MAMMAL SURVEYS IN THE GREATER KUPARUK AREA, NORTHERN ALASKA, 2007

FINAL REPORT

Prepared for:

ConocoPhillips Alaska, Inc.
Greater Kuparuk Area
P. O. Box 100360
Anchorage, AK 99510

Prepared by:

Brian E. Lawhead
and
Alexander K. Prichard

ABR, Inc.—Environmental Research & Services
P. O. Box 80410
Fairbanks, AK 99708

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EXECUTIVE SUMMARY

- The focus of this study was the distribution, abundance, and calf production of Central Arctic Herd (CAH) caribou between the Colville and Kuparuk rivers in northern Alaska during May–October 2007. Surveys were conducted in spring, the calving season, postcalving, and late summer through fall; no surveys were conducted during the insect season in July. Incidental sightings of muskoxen and bears were recorded during aerial surveys.
- A fixed-wing airplane was used to survey the calving distribution and abundance of caribou twice in 2007, around the peak of calving (2–5 June) and after most cows had calved (10–12 June). Summary maps of caribou density were prepared to compare distribution and density in 2007 with long-term averages from regional calving surveys since 1993. A helicopter was used to sample age and sex composition on 13 June. Additional aerial surveys of caribou distribution and abundance were conducted in early May, late June, and August–October in the Colville East survey area between the Colville River and the western Kuparuk Oilfield.
- The timing of snow melt was about average in 2007. Significant snowfall on 5–6 May resulted in the greatest snow depth on record on 15 May at the Kuparuk airstrip, but the snow began melting rapidly by the end of May and was largely gone during the first week of June. Temperatures were slightly above average in early June.
- On the first calving survey (2–5 June), 791 caribou were observed, including 71 calves (9%), among the 3 calving survey areas. Applying a correction factor to adjust the early June counts for low sightability caused by patchy snow cover and expanding the counts to include the entire survey area resulted in a total estimate (± 80% confidence interval [CI]) of 2,702 ± 723 large (adult + yearling) caribou and a mean density of 0.83 ± 0.22 large caribou/km² among all 3 survey areas.
- On the second calving survey (10–12 June), 7,989 caribou were observed, including 1,948 calves (24%), among the 3 survey areas, resulting in an expanded total estimate of 15,978 ± 988 caribou (adults and calves) and a mean density of 4.91 ± 0.30 caribou/km². The highest calving density in 2007 occurred in the Colville East survey area and were the highest recorded since surveys began in 1993.
- Calf production by the western segment of the CAH was estimated at 73.9 calves:100 cows (n = 5,085 caribou) on 13 June, slightly higher than the mean annual production estimated during 1978–2007 (73.2 calves:100 cows). Calf production has exceeded 70 calves:100 cows in 11 of the last 12 years.
- On 10 June 2007, 226 caribou were estimated to be in the Kuparuk Field survey area, of which 50 caribou (including 7 calves) were estimated to be north of the Spine Road and east of the Oliktok Point Road.
- Mean daily temperatures at the Kuparuk airstrip were below average in June, close to average in July, and above average in early August. Temperature and wind speed data for 2007 suggest that activity by mosquitoes and oestrid flies was low to average early in the summer and slightly greater than average in August.
- The densities of caribou in the Colville East survey area outside of the calving season were low to moderate on 15 May, high in late June, low in August, and increased again in September and October. The mean density for May–October surveys in 2007 (1.10 caribou/km²) was higher than the densities observed during 2001–2006 (0.07–0.75 caribou/km²), resulting mainly from high densities on 2 postcalving surveys in late June.
- Between early May and mid-October 2003, 17 sightings of muskoxen were recorded in the study area. A mixed-sex group numbering up to 19 animals was found near the Colville River; no calves were observed with this group. Large mixed-sex groups totaling at least 34 animals were found near the Kuparuk River; a maximum of 2 calves were observed at one time with Kuparuk River groups.

- Sixteen grizzly bear sightings, totaling 18 adults and 11 cubs, were recorded within 75 km of the coast in the Kuparuk–Colville region during the 2007 aerial surveys. Five polar bear sightings, totaling 5 adults and 4 cubs, were observed on or near the Kuparuk and Colville river deltas during a swan survey on 21 August. No moose, wolves, or wolverines were observed on aerial surveys in 2007.

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ACKNOWLEDGMENTS

This study was funded by ConocoPhillips Alaska, Inc. (CPAI) and the Greater Kuparuk Area owners, and was administered by Caryn Rea, Senior Staff Biologist for CPAI, for whose support we are grateful. CPAI environmental personnel working at Kuparuk—especially senior environmental coordinators Jeanette Moser, Henry Platt, Shannon Donnelly, and Jeff Smith—provided assistance and support. Valuable logistical support in the field was provided by Mary Mae Aschoff and Justin Blank.

Robert Wing, Bob Eubank, Bob Mumford, and Sandy Hamilton (Arctic Air Alaska) and Bill Saathoff (Maritime Helicopters) provided safe and efficient piloting of survey aircraft under flying conditions that often were less than optimal. Dedicated assistance in the field was provided by ABR employees Jeremy Maguire, Tim Obritschkewitsch, Pamela Seiser, Torsten Bentzen, and Mathias Eriksson. Excellent support during data collection, analysis, and report preparation was provided by Allison Zusi–Cobb, Will Lentz, Matt Macander, Tony LaCortiglia, and Pamela Odom. Robert Burgess and Caryn Rea reviewed the draft report.

INTRODUCTION

Four herds of barren-ground caribou (*Rangifer tarandus granti*) inhabit Alaska north of the Brooks Range. These four herds vary in their use of calving, insect-relief, and wintering ranges (Murphy and Lawhead 2000). The Western Arctic Herd (WAH) is currently the largest herd in Alaska, estimated by the Alaska Department of Fish and Game (ADFG) at 490,000 caribou in July 2003 (Dau 2005); a photocensus was conducted in July 2007 but the results are not yet available. The WAH calves in the Utukok uplands of the western Brooks Range, moves into the western Brooks Range during the insect season, and migrates south long distances to winter in western Alaska. The Teshekpuk Herd (TH) calves near Teshekpuk Lake, about 130 km west of Kuparuk, uses coastal habitats as well as some inland sites for insect relief, and generally winters on the Arctic Coastal Plain. The Central Arctic Herd (CAH) calves on the coastal plain between the Colville and Canning rivers, uses coastal areas for insect relief, and winters in the Brooks Range, mainly in the southern foothills in recent years (Arthur and Del Vecchio 2007). The Porcupine Herd (PH) typically calves in the northeastern corner of Alaska in the Arctic National Wildlife Refuge (ANWR) and the adjacent Yukon (Griffith et al. 2002), moves into the Brooks Range for insect relief (Walsh et al. 1992), and winters in the northern Yukon and the eastern Brooks Range in Alaska (Griffith et al. 2002).

The CAH is the primary herd using the oilfield region on the central coastal plain. From the early 1970s to 2002, the CAH grew at an overall rate of 7% per year. The herd grew rapidly from about 5000 animals in the mid-1970s (Lenart 2001) to the early 1990s, reaching a count of 23,444 caribou in July 1992 (Taylor 1993) before declining 23% to 18,093 caribou in July 1995 (Woolington 1995). In July 1997, the herd was estimated at 19,730 animals (Lenart 1999). The herd has increased at an average annual rate of 8.5% since 1995, reaching 27,128 in July 2000 and 31,857 in July 2002, the most recent photocensus (Lenart 2001, 2003). The 2002 count was the maximum size recorded to date for the CAH. A photocensus was planned for 2007 by ADFG but could not be accomplished due to time and logistical constraints.

Similar to the CAH, the WAH and TH increased substantially in size since the mid-1970s (Murphy and Lawhead 2000). The TH experienced a dip in numbers in the early to mid-1990s similar to that seen in the CAH, but increased steadily since 1995 to its peak count of 45,166 in the most recent census in July 2002 (Carroll 2003). A photocensus of the TH was begun in July 2007 but had to be suspended due to poor weather conditions (L. Parrett, ADFG, pers. comm.). In contrast to the other three herds, the PH decreased steadily in size for more than a decade, from a high of ~178,000 animals in 1989 to ~123,000 in the most recent estimate in July 2001 (Griffith et al. 2002). A photocensus of the PH was flown in July 2007 but the quality of some photos was poor due to mountain shadows (S. Arthur, ADFG, pers comm.).

The Kuparuk Oilfield and surrounding area (known as the Greater Kuparuk Area, or GKA) is located on the outer coastal plain in the western portion of the summer range of the CAH. Since 1978, shortly before development of the Kuparuk Oilfield, considerable interest has focused on the use of the oilfield and surrounding area (particularly the Milne Point Unit) by the CAH during calving. The Kuparuk–Milne Point area is one of two locales (the other being the Bullen Point area east of the Prudhoe Bay Oilfield) that consistently received concentrated use during the calving season from the late 1970s to the late 1980s, as determined by systematic aerial surveys beginning in 1978 (Whitten and Cameron 1985, Lawhead and Cameron 1988). Studies by ADFG (Dau and Cameron 1986, Cameron et al. 1992) reported local avoidance of oilfield facilities and human activities by cows with young calves in this general concentration area during the calving season. From 1978 through 1992, ADFG conducted aerial transect surveys of caribou distribution annually during the latter portion of the calving season (usually 10–15 June). After 1992, however, that annual effort was cut back because of budget constraints; ADFG's next transect survey was conducted in June 1997 and another was conducted in June 2000. ABR has conducted similar calving surveys of the western segment of

the CAH every year since 1993 (except 1994), as well as conducting calving surveys in the region in several earlier years (1983, 1984, 1987).

The data from transect and reconnaissance surveys described in this report complement the data from ADFG telemetry studies. Since 1992, ADFG survey efforts have focused primarily on tracking radio-collared female caribou, following a known-age sample of up to 60–80 radio-collared cows annually (Arthur and Del Vecchio 2007; E. Lenart and S. Arthur, ADFG, pers. comm.). In 2007, 69 conventional VHF radio-collars were transmitting on CAH females (E. Lenart, ADFG, pers. comm.), including 61 adults (age 3 years or older) and 8 2-yr-olds. During 2001–2004, 60–65 newborn calves were outfitted annually with VHF collars by ADFG, supported by funding from ConocoPhillips Alaska, Inc. (CPAI), to study calf growth rates and survival (Arthur and Del Vecchio 2007).

In late July 2001, 10 female CAH caribou were outfitted with satellite collars by ADFG, in a cooperative study with the North Slope Borough (NSB) Department of Wildlife Management and the U.S. Bureau of Land Management (BLM), to study distribution and movements of the herd throughout the year (G. Carroll, ADFG, pers. comm.). In March 2003, 26 Global Positioning System (GPS) collars were placed on CAH caribou by ADFG to track the movements of specific caribou in relation to oilfield infrastructure (Arthur and Del Vecchio 2007). Another 27 GPS collars were deployed in March 2004 and 4 more were deployed in March 2006 (Arthur and Del Vecchio 2007). GPS collars on 29 females in the CAH still were transmitting in summer 2006 (S. Arthur, ADFG, pers. comm.), but no GPS or satellite collars were active on CAH caribou in 2007.

This study was conducted under contract to CPAI to fulfill the mandate for ongoing caribou research in the Kuparuk River Unit Agreement by monitoring the distribution and abundance of caribou in and near the Kuparuk Oilfield in 2007. Work was conducted primarily during the caribou calving season and secondarily during late winter, late summer, and fall in the area between the Kuparuk Oilfield and the Colville River delta; the surveys in 2007 did not cover the insect season.

Although the impetus for this study was caribou research, the extensive aerial-survey coverage provided an opportunity to record data on the distribution and abundance of muskoxen (*Ovibos moschatus*) and brown (grizzly) bears (*Ursus arctos*) as well.

The 2007 study had four objectives:

- Document the distribution and abundance of caribou in the region between the Kuparuk and Colville rivers during the calving season (early to mid-June);
- Sample the sex and age composition of caribou in the Kuparuk–Colville region at the end of the calving season (mid-June) to quantify initial calf production;
- Record the distribution and abundance of caribou between the Colville River delta and the Kuparuk Oilfield during spring, late summer, and fall; and
- Record the distribution and abundance of other large mammals encountered during caribou surveys in the Kuparuk–Colville region.

