CARIBOU DISTRIBUTION ON THE CALVING GROUNDS OF THE CENTRAL ARCTIC HERD, 1987

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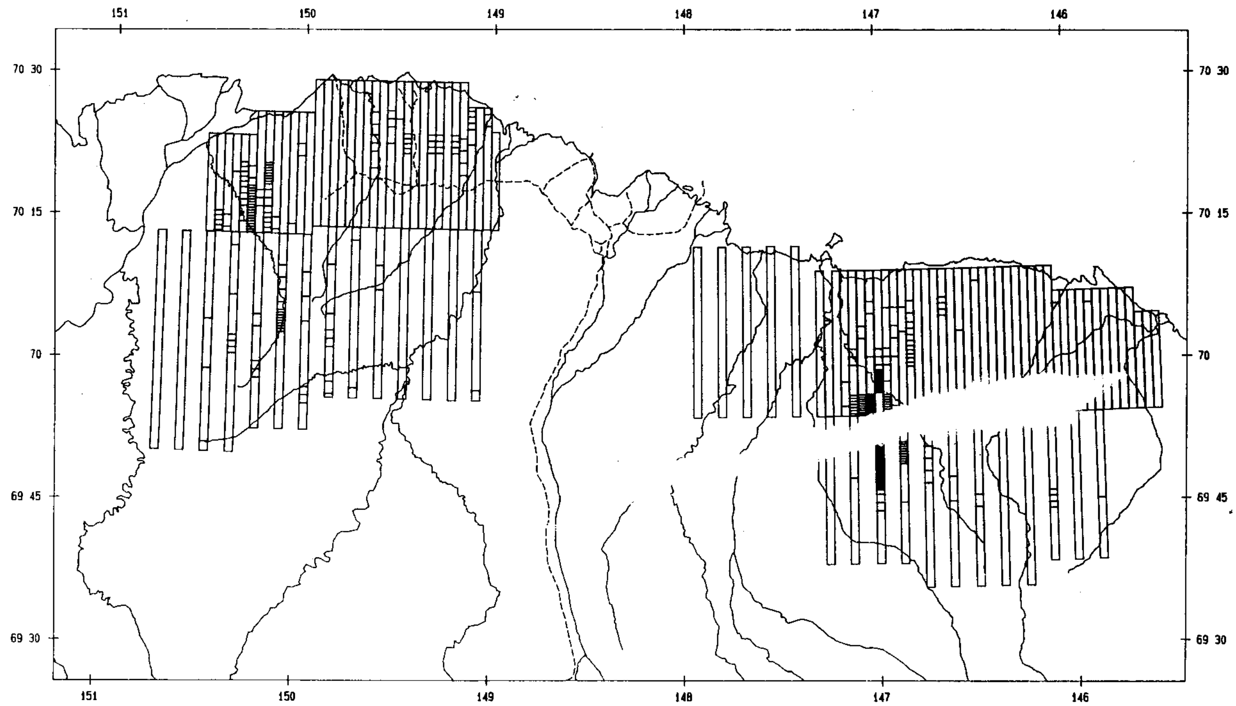

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Final Report

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and
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EXECUTIVE SUMMARY

1. In 1987, Alaska Biological Research, Inc. (ABR) and the Alaska Department of Fish and Game (ADF&G) cooperated in extensive aerial surveys of caribou on the calving grounds of the Central Arctic Herd of northern Alaska. The study goal was to compare distribution, relative abundance, and chronology of use among various portions of the calving grounds, with emphasis on the Kuparuk Oilfield and vicinity.

2. Caribou were counted and classified into sex and age categories on fixed-width, systematically spaced strip transects oriented in north-south directions between the Colville and Canning river deltas, within 64 km of the Beaufort Sea coast. Between 23 May and 17 June, a fixed-wing aircraft was used to survey 1.6-km-wide strip transects, spaced at intervals of 1.6 km to 4.8 km, in five survey areas. Between 11 and 15 June, a helicopter was used to survey 3.2-km-wide strip transects, spaced at intervals of 3.2 km and 9.7 km, across the calving grounds. Between 5 and 14 June, 38 radio-collared cows were tracked and located on the calving grounds. Snow-cover percentages were estimated from aerial photographs taken in various portions of the study area during the calving period.

3. Variability in the patchiness of snow cover, and generally delayed snowmelt in 1987, caused differences in sightability (probability of detection) of caribou among surveys; hence, results were not directly comparable among all surveys. However, relative differences in distribution and abundance within surveys provided a basis for comparisons. From the presumed peak of calving through the end of the calving period, the highest densities of caribou, including calves, were southwest of the two concentration areas delineated in previous years between Oliktok Point and the Kuparuk River (west of the Sagavanirktok River) and between Bullen Point and the Canning River (east of the Sagavanirktok River). Those two areas were still used, but to a much lesser degree than observed previously. Numbers of adult caribou using those areas remained relatively stable during the calving period.

4. The number of caribou counted in the western concentration area, encompassing the Kuparuk Oilfield and vicinity, was among the lowest on record, particularly in terms of proportional use (given herd expansion over the last decade). The numbers of adult caribou counted in the overall area near the coast between the Colville and Kuparuk rivers remained stable or increased slightly during the calving period. Within that area, however, the numbers observed on transects between Kalubik Creek and the Milne Point Road (including all Kuparuk Oilfield facilities) decreased, indicating redistribution of caribou during the period. In late May, before peak calving, use of dust shadows along roads in the oilfield was extensive, but caribou moved away from roads by peak calving and thereafter; this movement was attributed primarily to increased forage availability as snow melted and to the sensitivity to disturbance of cows with young calves.

5. The sex and age composition of all caribou classified on helicopter and fixed-wing surveys during 11-17 June (totaling 4937 and 2950 animals, respectively) was 49-51% cows, 38% calves, 10-11% yearlings, and 2% bulls. The observed calf:cow ratio was 75-78 calves:100 cows, and the yearling:cow ratio was 19-21 yearlings:100 cows.

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ACKNOWLEDGMENTS

The portion of this project conducted by Alaska Biological Research, Inc. was funded by the Kuparuk River Unit owners and administered by ARCO Alaska, Inc.; we thank M.R. Joyce, Senior Environmental Coordinator for ARCO Alaska, for his contributions throughout the project. Work conducted by the Alaska Department of Fish and Game was funded by Federal Aid in Wildlife Restoration Projects W-22-6 and W-22-7. We thank the following personnel, who provided valuable assistance during data collection, analysis, and(or) report preparation: at ABR, N. Brown, C.L. Cranor, S. Kennedy, K. Knutzen, S.M. Murphy, R.J. Ritchie, and L.N. Smith; and at ADF&G, C.S. Gewin, D.J. Reed, R.T. Shideler, W.T. Smith, and J. Venable. S.M. Murphy, R.J. Ritchie, and M.R. Joyce offered useful suggestions for improving draft versions of this report.

INTRODUCTION

The potential impacts of petroleum development on populations of barren-ground caribou (Rangifer tarandus granti) have become a prominent issue in Alaska and Canada. For the Central Arctic Herd (CAH) of northern Alaska, which is perhaps the best-known example of a caribou herd in contact with petroleum development (Shideler 1986), the presence of the Prudhoe Bay and Kuparuk oilfields within the calving grounds is a principal concern of the Alaska Department of Fish and Game (ADF&G), the agency vested with management responsibility (Cameron 1983).

Biologists have long recognized the heightened sensitivity to disturbance of caribou cows with young calves (de Vos 1966; Lent 1966; Kelsall 1968; Bergerud 1974). Many biologists and management agencies are concerned that development on calving grounds could result in displacement of caribou from important habitats, possibly resulting in population declines (e.g., Elison et al. 1986). However, efforts to identify common characteristics among all calving grounds have proved fruitless (Fleck and Gunn 1982, Shideler 1986), and as yet no consensus has been reached regarding these potential impacts.

Since 1978, caribou surveys on the CAH calving grounds have been conducted annually by ADF&G (Whitten and Cameron 1985; Cameron et al. 1985, in press). Industry-sponsored surveys have also been conducted at various levels of coverage: in 1980-1982 by ARCO Alaska biologists (Keene and Gavin 1984), in 1981-1983 by Renewable Resources Consulting Services (RRCS) (Carruthers et al. 1984, Jakimchuk et al. 1987), and in 1983 and 1984 by Alaska Biological Research (ABR) (Lawhead and Curatolo 1984, Curatolo and Reges 1984). The results of those studies demonstrate that parturient cows are distributed widely over the coastal plain and that the distribution of caribou on the calving grounds varies substantially among years, apparently in response to variations in the accumulation and ablation of snow cover and the extent of seasonal flooding (Whitten and Cameron 1985, Jakimchuk et al. 1987). Nevertheless, two consistently used areas of relatively high density have been identified within 24 km of the coast: one between Oliktok Point and the Kuparuk River (west of Prudhoe Bay), encompassing the Kuparuk and Milne Point oilfields, and the other between Bullen Point and the Canning

River delta (east of Prudhoe Bay) (Curatolo and Reges 1984, Lawhead and Curatolo 1984, Whitten and Cameron 1985).

In the dozen or so years since the CAH was recognized as a distinct herd, it has experienced steady growth at a high rate (Whitten and Cameron 1983a), and was estimated grossly by both ADF&G and RRCS (unpubl. data) to number approximately 16,000 animals in summer 1986. During this period of growth, avoidance of the Prudhoe Bay Oilfield by cows with calves has been noted (Whitten and Cameron 1985), although there are no data to suggest that the Prudhoe Bay area was ever high-density calving habitat (Shideler 1986). In addition, localized displacement of cows with neonatal calves has been demonstrated along the Milne Point Road (Dau and Cameron 1986a, 1986b). The general Oliktok/Kuparuk concentration area (which encompasses the Milne Point Road) has continued to be used despite this displacement, however, and to date no related effects on herd productivity have been detected (Whitten and Cameron 1985, Dau and Cameron 1986a).

The issues regarding development on calving grounds are far from resolved, however. Continued monitoring is necessary to document the occurrence and clarify the probable causes of annual and longer-term variations in distribution and abundance, especially as they relate to petroleum development. To better understand the nature of caribou use of the Kuparuk Oilfield, ARCO Alaska contracted ABR to conduct surveys during the 1987 calving period. ABR and ARCO Alaska identified two specific objectives for study:

1) determine the numbers, density, and sex/age composition of caribou using the two previously described concentration areas, with emphasis on the Kuparuk Oilfield, and the uplands immediately south of both concentration areas; and

2) document chronological shifts in caribou distribution and abundance as the calving season progressed, especially in relation to snow and meltwater cover and oilfield facilities.

ADF&G already had planned to track radio-collared cows and to repeat its annual survey of the CAH calving grounds in 1987. ADF&G's study objectives focused on documenting the distribution and relative abundance of caribou on the calving grounds, with emphasis on the Kuparuk Oilfield area; collecting sex/age-composition data, especially for initial production of calves; and obtaining relocations of radio-collared cows to determine actual calving locations for that sample of marked animals.

To increase efficiency, all parties involved agreed to undertake a cooperative project by sharing information (especially during data collection) and jointly producing this report.

STUDY AREA

The general study area extended from the Colville and Itkillik rivers on the west to the Canning and Tamayariak rivers on the east, and from the Beaufort Sea coast inland to approximately 69°30' N latitude (Figure 1). The Trans-Alaska Pipeline System and Dalton Highway bisect the area, running south from the Prudhoe Bay Oilfield. The Kuparuk Oilfield (Figure 2) is west of the Prudhoe Bay Oilfield; the two are connected by the Spine Road.

Most of the study area falls within the Arctic Coastal Plain physiographic province (Wahrhaftig 1965), a smooth, poorly drained plain containing numerous thaw lakes. Several groups of low hills, northern extensions of the Arctic Foothills province, constitute the only upland areas of appreciable elevation (up to about 500 m). Uplands of interest in this study are a plateau southwest of the Kuparuk Oilfield, drained by the Kachemach, Miluveach, Ugnuravik, and Sakonowyak rivers (Figure 2), and a group of low hills between the Kavik and Canning rivers at about 69°45' N latitude. Other uplands include the Franklin Bluffs plateau, abutting the Sagavanirktok River about 50 km south of Prudhoe Bay, and the White Hills, between the Toolik and Kuparuk rivers. The geology, permafrost, climate, landforms, soils, and vegetation of the central Arctic Coastal Plain are described in detail by Walker et al. (1980).

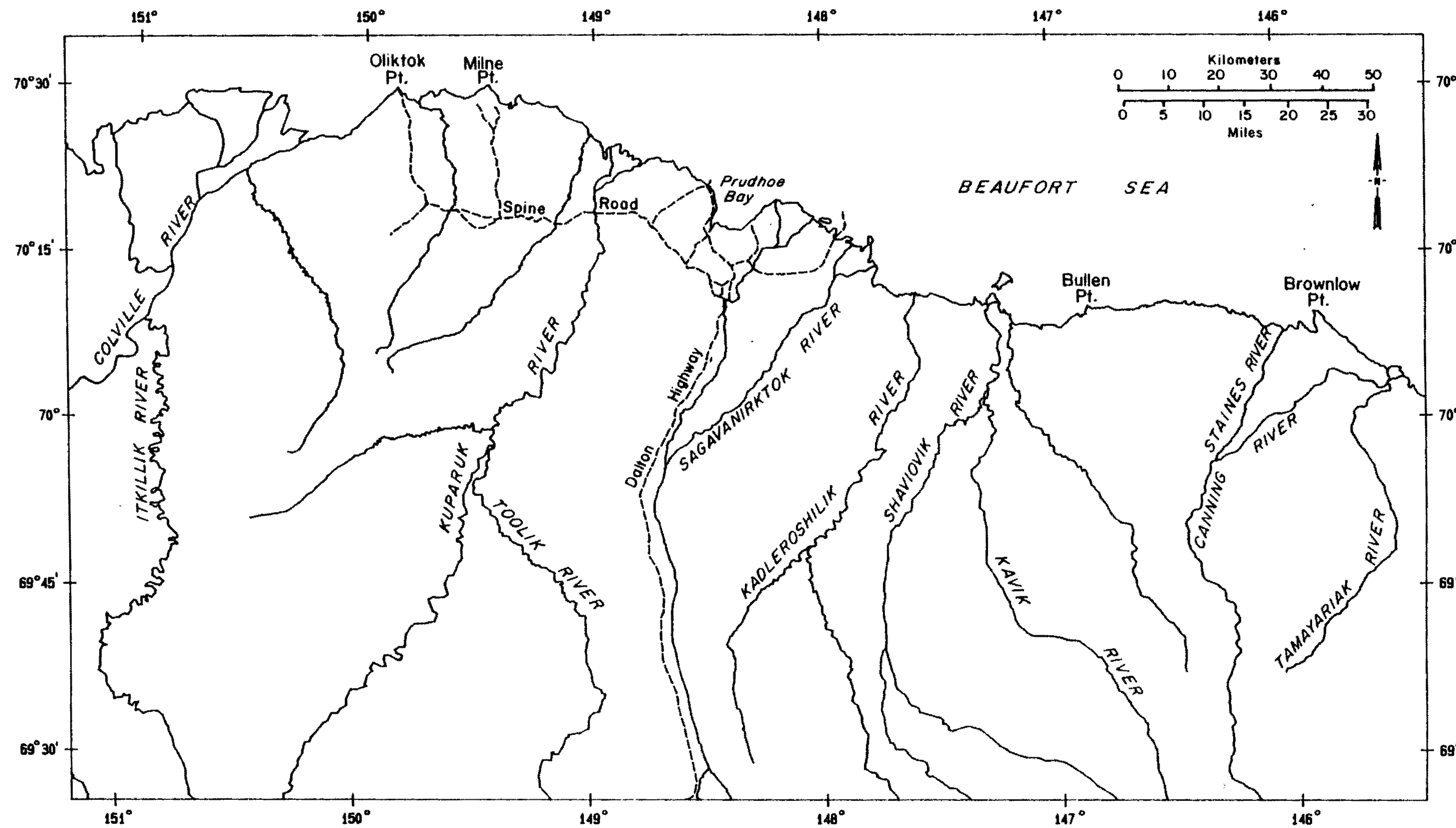

Figure 1. General study area for caribou surveys on the Central Arctic Herd calving grounds, Alaska, 23 May-17 June 1987.

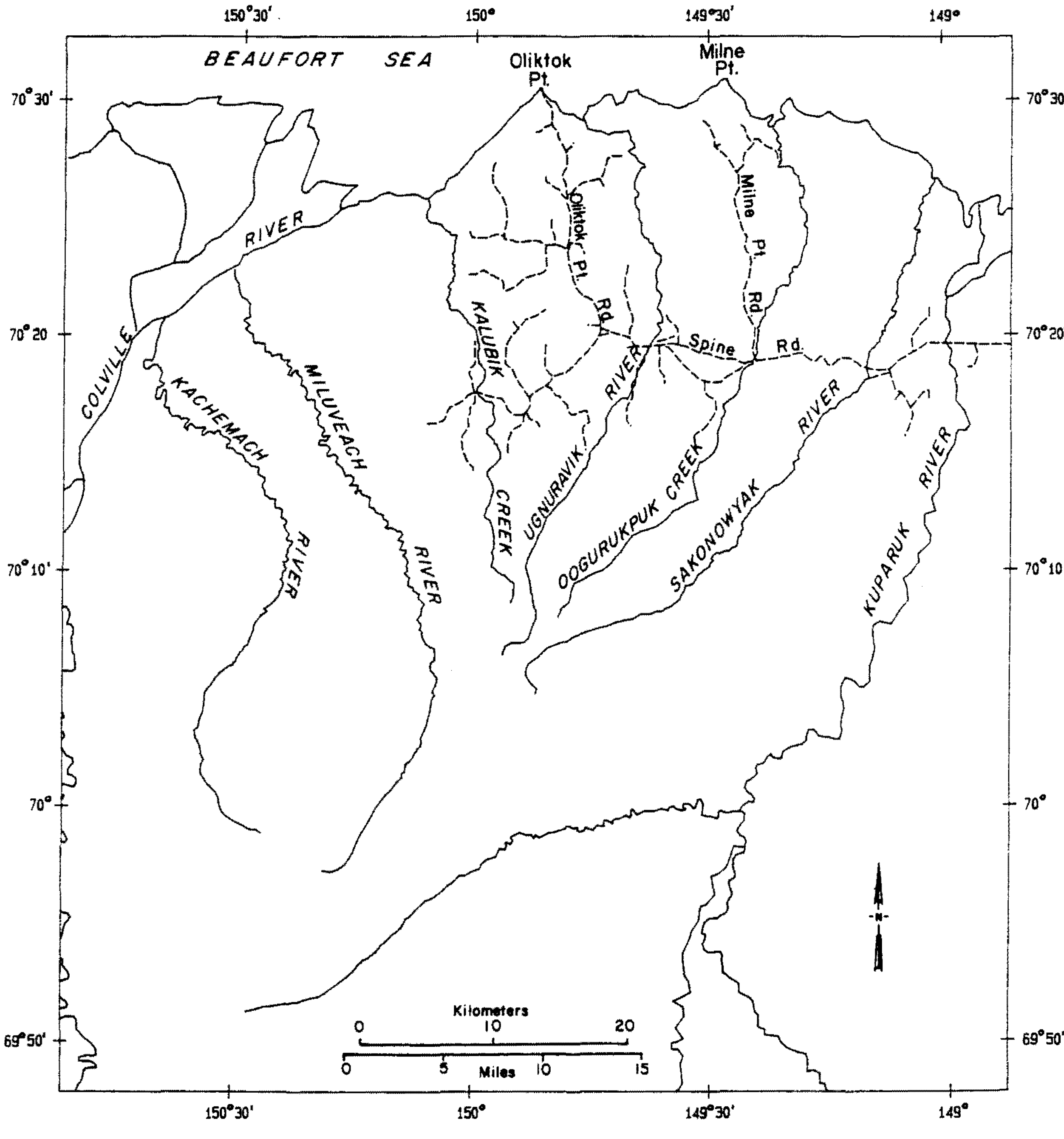

Figure 2. Western portion of study area for caribou surveys on the Central Arctic Herd calving grounds, 23 May-17 June 1987.

