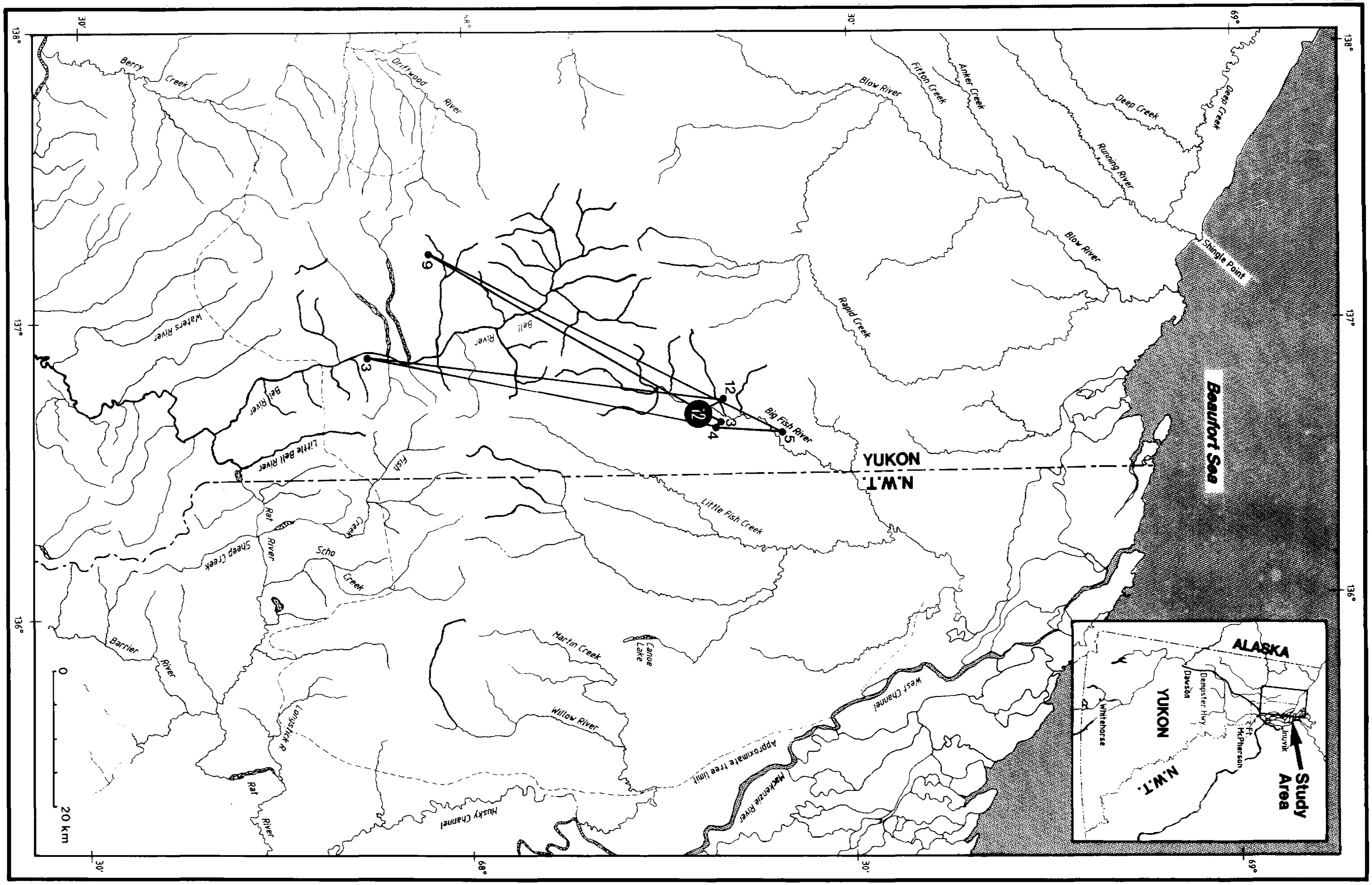

Fig. 2n. Locations (●) of radio-collared male moose as determined from monitoring flights; ⬤ - capture location (number is moose ID #); 1, ..., 12 - Jan., ..., Dec. The animal was radio-collared in October 1987.