STUDY AREA

The study area extended east from the Colville River delta to the Kuparuk River, and north from about latitude 70º N to the Beaufort Sea coast (Figure 1). This area encompassed the entire Kuparuk Oilfield; the Alpine Project pipeline corridor between the Kuparuk Oilfield and Colville River delta; the Milne Point Oilfield; and the western Prudhoe Bay Oilfield (west of the Kuparuk River). Aerial surveys of caribou calving were conducted in three survey areas: (1) the Kuparuk Field survey area (1,035 km²), including the Kuparuk and Milne Point oilfields from Kalubik Creek east to the Kuparuk River; (2) the Kuparuk South survey area (788 km²), located south of the Kuparuk Oilfield; and (3) the Colville East survey area (1,432 km²), located between the Colville River and the western Kuparuk Oilfield.

The calving survey areas have been modified slightly over the years to optimize survey effort in areas of consistently higher use. In 2002, the westernmost transect of the Colville East survey area and the two easternmost transects of the Kuparuk Field survey area were dropped and the Kuparuk South survey area was extended eastward to the Kuparuk River. The net result was an

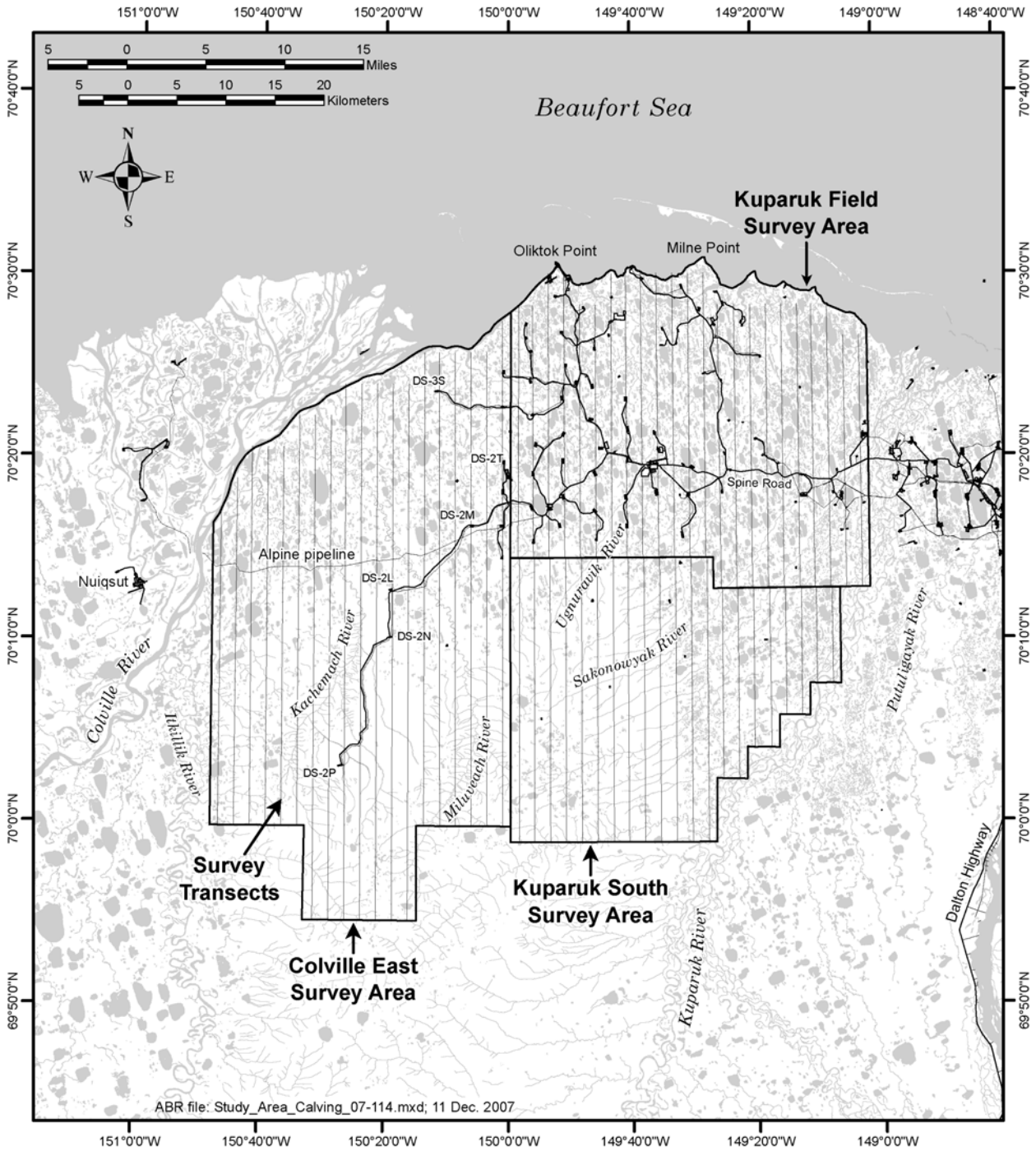


Figure 1. Survey areas and transect lines for systematic aerial surveys of caribou in the Kuparuk–Colville region, northern Alaska, during the 2007 calving season.

expansion of total coverage from 3,188 to 3,255 km².

Surveys during late summer–fall covered the Colville East survey area, which was extended in the southwestern and southeastern corners to form a rectangle on the southern end for this survey period (thereby expanding the survey area to 1,700 km²).

The landscape in the Kuparuk–Colville region slopes down gently from upland, moist tussock tundra in the upper reaches of the Sakonowyak, Ugnuravik, Kalubik, Miluveach, and Kachemach drainages to moist and wet coastal tundra near the coast. The study area is characterized by permafrost-related features, such as oriented thaw-lakes, drained-lake basins, beaded streams, and pingos. The physiography, vegetation, and climate of the central Arctic Coastal Plain were described by Walker et al. (1980).

METHODS

CARIBOU CALVING SEASON

Two systematic aerial surveys of caribou distribution and numbers were conducted in the Kuparuk Field, Kuparuk South, and Colville East survey areas in 2007 (Figure 1): one near the peak of calving (2–5 June) and one a week later (10–12 June). The surveys were scheduled during the same date ranges as those conducted in previous years in early and mid-June (1–8 and 9–16 June, respectively, in 1993 and 1995–2006; Appendix A). Caribou were counted by two observers looking on opposite sides of a Cessna 206 airplane; a third observer recorded data on the second set of surveys (10–12 June). In each survey area, the pilot navigated along north–south-oriented transect lines using coordinates loaded into a GPS receiver. The pilot maintained the aircraft speed at ~150 km/h and the altitude at ~90 m (300 ft) above ground level (agl) using a radar altimeter. Transect lines were spaced at intervals of 1.6 km (1 mi), following section lines on U.S. Geological Survey topographic maps.

Observers counted caribou within a 400-m-wide strip on each side of the flight line, for a sampling intensity of 50% (0.8 km of each 1.6 km). The strip width was delimited visually using tape markers on the struts and windows of the aircraft, following the method of Pennycuick and Western (1972). Tape markers were positioned to indicate distances of 200 m and 400 m from the inner edge of the strip. For each caribou group observed within the strip, the location was recorded using a GPS receiver, the number of adults and calves were recorded, and the group was assigned to a distance category (one of four 100-m zones). For production of map figures, caribou were assigned to the midpoint of the distance zone (i.e., 50, 150, 250, 350 m) in which they were seen. For color maps of calving density (described below), caribou groups were pooled into the same 3.2-km-long transect segments used in previous years (Lawhead and Prichard 2007) for comparative purposes.

The percentage of ground surface covered by snow was estimated visually in the survey area as an index to survey conditions. The patchy background of snow and bare ground resulting from spring snowmelt is the most important factor diminishing sightability—defined as "the probability that an animal within the observer's field of search will be seen by that observer" (Caughley 1974: 923)—during the calving season (Lawhead and Cameron 1988). One way to adjust counts made during poor viewing conditions is to estimate sightability using a double-survey technique and then calculate a sightability correction factor (SCF) for post-survey adjustment of counts (Gasaway et al. 1986). In 1993, an SCF (1.88) for large caribou was calculated for patchy (20–70%) snow cover during calving season surveys (Lawhead et al. 1994); no SCF was available for calf counts. We applied the SCF for large caribou to the counts from the early calving season survey (2–5 June 2007) because of patchy snow cover in the first week of June. By the time of our second calving survey (10–12 June), nearly all snow had melted and sightability was high enough that use of the SCF was not necessary.

Population estimates for total caribou and for calves were extrapolated from their respective counts and standard errors using formulas modified from Gasaway et al. (1986). Because surveys covered 50% of the study area, the "observable population" (i.e., the estimated number of caribou in the entire survey area) was estimated by doubling the number of caribou observed. In this report, these estimates are followed by an 80% confidence interval (CI); for example, an observable population estimate of 70 ± 30 caribou means that the 80% CI ranges from 40 to 100 caribou.

Because the transect survey method using fixed-wing aircraft tends to undercount calves, a helicopter (Bell 206-LIII "Long Ranger") was used

to sample the sex and age composition (cows, calves, yearlings, and bulls) of caribou groups in portions of all three survey areas on 13 June 2007. Helicopter speed ranged from 40 to 125 km/h (slowing frequently to observe groups closely) and altitude ranged from 30 to 60 m (100–200 ft) agl to facilitate accurate identification of sex and age classes. We followed a nonsystematic survey path on this survey to maximize the number of groups encountered, using a GPS receiver to avoid duplicate counts, and making an effort to include areas of both high-density (concentrated) calving and low-density peripheral areas, based on the distribution surveys on 10–12 June.

To summarize calving distribution and abundance data from early and mid-June (1–8 and 9–16 June), we used the inverse distance-weighted (IDW) interpolation technique of the *Spatial Analyst* extension of *ArcView* GIS software (Environmental Systems Research Institute, Inc. [ESRI], Redlands, CA) to map caribou densities in 2007 and over all years (1993 and 1995–2007). This analysis used the total numbers of caribou and of calves pooled in each 3.2×0.8-km segment of the transect strips; mean values were calculated for segments over all years. The IDW interpolation technique calculated a density surface using each segment centroid and the distance-weighted values for the 14 nearest centroids (200-m grid cells, power = 1). This analysis produced color maps showing surface models of the density of all caribou (large caribou + calves) and all calves observed over the entire survey area, to create an easily understood visual portrayal of the data.

CARIBOU SURVEYS IN SPRING AND LATE SUMMER–FALL

In addition to calving surveys, aerial transect surveys were conducted in the expanded Colville East survey area (1,700 km²) in early May, late June, August, and October. Surveys followed the same protocol as calving surveys, but because visibility was better (either complete snow cover or none), surveys were flown at ~150 m (500 ft) agl and caribou were recorded within an 800-m-wide strip on each side of the airplane. Transects were spaced at intervals of 3.2 km to maintain 50% sampling coverage.

OBSERVATIONS OF OTHER MAMMALS

Locations and numbers of large mammals other than caribou were noted and mapped as incidental observations during aerial surveys in the three calving survey areas and in the Colville East survey area during late summer–fall surveys. Additional observations were reported by observers conducting surveys for other species and by CPAI employees.

RESULTS AND DISCUSSION

CARIBOU CALVING SEASON

HABITAT AND SURVEY CONDITIONS

Air temperatures in spring 2007 were colder than average. Snow depth was close to the long-term average in early April, but significant snowfall on 5–6 May resulted in the snow depth on 15 May being the highest on record for the Kuparuk airstrip. The snow melted rapidly by the end of May and was largely gone by the first week of June (Figure 2, Appendix A). The average daily temperature at the Kuparuk airstrip did not exceed freezing until 4 June. The cumulative sum of thawing-degree days (TDD) was slightly above average in early June (Appendix A).