METHODS

The primary sampling method employed was aerial survey of systematically spaced, fixed-width strip transects (Caughley 1977, Norton-Griffiths 1978). All surveys were conducted between 21 May and 17 June 1987 (Table 1), encompassing the entire calving period. CAH calves have been seen as early as 21 May (Keene and Gavin 1984) and virtually all are born by mid-June, with peak calving normally occurring during the first week of June (Cameron et al. 1983, Lawhead and Curatolo 1984, Curatolo and Reges 1984).

Fixed-Wing Surveys

A Piper PA-18 "Super Cub," with pilot and one observer, was used to survey 1.6-km(1-mi)-wide, north-south-oriented strip transects in five areas of the CAH calving grounds (Figure 3). In Areas A and C, which encompassed the two concentration areas described previously, transect centerlines were spaced at 1.6-km intervals to give 100% sample coverage; that is, total counts were planned (Table 2). In the remaining three areas (B, D, and E), in which lower caribou densities were expected, transects were spaced at 4.8-km intervals to give 33% sample coverage (Table 2). Township and section lines printed on 1:63,360-scale U.S. Geological Survey (USGS) topographic maps were selected as transect centerlines.

Surveys were flown at either 90 m or 150 m altitude above ground level (agl) and either 115 km/h or 145 km/h airspeed (Table 2). The higher altitude and airspeed primarily were used early in the period when snow cover was relatively uniform and few calves had been born. As snow cover became patchy and caribou (especially calves) became more difficult to see, altitude and airspeed were lowered to increase the proportion of animals detected.

Transect strip-width was controlled visually using markers taped on the aircraft lift struts (Pennycuick and Western 1972); one set of markers was used for each of the two altitudes. Because of the numerous lakes in the region and the high quality of the USGS maps, strip width often could be confirmed directly, when necessary.

All caribou seen within the strip were counted and classified into sex and age categories using a hand-held counter and low-power binoculars, when

Table 1. Timing of transect surveys and radio-tracking flights on the Central Arctic Herd calving grounds, 23 May-17 June 1987.

Date	Fixed-wing Survey Areas[a]					Area-wide Helicopter Surveys[b]	Radio-tracking Flights
	A	B	C	D	E		
May 23	X	-	-	-	-	-	-
29	X	-	-	-	-	-	-
June 4	-	X	X	-	-	-	-
5	-	-	X	-	-	-	X
6	X	-	-	X	-	-	X
7	X	-	-	-	-	-	X
10	-	-	-	-	X	-	-
11	-	-	X	-	-	X	-
12	-	-	X	-	X	X	-
13	-	-	-	X	-	X	X
14	-	X	-	-	-	X	X
15	X	-	-	-	-	X	-
17	X	-	-	-	-	-	-

[a] See Figure 3 for area and transect locations; dash indicates no survey.
[b] See Figure 5 for transect locations and Table 6 for specific date(s) per transect.

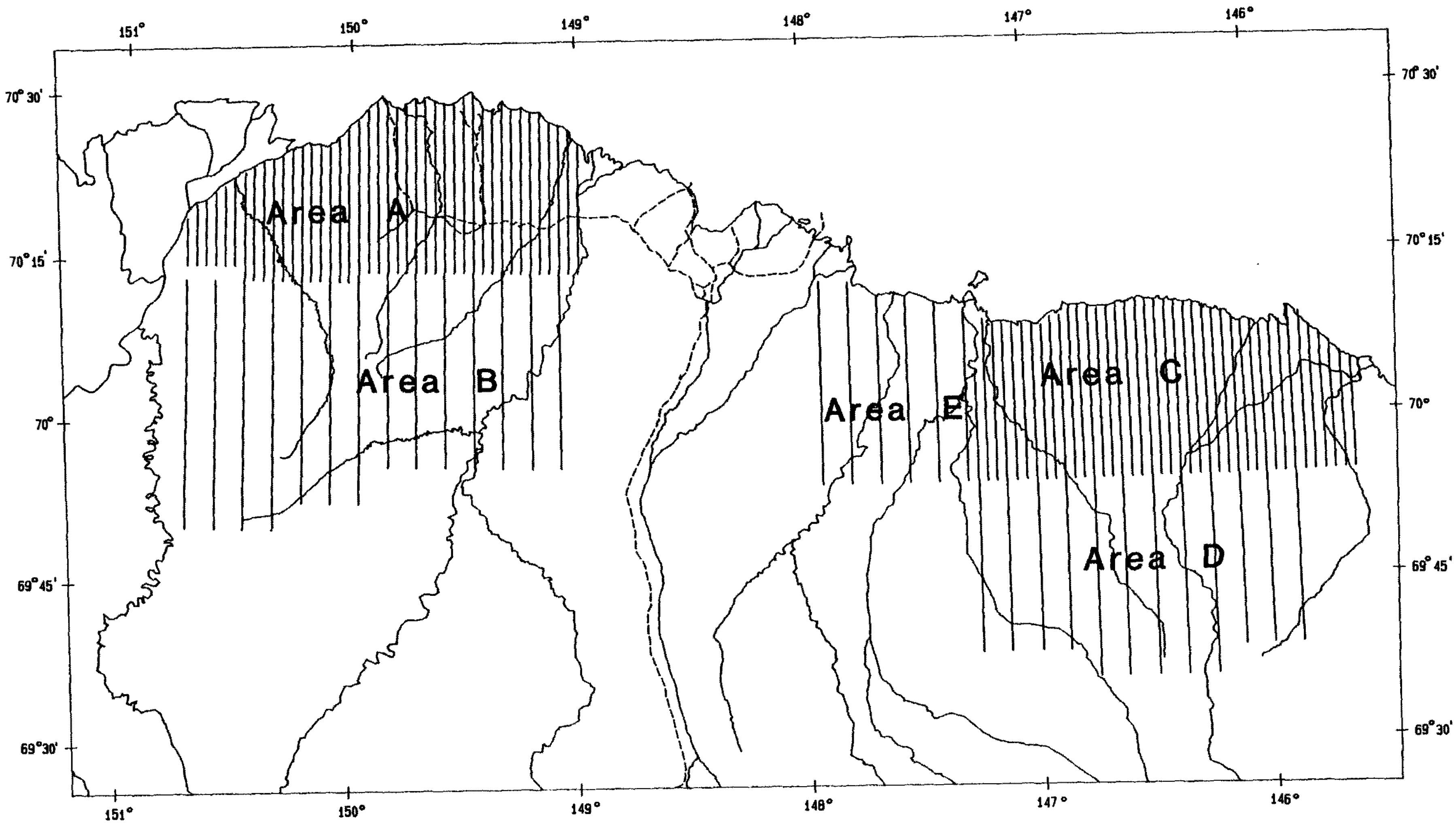

Figure 3. Specific study areas and strip-transect centerlines (1.6-km and 4.8-km spacing) for caribou surveys by fixed-wing aircraft on the Central Arctic Herd calving grounds, 23 May-17 June 1987.

Table 2. Details of surveys conducted by fixed-wing aircraft on the Central Arctic Herd calving grounds, 23 May-17 June 1987.

Survey Area[a]	Area (km^2)	Total No. of Transects	Survey Date	Sampling Intensity[b] (%)	Proportion of Area Surveyed (%)	Altitude (m agl)	Airspeed (km/h)
A	1590	42	23 May	100	45	150	145
			29 May	100	100	90	145
			6-7 June	100	86	90	115
			15/17 June	100	86	90	115
B	2320	14	4 June	33	67	90	145
			14 June	33	100	90	115
C	1760	40	5 June	50	88	150	145
			11-12 June	100/50	100	90	115
D	1660	12	6 June	33	100	150	145
			13 June	33	100	90	115
E	790	6	10 June	33	33	90	115
			12 June	33	100	90	115

[a] See Figure 3 for area and transect locations.
[b] 100% = 1.6-km transect spacing, 50% = 3.2-km spacing, 33% = 4.8-km spacing.

necessary. The observer searched on both sides of the transect centerline while the pilot navigated and searched the centerline ahead of the airplane. To maximize survey efficiency, the observer did not record the exact location of each group encountered, but rather totaled caribou for an entire transect or segments thereof. For the first two surveys in Area A (23 and 29 May), counts were tallied by transect only. On the remaining surveys, all transect lines were subdivided into 4.8-km segments (except near the coast, because transects were not evenly divisible into these segments) and caribou numbers were tallied for each segment. However, because of the summation by transect on the first two surveys, the numbers of the transects in Area A are included for later reference (Figure 4).

Survey data were compiled and summarized using Ashton-Tate "dBase III" software. The geographic coordinates of the midpoint of each transect segment were determined using a digitizing system (an Altek digitizing table coupled to an IBM XT micro-computer), and were added to the computer file containing the classified counts for each segment on each survey day, allowing selected survey data to be plotted on digitized maps of the study area (using a Hewlett-Packard HP-7475A plotter coupled to a PC's Limited [IBM AT clone] micro-computer). The density-plotting computer program depicted only densities of 0.4 caribou/km^2 or greater for each 7.8-km^2 segment block; that is, one line on a plot represents three animals. Thus, a number of low-density transect segments are represented as having no caribou. The maximal density depicted by the program is 7.7 caribou/km^2, or 60 animals per segment block (even though more may have been seen).

Helicopter Surveys

On 11-15 June 1987, low-level surveys were conducted in a Bell 206-B "Jet Ranger" helicopter between the Colville and Canning rivers; altitude was 30-50 m agl and airspeed was 110-130 km/h. The survey team consisted of three observers and the pilot. Caribou were counted and classified into sex and age categories within 28 north-south-oriented strip transects (Figure 5), each 3.2 km wide. Procedures have been described in more detail by Whitten and Cameron (1985) and Cameron et al. (1985).

Between the Colville and Kuparuk river deltas, 17 transects were surveyed: 7 between the coast and 70°00' N latitude at 9.7-km intervals,

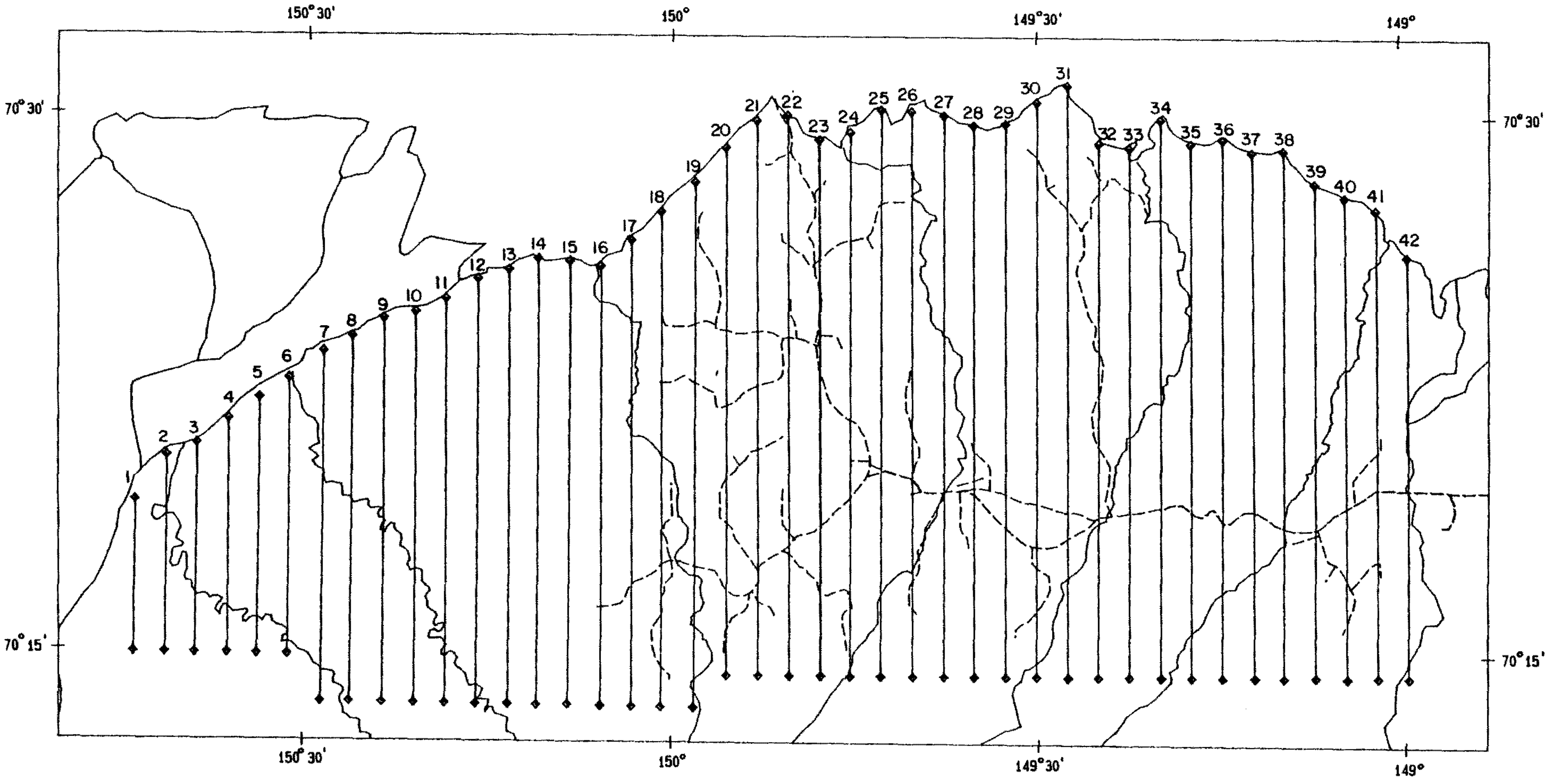

Figure 4. Strip-transect centerlines (1.6-km spacing) for caribou surveys by fixed-wing aircraft in Area A, Central Arctic Herd calving grounds, 23 May-17 June 1987.

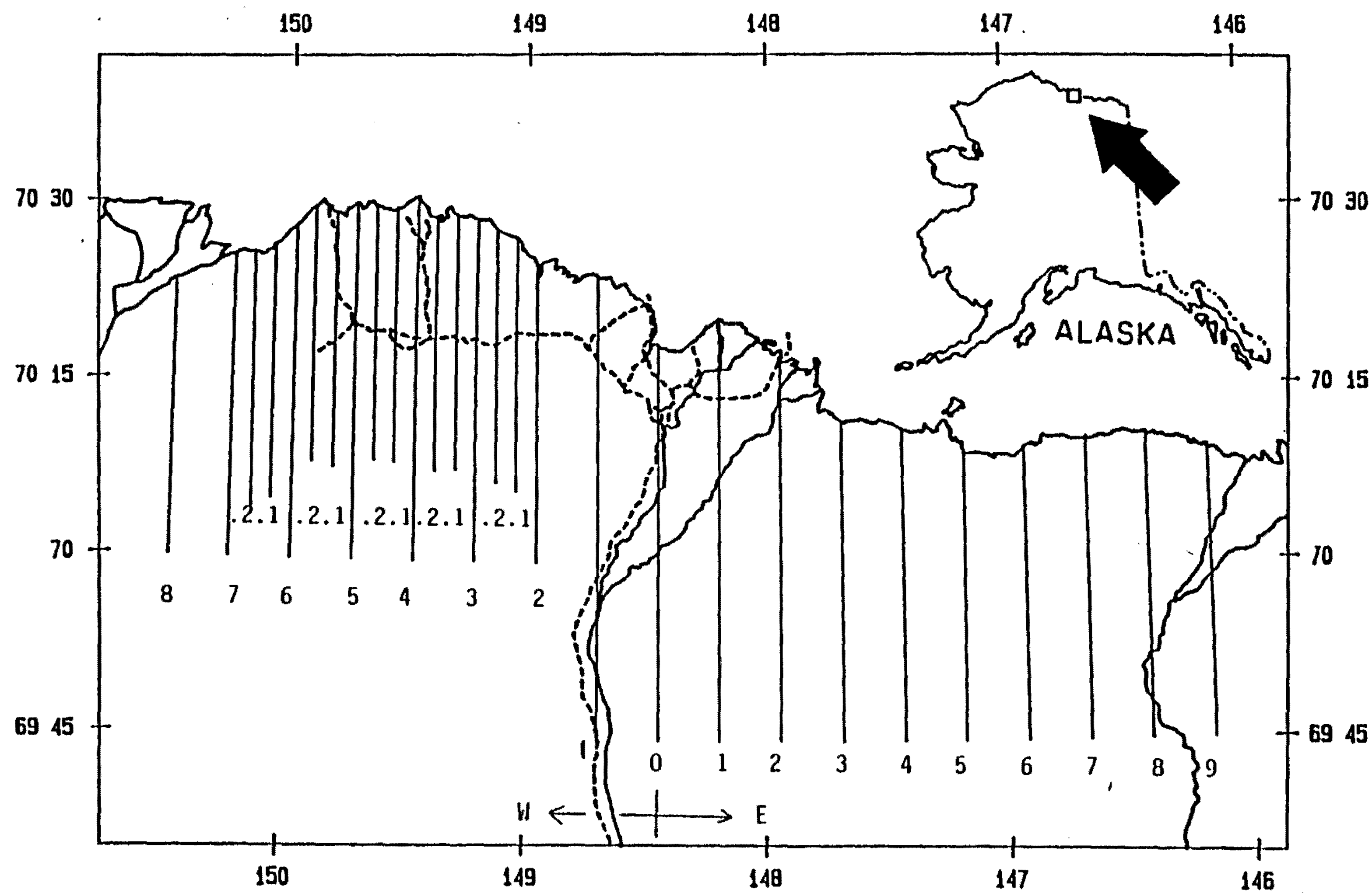

Figure 5. Strip-transect centerlines (3.2-km and 9.7-km spacing) for caribou surveys by helicopter on the Central Arctic Herd calving grounds, 11-15 June 1987.

and 10 extending inland 40 km from the coast and positioned among the former such that coverage was continuous over the area encompassing oilfield development in the Kuparuk region. The 11 remaining transects, located between the Kuparuk and Canning river deltas, were spaced at 9.7-km intervals between the coast and 69°45' N latitude.