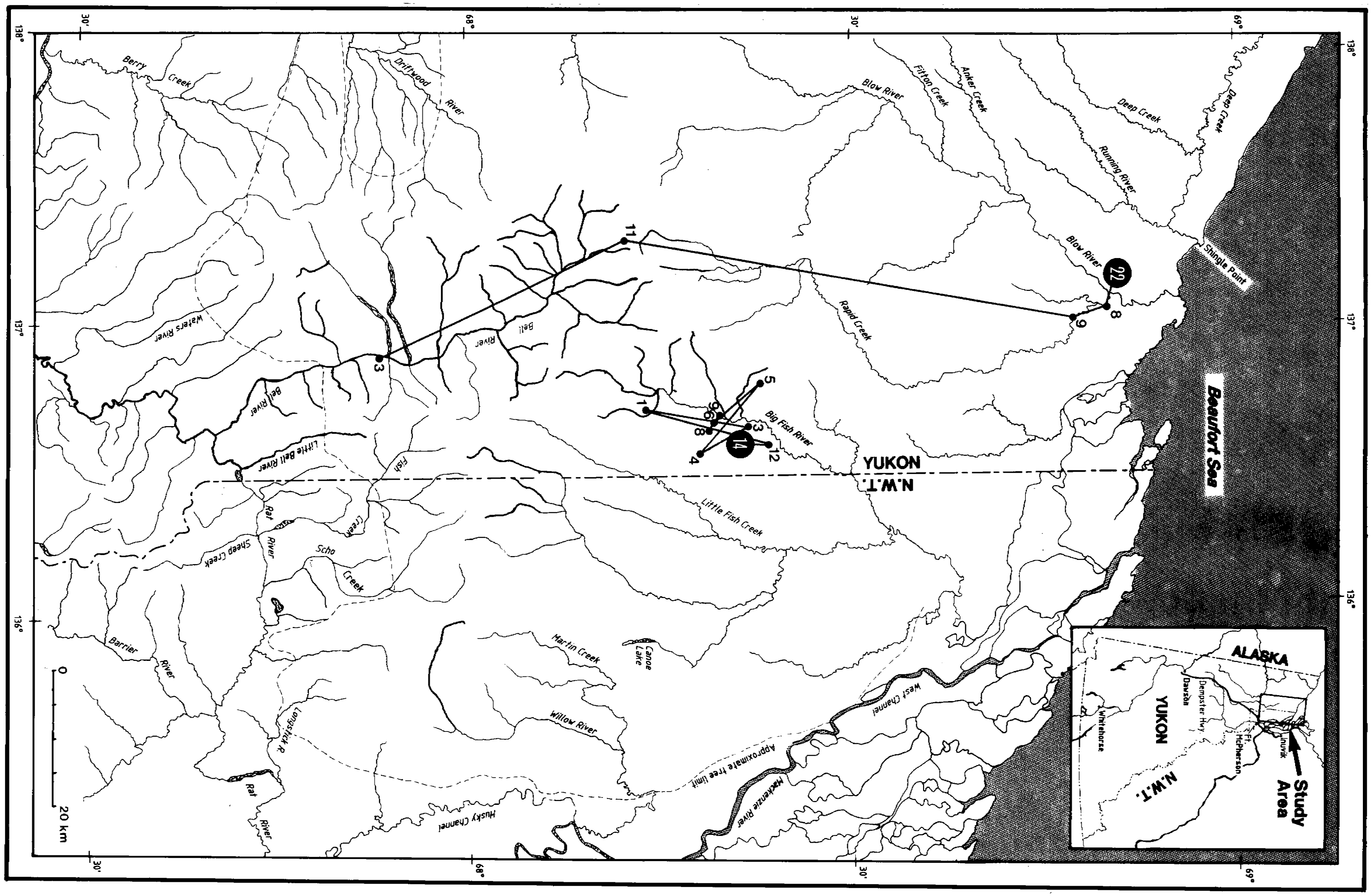

Fig. 2o. Locations (●) of radio-collared male moose as determined from monitoring flights; ⬤ - capture location (number is moose ID #); 1, ..., 12 - Jan., ..., Dec. Moose # 14 and # 22 were radio-collared in October 1987 and July 1988, respectively.