Snow cover was patchy during the first calving surveys on 2–5 June. The complex visual pattern created by snowmelt required adjustment of those counts for low sightability using the SCF for large caribou (Lawhead et al. 1994). Most of the snow cover had melted in the survey areas by the time of the second calving surveys on 10–12 June. The snow remaining at that time consisted mostly of deep linear drifts along upland drainages and lake edges and was not great enough to warrant use of the SCF.

DISTRIBUTION AND ABUNDANCE IN 2007

The number of caribou in the calving survey areas increased substantially between the early and mid-June surveys, as a result of both poor sightability early on and continued movement of caribou into the survey areas.

During 2–5 June, we counted 791 caribou, including 71 calves (9%), in all three calving survey areas combined. During 10–12 June, we counted 7,989 caribou, including 1,948 calves (24%), in all 3 areas. Doubling these 50% sampling

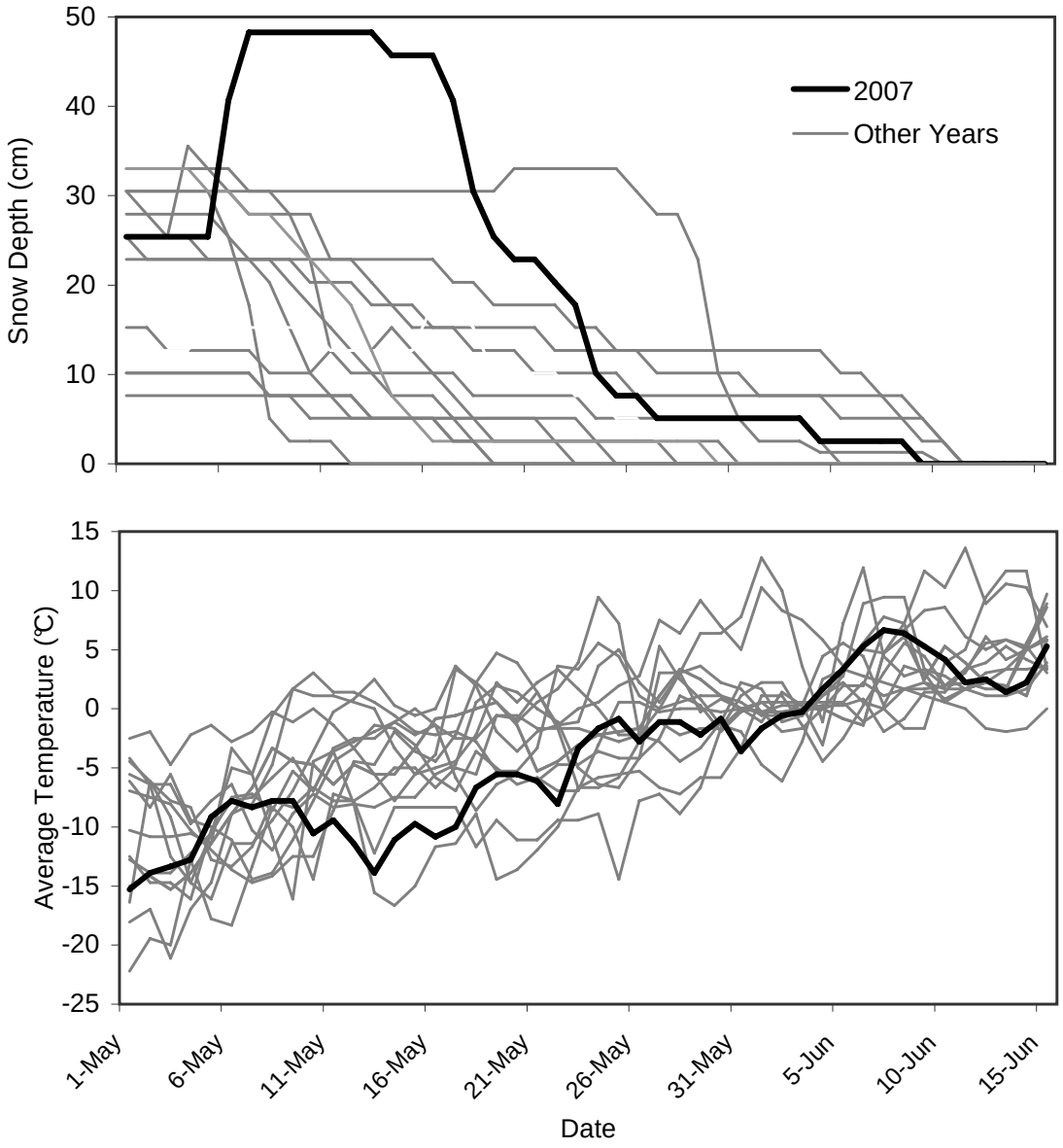


Figure 2. Snow depth (cm) and average daily temperature (° C) at the Kuparuk airstrip during 1 May–15 June 2007, compared with 1993 and 1995–2006.

counts and applying the SCF to the early June counts produced population estimates of 2,702 ± 723 large caribou among all three survey areas in early June, compared with 12,082 ± 735 large caribou and 3,896 ± 275 calves in mid-June (Table 1).

The average densities among all three survey areas combined were 0.83 ± 0.22 large caribou/km² in early June and 3.71 ± 0.23 large caribou/km² (4.91± 0.30 total caribou/km²) in mid-June (Table 2). The density of caribou was highest near the common border of the Colville East and Kuparuk South survey areas. The density of large caribou in Kuparuk South and Colville East on both surveys was 6–13 times higher than in the Kuparuk Field survey area (Figures 3–8, Table 2).

Compared with previous years, the overall number and density of caribou in mid-June were greater than average in the Kuparuk South and Colville East survey areas and the greatest numbers

Table 1. Estimated numbers of caribou (±80% CI) during the 2007 calving season in the Colville East, Kuparuk South, and Kuparuk Field survey areas, Alaska.

Survey Area	Date	Total Area (km²)	Unadjusted Estimate [a]			SCF-Adjusted (Large Only)[c]
			Total	Large [b]	Calves	
Colville East	June 2, 4–5	1,432	1,218 ± 87	1,116 ± 77	102 ± 17	2,094 ± 563
	June 11–12	1,432	10,626 ± 765	8,030 ± 570	2,596 ± 217	
Kuparuk South	June 4–5	788	300 ± 36	264 ± 32	36 ± 10	495 ±142
	June 10–11	788	4,900 ± 508	3,660 ± 374	1,240 ± 141	
Kuparuk Field	June 3–4	1,035	64 ± 17	60 ± 16	4 ± 3	113 ± 42
	June 10	1,035	452 ± 63	392 ± 55	60 ± 13	
Total	June 2–5	3,255	1,582 ± 103	1,440 ± 93	142 ±20	2,702 ± 723
	June 10–12	3,255	15,978 ± 988	12,082 ± 735	3,896 ± 275	

[a] Estimates are actual counts multiplied by 2 to account for 50% sampling intensity.
[b] Adults + yearlings.
[c] Applied Sightability Correction Factor of 1.88 (Lawhead et al. 1994).

Table 2. Estimated density of caribou (number per km² ±80% CI) in the Colville East, Kuparuk South, and Kuparuk Field survey areas, June 2007.

Survey Area	Date	Unadjusted Density			SCF-Adjusted (Large Only)[b]
		Total	Large [a]	Calves	
Colville East	June 2, 4–5	0.85 ± 0.06	0.78 ± 0.05	0.07 ± 0.01	1.46 ± 0.39
	June 11–12	7.42 ± 0.53	5.16 ± 0.40	1.81 ± 0.15	
Kuparuk South	June 4–5	0.38 ± 0.05	0.34 ± 0.04	0.05 ± 0.01	0.63 ± 0.18
	June 10–11	6.22 ± 0.64	4.64 ± 0.47	1.57 ± 0.18	
Kuparuk Field	June 3–4	0.06 ± 0.02	0.06 ± 0.02	0.00 ± 0.00	0.11 ± 0.04
	June 10	0.44 ± 0.06	0.38 ± 0.05	0.06 ± 0.01	
Total	June 2–5	0.49 ± 0.03	0.44 ± 0.03	0.04 ± 0.01	0.83 ± 0.22
	June 10–12	4.91 ± 0.30	3.71 ± 0.23	1.20 ± 0.08	

[a] Adults + yearlings.
[b] Applied Sightability Correction Factor of 1.88 (Lawhead et al. 1994).

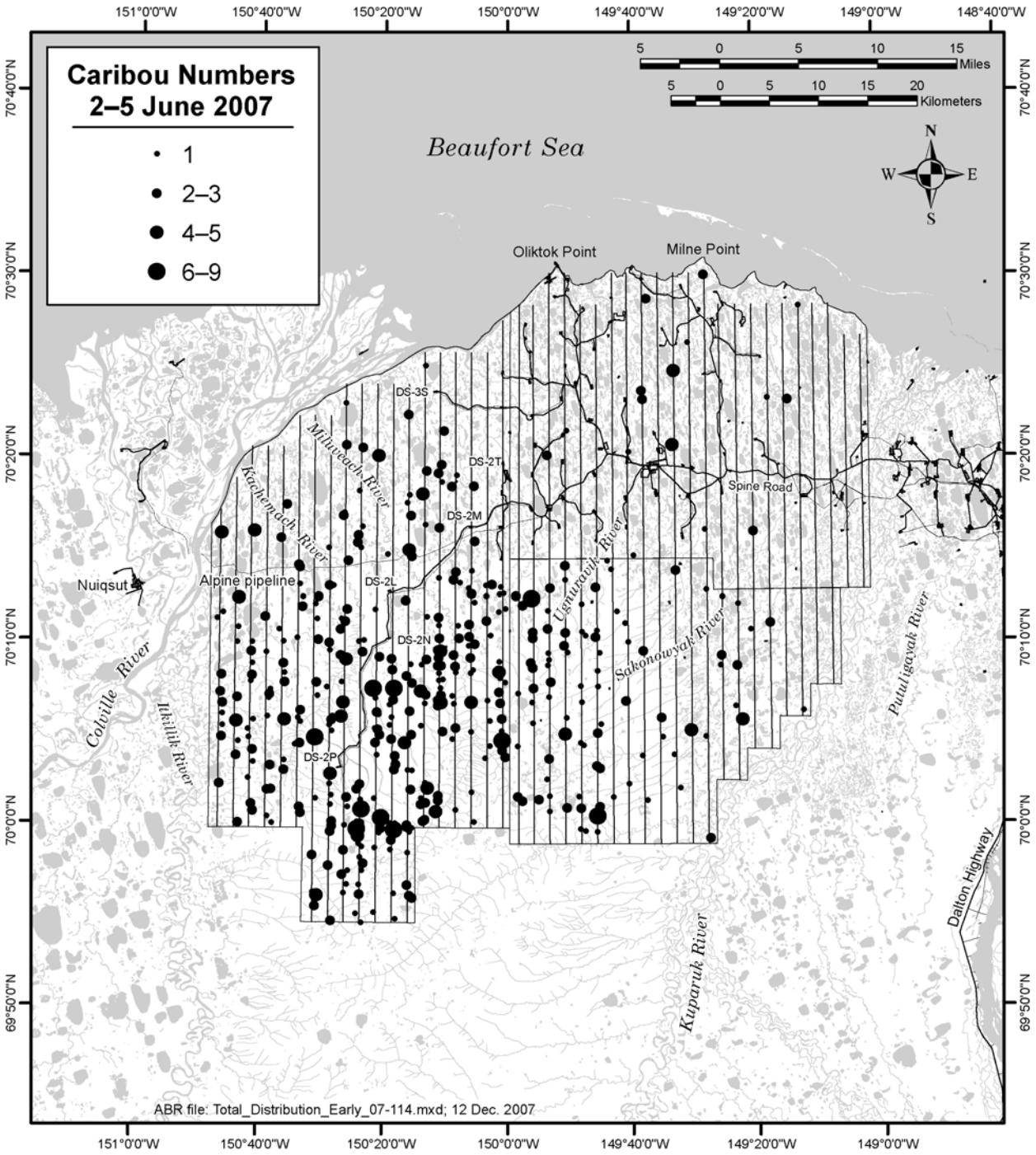


Figure 3. Distribution and group size of all caribou (adults and calves) in the Kuparuk–Colville calving survey areas, 2–5 June 2007.