Caribou group locations were noted on 1:63,360-scale USGS topographic maps and(or) recorded directly as latitude/longitude coordinates using an LRN-70 navigation system in the survey helicopter. Geographic coordinates were generated later or verified using the digitizing system described above. These location coordinates and the sex/age-composition data for each group were entered in a computer file. Point locations were retrieved on the basis of selected variables and were plotted schematically as relative caribou density. Transects were divided into 10.4-km^2 blocks, rather than the 7.8-km^2 blocks used for the fixed-wing surveys. The minimal density depicted is 0.4 caribou/km^2, but the larger block size results in one line representing four caribou per block, not three. The maximal density (7.7 caribou/km^2) depicted for the helicopter surveys is thus 80 caribou per block.

Radio Telemetry

On 5-7 and 13-14 June 1987, radio-collared female caribou of the CAH were tracked and relocated between the Colville and Canning rivers by fixed-wing aircraft; the procedures used have been described by Whitten and Cameron (1983b) and Cameron et al. (1986). The location of each cow was noted on a 1:250,000-scale USGS topographic map, and the presence or absence of a calf was recorded. Point locations were subsequently digitized, entered in a computer file (as above), and displayed on a regional base map.

Snow Cover

Snow conditions were assessed to provide background information for comparison with caribou distribution and to evaluate survey effectiveness. Oblique photographs (color slides) of snow cover were taken with a 35-mm camera at, or as near as possible to, pre-selected points in a coarse grid pattern (about 10-km spacing) in each fixed-wing survey area. An effort was made to depict the most representative conditions; large lakes were avoided in photographs, as were other features that were judged to be atypical of the locality (e.g., persistent, heavily drifted snowbanks or snow-free stream banks). This approach was admittedly subjective, but was effective for documenting the survey conditions while not interfering with caribou counts on transects or adding substantially to the amount of flight time required. Emphasis was placed on the period when snow cover was in the intermediate stages of melt-off, when it is more difficult for a field observer to estimate percent cover. Date, frame number, and location were recorded for each photograph. Four biologists (including the survey observer), with experience in estimating cover values, viewed the projected slides and independently estimated the percentages of snow and meltwater cover to the nearest 10% (or 5% for 0-10% and 90-100%). The four estimates were then averaged and rounded to the nearest integer to obtain a single cover estimate for each location sampled. Although less precise and repeatable than a sampling method using point, grid, or line-intercept sampling, this approach was less time-consuming and still provided useful estimates. These estimates were assigned the geographic coordinates of the nearest transect-segment midpoint for plotting on digitized maps.

Sex and Age Composition

During the helicopter surveys, all animals seen were classified into sex and age categories on the basis of body size, genitalia, and(or) antler development (Whitten and Cameron 1985). During the fixed-wing surveys, caribou were classified as often as possible using body size, calf presence, and(or) antler development as criteria, but some "large" caribou (adult or yearling, as opposed to "small" calves) could not be classified confidently, especially when relatively far from the transect centerline. The inclusion of these unclassified caribou confounds analysis of composition percentages; therefore, results are presented in two ways. In the first (unadjusted), the number of unclassified animals was simply subtracted from the total observed and the composition percentages were then calculated using the new total. In the second (adjusted), the number of unclassified large caribou was subdivided according to the observed proportions of cows, yearlings, and bulls in the classified portion of the count, and those derived numbers were added to the appropriate categories to arrive at new, estimated percentages.

RESULTS

SNOW COVER

As is often the case during late May and early June on the Arctic Coastal Plain, inclement weather was common during the 1987 calving period (Appendix B). Persistent cloud cover and fog caused snowmelt to be delayed, similar to about half of the years in which calving surveys have been conducted; an unseasonably heavy snowfall on 10 June contributed to this delay (Appendix B).

Snow cover in Area A on both 23 May and 29 May was 95%-100%, except for areas of lower cover within about 100-200 m of roads (primarily on the downwind [west or south] side). These areas, often called dust shadows, are formed as "fugitive" dust from roads settles on the snow, decreasing the albedo and accelerating ablation (Everett 1980). On the 6-7 June surveys, snow cover ranged from about 30% to 80% across Area A (Figure 6), and by the 15/17 June surveys, cover had decreased to 10% or less (Figure 7), although the observer estimated up to 20% in some portions not photographed on the latter surveys.

In Area B, snow cover was greater and more persistent in the uplands at the head of the Miluveach and Kachemach rivers. However, cover was also more variable, and was consistently lower near the Itkillik and Kuparuk rivers and on the northern ends of the transects than at higher elevations. On 4 June, average snow cover ranged from 28% to 55% for the westernmost transect (the only one for which photographs were obtained, due to a camera malfunction). Additional ocular estimates ranged from 10-20% on westward-facing hill slopes at the southern end of the second transect from the west, to 50-80% for most of the remainder of the area, to 95-100% at the highest elevations (much of which could not be surveyed due to low clouds and fog). The distribution of snow cover on 14 June showed a similar pattern, with greater cover at higher elevations (Figure 7).

East of the Sagavanirktok River, in Areas C and D, the snowmelt pattern was different. On 5-6 June, snow cover decreased steadily with increasing distance from the coast, irrespective of elevation (Figure 6); also, snow cover was lower east of the Canning River. By 11 June, cover values for the western portion of Area C remained greater near the coast than inland,

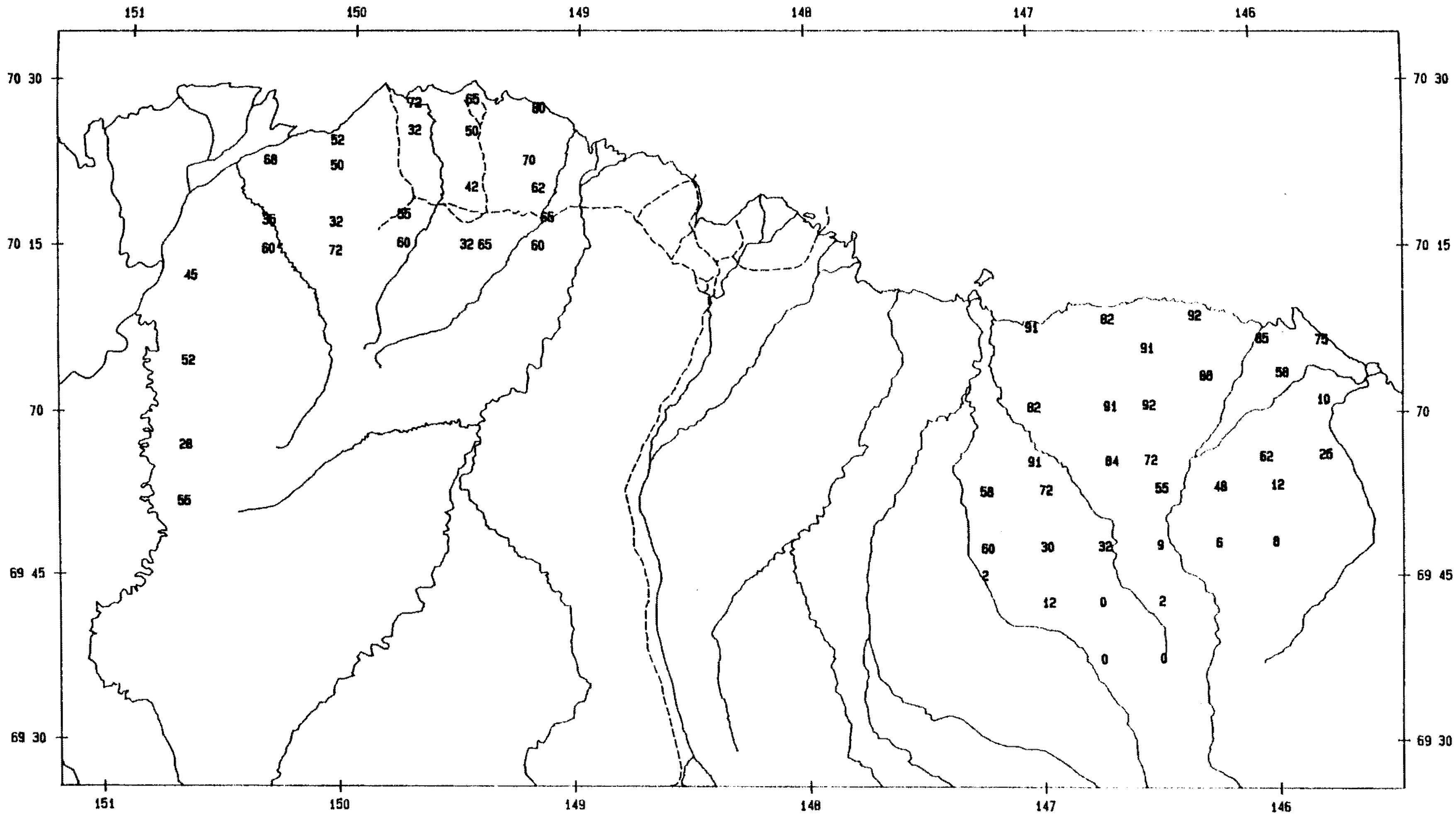

Figure 6. Estimated snow cover (%) at selected locations in fixed-wing survey Areas A-D on the Central Arctic Herd calving grounds, 4-7 June 1987.

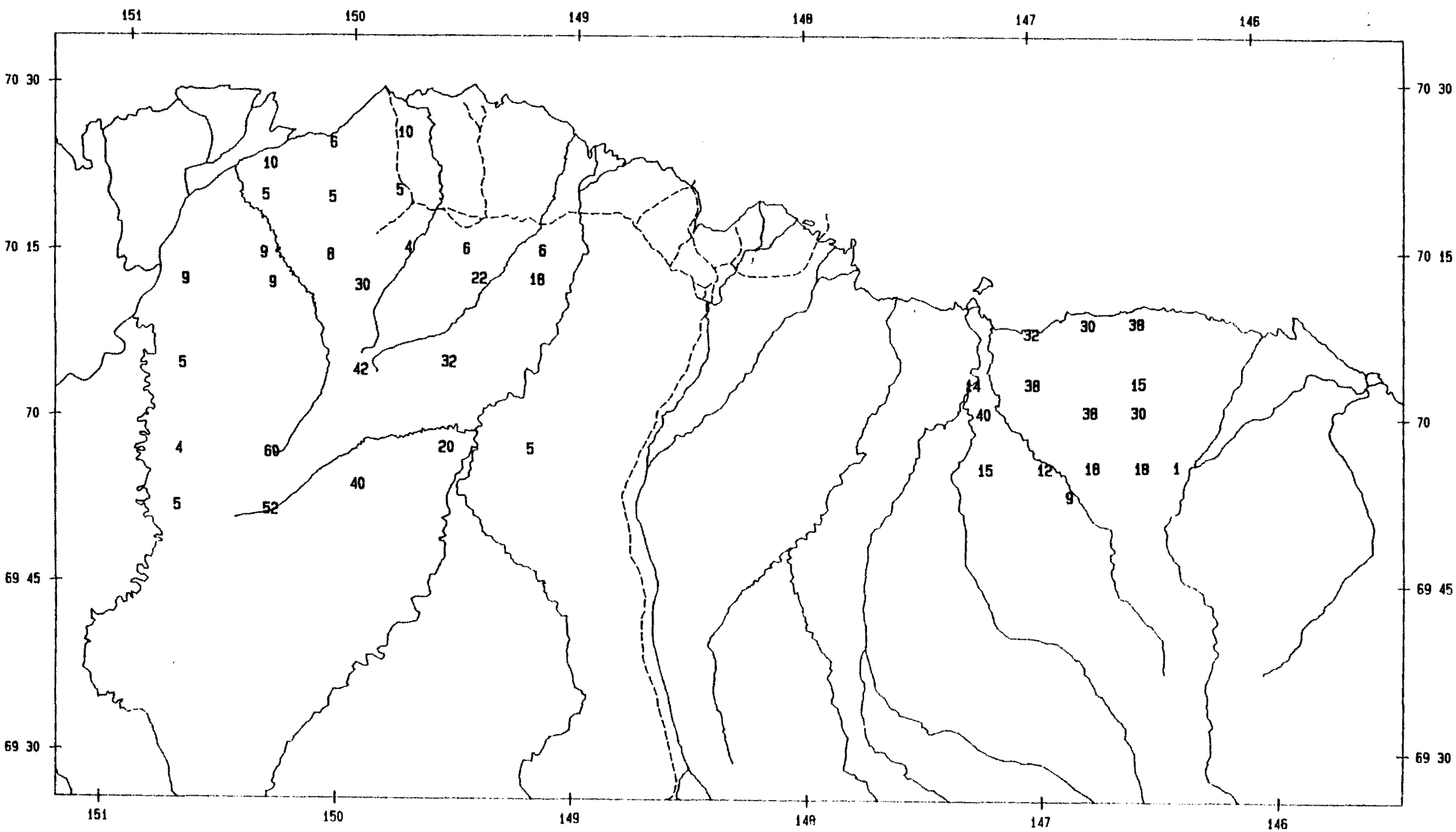

Figure 7. Estimated snow cover (%) at selected locations in fixed-wing survey Areas A-D on the Central Arctic Herd calving grounds, 11-15 June 1987.

largely due to the 10 June snowfall (Appendix B) which was heaviest near the coast, and Area D was essentially snow-free by 13 June (Figure 7). No photographs of Area E were taken, but the observer estimated 10-40% snow cover on 12 June.

FIXED-WING SURVEYS

Western Areas (A and B)

Area A (Figure 3) was surveyed four times in 1987. On the first flight (23 May), only transects 16-34 (Figure 4) could be surveyed due to deteriorating weather conditions; however, the area surveyed encompassed all oilfield facilities from Kalubik Creek to just east of the Milne Point Road. The entire area was covered on the second survey (29 May). The third (6-7 June) and fourth (15/17 June) surveys both were conducted over 2-day periods (due to time constraints and, on the latter, to coastal fog). The third survey was interrupted along the Milne Point Road and the fourth survey along the Oliktok Point and Spine roads; no coverage was duplicated on the second day of either survey. Both June surveys covered transects 7-42; transects 1-6 had been deleted after the 29 May survey because few caribou had been seen.

Summaries of caribou seen among transects and surveys in Area A (Table 3) reveal several distributional trends during the calving period. The first is a tendency for highest numbers of caribou to occur in the western half of the survey area, although relatively high numbers were observed on some eastern transects throughout the period.

The second trend is a general decrease during the calving period in the numbers of caribou seen on transects 16-34, the area encompassing the Kuparuk and Milne Point oilfield facilities. This trend is evident when counts are totaled for groups of transects (16-34 and 7-42) that were surveyed most often (Table 4). Numbers of "large" caribou decreased from the first to the fourth surveys for transects 16-34, but apparently were stable for transects 7-42 from the second to fourth surveys, indicating movement out of the former area during the period. Lowest numbers were observed on 6-7 June, when snow cover was intermediate and the proportion of caribou detected (of those present) was the lowest of all the surveys (see Discussion: Survey Conditions and Sightability).

Table 3. Sex and age composition[a] (number) of caribou observed on 1.6-km-wide strip transects during four surveys by fixed-wing aircraft in the Kuparuk Oilfield and vicinity (Area A), 23 May-17 June 1987.

	23 May						29 May						6-7 June						15/17 June						
Transect[b]	C	c	Y	B	U	T	C	c	Y	B	U	T	C	c	Y	B	U	T	C	c	Y	B	U	T	Transect
1	-	-	-	-	-	-	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	1
2	-	-	-	-	-	-	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	2
3	-	-	-	-	-	-	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	3
4	-	-	-	-	-	-	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	4
5	-	-	-	-	-	-	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	5
6	-	-	-	-	-	-	0	0	0	0	14	14	-	-	-	-	-	-	-	-	-	-	-	-	6
7	-	-	-	-	-	-	0	0	0	0	2	2	0	0	0	0	3	3	1	1	1	0	0	3	7
8	-	-	-	-	-	-	0	0	0	0	4	4	4	0	0	0	2	6	18	16	4	0	2	40	8
9	-	-	-	-	-	-	4	0	2	0	2	8	1	0	2	0	0	3	12	10	3	0	1	26	9
10	-	-	-	-	-	-	26	0	12	0	0	38	3	2	1	0	0	6	3	3	3	0	4	13	10
11	-	-	-	-	-	-	9	0	5	0	1	15	11	9	3	0	0	23	40	34	3	3	16	96	11
12	-	-	-	-	-	-	16	0	2	0	4	22	11	6	3	0	1	21	67	62	2	0	5	136	12
13	-	-	-	-	-	-	18	0	5	0	0	23	13	11	2	0	0	26	14	10	1	0	4	29	13
14	-	-	-	-	-	-	23	1	5	1	1	31	22	16	2	0	6	46	59	51	6	0	5	121	14
15	-	-	-	-	-	-	0	0	0	0	0	25	22	20	1	0	0	43	14	9	3	0	12	38	15
16	52	0	12	0	13	77	22	2	3	0	24	51	9	6	4	0	3	22	0	0	0	0	5	5	16
17	16	0	0	0	24	40	43	3	3	0	13	62	3	2	1	0	1	7	3	3	0	0	5	11	17
18	11	0	2	0	5	18	28	0	11	0	14	53	2	1	0	0	0	3	9	8	2	1	2	22	18
19	12	0	5	3	9	29	7	0	1	6	11	25	4	3	2	0	3	12	0	0	0	0	2	2	19
20	15	0	6	0	24	45	7	0	1	0	1	9	0	0	0	0	0	0	4	1	0	0	2	7	20
21	8	0	2	0	7	17	8	0	2	1	2	13	6	3	1	0	2	12	0	0	0	0	4	4	21
22	11	0	3	0	11	25	4	0	0	0	15	19	0	0	0	2	0	2	0	0	0	0	0	0	22
23	18	0	8	0	19	45	10	0	2	0	10	22	0	0	0	1	2	3	0	0	0	0	1	1	23
24	7	0	4	0	0	11	10	0	1	0	2	13	0	0	0	0	0	0	0	0	0	2	3	5	24
25	11	0	5	0	1	17	6	0	7	0	13	26	2	2	2	0	1	7	0	0	0	1	6	7	25
26	10	0	2	0	0	12	15	0	3	1	7	26	3	0	0	0	1	4	17	5	5	1	3	31	26
27	11	0	3	2	0	16	6	0	0	0	0	6	0	0	0	0	1	1	23	20	4	0	4	51	27
28	32	0	5	2	5	44	3	0	1	0	2	6	11	6	2	0	1	20	4	2	6	0	5	17	28
29	0	0	0	1	2	3	3	0	1	0	1	5	15	6	4	0	3	28	14	13	1	0	2	30	29
30	16	0	3	0	1	20	12	1	3	0	2	18	0	0	0	0	1	1	7	5	0	0	2	14	30
31	9	0	0	0	0	9	5	0	1	0	10	16	0	0	1	0	8	9	25	17	5	3	5	55	31
32	8	0	2	0	3	13	4	0	2	0	7	13	1	0	1	2	5	9	0	0	2	0	4	6	32
33	2	0	1	0	1	4	11	0	3	0	0	14	0	0	0	1	0	1	4	3	1	1	1	10	33
34	1	0	2	0	0	3	12	1	1	1	1	16	10	2	1	0	2	15	24	14	2	0	1	41	34
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36	-	-	-	-	-	-	0	0	0	0	16	16	6	4	2	0	0	12	2	1	0	0	0	3	36
37	-	-	-	-	-	-	2	0	0	0	8	10	14	10	3	0	5	32	15	14	0	0	0	29	37
38	-	-	-	-	-	-	1	1	0	0	0	2	5	4	0	0	3	12	18	16	1	0	1	36	38
39	-	-	-	-	-	-	7	0	0	0	0	7	2	1	1	0	2	6	19	18	1	0	4	42	39
40	-	-	-	-	-	-	5	0	1	0	0	6	6	2	2	0	1	11	0	0	2	1	0	3	40
41	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	3	0	3	7	6	2	0	0	15	41
42	-	-	-	-	-	-	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	42
TOTAL	250	0	65	8	125	448	353	10	83	10	193	649	194	120	41	9	57	421	437	355	60	13	114	979	

[a] C = cows, c = calves, Y = yearlings, B = bulls, U = unclassified large caribou (does not include calves), T = total.
[b] See Figure 4 for transect locations; dash indicates no survey.