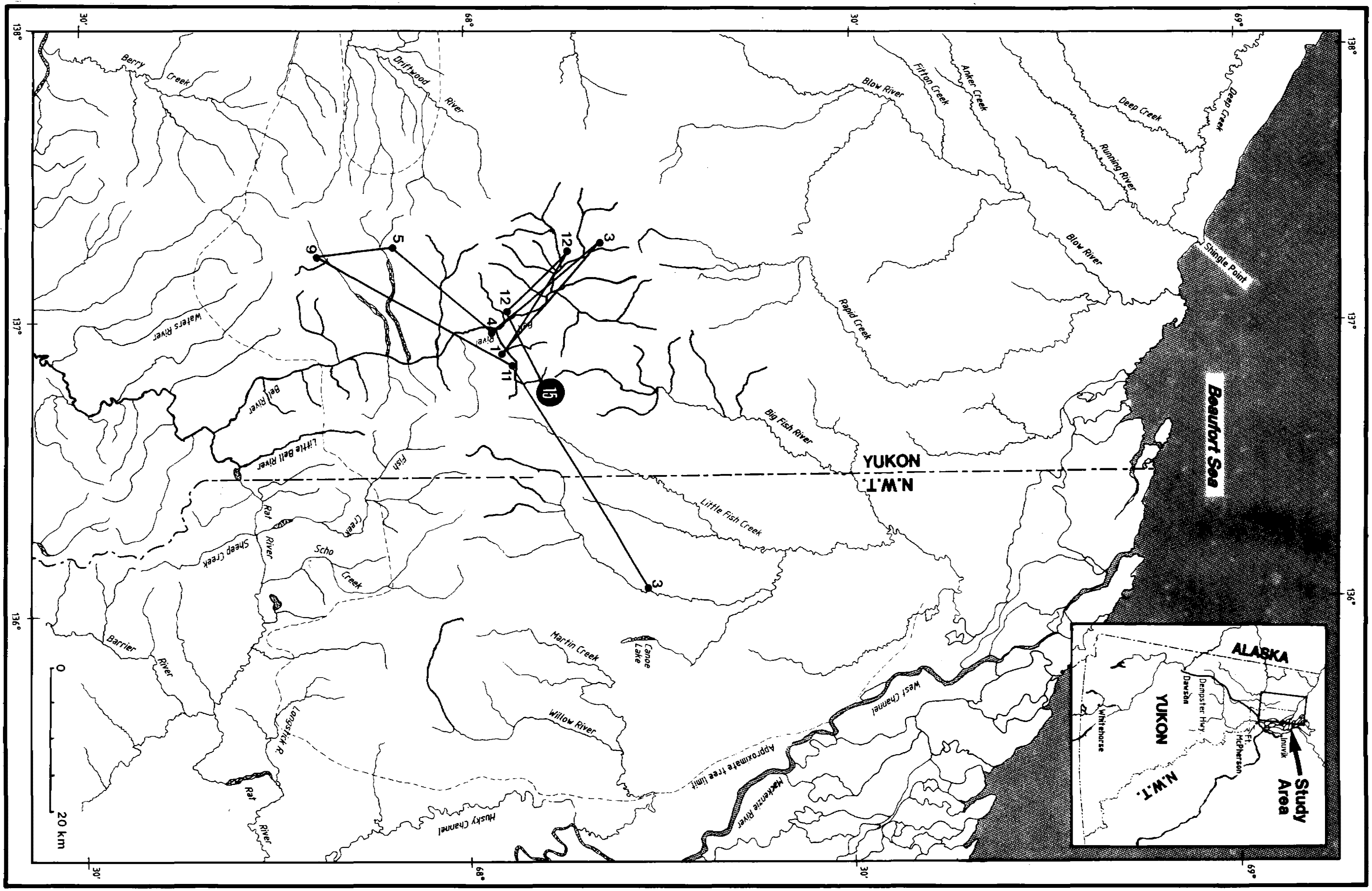

Fig. 2p. Locations (•) of radio-collared male moose as determined from monitoring flights; ● - capture location (number is moose ID #); 1, ..., 12 - Jan., ..., Dec. The animal was radio-collared in October 1987.