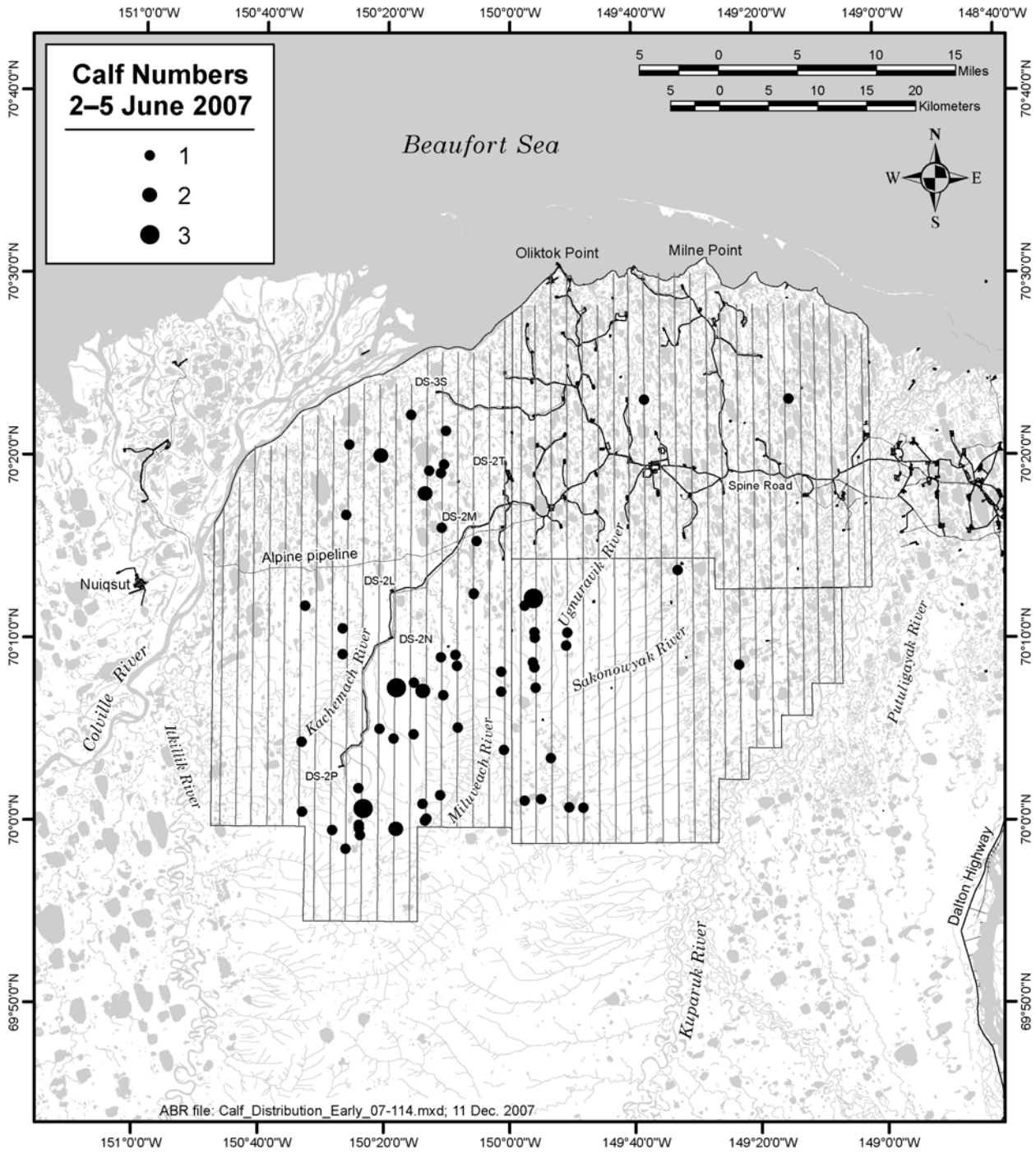


Figure 4. Distribution and number of calf caribou in the Kuparuk–Colville calving survey areas, 2–5 June 2007.

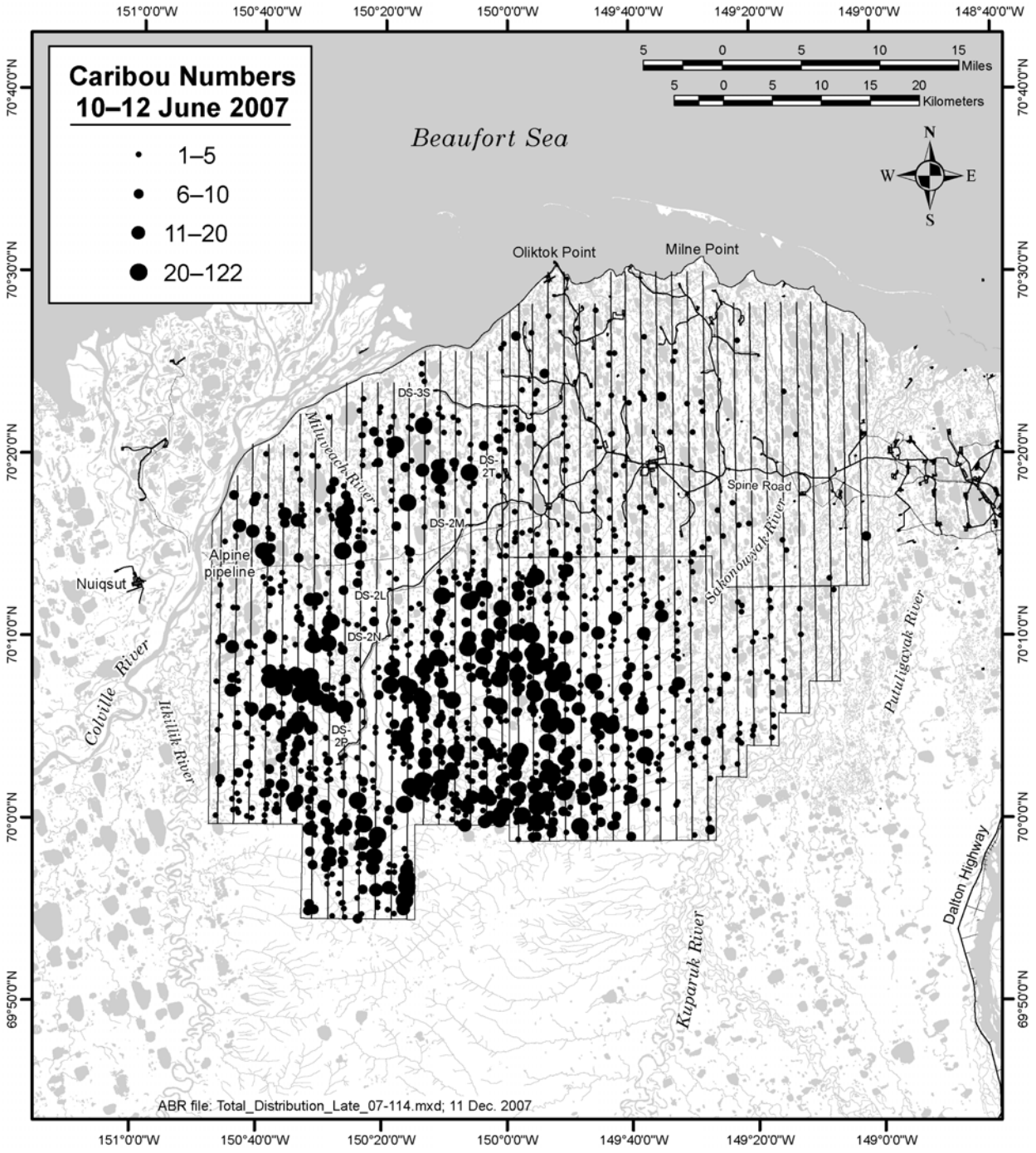


Figure 5. Distribution and group size of all caribou (adults and calves) in the Kuparuk–Colville calving survey areas, 10–12 June 2007.

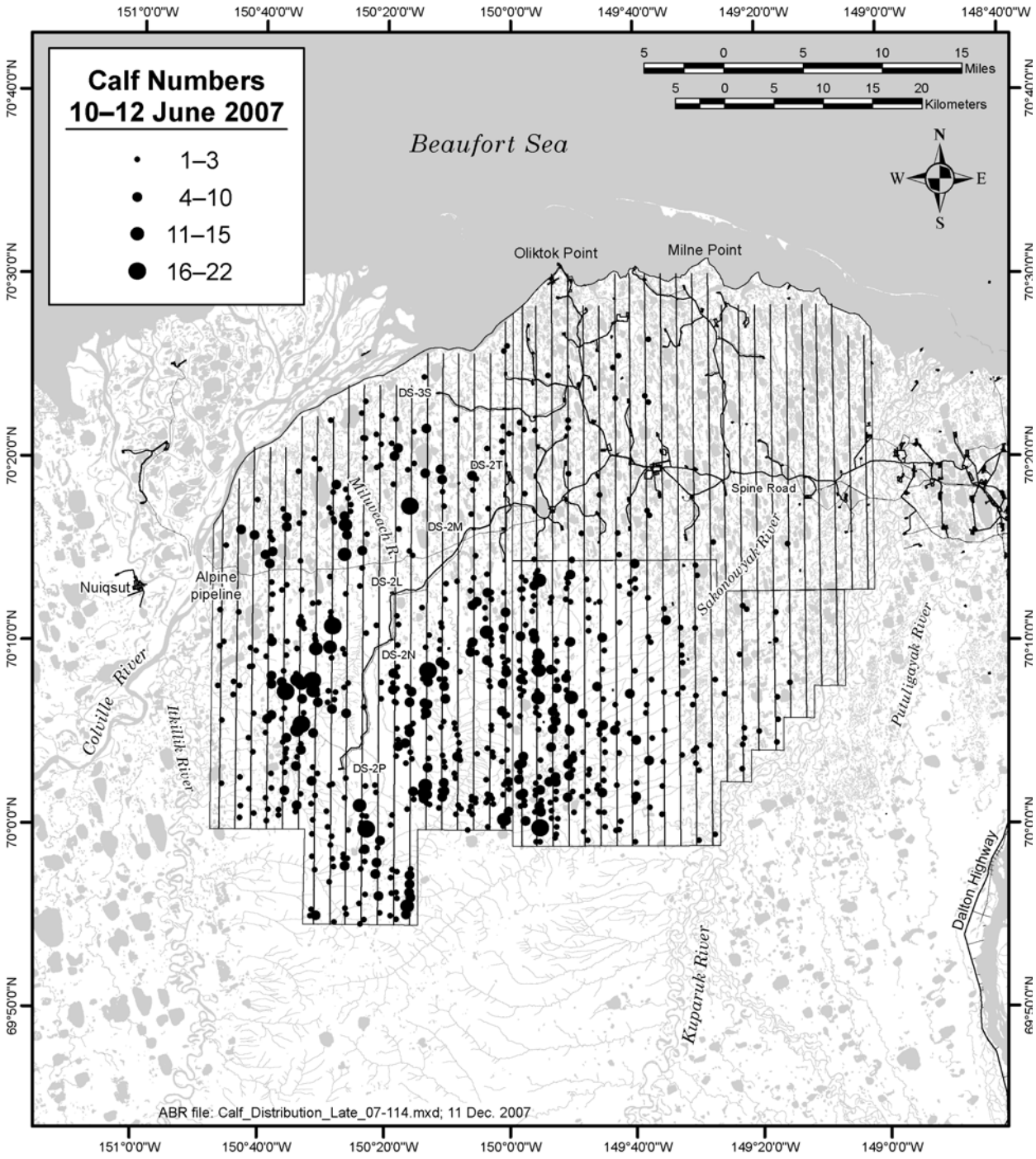


Figure 6. Distribution and number of calf caribou in the Kuparuk–Colville calving survey areas, 10–12 June 2007.