Table 4. Sex and age composition (number) of caribou observed on selected groups of 1.6-km-wide strip transects during repeated surveys by fixed-wing aircraft in the Kuparuk Oilfield and vicinity (Area A), 23 May-17 June 1987.

Transect Numbers[a]	Date	Sex/Age Class (number)						
		Cow	Calf	Yrlg.	Bull	Uncl.[b]	Large[c]	Total
16-34	23 May	250	0	65	8	125	448	448
	29 May	216	7	46	9	135	406	413
	6-7 June	66	31	19	6	34	125	156
	15/17 June	134	91	28	9	57	228	319
7-42	29 May	353	10	83	10	179	625	635
	6-7 June	194	120	41	9	57	301	421
	15/17 June	437	355	60	13	114	624	979

[a] See Figure 4 for transect locations; transects are grouped according to amount of coverage repeated on all survey dates listed.
[b] Unclassified large caribou (does not include calves).
[c] Total minus calves.

For the 6-7 and 15/17 June surveys, map plots of the numbers, by transect segment, of all caribou (Appendix Figures A-1 and A-3) and of calves only (Appendix Figures A-2 and A-4) provide more detail on caribou distribution. Most caribou were seen west of the Kuparuk Oilfield; other portions of the area that received relatively high use were between the Oliktok Point and Milne Point roads, and between the latter road and the Kuparuk River.

Area B (Figure 3) was surveyed on 4 and 14 June. Low clouds and fog at higher elevations prevented a complete survey on 4 June; 73 (67%) of the 109 transect segments were surveyed. The entire area was surveyed on 14 June. Total counts were similar in the 73 segments surveyed on both dates: 223 on 4 June and 265 on 14 June (Table 5). An additional 228 caribou (46% of survey total, including 53% of calves) were counted on 14 June in the remaining 33% of the area (i.e., those segments not surveyed on 4 June). These counts, depicted in map plots of numbers of all caribou (Appendix Figures A-1 and A-3) and of calves only (Appendix Figures A-2 and A-4), indicate greater relative use of the higher elevations of Area B, centered roughly on the upper Miluveach River.

Schematic plots of the observed densities of total caribou and calves by transect segment provide synoptic overviews of the results of the fixed-wing surveys in Areas A and B near the peak of calving (Figures 8 and 9) and the end of the calving period (Figures 10 and 11). Concentration of most caribou to the west and southwest of the Kuparuk Oilfield is evident, as is a less-pronounced concentration in the area north of the Spine Road and east of the Oliktok Point Road, in the calving concentration area documented in previous years.

<u>Eastern Areas (C, D, and E)</u>

Area C (Figure 3) was surveyed on 5 and 11-12 June (Table 2). On 5 June, sampling intensity was reduced from 100% to 50% to avoid duplication from navigational errors in the nearly featureless central portion of the area (although accurate navigation did not prove to be difficult). Counts on the westernmost transects (Table 5, Appendix Figures A-5 and A-6) were thought to be substantially lower than the actual numbers present because of glare and patchy snow; counts on the central and eastern transects were

Table 5. Sampling intensity and sex and age composition (numbers) of caribou observed on 1.6-km-wide strip transects during repeated surveys by fixed-wing aircraft in various portions of the Central Arctic Herd calving grounds, 23 May-17 June 1987.

Area[a]	Date	Sampling Intensity[b] (%)	Sex/Age Class (number) Cow	Calf	Yrlg.	Bull	Uncl.[c]	Large[d]	Total
A	23 May	100[e]	250	0	65	8	125	448	448
	29 May	100	353	10	83	10	193	639	649
	6-7 June	100	194	120	41	9	57	301	421
	15/17 June	100	437	355	60	13	114	624	979
B	4 June[f]	33	123	30	25	0	45	193	223
	(14 June[f]	33	95	81	21	7	61	184	265)
	14 June	33	207	171	30	12	73	322	493
C	5 June	50	77	45	6	2	55	140	185
	11 June	100[g]	422	335	60	3	32	517	852
	11-12 June	50[h]	43	36	6	0	3	52	88
D	6 June	33	22	8	11	10	53	96	104
	13 June	33	348	236	153	23	252	776	1012
E	10 June	33[i]	3	1	3	0	2	8	9
	12 June	33	4	0	2	0	5	11	11

[a] See Figure 3 for area and transect locations.
[b] 33% = 4.8-km transect spacing; 50% = 3.2-km spacing; 100% = 1.6-km spacing.
[c] Unclassified large caribou (does not include calves).
[d] Total minus calves.
[e] Transects 16-34 surveyed (Figure 4).
[f] For 2/3 of area (73 of 109 transect segments) surveyed on both days.
[g] Western 1/3 of area (13 of 40 transects) surveyed.
[h] Eastern 2/3 of area (27 of 40 transects) surveyed.
[i] Western 1/3 of area (2 of 6 transects) surveyed.

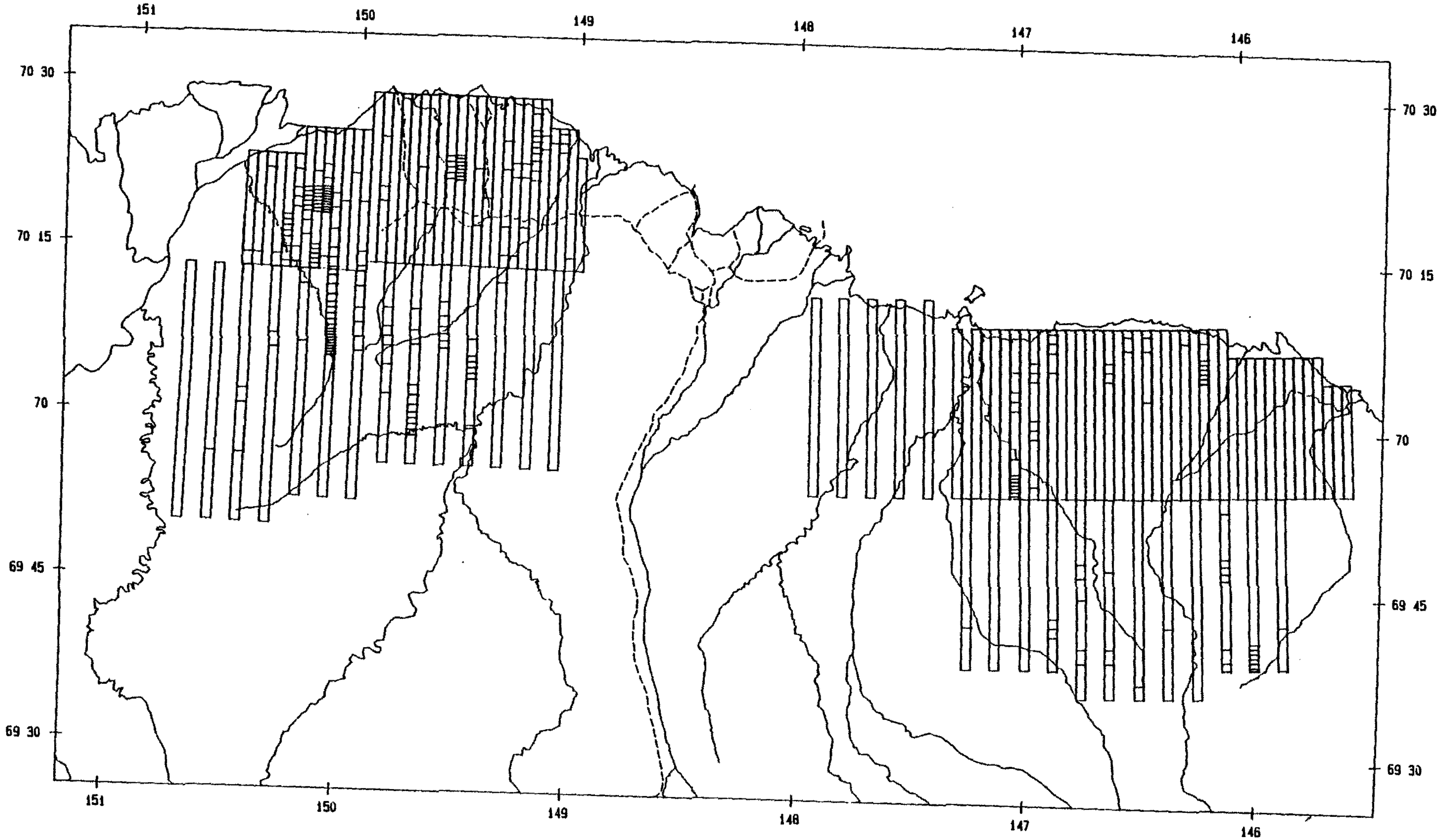

Figure 8. Distribution and relative density of all caribou observed on fixed-wing surveys of the Central Arctic Herd calving grounds, 4-7 June 1987. Gradations in shading depict average densities in 7.8-km^2 transect segments, from $\leq 0.4/km^2$ (no lines) to $\geq 7.7/km^2$ (20 lines per segment).

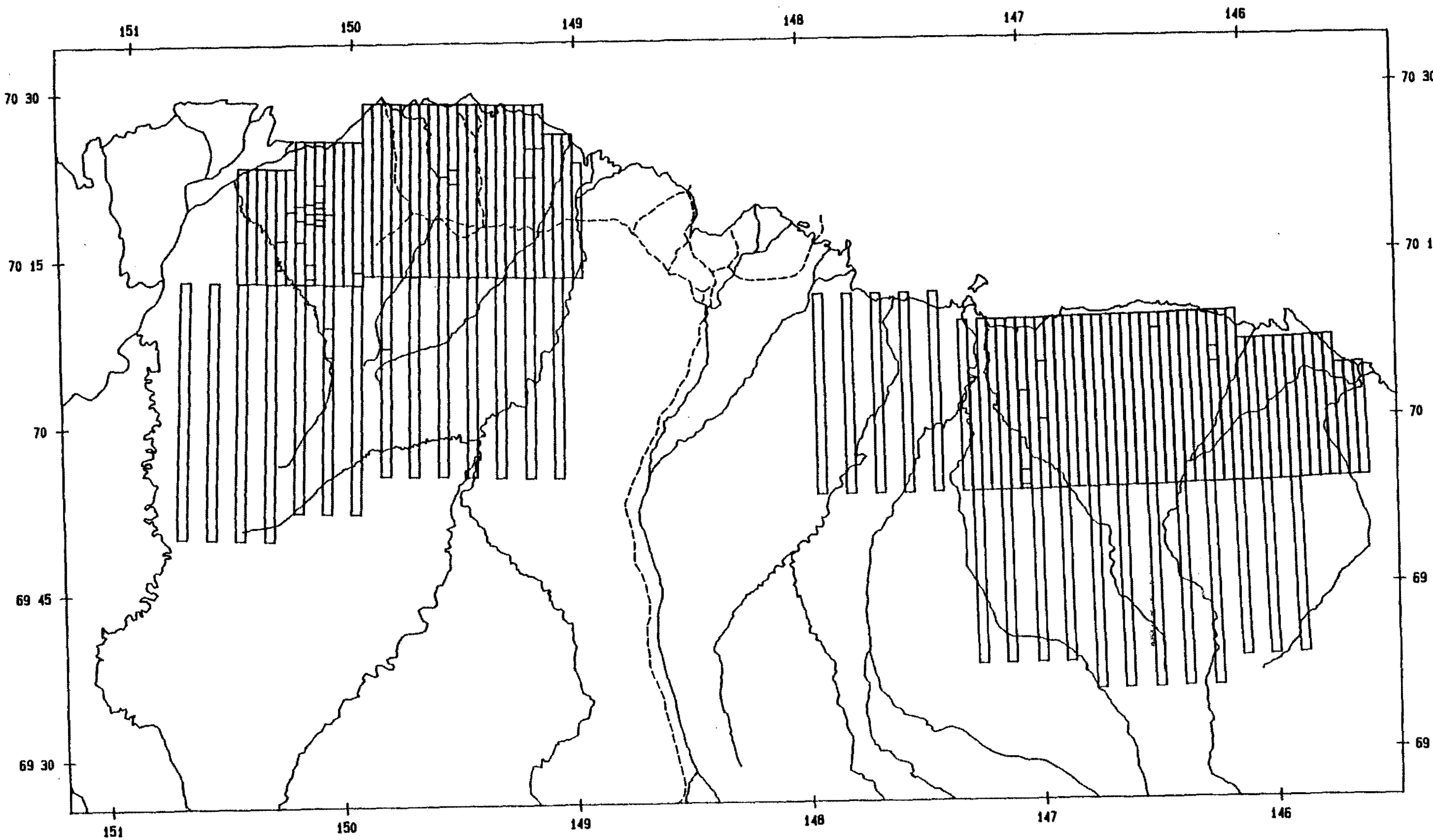

Figure 9. Distribution and relative density of caribou calves observed on fixed-wing surveys of the Central Arctic Herd calving grounds, 4-7 June 1987. Gradations in shading depict average densities in 7.8-km^2 transect segments, from $\leq 0.4/km^2$ (open) to $\geq 7.7/km^2$ (20 lines per segment).

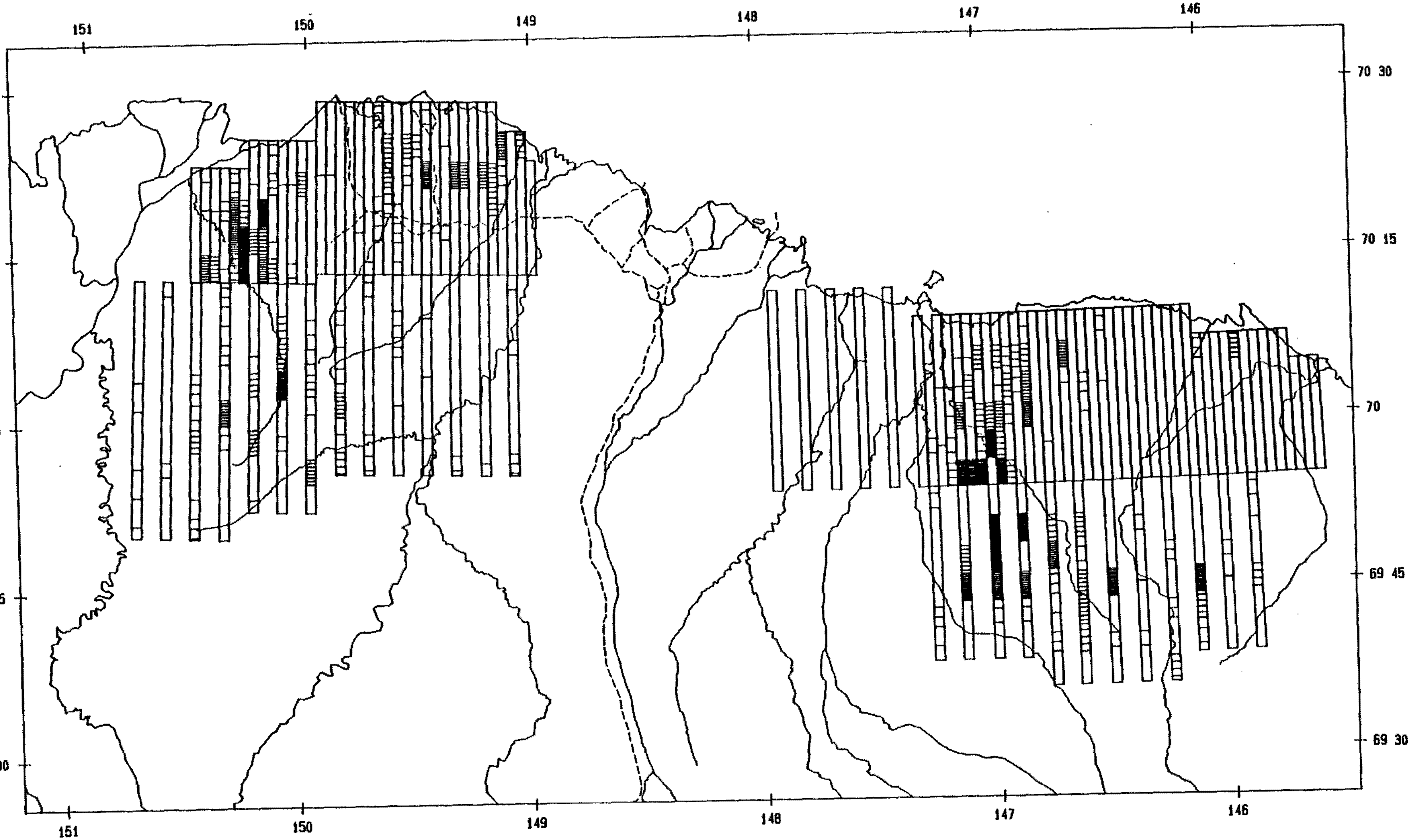

Figure 10. Distribution and relative density of all caribou observed on fixed-wing surveys of the Central Arctic Herd calving grounds, 11-17 June 1987. Gradations in shading depict average densities in 7.8-km^2 transect segments, from $\leq 0.4/km^2$ (open) to $\geq 7.7/km^2$ (20 lines per segment).