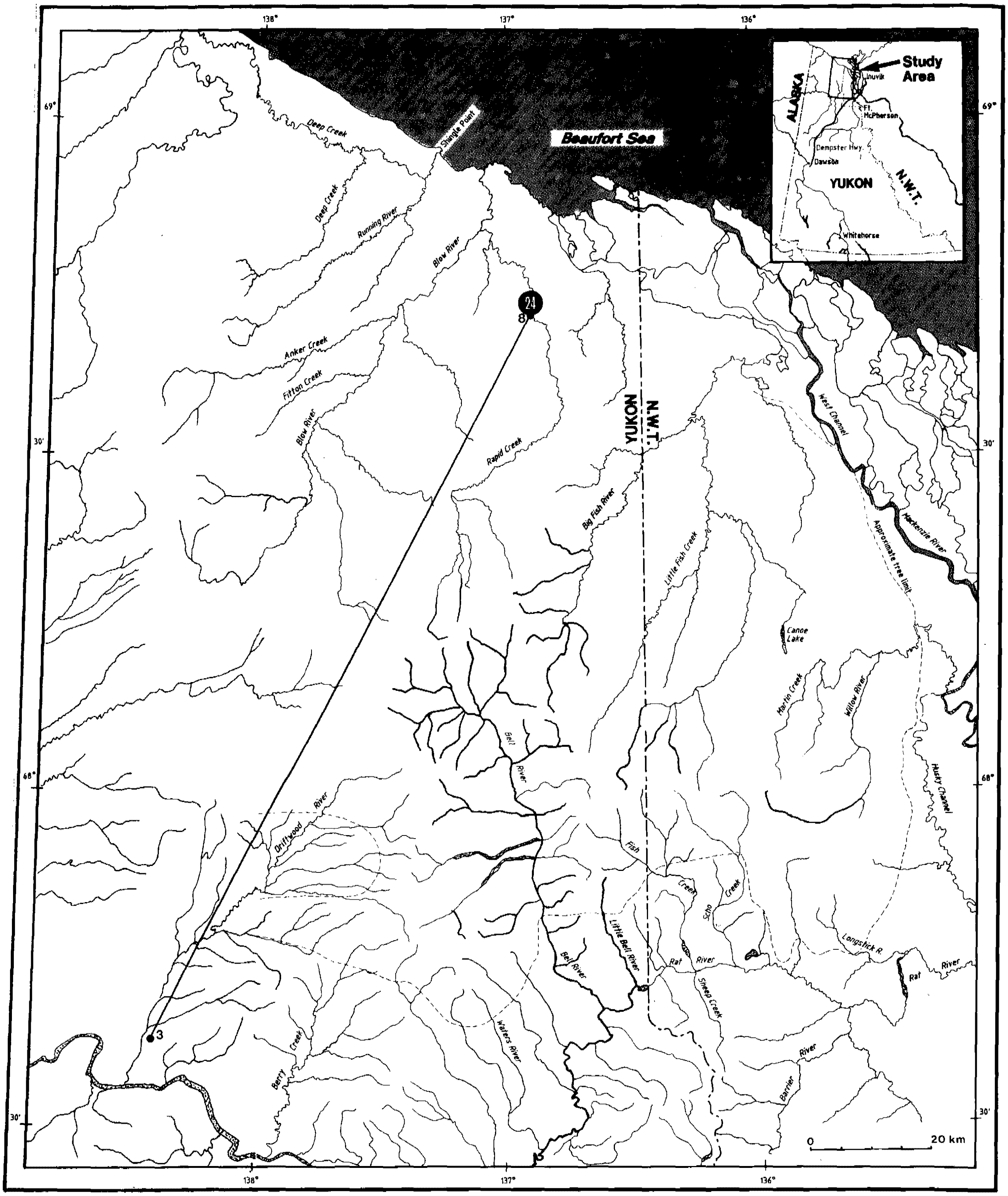

Fig. 2q. Locations (•) of a radio-collared male moose as determined from monitoring flights; ⬤- capture location (number is moose ID #); 1, ..., 12 - Jan., ..., Dec. The animal was radio-collared in July 1988.

Table 8. Radio frequency information and locations of moose captured in the northern part of the study area, July 1988.

Moose ID#	Sex	Number of Calves	Age	Radio Frequency (MHz)	Capture Location (UTM)	General Location
21	F	1	4	152.742	ML 5688	Tribuatary of Cache Ck
22	M	-	3	150.135	MM 1338	Blow River
23	F	-	?	150.290	MM 1944	Blow River
24	M	-	3(4)	152.472	MM 2324	Rapid Creek
26	F	2	5-6	150.450	ML 1335	Blow River
27	F	-	6	152.752	ML 1538	Blow River

Table 9. Body measurements* of moose captured in the northern Richardson Mountains during July, 1988.

Moose ID#	Sex	Age	Total Length	Tail Length	Body Circumference	Foreleg Length	Hindleg Length	Shoulder Height	Neck Girth		Antler Spread	Palm Width		Palm Length		Shaft Circumference	
									Min	Max		Lft.	Right	Lft.	Right	Left	Right
21	F	4	284	13	182	--	83	191	74	87	--	--	--	--	--	--	--
22	M	3	278	10	173	--	83	183	72	82	79	16	27	36	36	17	16
23	F	-	-	--	-	--	--	-	--	--	--	--	--	--	--	--	--
24	M	7	-	--	-	--	--	-	--	--	131	24	25	64	63	21	20
25	M	3(4)	246	7	-	62	79	-	--	--	69	7	8	26	28	15	14
26	F	5-6	289	9	-	--	--	-	76	92	--	--	--	--	--	--	--
27	F	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.

south and lower elevations as winter progressed. This trend appeared to be reversed during spring. The most striking display of seasonal movements was exhibited by moose captured on the North Slope. All of these moose with which radio contact was maintained had moved longer minimum distances (up to 100 km from their mid-summer range) by March 1989 than any other radio-collared moose during this period. Moose captured on the South Slope generally were associated with that region during successive flights. Of 17 animals radio-collared on the South Slope only two (# 15, 16) appear to have spent some time on the North Slope. Nine moose have been captured on the North Slope. All but one have been located since capture. Only one of these (13%) appears to have stayed year-round on the North Slope.

Habitat Use

Surveys

Moose locations were analyzed with respect to their association with vegetation types. A total of 118, 243 and 223 locations from the April, November 1988, and March 1989 surveys, respectively, were analyzed (Table 10). During all surveys moose were most often associated with shrub vegetation. This held particularly for November when moose were

Table 10. Distribution of association with vegetation types of moose observed during aerial surveys in the northern Richardson Mountains, expressed as proportions of combined sightings of adult moose.