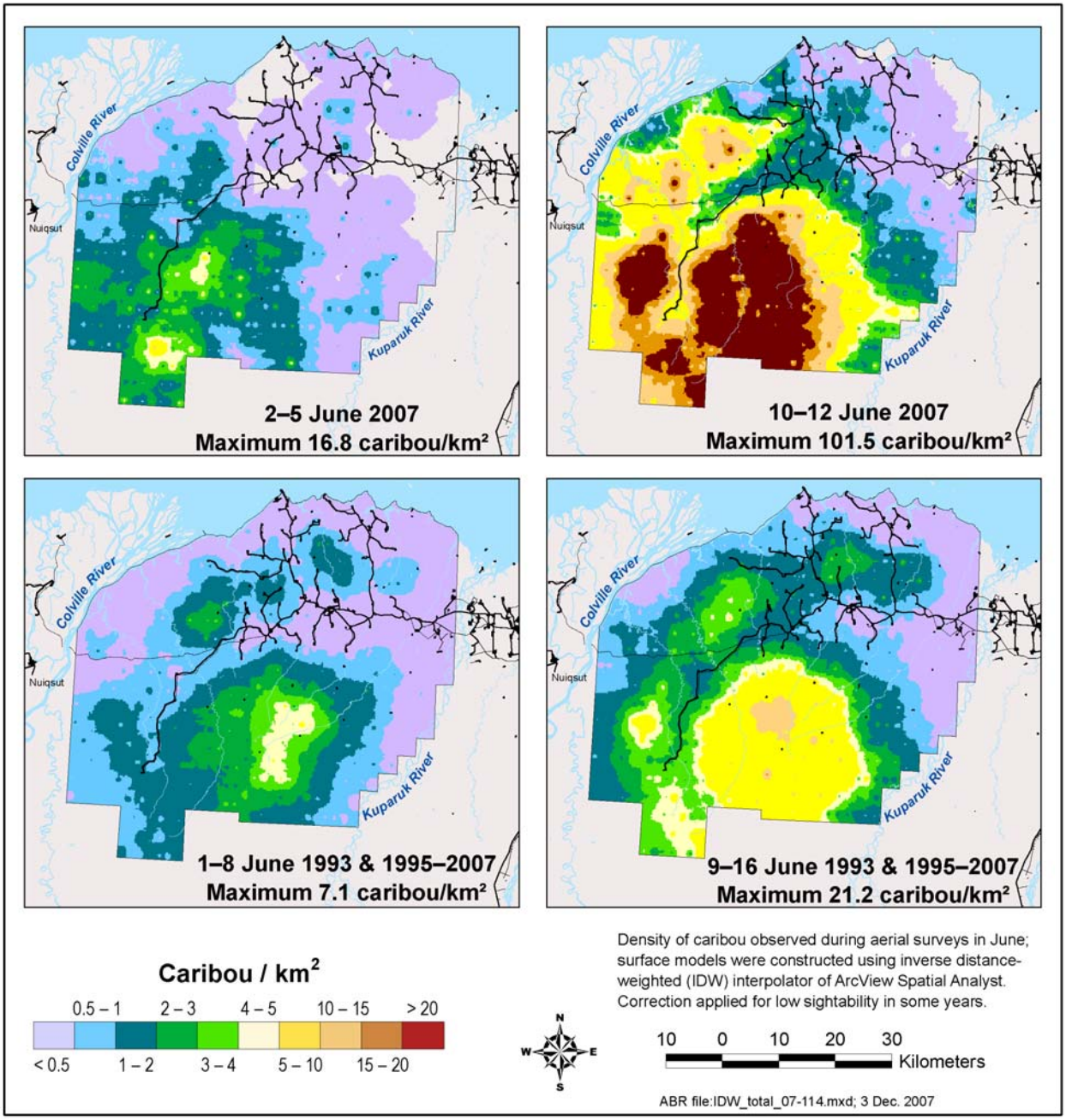


Figure 7. Distribution and density of all caribou in the Kuparuk–Colville calving survey areas during 2–5 June and 10–12 June 2007 (top) and distribution and mean density of all caribou during early June and mid-June in the Kuparuk–Colville calving survey areas, 1993 and 1995–2007 (bottom).

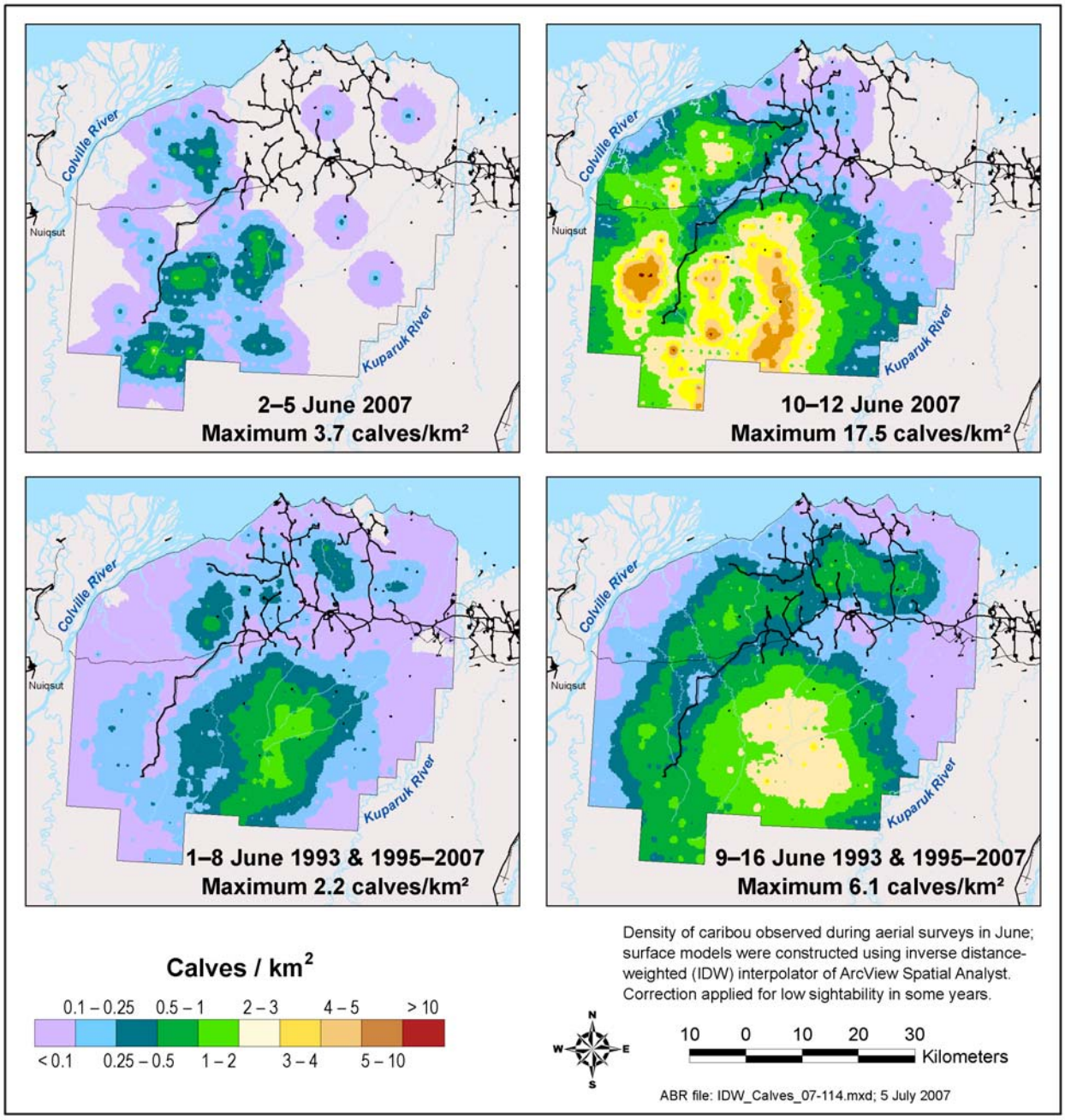


Figure 8. Distribution and density of calf caribou in the Kuparuk–Colville calving survey areas during 2–5 June and 10–12 June 2007 (top) and distribution and mean density of calf caribou during early June and mid-June in the Kuparuk–Colville calving survey areas, 1993 and 1995–2007 (bottom).

and density were recorded in the Colville East survey area, which had the highest number and densities recorded since 1993 (Table 3, Appendix B). In 2007 the high-density calving area was again farther west than has been seen in most years since 1993, similar to the distribution in 2003–2005 when the highest densities during calving occurred in the Colville East survey area. In contrast, the distribution in 2006 was closer to the typical pattern seen in most years since 1993 with the highest density calving in the Kuparuk South survey area (Lawhead and Prichard 2007).

In 2007, very few caribou were observed in the Kuparuk Field survey area during calving and the density was far below the long-term average, even though the densities in the other two survey areas were very high (Table 3, Appendix B). On 10 June, 50 of the caribou (including 7 calves) counted in the Kuparuk Field survey area (22% of the total number and 23% of the calves) were located north of the Spine Road and east of the Oliktok Point Road, an area encompassing ~50% of the Kuparuk Field survey area. The proportion of cows recorded in this area was the lowest seen in the last decade. The proportions north and east of those roads averaged 53% of total caribou and 54% of calves between 1996 and 2006, within a wide range (28–77% of total and 22–86% of calves; Lawhead et al. 1997, 1998; Lawhead 1999; Lawhead and Johnson 2000; Lawhead and Prichard 2001, 2002, 2003a, 2003b, 2005, 2006, 2007). These proportions have decreased from 70% in the mid- to late 1990s, to 50% or less since 2002, and 22% this year. In most former years, the area north and east of those roads received consistent low-density use annually by several hundred cows exhibiting average to high levels of calf production, with fewer yearlings and bulls than in areas farther south at that season.

CALVING DISTRIBUTION AND DENSITY SINCE 1993

For comparative purposes, annual data were compiled from calving surveys in 1993 (Lawhead et al. 1994, Smith et al. 1994) and 1995–2007 (Johnson et al. 1996, 1997, 1998; Lawhead et al. 1997, 1998; Lawhead 1999; Lawhead and Johnson 2000; Lawhead and Prichard 2001, 2002, 2003a,

Table 3. Estimated density of caribou (number per km²) in the Colville East, Kuparuk Field, and Kuparuk South survey areas in mid-June 1993 and 1995–2007.

	Colville East		Kuparuk Field		Kuparuk South		Timing of
Year	Total	Calves	Total	Calves	Total	Calves	Snow Melt
1993	2.40	0.61	0.65	0.16	–	–	Intermediate
1995	1.52	0.23	–	–	5.05	0.97	Intermediate
1996	1.97	0.58	2.16	0.79	7.25	2.62	Early
1997*	3.05	0.92	0.28	0.07	2.40	0.69	Late
1998	1.39	0.23	0.62	0.18	10.22	3.68	Early
1999	1.47	0.37	1.17	0.41	3.26	1.03	Late
2000*	0.65	0.13	0.36	0.09	0.53	0.14	Late
2001	0.78	0.13	0.60	0.15	3.54	1.01	Late
2002	4.35	0.72	0.86	0.22	6.06	1.48	Early
2003	1.95	0.43	0.48	0.14	1.69	0.46	Intermediate
2004	5.28	1.73	0.56	0.17	3.63	1.06	Intermediate
2005	1.92	0.51	0.07	0.02	0.30	0.09	Intermediate
2006	2.83	0.71	0.88	0.24	10.61	3.14	Intermediate
2007	7.42	1.81	0.44	0.06	6.22	1.57	Intermediate
Mean	2.64	0.65	0.70	0.21	4.67	1.38	

* Applied Sightability Correction Factor of 1.88 (Lawhead et al. 1994).

2003b, 2005, 2006, 2007, this study). These annual data were used to generate mean values over the entire 14-yr period for each 3.2-km transect segment (Figures 7 and 8; note that some portions of the study area had fewer years of data). The corresponding observable population estimates and calculations of density in each area depict the variability in numbers and densities among areas and years (Appendix B). The summary data since 1993 demonstrate that the area of greatest calving activity (in terms of caribou distribution and density) consistently was located south or southwest of the Kuparuk Oilfield (Figures 7 and 8).