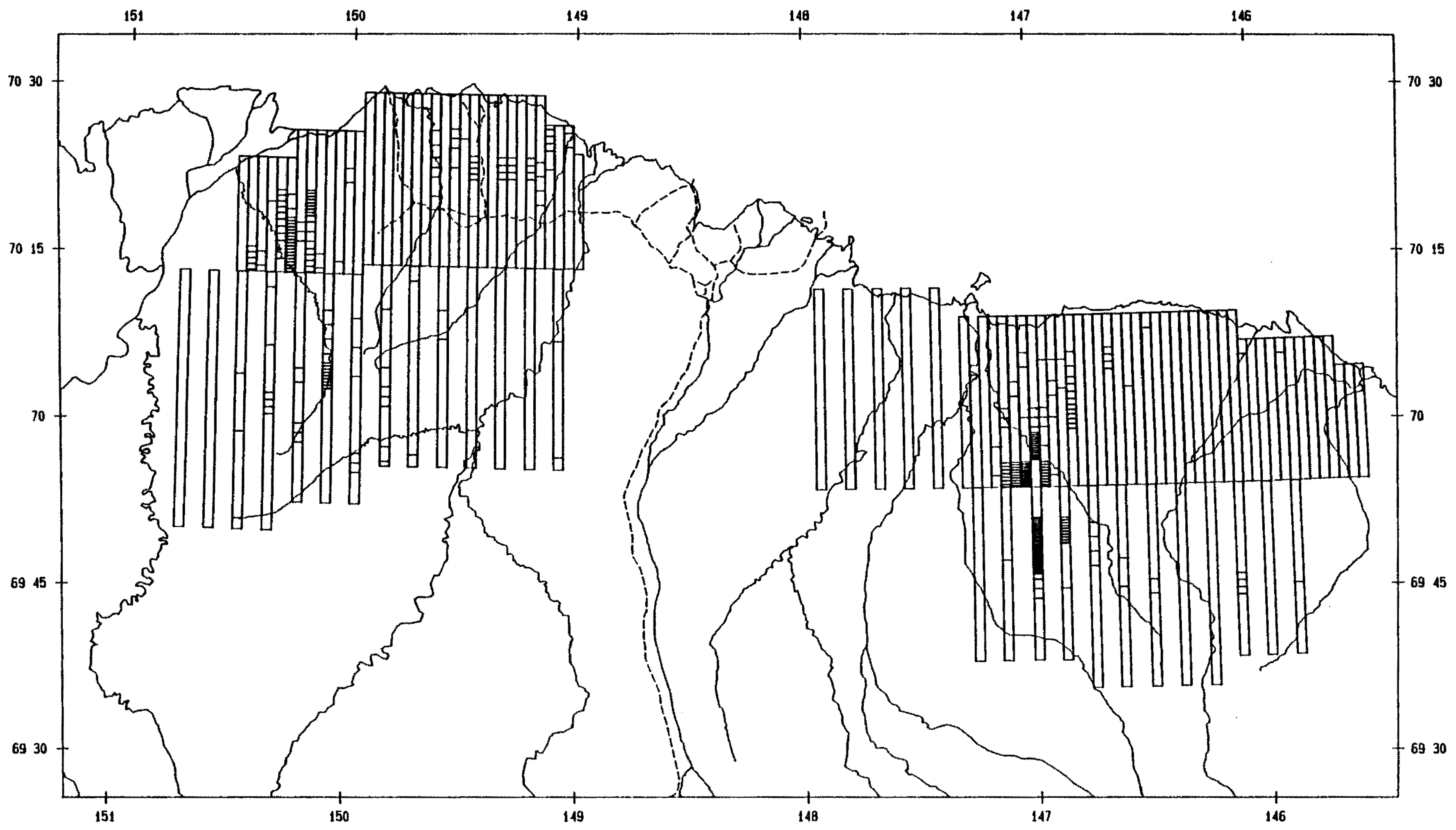

Figure 11. Distribution and relative density of caribou calves observed in fixed-wing surveys of the Central Arctic Herd calving grounds, 11-17 June 1987. Gradations in shading depict average densities in 7.8-km^2 transect segments, from $\leq 0.4/km^2$ (open) to $\geq 7.7/km^2$ (20 lines per segment).

thought to be more representative.

Because most caribou on 5 June were seen in the western portion, Area C was extended west to the Shaviovik River by adding five transects for the second survey. A total count (100% coverage) was planned for 11 June, but only the westernmost 13 transects could be surveyed at that level of coverage due to deteriorating weather. The remaining transects were flown on 11-12 June at 50% coverage. Nevertheless, these surveys demonstrated clearly that caribou were concentrated in the western third of the area, particularly the southwestern portion (Table 5, Appendix Figures A-7 and A-8).

Area D (Figure 3) was surveyed completely on 6 and 13 June (Table 2). As in Area C, the first survey counts (Table 5; Appendix Figures A-5 and A-6) were undoubtedly low because of patchy snow cover over the northern portion of the area. By the second survey, snow cover had virtually disappeared and the number of caribou observed was much higher (Table 5; Appendix Figures A-7 and A-8). The single highest count for any transect segment was recorded in Area D on 13 June: 232 caribou, including 87 calves. Not all of the difference in numbers counted between the two surveys was due to survey conditions, however; several of the groups encountered on 13 June were large nursery bands moving slowly southward into the low hills northeast of the Kavik River (other such groups were visible off transect). No similar groups had been found on 6 June, and it is possible that some of the animals that had calved farther north were moving inland at the time of the second survey.

Area E (Figure 3) was added to the study in the field after telemetry surveys indicated that more animals than expected might have been present in that area. A partial survey was flown on 10 June and a complete survey was flown on 12 June. Very few caribou were counted on either survey (Table 5), due in part to patchy snow cover and correspondingly low detectability of caribou. However, no indications of large numbers of caribou were noted in that general area on several overflights to and from Areas C and D on other days, although helicopter surveys (described below) a few days later revealed moderate numbers in several portions of the area.

Plots of the observed densities of all caribou (Figures 8 and 10) and of calves only (Figures 9 and 11), for all surveys during 5-13 June in the eastern survey areas, clearly show that the distribution of parturient caribou was southwest of the previously identified concentration area between Bullen Point and the Canning River delta. In fact, caribou were conspicuously absent from most of the eastern portion of Area C.

HELICOPTER SURVEYS

The helicopter surveys conducted on 11-15 June were intended to sample intensively the distribution and relative abundance of caribou across the calving grounds in as short a period as possible. Timing was nearly identical to the last complete fixed-wing surveys (11-17 June).

Numbers of caribou counted during helicopter surveys varied substantially among transects, ranging from 0 to 988 (Table 6). Caribou were most abundant in the western and eastern thirds of the overall calving grounds; few animals were observed in the central portion between the Kuparuk and Shaviovik rivers (i.e., transects W2-E4 [Figure 5]). Plots of observed density among transects for both total caribou (Figure 12) and calves only (Figure 13) provide an approximate "point-in-time" illustration of distribution and relative abundance late in the calving period. Both plots show clearly that most caribou were distributed to the southwest of the two areas in which caribou have concentrated late in the calving period in most years surveyed.

RADIO TELEMETRY

During 5-14 June, 38 radio-collared cows were located from fixed-wing aircraft (Table 7). Four or five additional cows whose transmitters should have been functioning could not be located. Most (33) collared cows were found during 5-7 June and their distribution was used to delineate coverage for the helicopter surveys and to evaluate whether transect placement for the fixed-wing surveys was adequate. Only one location per animal could be obtained during the calving period due to poor weather and the commitment of personnel to helicopter surveys.

The distribution of collared animals was similar to that revealed by the transect surveys. The collared cows were dispersed across the calving grounds, but tended to concentrate in the same general areas that contained the highest caribou densities found on transects (Figure 14).

Table 6. Sex and age composition of caribou observed on 3.2-km-wide strip transects during helicopter surveys of the Central Arctic Herd calving grounds, 11-15 June 1987.

		Sex/Age Class (number)				
Transect[a]	Date	Cow	Calf	Yrlg.	Bull	Total
W 8	15 June	55	38	11	0	104
W 7	13 June	338	283	35	2	658
W 6.2	12/13 June	200	170	18	2	390
W 6.1	12 June	114	85	23	2	224
W 6	12 June	116	83	19	8	226
W 5.2	12 June	88	64	11	6	169
W 5.1	12 June	13	8	2	4	27
W 5	11/12 June	67	42	20	2	131
W 4.2	11 June	71	62	13	3	149
W 4.1	11 June	34	26	2	1	63
W 4	11 June	12	7	5	2	26
W 3.2	11 June	33	19	12	1	65
W 3.1	11 June	94	79	5	5	183
W 3	11 June	45	36	13	4	98
W 2.2	11 June	14	10	0	1	25
W 2.1	11 June	5	2	3	10	20
W 2	11 June	5	3	2	9	19
W 1	13 June	0	0	0	0	0
0	13 June	14	8	8	2	32
E 1	13 June	31	17	21	1	70
E 2	13 June	57	38	16	0	111
E 3	13 June	37	32	8	0	77
E 4	14 June	30	15	12	3	60
E 5	14 June	267	178	58	10	513
E 6	14 June	514	412	60	2	988
E 7	14/15 June	141	80	63	4	288
E 8	15 June	15	11	12	16	54
E 9	15 June	84	50	25	8	167
TOTAL		**2494**	**1858**	**477**	**108**	**4937**

[a] See Figure 5 for transect locations.

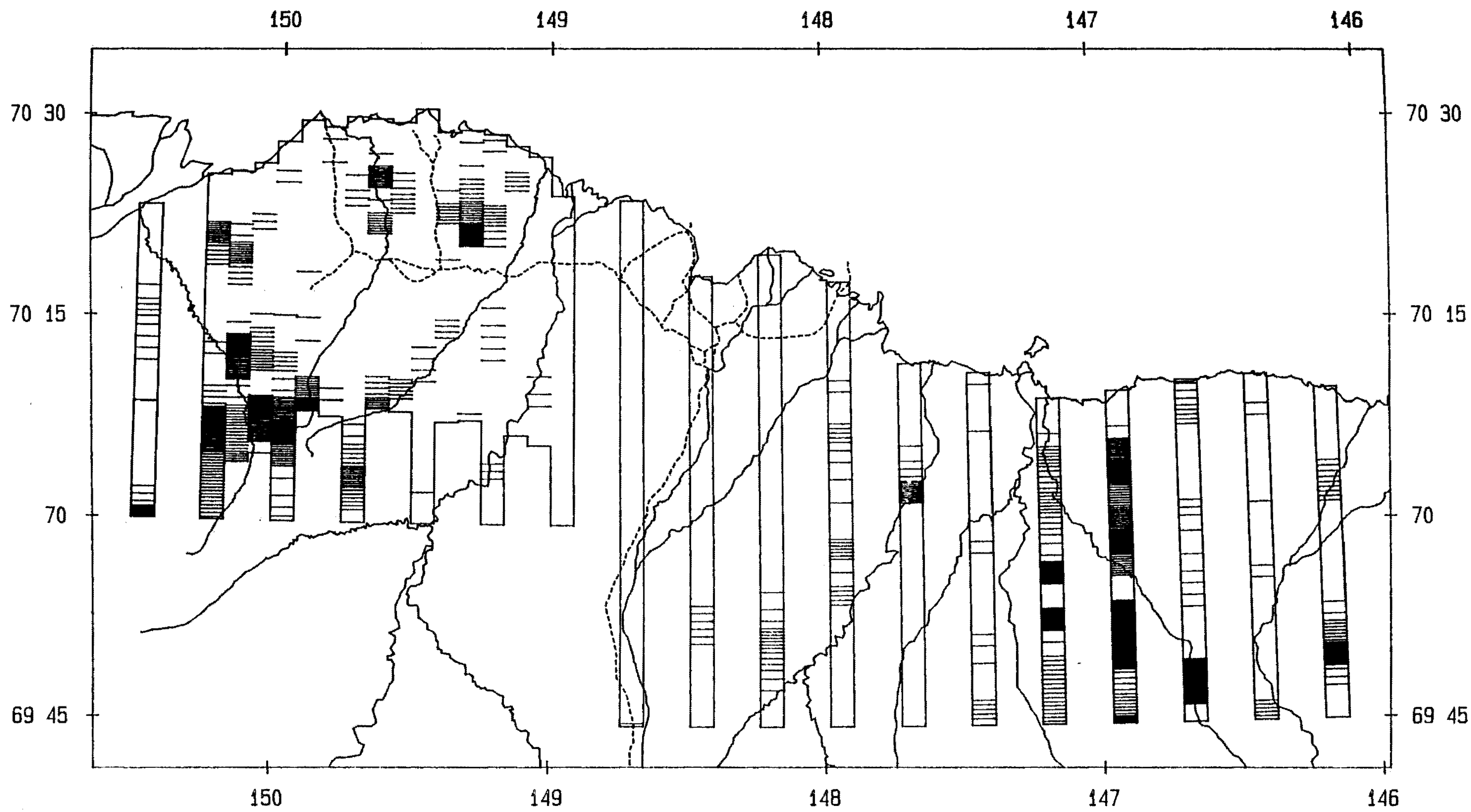

Figure 12. Distribution and relative density of all caribou observed on helicopter surveys of the Central Arctic Herd calving grounds, 11-15 June 1987. Gradations in shading depict average densities in 10.4-km^2 transect segments, from $\leq 0.4/km^2$ (open) to $\geq 7.7/km^2$ (solid).

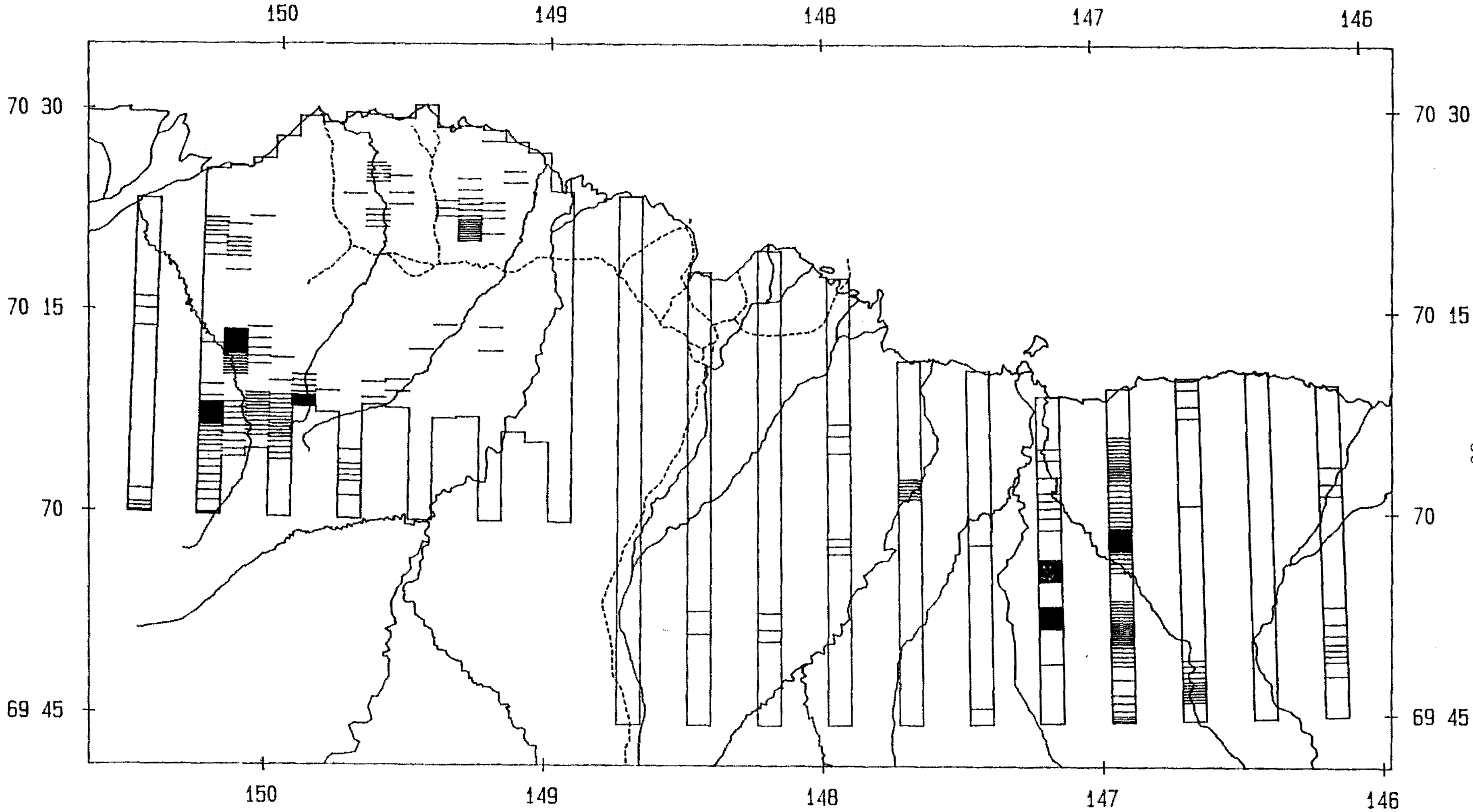

Figure 13. Distribution and relative density of caribou calves observed on helicopter surveys of the Central Arctic Herd calving grounds, 11-15 June 1987. Gradations in shading depict average densities in 10.4-km^2 transect segments, from $\leq 0.4/km^2$ (open) to $\geq 7.7/km^2$ (solid).

Table 7. Relocation dates and calf production of radio-collared female caribou of the Central Arctic Herd, 5-14 June 1987.

	Number			
Date	Relocated	With Calf	Without Calf	Unknown[a]
5 June	7	4	3	0
6 June	17	12	5	0
7 June	9	6	3	0
13 June	1	0	0	1
14 June	4	1	2	1
TOTAL	**38**	**23** (64%)[b]	**13**	**2**

[a] Calf presence or absence undetermined.
[b] Proportion of cows with calves; $\underline{N} = 36$.

SEX AND AGE COMPOSITION

To allow direct comparison of the results of fixed-wing and helicopter surveys, only data from fixed-wing surveys during 11-17 June have been used for analysis of sex and age composition (Table 8). Adjusting the counts from fixed-wing surveys to account for unclassified caribou (see Methods) resulted in two composition estimates for each sex/age category, and thus also for the ratio of calves:100 cows. Because of the adjustment method used, the difference between unadjusted and adjusted calf percentages (and the corresponding calf:cow ratios) is directly related to the proportion of unclassified caribou in the total (Table 8); therefore, the unadjusted figures are more useful for comparisons among areas. The adjustment method does not affect the ratio of yearlings:100 cows, so only one estimate is presented for each survey area.