Survey Period	Vegetation Type*					n
	Coniferous	Deciduous	Con/Dec	Shrub		
				<2m	>2m	
April, 1988	2.5	5.1	28.8	23.7	39.8	118
November, 1988	0.4	0.4	4.5	88.1	-	243
March, 1989	13.9	0.9	38.1	2.2	44.8	223

* Dominant vegetation type; coniferous - predominately white spruce, deciduous - mostly aspen, con/dec - predominately white spruce/aspen mixture, shrub - willow and/or alder.

association with shrub vegetation almost to the exclusion of any other vegetation type. During both late winter surveys shrub vegetation >2m was used more frequently than shrub vegetation <2m compared to the fall survey when no observations were made in the latter vegetation type. Moose were most often associated with tree vegetation during late winter than during fall surveys, and more so with mixed coniferous/deciduous vegetation than with vegetation dominated mainly by either deciduous or coniferous trees.

Aerial Monitoring

Moose locations were pooled by season (Table 11). During all four seasons moose were most often associated with shrub vegetation. The relative use of the two categories of shrub vegetation during spring 1988, fall 1988 and winter 1988-1989 was similar to that observed during the surveys in these periods. Use of shrub <2m increased during summer while use of shrub >2m decreased concurrently. Association with tree vegetation was similar to that observed during surveys in the same periods. During summer moose were more frequently associated with tree vegetation than during fall, but less so than during spring or winter.

Table 11. Seasonal distribution of association with vegetation types of moose in groups with radio-collared animals located in the northern Richardson Mountains, expressed as proportions of combined sightings of adult moose.

Season	Vegetation Type*					n
	Coniferous	Deciduous	Con/Dec	Shrub		
				<2m	>2m	
Spring 1988	4.6	0.0	22.7	36.4	36.4	22
Summer 1988	8.7	2.2	10.9	65.2	13.0	46
Fall 1988	0.0	0.0	5.6	88.9	5.6	36
Winter'88-'89	22.5	2.5	19.5	2.5	52.5	40

* Dominant vegetation type; coniferous - predominately white spruce, deciduous - mostly aspen, con/dec - predominately white spruce/aspen mixture, shrub - willow and/or alder.

DISCUSSION

Population Status

The presence of radio-collared moose on the study area during the April 1988 survey provided the first opportunity to assess visibility bias. Visibility appeared to be low (27%) during this survey and the results should be cautiously interpreted with respect to abundance. The November 1988 survey produced a higher visibility estimate (73%). However, precision was still unacceptably low until a helicopter survey was done in March 1989 and visibility was increased to 93%.

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 (Smits 1988), April 1988 and March 1989 at 16.0%, 15.7% and 16.2%, respectively. The adult mortality rate computed from all radio-collars is based on a sample smaller than 10% of the moose population. There are errors inherent in determining mortality rates from such a relatively small sample and the estimated 16.3 - 16.8% mortality rate computed 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; G. Glover, pers. commun.) and 2) one 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. Consequently, I consider it more likely that the moose population remained stable or increased slightly during the period of study.

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 recruitment rates observed in April 1988 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. The relatively low recruitment rate in April 1988 is therefore more likely a result of early calf mortality. Observation of cow-calf groups during October 1987 - March/April 1988 suggests that calf mortality may have been as high as 0.43 during this period. The recruitment rate was similarly low in March 1989. However, no calf mortality was apparent between November 1988 and March 1989 as indicated by calf/cow ratios observed during surveys. 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. Calf mortality is therefore likely to have taken place before november 1988. The limited amount of information from radio-collared cows suggests that most mortality took place before November. 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 are typical of moose populations subject to heavy predation (Hauge and Keith 1981; Gasaway et al. 1983; Messier and Crete 1985; Larsen et al. 1987).

Seasonal Distribution

The results suggest the existence of two main phenotypes of moose, 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.

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*note that those moose radio-collared on the North Slope in July 1988 have recently (July 1988) been located on the North Slope again.

In other studies a high degree of traditionality in seasonal home range use by individual moose has been observed (Van Ballenberghe 1977; Cederlund et al. 1987; Sweanor and Sandegren 1988, 1989). This type of behaviour, particularly in combination with low dispersal rates in moose (as suggested by Gasaway et al. 1980; Cederlund et al. 1987) would have serious management implications for moose on the North Slope. If moose numbers on the North Slope would ever be reduced to low levels, recovery would mainly have to take place through increase of moose resident on the North Slope with little ingress from South Slope moose. Our data however, are at this time too limited to support the notion of traditionality in seasonal home range use by moose summering on the North Slope.