In general, the historically used Kuparuk–Milne concentration area continued to be used at levels within the range observed during 1979–1987 (~300–2,100 caribou north of the Spine Road; Figure 6 in Cameron 1994), although high numbers have not been seen in the Kuparuk Field survey area since 1996 (Appendix B) and the density of calving caribou in the area surrounding the Milne Point Road has declined since the 1980s (Noel et al. 2004). In mid-June 2007, we estimated that 452 caribou were present in the Kuparuk Field survey area, less than one fifth of the peak number in 1996. The estimated numbers in the Kuparuk Field survey area during our mid-June surveys in 1993 and 1995–2007 ranged from 54 to 2,458 caribou (Appendix B).

An additional area of locally high densities during the calving season was located northwest of CPF-2 and south of DS-3S (Figures 7 and 8), the newest Kuparuk drill site, which was constructed during late winter 2002. Caribou density in that area during the calving season was low in 2000 and 2001, but increased during 2002–2007.

In most years since 1995, the mean density has been highest in the Kuparuk South survey area; however, in 2007 and several other recent years the highest calving densities occurred farther west in the Colville East survey area (Table 3). The highest density of calving animals has occurred in Colville East in 6 of the 13 years since 1995, including 2003–2005 (Table 3). In 2007 and other recent years, caribou densities were low in the area directly adjacent to the Tarn (DS-2N) and Meltwater roads (DS-2P), consistent with localized avoidance of the area within 2–4 km of roads during calving by maternal caribou (Lawhead et al. 2002, 2003, and 2004, Lawhead and Prichard 2005, 2006, 2007).

SEX AND AGE COMPOSITION AT CALVING

During the age and sex composition survey on 13 June 2007, we counted 5,085 caribou in portions of the Kuparuk Field, Kuparuk South, and Colville East survey areas and adjacent areas nearby (Figure 9). The sample comprised 2,768 cows, 2,045 calves, 267 yearlings, and 5 adult bulls (Table 4). Based on this count, our estimate of initial calf production in 2007 was 73.9 calves:100 cows for the western segment of the CAH. The calf:cow ratio north of the Spine Road (51.2 calves:100 cows) was not significantly lower than that south of the Spine Road (73.9 calves:100 cows; P = 0.166, Fisher's Exact Test). Yearlings composed 5.3% of the total composition sample, for an overall ratio of 9.6 yearlings:100 cows (Table 4). The yearling ratio north of the Spine Road (7.0 yearlings:100 cows) did not differ significantly from that south of the Spine Road (9.7 yearlings: 100 cows; P = 0.794, Fisher's Exact Test).

At 73.9 calves: 100 cows, our estimate of calf production by the western segment of the CAH in 2007 was just above the long-term average (73.2 calves:100 cows) for 1978–2007 (Figure 10). After a dip between the mid-1980s and mid-1990s, calf production increased in 1996 and has exceeded the long-term average in 11 of the last 12 years; the trend has declined slightly during that time but calf production remains high (Figure 10). The exception occurred in 2004, when some TH caribou also were present in the study area during the calving season (Lawhead and Prichard 2005). Our 2007 estimate is lower than ADFG's preliminary estimated parturition rate of 93% for adult cows (n = 59) and the late June survival count of 81 calves:100 cows (n = 57), based on radio-collared females aged 3 years and older (E. Lenart, ADFG, pers. comm.). Our estimated calf:cow ratio, obtained about a week and a half after the normal peak of calving during the first week of June, was more similar to ADFG's late June count, suggesting that most calf mortality in June occurred within the first 10 days following birth. Our estimate also classifies 2-year-olds as cows. Because 2-year olds have low rates of parturition, our calf estimate should be lower than

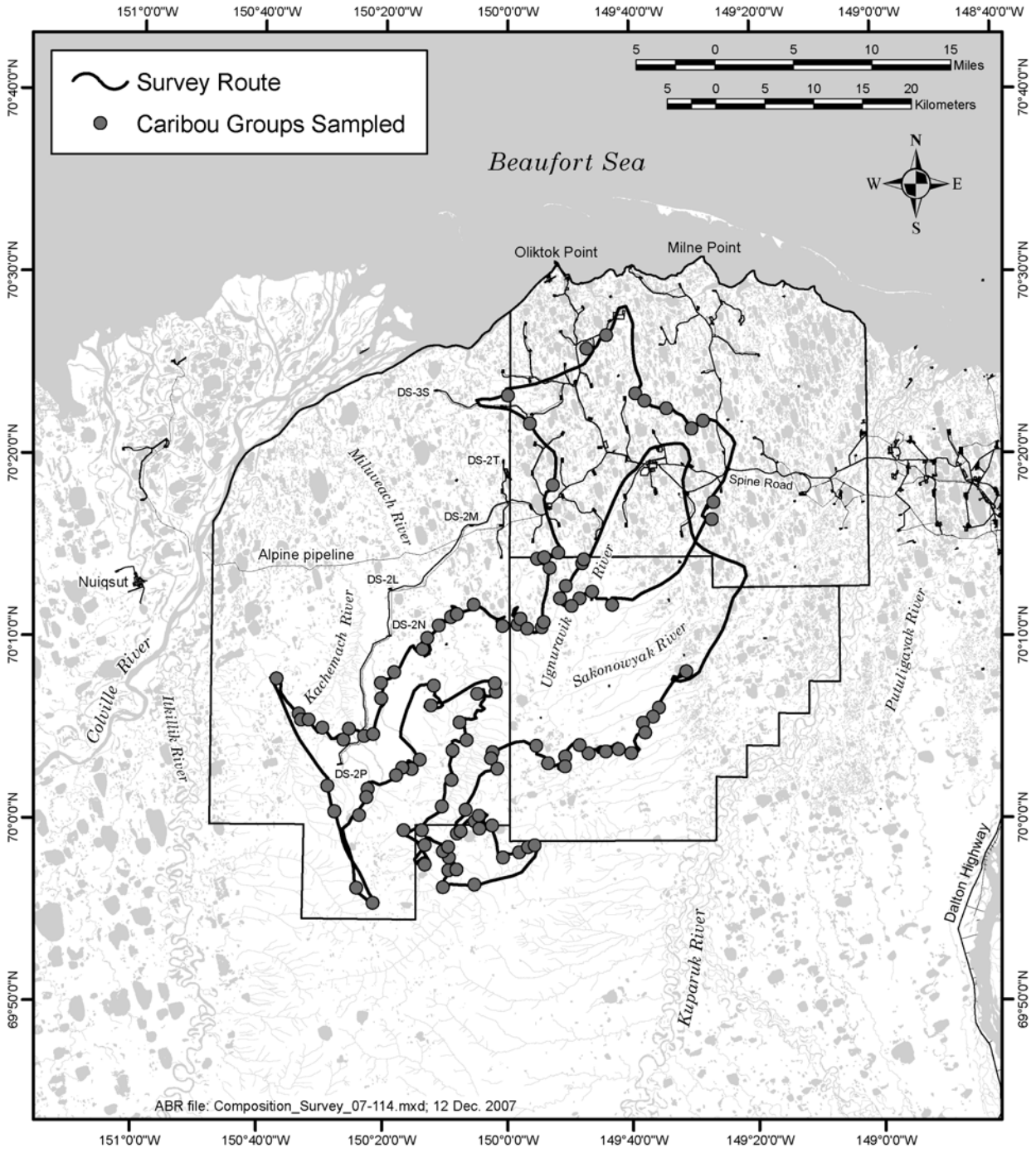


Figure 9. Route of aerial survey and location of groups sampled to quantify sex and age composition of caribou in the Kuparuk–Colville calving survey areas, 13 June 2007.

Table 4. Sex and age composition of caribou in the Kuparuk–Colville region on 13 June 2007.

Survey Area	No. of Groups	Total No.	Cows		Calves		Yearlings		Bulls		Calf Ratio [a]	Yrlg. Ratio [b]
			No.	%	No.	%	No.	%	No.	%		
North of Spine Rd.	10	68	43	63.2	22	32.4	3	4.4	0	0	51.2	7.0
South of Spine Rd.	98	5,017	2,725	54.3	2,023	40.3	264	5.3	5	0.1	74.2	9.7
Total	108	5,085	2,768	54.4	2,045	40.2	267	5.3	5	0.1	73.9	9.6

[a] Calves:100 cows.
[b] Yearlings:100 cows.

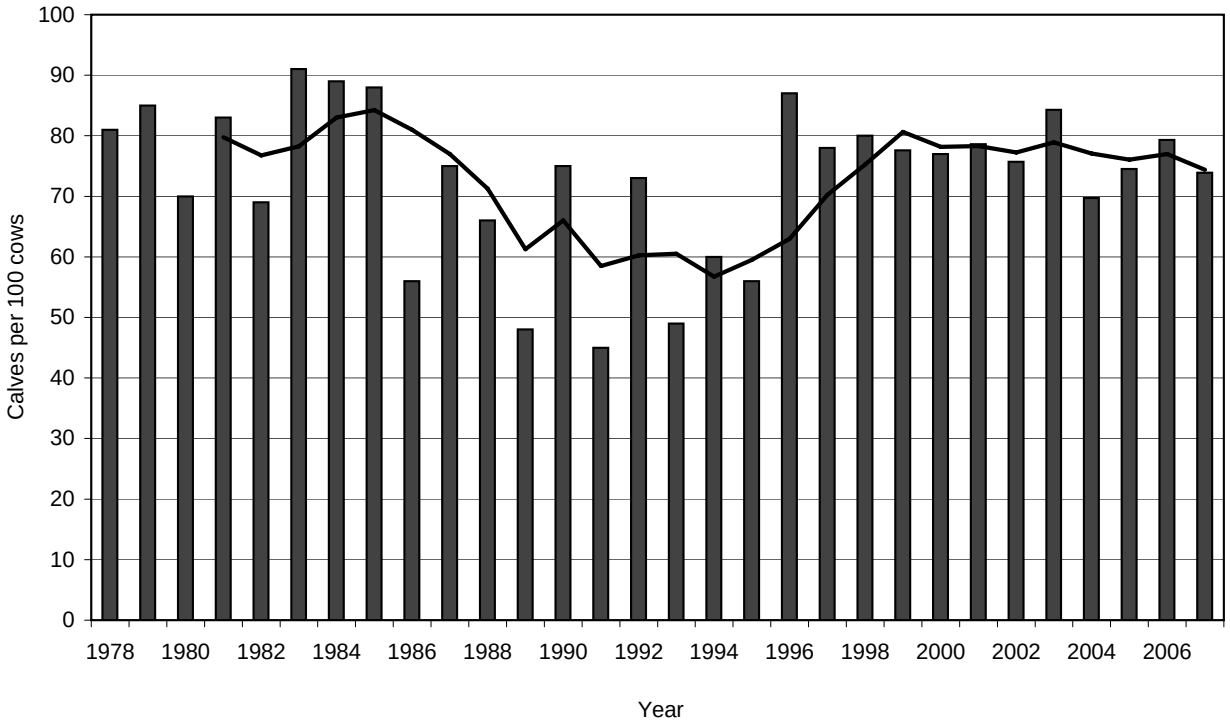


Figure 10. Estimated production of calf caribou (calf:cow ratio [bars] and 4-year moving average [line]) by the western segment of the Central Arctic Herd, based on aerial surveys in mid-June 1978–2007. Data sources: Fancy et al. (1992) for 1978–1990; Woolington (1995) for 1991–1992; Smith et al. (1994) for 1993; Cameron (1994) for 1994; Cameron (pers. comm.) for 1995; Johnson et al. (1997, 1998) for 1996–1997; Lawhead (1999) for 1998; Lawhead and Johnson (2000) for 1999; Lawhead and Prichard (2001, 2002, 2003a, 2003b, 2005, 2006, 2007, this study) for 2000–2007.

the ADFG estimate, which was based on adult caribou at least 3 years old.