In all areas, adult cows dominated the counts, constituting half (46-51%) of the animals seen; adult bulls (1-3%) were virtually absent from the calving grounds. The composition data from fixed-wing surveys were similar among Areas A, B, and C, but Area D had proportionately fewer calves and more yearlings than the other areas, indicating more southerly distribution of non-parous cows and yearlings in the eastern portion of the calving grounds. The unadjusted overall composition percentages from fixed-wing surveys were nearly identical with those observed during helicopter surveys (Table 8). Taken together, the two methods provided estimates of 75-78 calves:100 cows and 19-21 yearlings:100 cows on the CAH calving grounds in 1987.

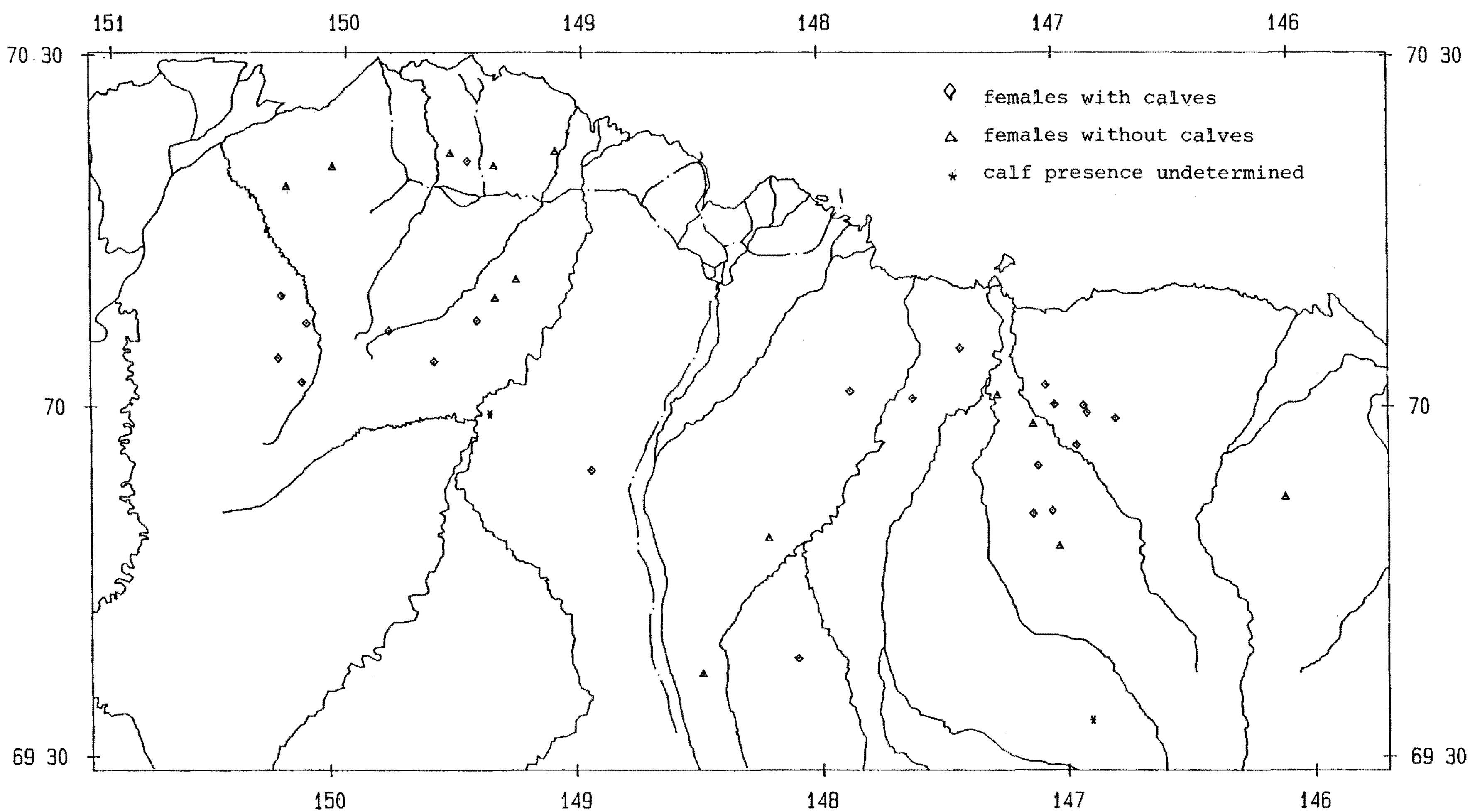

Figure 14. Locations of 38 radio-collared female caribou of the Central Arctic Herd, 5-14 June 1987. (Two were together, so only 37 points are depicted.)

Table 8. Sex and age composition of caribou observed during transect surveys by fixed-wing aircraft and helicopter on the Central Arctic Herd calving grounds, 11-17 June 1987.

Survey Type and Area[a]	Adjusted[b]	Sex/Age Class [% (number)] Cow	Calf	Yrlg.	Bull	Uncl.[c]	Total	Calves: 100 Cows	Yrlg.: 100 Cows
Fixed-wing									
A	no	50 (437)	41 (355)	7 (60)	2 (13)		865	81	14
	yes	55 (535)	36 (355)	7 (73)	2 (16)	(114)	979	66	
B	no	49 (207)	41 (171)	7 (30)	3 (12)		420	83	14
	yes	54 (268)	35 (171)	8 (39)	3 (16)	(73)	493	64	
C	no	51 (465)	41 (371)	7 (66)	1 (3)		905	80	14
	yes	53 (495)	39 (371)	7 (70)	1 (3)	(35)	940	75	
D	no	46 (348)	31 (236)	20 (153)	3 (23)		760	68	44
	yes	51 (515)	23 (236)	22 (227)	3 (34)	(252)	1012	46	
Overall	no	**49** (1457)	**38** (1133)	**11** (309)	**2** (51)		2950	**78**	**21**
	yes	54 (1837)	33 (1133)	11 (390)	2 (64)	(474)	3424	62	
Helicopter									
Overall	--	**51** (2494)	**38** (1858)	**10** (477)	**2** (108)	---	4937	**75**	**19**

[a] See Figure 3 for area locations.
[b] Adjusted to account for unclassified caribou: no = unclassified excluded; yes = unclassified included (see Methods).
[c] Unclassified large caribou (does not include calves).

DISCUSSION

Survey Conditions and Sightability

With few exceptions, the single characteristic common to virtually all aerial surveys of wildlife is that all of the animals present in a survey area are not detected (Graham and Bell 1969). Sightability, defined as "the probability that an animal within the observer's field of search will be seen by that observer" (Caughley 1974:923), is determined by complex interactions among features of the population under study, the environment, the survey design, and the observer. Among the most important of these factors are aircraft altitude, speed, and transect strip-width, all of which are inversely related to sightability (Pennycuick and Western 1972, Caughley 1974). Additional factors of particular relevance to this study include illumination (including sun glare from snow and meltwater), dispersion and movement of animals among transects, and observer fatigue (Graham and Bell 1969, Norton-Griffiths 1978).

The most profound influence on sightability of caribou on the CAH calving grounds, however, is the visual complexity of the background created by variable, patchy snow cover during spring melt. This background changes substantially during the calving period, from total cover at the start of calving, through complex patchiness at intermediate levels, to (typically) no cover by the end of the period. With good illumination, caribou are conspicuously dark against heavy snow cover and are conspicuously light (due to the "bleached" appearance of their winter coats) against a snow-free background. At intermediate cover levels, however, caribou are difficult to see in the patches of open ground created as snow melts. Therefore, sightability is probably highest when snow cover is complete or nearly so (e.g., >80%), decreases to its lowest point at cover values somewhere between 20% and 80%, and increases again as cover decreases below about 20%. In 1987, sightability was highest on 23 and 29 May and lowest during 4-7 June (approximate peak of calving). Sightability during 11-17 June was generally intermediate to that of the other surveys.

The standard approach for estimating "true" (absolute) numbers or density is to measure or estimate survey biases and develop an appropriate correction factor to apply to the sample counts (Jolly 1969, Caughley

1974). In developing a correction factor, subsamples of the sampling units are counted by a more accurate method (e.g., a ground count) to obtain a true count for comparison. No reliable correction factors were available to us, although approximations were obtained on two occasions.

Comparison of a count from a single low-level pass by fixed-wing aircraft (below survey altitude), across the southern end of Area C on 6 June, with survey counts in the same area on the preceding day suggested that perhaps only 40% of the caribou present had been detected on 5 June, when snow cover was 50-90%. On 7 June, the fixed-wing crew obtained a rough estimate of sightability for one transect segment in Area A by landing after it had been surveyed and counting all animals considered to be within the segment. That exercise indicated that half of the animals present (dispersed individuals, some lying down) had not been detected from the air; snow cover was 50-60%. No estimates of sightability were made for the helicopter surveys, but the observers thought that the proportion of animals missed was appreciable, perhaps as high as 50-60% in some areas of patchy snow.

Gross density estimates can be made from our data at present, but the confidence intervals will be large until additional work is done to quantify the biases for both fixed-wing and helicopter surveys. To adjust the counts from all surveys over the calving period, we would need to quantify snow cover on each survey, develop a sliding scale of correction factors that included all snow-cover classes, and then apply the appropriate correction factors to the sample counts. Counts obtained on different surveys cannot be compared directly unless sightability is constant among the surveys, which was rarely the case in 1987.

The results of our surveys can be used to examine relative differences in caribou abundance, however. Even though biases differed among surveys, they remained reasonably constant during a single survey. Thus, although chronological changes in absolute numbers cannot be identified with certainty, the relative distribution of caribou numbers within surveys can be used as an indirect indicator of a shift when comparing several surveys. This approach fulfilled our primary study goal.

Distribution and Relative Abundance

Several striking patterns are evident in the distribution of caribou observed on the CAH calving grounds in 1987. On both sides of the Sagavanirktok River, the areas of highest observed densities were southwest of the concentration areas identified in previous years.

West of the Sagavanirktok River, the highest densities were between 15 and 50 km inland, mostly west and southwest of the area between Oliktok Point and the Kuparuk River. Although sightability differences among years (Cameron et al. 1985) confound direct comparisons, the total numbers seen on 12 transects in the Kuparuk area (Transects W2-W6 [Figure 5], extending 40 km inland) were among the lowest recorded since 1978, when annual helicopter surveys began (Cameron et al. 1985, Smith and Cameron 1986). Proportional use of the area in 1986 and 1987 was especially low, inasmuch as the population has been growing over the past decade. Caribou numbers seen in 1987 in the area surveyed annually were lower than those presented in Table 6 because four of the 1987 transects were longer than 40 km. The adjusted 1987 numbers for that area were 598 adult ("large") caribou and 366 calves. Adult numbers were similarly low in 1986, which phenologically was even later than 1987, with 622 adult caribou (and 249 calves) being counted in the same area. Even when extensive inland calving was noted previously (e.g., 1978, 1980, 1982), caribou densities were relatively high within 16-24 km of the coast in the Kuparuk area (Whitten and Cameron 1985). In 1983-1985, caribou numbers near the coast were higher than in either 1986 or 1987 (Lawhead and Curatolo 1984, Curatolo and Reges 1984, Smith and Cameron 1986). The area between the Colville River and the Kuparuk Oilfield has not been surveyed intensively in previous years, but there have been no indications of past use as high as that seen in 1987.

Repeated surveys in 1983-1984 indicated that caribou numbers increased in the overall Kuparuk concentration area during the calving period (Lawhead and Curatolo 1984, Curatolo and Reges 1984, Smith et al. 1985). No such increase was evident in 1987. The total number of adult caribou counted on transects 7-42 (Area A) was 625 on 29 May and 624 on 15/17 June (Table 4); in fact, there may have been a slight increase because sightability was somewhat lower on the latter survey (although it was good on both).

In examining the decrease of caribou on transects 16-34 during the calving period, the most meaningful comparisons among surveys are relative, based on proportions observed within single surveys when sightability was similar among transects. This approach shows that transects 16-34, which included 57% (110) of the 193 segments constituting transects 7-42, contained 65%, 37%, and 33% of the total numbers of caribou counted (on transects 7-42) on 29 May, 6-7 June, and 15/17 June, respectively. For cows, these proportions were 61%, 34%, and 37%, and for calves, 70%, 26%, and 26%, respectively. That this decrease occurred while the overall number of large caribou in Area A remained relatively stable indicates that some caribou had moved from transects 16-34 into other portions of Area A (i.e., west of the oilfield and east of the Milne Point Road). The movements of two of the three collared animals sighted in the oilfield in late May (Appendix C) and relocated elsewhere from the air in early June provide limited supporting evidence for this shift.

Use of dust shadows was extensive on the 23 and 29 May surveys (and on the 25 May road survey [Appendix C]), but declined to low levels by the 6-7 June survey; no dust shadows were discernible by 15 June. This movement away from roads by the time of peak calving probably was due to a combination of factors, the two most important being the general increase in the availability of forage away from roads as snow melted and the sensitivity of parturient cows to disturbance. Avoidance of roads by cows with young calves during the late calving period has been documented previously in the area (Curatolo and Reges 1984; Dau and Cameron 1986a, 1986b).

East of the Sagavanirktok River, a strikingly similar pattern of distribution was evident: the highest observed densities of caribou were southwest of the concentration area identified previously (within 24 km of the coast between Bullen Point and the Canning River delta). The highest densities were found between 8 and 50 km inland between the Shaviovik River and Bullen Point; most of the animals were more than 16 km from the coast. The best information on this distribution came from the helicopter and fixed-wing surveys during 11-15 June, but the 5-6 June fixed-wing surveys indicated that the pattern was similar during peak calving. Due to sightability differences, strong conclusions cannot be drawn regarding the magnitude of counts among surveys. However, compared with the 5 June count, the relatively large number of adult caribou observed on 11-12 June in

Area C, suggests that numbers had increased in the area by more than could be accounted for simply by improved sightability. It is also possible that the fixed-wing counts on 13 June in Area D were inflated by movement of some caribou south from Area C; inland shifts after the peak of calving were noted in that area in 1983 (Lawhead and Curatolo 1984) and 1984 (Curatolo and Reges 1984). Despite this possibility, however, helicopter surveys recorded high caribou densities in the southwestern portion of Area C on 14-15 June.

Although no work was done specifically to clarify the causes for the overall distribution observed in 1987, the postulated relationship of more inland calving in years of delayed snowmelt (Whitten and Cameron 1985) at first seems to apply. Snow ablation in 1987 appeared to be delayed by persistently cool, overcast weather in late May and early June. Snow cover began disappearing rapidly during the mild weather of 4-7 June, but the return of cool, cloudy weather and the heavy snowfall of 10 June retarded that process. Some coastal areas still had 20% snow cover on 17 June. In contrast, snow cover had decreased to comparable levels by at least a week earlier in 1983 and 1984, when considerable coastal calving was observed (ABR and ADF&G, unpubl. data; Curatolo and Reges 1984).

However, comparison of snow-cover estimates with the observed distribution of caribou demonstrates that the postulated influence of delayed snowmelt was applicable in only the broadest sense in the 1987 season. The pattern of more inland high-density use was strikingly similar on both sides of the Sagavanirktok River, yet the pattern of snowmelt along coastal-inland gradients was fundamentally different for those areas of concentrated use. West of the Sagavanirktok River, snow cover disappeared earlier near the coast than farther inland, whereas the converse was true in the eastern portions of the calving grounds.

Sex and Age Composition

The preponderance of female caribou in all areas surveyed during calving, with bulls remaining farther south, was consistent with the expected pattern of sexual segregation at that season (Cameron and Whitten 1979, Jakimchuk et al. 1987). Bulls were present in very low numbers, although a few more were seen inland (Areas B and D) than near the coast.

At 2% (Table 8), bulls were under-represented in composition counts from aircraft, although young bulls and non-parous (barren) cows are extremely difficult to differentiate. Yearlings are generally easier to classify during the calving period, although some small adults probably were included in that category. Calves are accurately classified but easily undercounted, especially in areas of patchy snow cover or when lying down.

Whether the unadjusted or adjusted fixed-wing counts provide more accurate estimates of calf numbers depends on the underlying reasons for caribou not being classified during surveys. Two such reasons were identified: 1) some caribou in groups near the transect centerline, even though seen well, simply could not be classified confidently in the limited time available, and 2) because the strip width was relatively broad, caribou not seen well because they were far from the centerline could not be classified confidently. In the former case, calf counts would be accurate and the adjusted figures would provide better estimates of calf:cow ratios. In the latter case, more calves would be missed in the groups containing unclassified animals, and the unadjusted figures would provide better estimates. In practice, both factors were known to have affected the survey results, but their relative importance was not assessed in the field. The unadjusted figures compare more favorably with the results of the helicopter surveys, which provide good calf estimates because of lower altitude, slower airspeed, and the increased visibility of calves that run to cows when disturbed. Therefore, on the fixed-wing surveys, more calves were evidently missed as the proportion of unclassified caribou increased, and the unadjusted percentages are more accurate estimates of the proportion of calves actually present.

Both the fixed-wing and helicopter surveys indicated that overall calf production was good in 1987, at 75-78 calves:100 cows (Table 8). These estimates are in the middle of the range of ratios observed in the Kuparuk concentration area in 1978-1986, which was 56-91 calves:100 cows (Cameron et al., in press). The slightly higher percentage from the fixed-wing surveys probably resulted from the exclusion of unclassified animals, a number of which were undoubtedly non-parous cows. The estimate of 64 calves:100 cows from the sample of radio-collared animals (23 calves for 36 cows; Table 7) is an underestimate because most of the cows were located on 5-7 June, before all calves had been born. Subsequent telemetry surveys after the calving period yielded a ratio of 80 calves:100 cows (n=40) (Cameron et al., in press), which is similar to the transect survey results.

Yearling percentages indicate good representation of that age class on the calving grounds, although the estimated ratios of 19-21 yearlings:100 cows are at the low end of the range observed in past years (19-35:100 for the Kuparuk area, 1981-85 [Smith and Cameron 1986]). This ratio suggests reasonably good overwinter survival by the 1986 calf cohort, which was the smallest (proportionately) yet recorded for the CAH, at 56 calves:100 cows in June 1986 (Cameron et al., in press). It should be noted, however, that the proportion of yearlings recorded on the calving grounds is not necessarily representative of the herd as a whole; in fact, it is often lower than that obtained from composition counts in April (Cameron et al. 1983), by more than could reasonably be expected from mortality between the April and June counts.