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 appears to have excellent moose habitat but where no moose were observed during the July helicopter search (nor were any moose observed in this valley during fall and late winter surveys). A comparison of the ratio of radio-collared moose to observed moose (corrected for visibility bias) during the March 1989 survey (1:20) 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 summer of 1988.

Moose radio-collared in the western part of the study area generally moved into the Driftwood River valley during winter, e.g. out of the study area, 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

Shrub vegetation was the most frequently used vegetation type in all seasons. Whether this constituted selection by moose of this vegetation type is not known without knowledge of its relative availability. Indeed, whether selection, avoidance, or random occurrence was involved in any of the seasonal moose/vegetation associations is not known for that reason.

Upon the completion of a vegetation map and subsequent calculation of relative availability of the various vegetation types (Nassiopoulos and Smits, in prep.), an analysis of preference/avoidance by vegetation type will be done.

FURTHER ACTIVITIES PLANNED

For the fiscal year 1989/90 the following research activities are planned:

1) Aerial monitoring of radio-collared moose every two months. The purpose of this is to refine information on seasonal distribution and adult mortality rates, particularly of moose that spend their summers on the North Slope.

2) The preparation of a vegetation map from satellite imagery (Thematic Mapper) and the subsequent calculation of the surface area of specified vegetation types. The purpose of this is to enable delineation of moose habitat in order to refine information on moose density and to quantitatively describe habitat use by moose.

LITERATURE CITED

Ballard, W.B., T.H. Spraker, and K.P. Taylor. 1981. Causes of neonatal moose calf mortality in southcentral Alaska. J. Wildl. Manage. 45: 335-342.

Ballard, W.B., S.D. Miller, and J.S. Whitman. 1988. Brown and black bear predation on moose in southcentral Alaska. Proc. Int. Congr. Game Biol. 18, in press.

Blower, J.G., L.M. Cook, and J.A. Bishop. 1981. Estimating the size of animal populations. George Allen and Unwin Ltd. London, England.

Boertje, R.D., W.C. Gasaway, D.V. Grangaard, and D.G. Kelleyhouse. 1988. Predation on moose and caribou by radio-collared grizzly bears in east central Alaska. Can. J. Zool. 66: 2492-2499.

Cederlund, G., F. Sandegren, and K. Larsson. 1987. Summer movements of female moose and dispersal of their offspring. J. Wildl. Manage. 51(2):342-352.

Doll, D., W.P. McCrory, and J.D. Feist. 1974. Observations of moose, wolf and grizzly bear in the northern Yukon Territory. In: McCourt, K.H. and L.P. Horstman (eds.). Studies of large mammal populations in northern Alaska, Yukon and Northwest Territories, 1973. Arctic Gas Biol. Rep. Ser. Vol. 22. Calgary.

Dubois, S., W. Gasaway, and D. Roby. 1981. Aerial classification of bull moose based on antler development. Unpubl. Rep. Alaska Department of Fish and Game. Fairbanks.

Franzmann, A.W., A. Flynn, and P.D. Arneson. 1975. Levels of some mineral elements in Alaskan moose hair. J. Wildl. Manage. 39(2): 374 -378.

Gasaway, W., S.D. Dubois, and K.L. Brink. 1980. Dispersal of subadult moose from a low density population in interior Alaska. Proc. North Am. Moose Conf. and Workshop 16: 314-337.

Gasaway, W.C., R.O. Stephenson, J.L. Davis, P.E.K. Shepherd, and O.E. Burris. 1983. Interrelationships of wolves, prey, and man in interior Alaska. Wildlife Monograph 84.