The ratio of 9.6 yearlings:100 cows in our composition sample was near the low end of the range of estimates reported for 1979–2000 (8–48; mean 25.3; n = 14) (Lenart 2003). Our estimate ranged between 4.1 and 39.6 yearlings:100 cows during 1996–2006 (mean = 14.4, n = 9). These low ratios are unexpected because calf production has been consistently high in recent years (Figure 10) and overwinter calf survival was high during 2001–2004 (Arthur and Del Vecchio 2007). Yearling:cow ratios are difficult to estimate because they rely on subjective classification of caribou into age groups by the observer (we have used the same observer on all surveys since 1997); additional variation in counts can be caused by annual differences in migration and distribution patterns of yearlings or changes in the proportion of nonreproductive 2-year-old cows (with small body size) in the population.

SUMMER WEATHER CONDITIONS

Information on summer weather was compiled for reference in interpreting insect-season conditions and the severity of insect harassment. The TDD sums for 2007 were below the long-term averages for late June and July, indicating cooler-than-normal temperatures, and were slightly higher than average in early August (Appendices C and D).

Weather conditions can be used to predict the occurrence of harassment by mosquitoes (*Aedes* spp.) and oestrid flies (*Hypoderma tarandi* and *Cephenemyia trompe*). The estimated probabilities of mosquito activity based on daily maximum temperatures (but ignoring wind speed; Russell et al. 1993) at the Kuparuk airstrip were below average in June, close to average in July, and above average in August (Appendix F). The estimated probability of oestrid fly activity (Mörschel 1999), based on average hourly wind speeds and temperatures recorded at Nuiqsut was moderately high in early July, >50% on 13 July, and >70% on 17 July, and then remained <50% during late July and early August (Appendices E and G). Thus, the available weather data indicate that the levels of insect activity and resulting harassment of caribou were low to average early in the summer and slightly greater than average in August.

Variability in weather conditions typically results in large fluctuations in insect activity and caribou density during the insect season as aggregations move rapidly through the study area. Caribou typically move toward the coast in response to mosquito harassment and then disperse inland when mosquito activity abates in response to colder temperatures or high winds.

CARIBOU SURVEYS IN SPRING AND LATE SUMMER–FALL

The mean density of caribou in the Colville East survey area was fairly high in mid-May (0.45 caribou/km²; Table 5; Figure 11) but much lower than the peak density recorded in the area during the second calving survey (7.42 caribou/km²; Table 2). Density was still high on the first postcalving survey on 18 June (4.66 caribou/km²), then declined to 2.24 caribou/km² by the time of the second postcalving survey on 24 June (Table 5), as most caribou in the area had moved north toward insect-relief habitat along the coast (Figure 12). Biologists conducting bird surveys on the Colville River Delta reported few mosquitoes on the delta in June 2007. Conditions were warm with little wind on 21 June but mosquitoes had not yet emerged in the northern delta. That brief period of warm weather probably pushed most caribou toward the coast, however, because mosquitoes emerge earlier inland. Cooler temperatures and higher winds persisted on the Colville River Delta for much of the rest of June.

Few caribou were found on surveys in August (0.04–0.10 caribou/km²). The number of caribou increased slightly in late September and October but was still lower than in June (Table 5, Figure 12). Although caribou groups were observed throughout the survey area, the highest densities were found near the southern portions of the transects.

The mean density of caribou in the Colville East survey area during spring and late summer–fall 2007 (0.22 caribou/km²) was in the middle of the range of mean densities observed in other recent years (0.07–0.75 caribou/km² in 2001–2006; Lawhead and Prichard 2002, 2003a, 2003b, 2005, 2006, 2007).

Table 5. Number and density of caribou in the Colville East survey area, May–October 2007 (excluding calving surveys).

Date	Area Surveyed [a] (km²)	Total Counted	Estimated Total	Density (caribou/km²)	Groups	Average Group Size
May 15	850	380	760	0.45	78	4.9
June 18	850	3,958	7,916	4.66	338	11.7
June 24	850	1,902	3,804	2.24	79	24.1
August 13	850	81	162	0.10	35	2.3
August 23	850	33	66	0.04	26	1.3
September 21–22	850	229	458	0.27	82	2.8
October 9	850	84	316[b]	0.19 [b]	12	7.0
October 24 [c]	339	147	294	0.43	23	6.4
Total	6,289	6,814	13,776	1.10	673	10.1

[a] 50% coverage of 1,700-km² survey area.
[b] Sightability Correction Factor of 1.88 applied due to patchy snow.
[c] Only the northern portion was surveyed due to patchy fog.

OBSERVATIONS OF OTHER MAMMALS

MUSKOX

Muskox sightings were recorded 13 times between 5 May and 21 August 2007 (Table 6) in two locales in the Kuparuk–Colville region: along the main channel of the Colville River and around the Kuparuk River delta (Figure 13). Another group was seen outside of the GKA study area near the Sagavanirktok River (a group of 10 animals seen while the crew was in transit from Fairbanks to Deadhorse) and one group was found in northeastern NPRA during surveys for the ASDP caribou monitoring study (Lawhead et al. 2008). Because individuals marked by ADFG could not be identified consistently, it was difficult to distinguish specific groups reliably on successive surveys. As in other years recently, two mixed-sex groups were seen in the study area, consisting of a group near the Colville River delta and a larger group near the Kuparuk River delta. The maximum count of the Colville group was 19 adults, with no calves recorded on three occasions during May and June (Table 6). Thirty-four adults and no calves were observed in the Kuparuk group on 10 June and 26 adults and 2 calves were observed there on 21 August.

The muskox population on the eastern North Slope of Alaska has declined rapidly in recent years, especially in ANWR, due in large part to increased predation by grizzly bears (Reynolds et al. 2002, Shideler et al. 2007) but also by unusual mortality events such as drowning (in 2004; R. Shideler, ADFG, pers. comm.; Lawhead and Prichard 2005). Two calves were killed by a grizzly bear near an oilfield road in Prudhoe Bay in the summer of 2007 (Shideler et al. 2007). Near the Colville River south of Nuiqsut, several muskoxen in a single group were killed and others wounded in an attack by at least one grizzly bear in late June 2003 (L. Parrett, ADFG, pers. comm.).

GRIZZLY BEAR

Sixteen grizzly bear sightings, totaling 18 adults and 11 cubs, were recorded within 75 km of the coast in the Kuparuk–Colville region during aerial surveys in 2007 (Figure 13, Table 6). On the Colville River delta, an adult bear with two large cubs was observed 4 times between 12 June and 22 September. It is unknown whether these sightings were of the same bears, but given the close proximity and similar descriptions it is likely that several of these sightings were of the same bears.

Most of the bears in 2007 were seen south of the Kuparuk Oilfield in June in the area of high-density calving by caribou. This pattern matches the distribution seen in previous years (Lawhead and Prichard 2003b). Grizzly bears prey on caribou calves (Whitten et al. 1992), so the

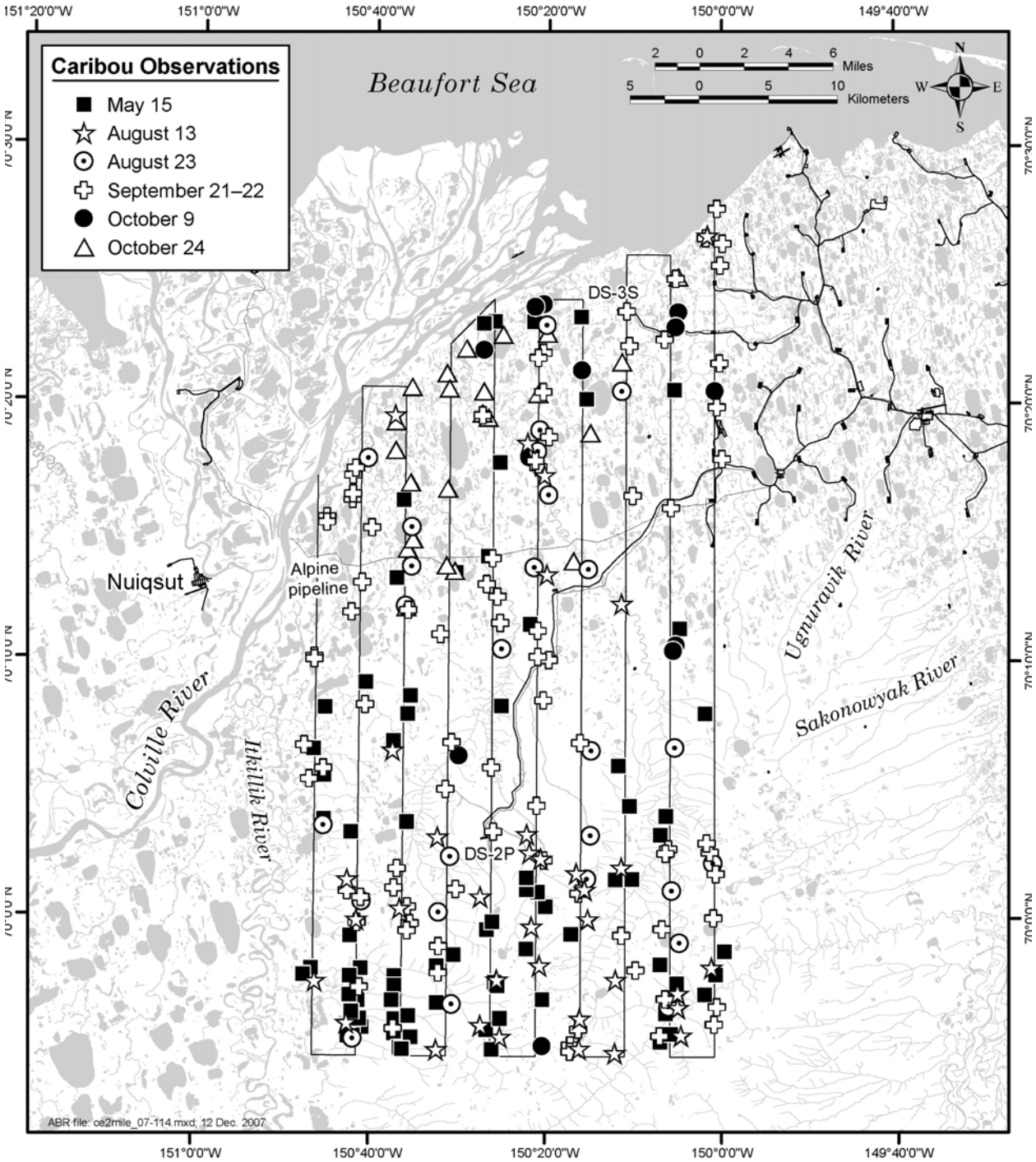


Figure 11. Distribution of caribou groups in the Colville East survey area during spring (May) and late summer–fall (August–October) surveys in 2007.