CONCLUSIONS

The cooperative surveys by ABR and ADF&G in 1987 provided the most detailed data yet obtained regarding the distribution of CAH caribou on the calving grounds. The inclusion of undeveloped portions of the calving grounds in the study for comparative purposes was important in placing the distribution pattern observed in and near the Kuparuk Oilfield in perspective. Although only general comparisons can be made between the two widely separated concentration areas, it was striking that the distributions in both areas were similarly shifted westward and inland from the locations reported in previous years. Thus, between-year differences in the chronology of snow melt are implicated as the primary causative factor for these distributional differences within the overall calving grounds, although disturbance-related factors may have been involved to an unknown degree in the Kuparuk area. The decrease in abundance of caribou observed near oilfield facilities during the calving period was attributed to two principal factors: increased forage availability away from dust-shadow areas as snow melt progressed and local avoidance of human activity by parturient cows. This local decrease near facilities probably contributed to the general decrease in numbers observed between Kalubik Creek and the Milne Point Road during the calving period.

Both fixed-wing and helicopter surveys were effective in delineating the relative levels of use of various portions of the overall calving grounds. The helicopter surveys provided higher counts and more accurate sex/age composition data, as would be expected for a method employing more observers, lower altitudes, slower airspeeds, and greater maneuverability. On the other hand, the fixed-wing aircraft surveys provided, at lower cost, composition data and information on distribution and relative abundance that compared favorably with that from the helicopter surveys.

Information gathered by either method in the future would be more useful if correction factors are derived to adjust for caribou that are present but not detected. Curatolo and Reges (1984) attempted to obtain ground counts for comparison with concurrent fixed-wing aerial counts, but were unsuccessful because caribou groups reacted at long distances to the observers on the ground and moved away before accurate counts could be made. The most effective way to develop such correction factors would be to do a fixed-wing survey first in an area, at normal altitude and airspeed, and then to count the same area by helicopter at very low altitude along the same transect(s) as the fixed-wing survey to provide a "true" count. Curatolo and Reges (1984) reported the results of concurrent fixed-wing and helicopter surveys in the Kuparuk concentration area on 12 June 1984, when snow cover was negligible. Under those conditions the total fixed-wing count was 90% of the total helicopter count. Of course, the number of animals missed on the helicopter survey could not be assessed objectively. This latter problem must be solved before absolute densities can be estimated accurately from transect counts, especially those made at different levels of snow cover.

Photographic sampling of snow cover in 1987 provided a useful means of evaluating the distribution of caribou in relation to snow cover. Inconsistencies in this comparison demonstrate that more quantitative study is required to understand the relationship between calving distribution and snow cover. We recommend that snow cover be quantified in the same or a similar way during future surveys to document the physical conditions prevailing at the time of the survey counts.

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APPENDIX A. **Counts of all caribou and caribou calves among transect segments in fixed-wing survey Areas A-D on the Central Arctic Herd calving grounds, 4-17 June 1987.**

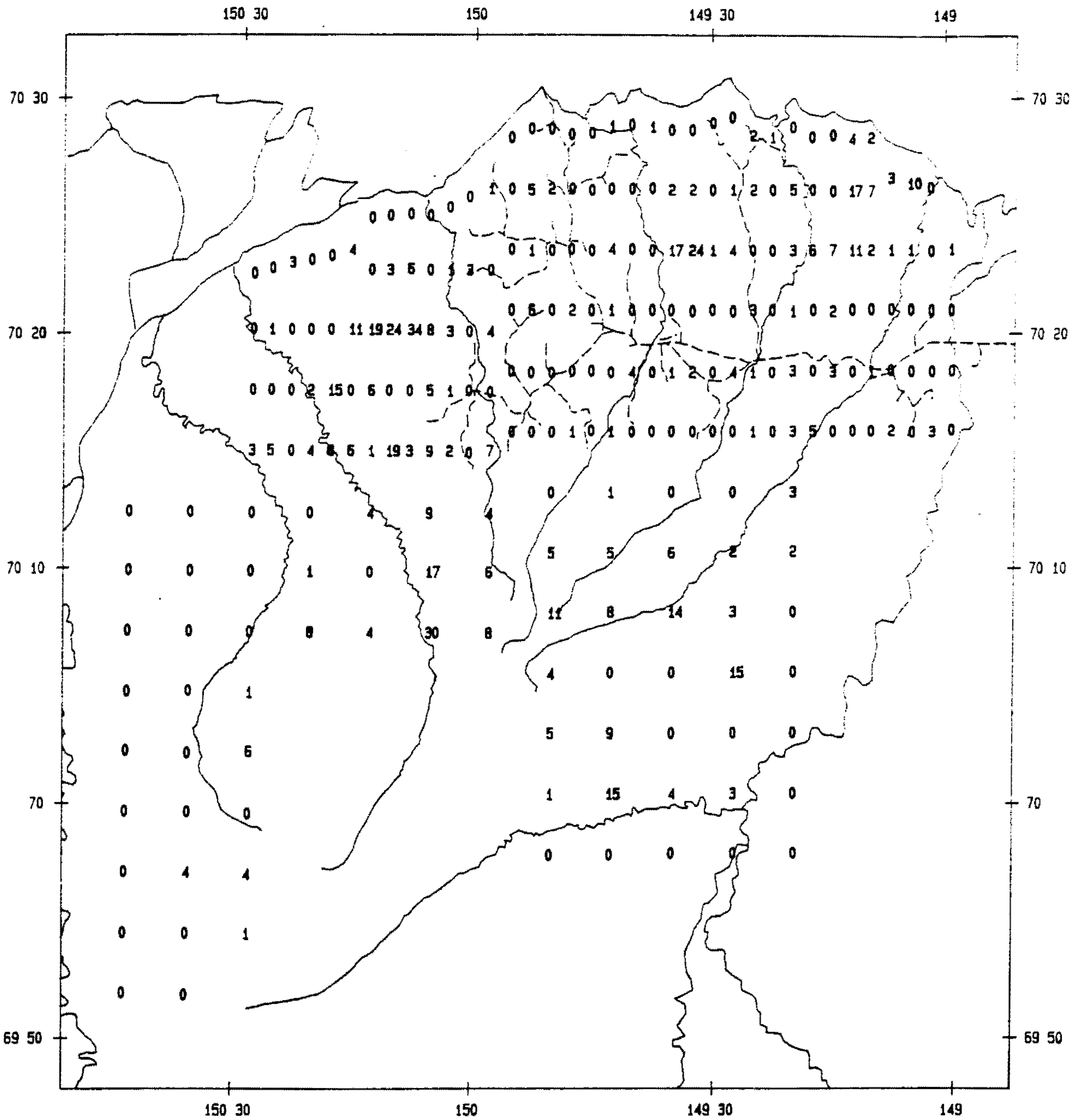

Figure A-1. Counts of all caribou observed among transect segments in fixed-wing survey Areas A and B on the Central Arctic Herd calving grounds, 4-7 June 1987.

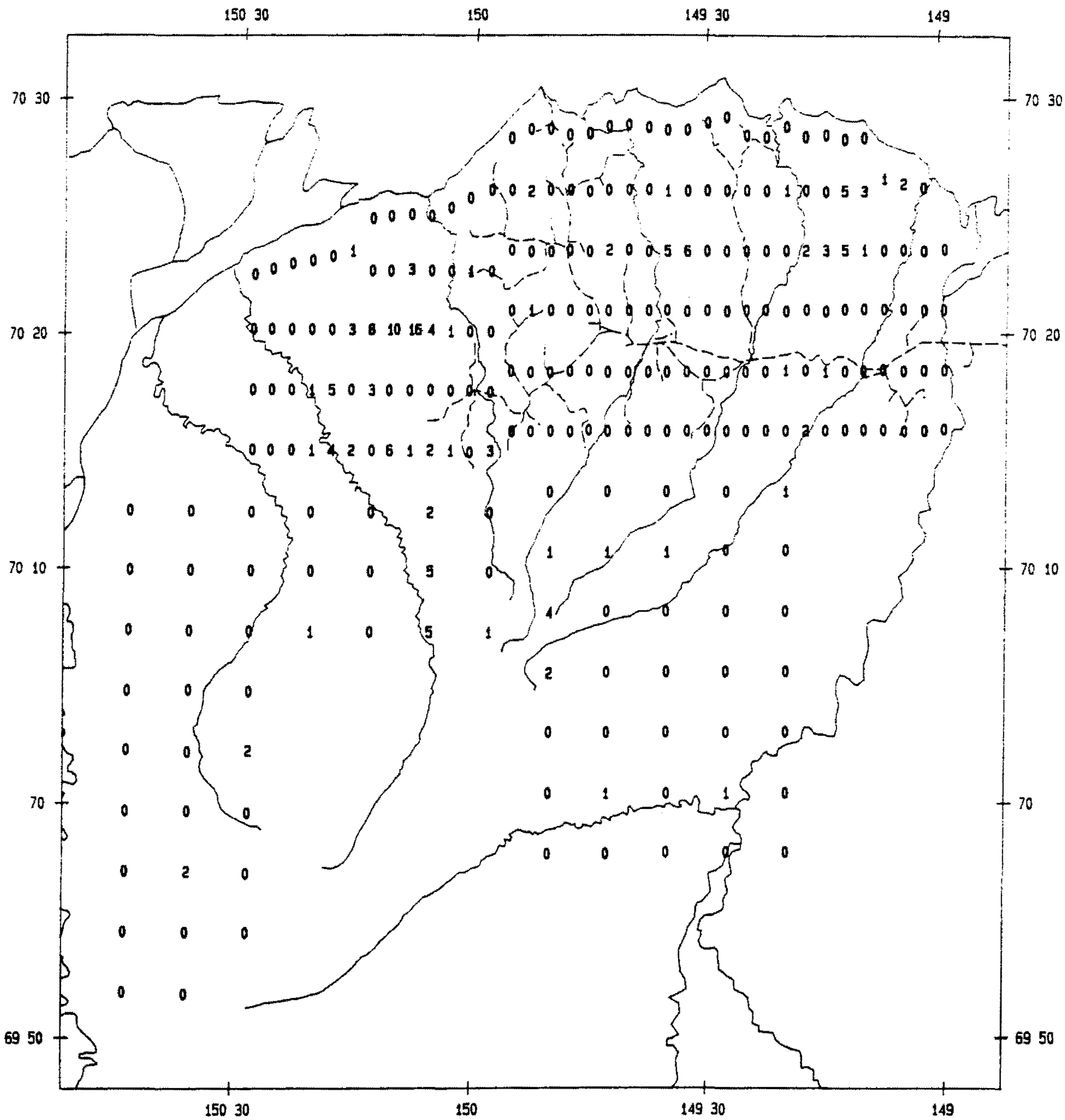

Figure A-2. Counts of caribou calves observed among transect segments in fixed-wing survey Areas A and B on the Central Arctic Herd calving grounds, 4-7 June 1987.

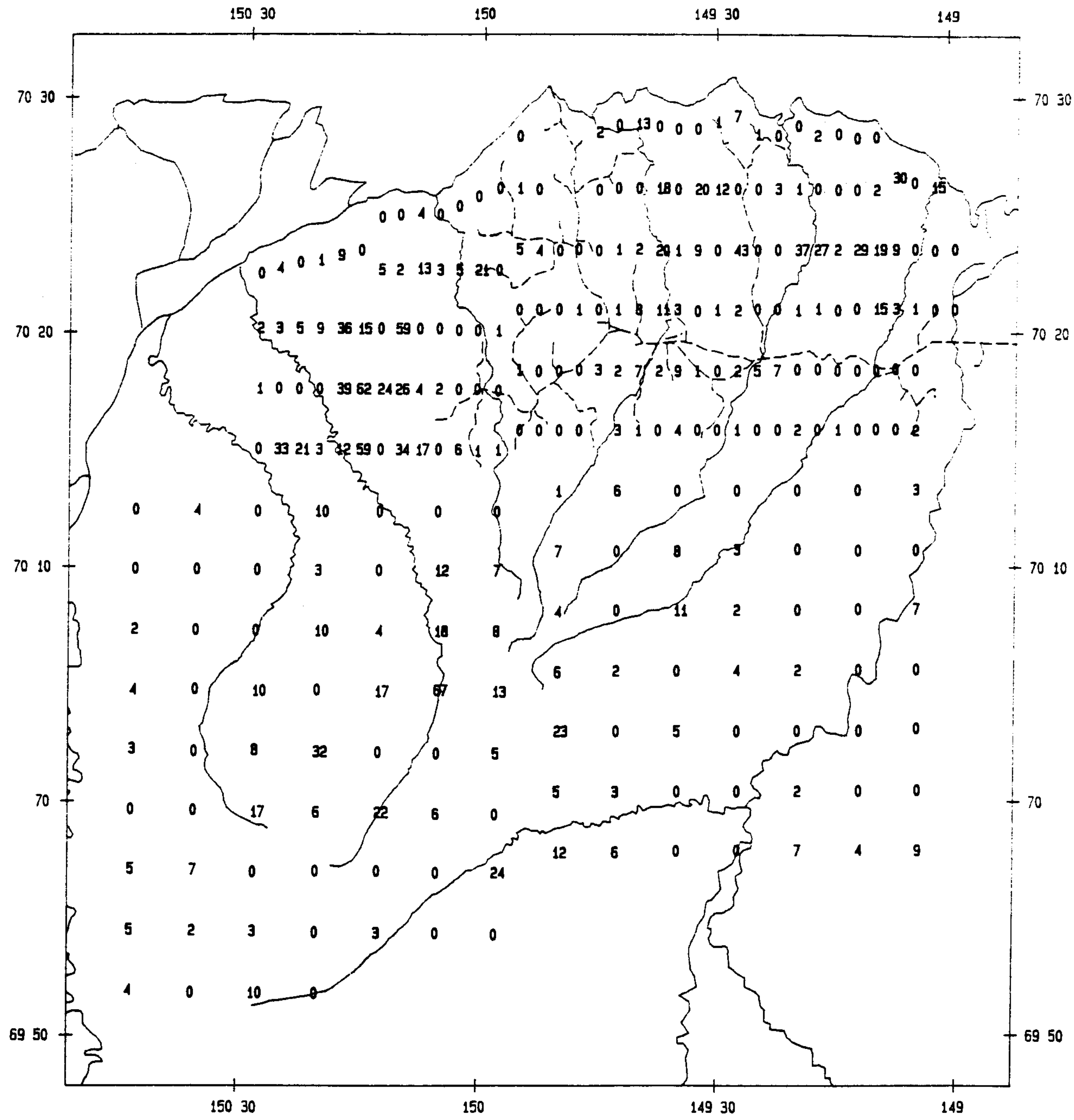

Figure A-3. Counts of all caribou observed among transect segments in fixed-wing survey Areas A and B on the Central Arctic Herd calving grounds, 14-17 June 1987.

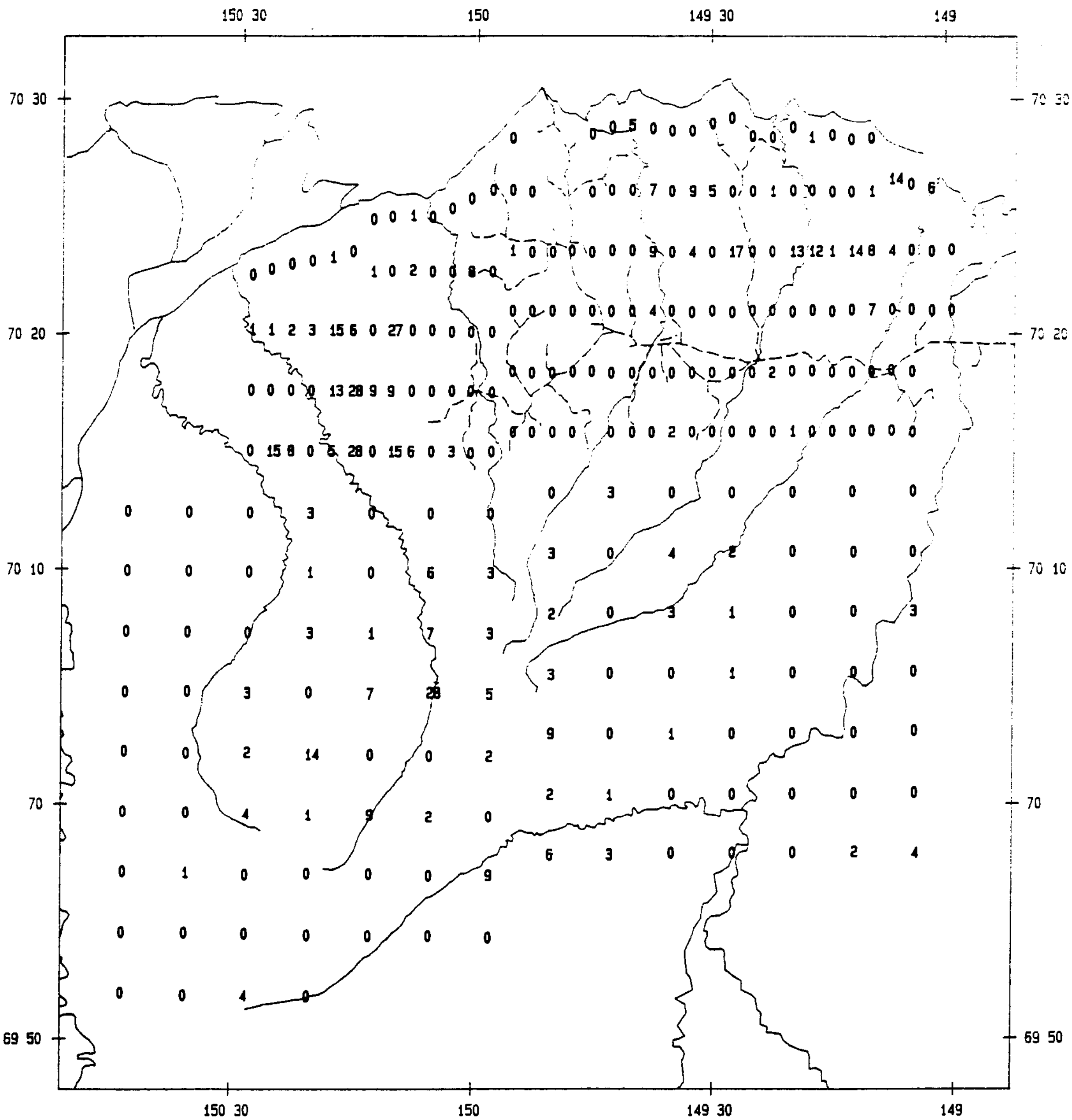

Figure A-4. Counts of caribou calves observed among transect segments in fixed-wing survey Areas A and B on the Central Arctic Herd calving grounds, 14-17 June 1987.