Glover, G.J. and D.G. Larsen. 1988. Immobilization of moose using combinations of carfentanil, fentanyl and xylazine, southwest Yukon, 1983. Unpubl. Rep. Yukon Department of Renewable Resources, Whitehorse.

Hauge, T.M. and L.B. Keith. 1981. Dynamics of moose populations in northeastern Alberta. J.Wildl.Manage. 45(3): 573-597.

Jakimchuk, R.D., E.A. deBock, H.J. Russell, and G.P. Semenchuk. 1974. A study of the Porcupine caribou herd, 1971. In: Jakimchuk, R.D. (ed.) The Porcupine caribou herd - Canada. Arctic Gas Biol. Rep. Ser., Vol. 4. Calgary.

Larsen, D.G., D.A. Gauthier, and R. Markel. 1987. Causes and rate of moose mortality in the southwest Yukon. J. Wildl. Manage. 53(3): 548-557.

Martin, L.D. and G.W. Garner. 1985. Population size, composition, and distribution of moose along the Canning and Kongakut Rivers within the Arctic National Wildlife Refuge, Alaska, spring and fall, 1984. ANWR Progress Report Number FY 85-6. U.S. Fish and Wildlife Service. Fairbanks.

Messier, F. and M. Crete. 1985. Moose-wolf dynamics and the natural regulation of moose populations. Oecol. (Berl.) 65: 503-512.

Mitchell, H. 1970. Rapid aerial sexing of antlerless moose in British Columbia. J. Wildl. Manage. 34: 645-646.

Peterson, R.O. 1977. Wolf ecology and prey relationships on Isle Royale. U.S. National Park Service, Sci. Monogr. Ser. No. 11.

Ruttan, R.A. 1974. Observations of moose in the northern Yukon Territory and Mackenzie River Basin, 1972. In: Ruttan, R.A. and D.R. Wooley (eds.). Studies of furbearers associated with proposed pipeline routes in the Yukon and Northwest Territories. Arctic Gas Biol. Rep. Ser. Vol. 9. Calgary.

Sergeant, D.E. and D.H. Pimlott. 1959. Age determination in moose from sectioned incisor teeth. J. Wildl. Manage. 23: 315-321.

Smits, C.M.M. 1988. Abundance, sex/age composition and seasonal distribution of moose in the northern Richardson Mountains. Annual progress report. Unpubl. Rep. Yukon Department of Renewable Resources. Whitehorse.

Sweanor, P.Y., and F. Sandegren. 1988. Migratory behavior of related moose. Holarctic Ecol. 11: 190-193.

Sweanor, P.Y., and F. Sandegren. 1989. Winter-range philopatry of seasonally migratory moose. J. Appl. Ecol. 26: 25-33.

Van Ballenberghe, V. 1977. Migratory behavior of moose in southcentral Alaska. Proc.13th Congr.Game Biol.:103-109.

Walton-Rankin, L. 1977. An inventory of moose habitat of the Mackenzie Valley and northern Yukon, March 1977. Can. Wildl. Serv. Rep., Ottawa.

Watson, G.H., W.H. Prescott, E.A. deBock, J.W. Nolan, M.C. Dennington, H.J. Poston and I.G. Stirling. 1973. An inventory of wildlife habitat of the Mackenzie Valley and the northern Yukon. Can. Wildl. Serv. Rep., Ottawa.

Wiken, E.B., D.M. Welch, G.R. Ironside, and D.G. Taylor. 1981. The northern Yukon: an ecological land survey. Ecological Land Classification Series, No. 6. Lands Directorate, Environment Canada. Vancouver/Ottawa.

Wolfe, M.L. 1977. Mortality patterns in the Isle Royale moose population. Am. Midl. Nat. 97: 267-279.

Wooley, D.R. 1976. Terrestrial mammal studies along the cross delta pipeline route, 1975. In: Jakimchuk, R.D. (ed.). Studies of mammals along the proposed Mackenzie Valley gas pipeline route, 1975. Arctic Gas Biol. Rep. Ser. Vol. 36. Calgary.