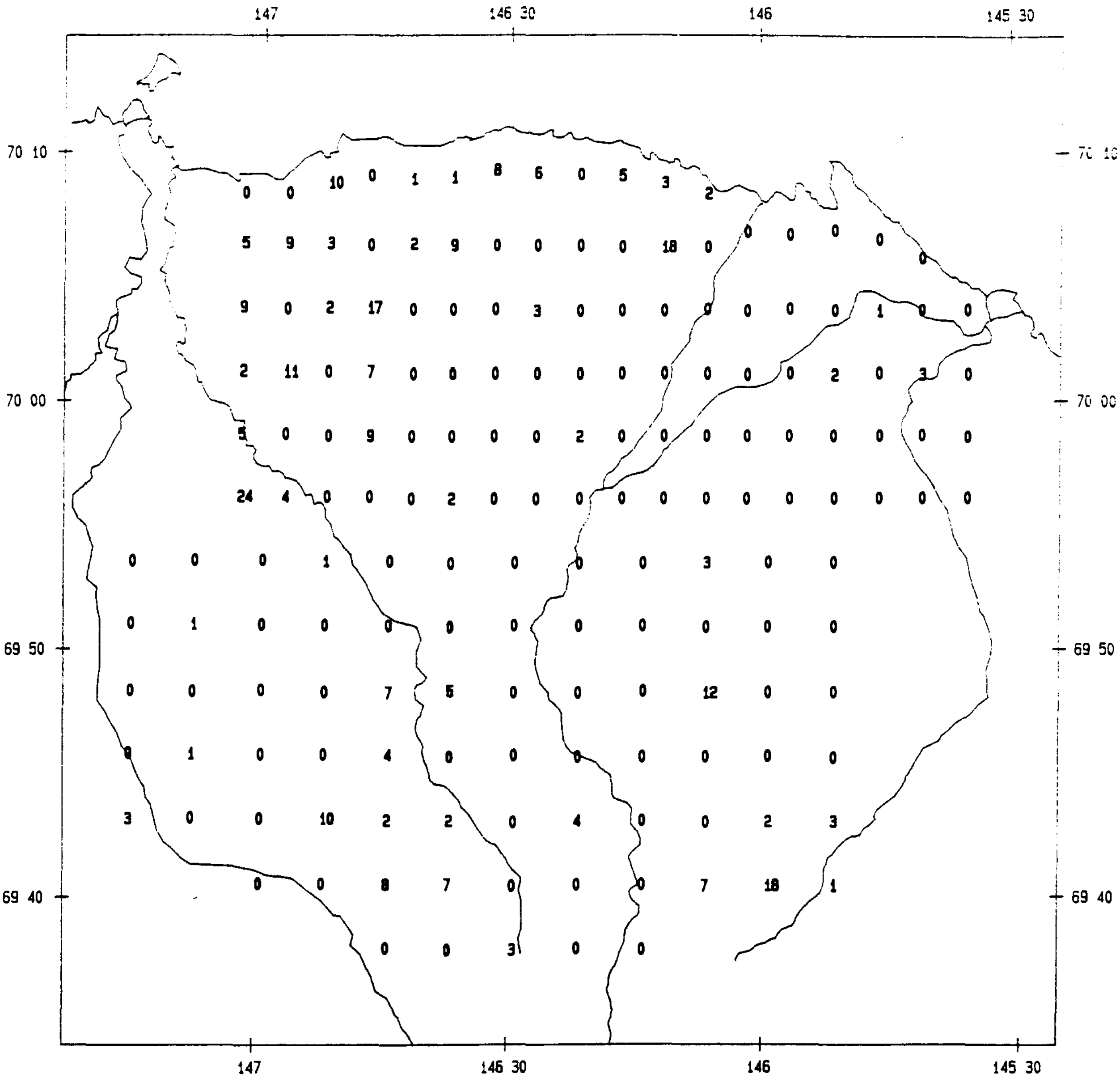

Figure A-5. Counts of all caribou observed among transect segments in fixed-wing survey Areas C and D on the Central Arctic Herd calving grounds, 5-6 June 1987.

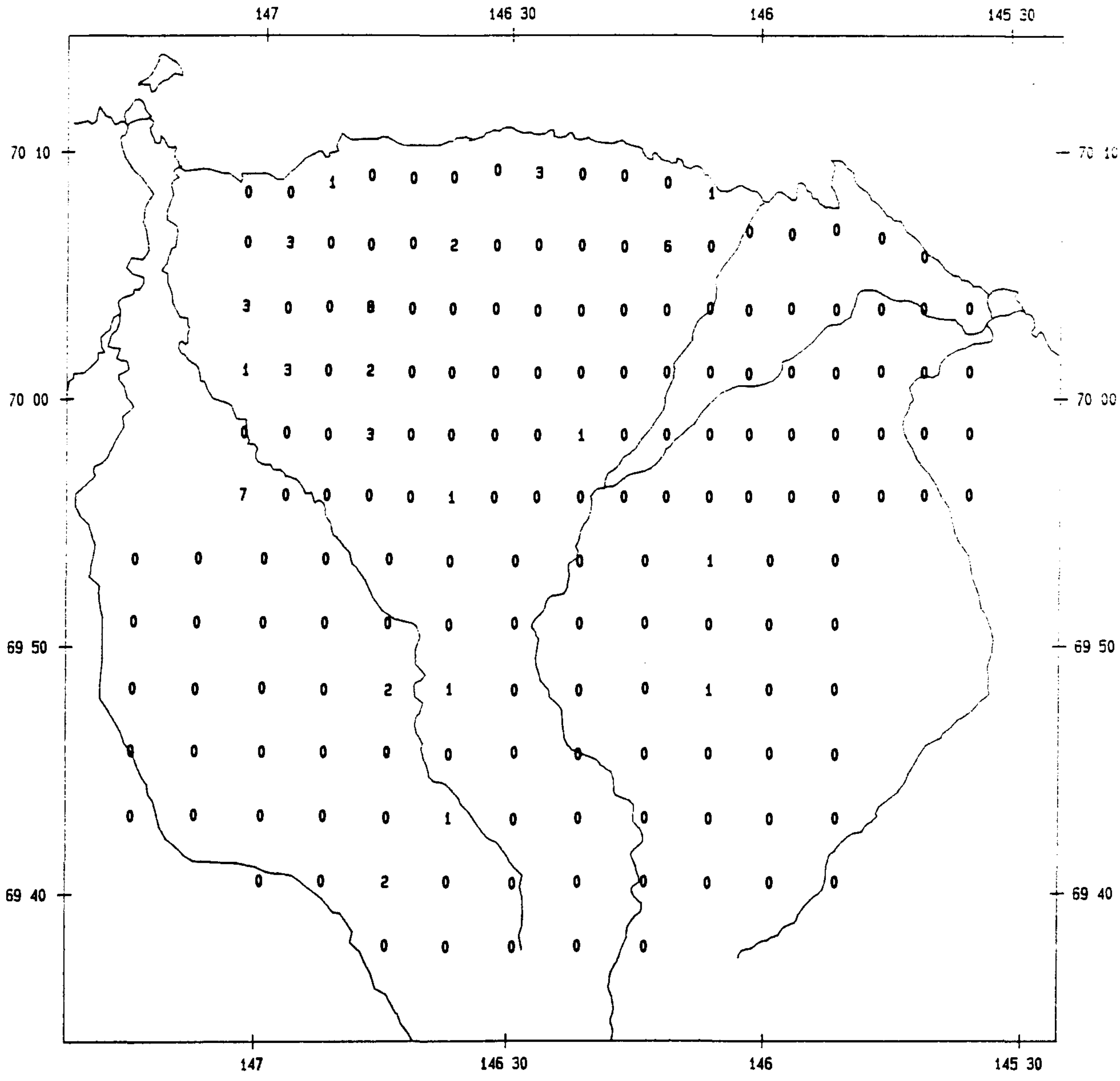

Figure A-6. Counts of caribou calves observed among transect segments in fixed-wing survey Areas C and D on the Central Arctic Herd calving grounds, 5-6 June 1987.

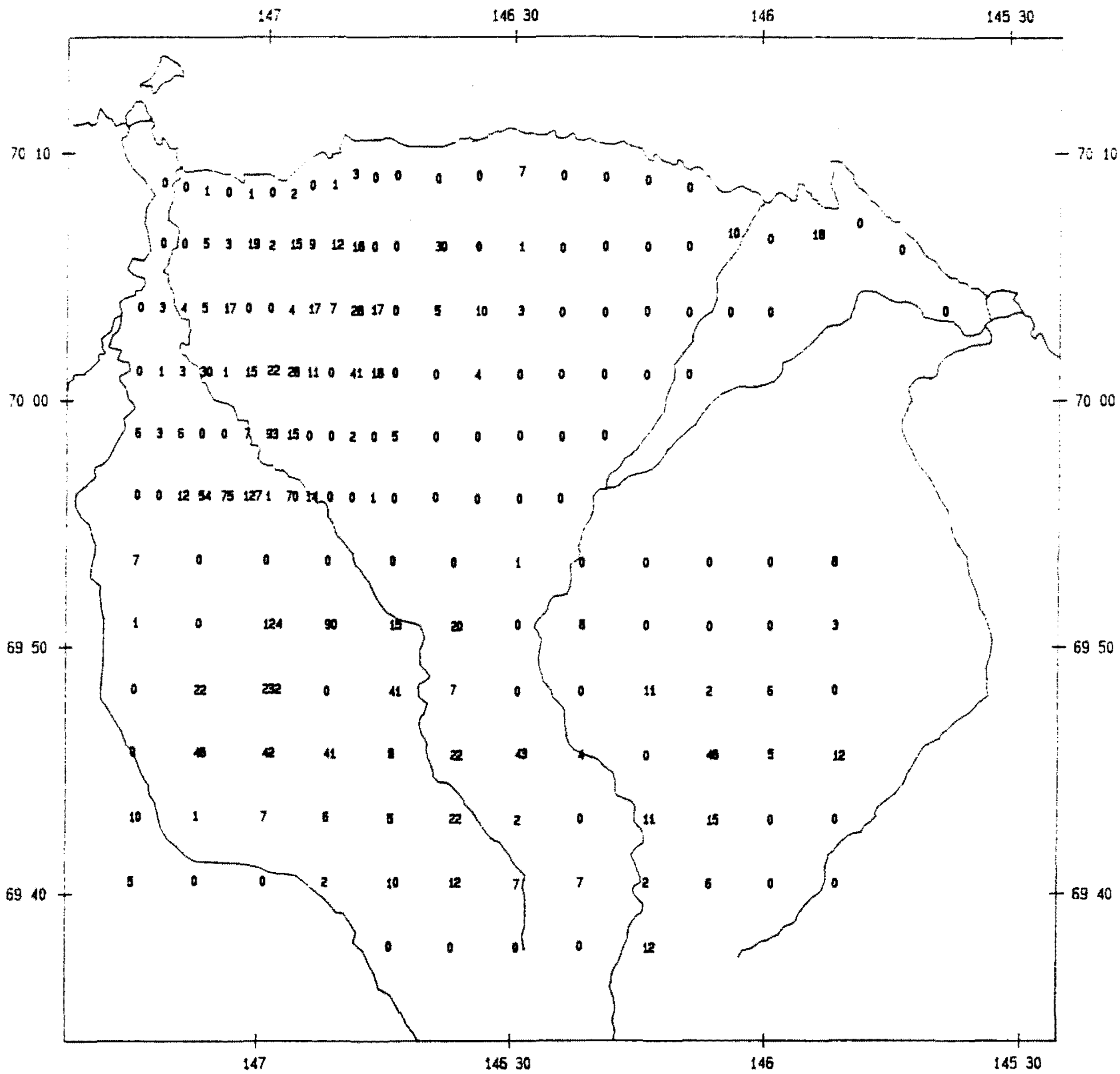

Figure A-7. Counts of all caribou observed among transect segments in fixed-wing survey Areas C and D on the Central Arctic Herd calving grounds, 11-13 June 1987.

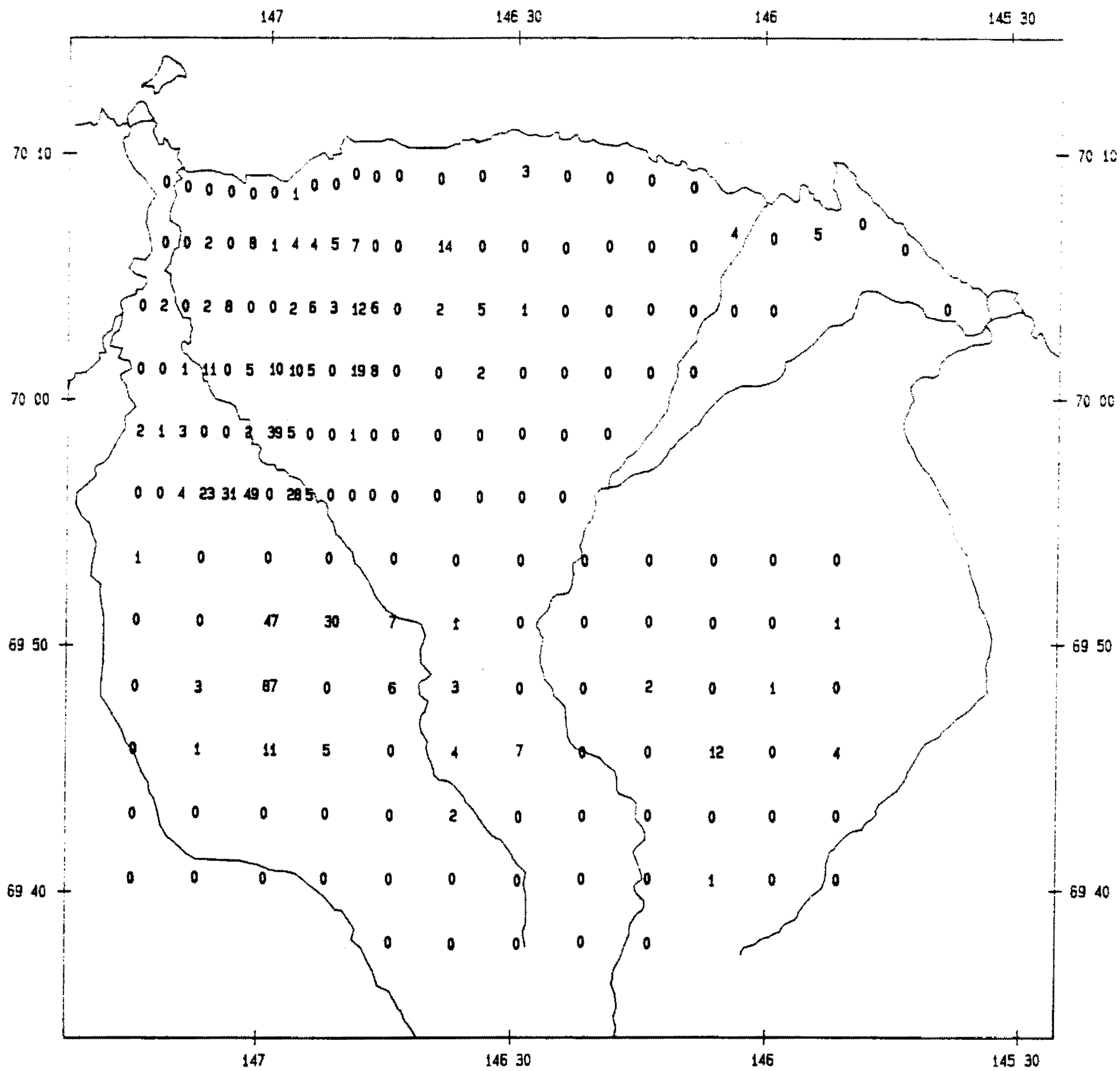

Figure A-8. Counts of caribou calves among transect segments in fixed-wing survey Areas C and D on the Central Arctic Herd calving grounds, 11-13 June 1987.

APPENDIX B. Weather and Flying Conditions

Field work began on 21 May and ended on 17 June 1987. Weather records from the Flight Service Station at Deadhorse Airport reveal that, during that 27-day period, fog was recorded on portions of 24 days and maximal wind speed exceeded 40 km/h on 12 days. The peak wind gust was 78 km/h, on 2 June. East and northeast winds predominated (22 days). Daily low temperatures ranged from -6.7°C on 22 May to 1.1°C on 17 June; daily high temperatures ranged from -4.4°C on 24 May to 9.4°C on 17 June. Daily highs were above 0°C on all days from 27 May on, except 4 and 9 June. The heaviest snowfall occurred on 10 June, with 18 cm of heavy, wet snow being recorded at the Prudhoe Bay Airport.

ABR flew approximately 75 h of fixed-wing surveys on 13 days (Table 1). Unsuccessful attempts were made on another 8 days, and no flying was possible on the remaining 6 days. ADF&G biologists conducted 30-35 h of helicopter surveys on 8 days during 4-15 June; in addition, 25 h were spent in a fixed-wing aircraft locating radio-collared caribou. The most serious impediments to aerial surveys were persistently low cloud ceilings, fog, and blowing snow driven by gusting winds; steady snowfalls and icing conditions were less common, but no less troublesome.

APPENDIX C. Kuparuk Oilfield Road Survey

On 25 May, ABR conducted an opportunistic survey by light truck on the road system in the Kuparuk Oilfield to obtain sex/age-composition data (for comparison with data from aerial surveys) and to map the distribution of caribou. Binoculars and a variable-power spotting scope were used in classifying all animals seen. Beginning at the Kuparuk River, groups were observed on both sides of 69 km (43 mi) of the road system, including the Oliktok Point Road and its western drill-site access roads, and the southwestern extension of the Spine Road and several drill-site access roads in that area. Group locations were recorded as accurately as possible on a 1:63,360-scale USGS map.

During the survey, 505 caribou were observed, virtually all of which were estimated to be within 3 km of roads. At least 335 (66%) were within 500 m of roads (distances were not estimated for all groups). The total count comprised 337 (67%) cows, 97 (19%) yearlings, 40 (8%) bulls, and 31 (6%) unclassified caribou (either antlerless cows or young bulls). No calves were seen, but 91% of a subsample of 275 cows still had hard antlers, indicating they were pregnant (although some obviously pregnant cows were antlerless).

A range of behaviors was observed, from two groups of pregnant cows that crossed repeatedly under elevated pipe having approximately 1 m of clearance above drifted snow, to two groups that ran from the observer's truck at distances of about 200 m and 600 m. The typical behaviors were feeding and lying, often in snow-free dust shadows along roads.

Two radio-collared cows were seen, but only one collar number could be read. That cow (OB 59), which had been collared just south of the oilfield area earlier in May, was seen near the junction of the Milne Point and Spine roads, and had been in the same vicinity on 22 and 23 May. She was subsequently located from the air in early June, with a calf, north of the Spine Road and west of the Milne Point Road. Two other collared cows were sighted in late May by ARCO Alaska personnel in the Kuparuk Oilfield (A. Schuyler, pers. comm.). OB 14 was seen near Central Processing Facility 2 on 23 May, and was subsequently located west of the oilfield on the 6 June telemetry survey. OB 56, which formerly had been collared with a satellite transmitter (Curatolo 1986), was seen near Drill Site 3B on 29 May, and was subsequently located southwest of the oilfield on the early June telemetry survey. Neither OB 14 nor OB 56 was accompanied by a calf in 1987.