concentration of bear sightings in high-density

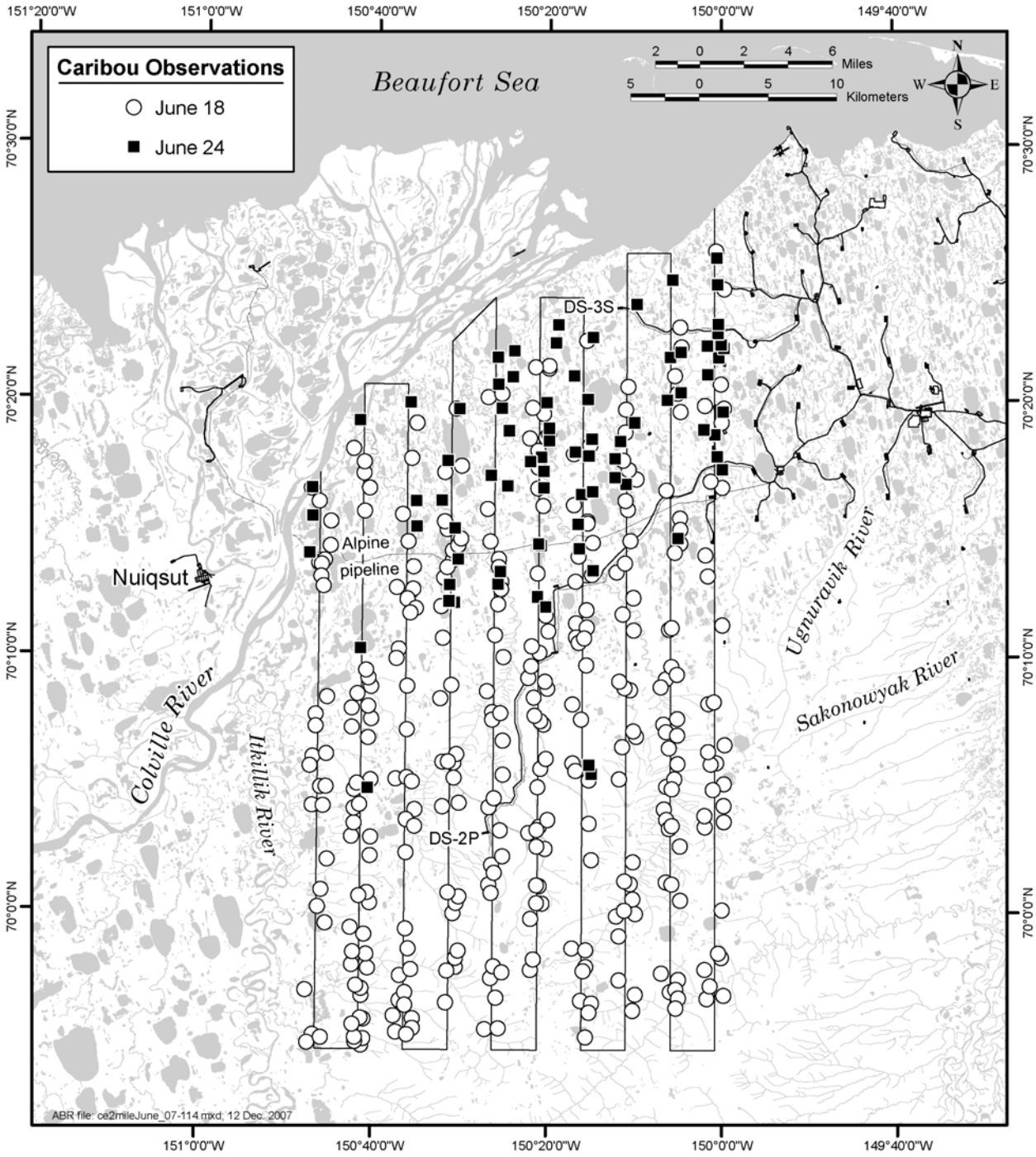


Figure 12. Distribution of caribou groups in the Colville East survey area during postcalving (late June) in 2007.

calving areas is not unexpected. Other contributing

Table 6. Locations and number of muskoxen and grizzly bears observed during aerial surveys in the Kuparuk–Colville region, May–October 2007.

Species	General Location	Date	Total	Adults	Young	Specific Location
Muskox	Colville River	May 5	19	19	0	S of Alpine Pipeline
		June 2	19	19	0	Mouth of Kachemach R.
		June 12	19	19	0	Mouth of Kachemach R.
		June 19	18	18	0	S of Mouth of Kachemach R.
		June 24	17	17	0	Miluveach R.
	Kuparuk River delta	June 4	9	8	1	Beechey Point
		June 10	7	7	0	W of Kuparuk R.
		June 10	6	6	0	W of Kuparuk R.
		June 10	21	21	0	W of Kuparuk R.
		August 21	6	5	1	W of Kuparuk R. delta
		August 21	10	10	0	Kuparuk R. delta
		August 21	12	11	1	Kuparuk R. delta
	Greater Kuparuk Area	June 10	2	2	0	N of Spine Rd.
Grizzly bear	Colville River delta	June 12	3	1	2	E of Kachemach R.
		June 24	3	1	2	Lower Kachemach R.
		September 21	3	1	2	N of Nuiqsut
		September 22	1	1	0	Near mouth of Kachemach R.
		September 22	3	1	2	Near mouth of Kachemach R.
	Upper Miluveach R.	May 15	3	1	0	E of DS-2P
		June 5	1	1	0	Upper Miluveach R.
		June 5	3	2	0	Upper Miluveach R.
		June 11	1	1	0	E of DS-2L
		June 11	1	2	0	Upper Miluveach R.
		June 11	1	1	0	Upper Miluveach R.
		June 11	1	1	0	Upper Miluveach R.
		June 12	1	1	0	Upper Miluveach R.
		June 12	1	1	0	Upper Miluveach R.
		June 12	4	1	3	Upper Miluveach R.
		June 24	1	1	0	Upper Miluveach R.
Polar bear	Colville River delta	August 21	3	1	2	Outer Colville R. delta
		August 21	1	1	0	Outer Colville R. delta
		August 21	1	1	0	Outer Colville R. delta
	Kuparuk River	August 21	3	1	2	Kuparuk R. delta
		August 21	1	1	0	N of Spine Rd.

factors include the greater abundance of high-quality upland and riparian habitats in the area south of the Kuparuk oilfield.

POLAR BEAR

Nine polar bears in 5 groups (5 adults and 4 cubs) were observed in the Kuparuk–Colville region during a swan survey on 21 August 2007 (Table 6, Figure 13). Three groups, including one sow with cubs, were on the outer Colville River delta, and two groups, including a sow with two large cubs, were near the Kuparuk River delta.

Although polar bears occur annually in and near the Kuparuk oilfield during winter, it is unusual for polar bears to occur there during summer. Other sightings of polar bears in the oilfield region during August (probably including some of the same individuals seen on the ABR swan survey) were reported to the U.S. Fish and Wildlife Service (C. Perham, USFWS, pers. comm.). Only one other polar bear has been recorded in the Kuparuk area during ABR aerial surveys in summer: a single bear was observed on three consecutive days (24–26 June) in 1998 near Mine Site D.

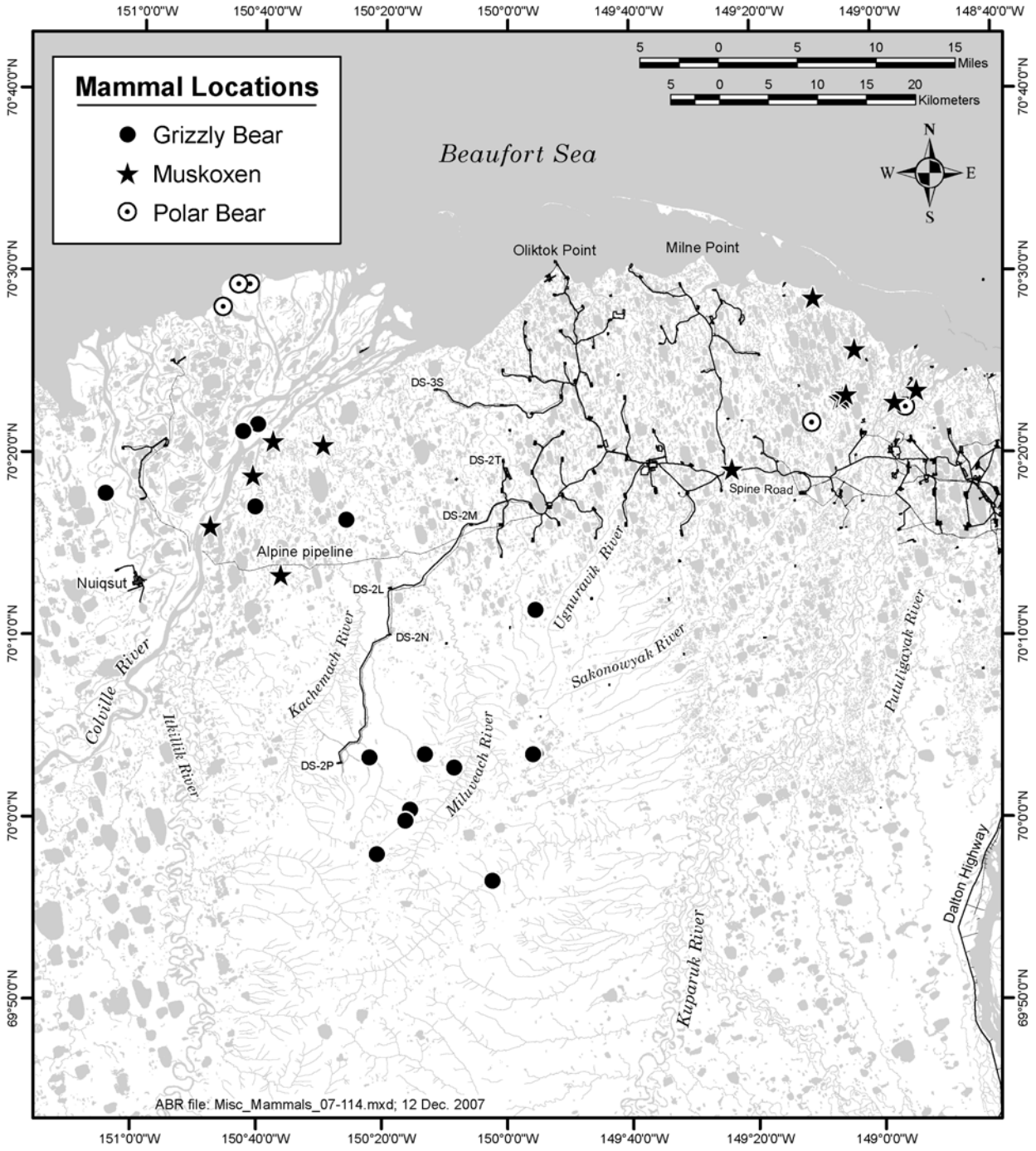


Figure 13. Distribution of muskoxen and grizzly bears observed during aerial surveys in the Kuparuk–Colville region, May–October 2007.

LITERATURE CITED

Arthur, S. M., and P. A. Del Vecchio. 2007. Effects of oil field development on calf production and survival in the Central Arctic Herd. Alaska Department of Fish and Game, Interim Research Technical Report, June 2001–March 2006. Project 3.46. Division of Wildlife Conservation, Juneau. 40 p.

Cameron, R. 1994. Distribution and productivity of the Central Arctic caribou herd in relation to petroleum development: Case-history studies with a nutritional perspective. Alaska Department of Fish and Game, research final report, Federal Aid in Wildlife Restoration Projects W-23-1–W-23-5, W-24-1–W-24-3, Study 3.35, Juneau. 35 p.

Cameron, R. D., D. J. Reed, J. R. Dau, and W. T. Smith. 1992. Redistribution of calving caribou in response to oil field development on the Arctic Slope of Alaska. Arctic 45: 338–342.

Carroll, G. 2003. Unit 26A: Teshekpuk Herd. Pages 280–303 *in* C. Healy, editor. Caribou management report of survey and inventory activities, 1 July 2000–30 June 2002. Alaska Department of Fish and Game, Juneau.

Caughley, G. C. 1974. Bias in aerial survey. Journal of Wildlife Management 38: 921–933.

Dau, J. R., and R. D. Cameron. 1986. Effects of a road system on caribou distribution during calving. Rangifer, Special Issue 1: 95–101.

Dau, J. 2005. Units 21D, 22A, 22B, 22C, 22D, 22E, 23, 24 and 26A caribou management report. Pages 177-218 in C. Brown, editor. Caribou management report of survey and inventory activities 1 July 2002–30 June 2004. Alaska Department of Fish and game. Project 3.0. Juneau.

Fancy, S. G., K. R. Whitten, N. E. Walsh, and R. D. Cameron. 1992. Potential impacts of petroleum exploration and development on the numbers, distribution, and status of caribou on the Arctic Coastal Plain. Pages 1–20 *in* T. R. McCabe, B. Griffith, N. E. Walsh, and D. D. Young, editors. Terrestrial research: 1002 area—Arctic National Wildlife Refuge, interim report, 1988–90. U.S. Fish and Wildlife Service, Anchorage.

Gasaway, W. C., S. D. DuBois, D. J. Reed, and S. J. Harbo. 1986. Estimating moose population parameters from aerial surveys. Biological Papers of the University of Alaska, No. 22, Fairbanks. 108 p.

Griffith, B., D. C. Douglas, N. E. Walsh, D. D. Young, T. R. McCabe, D. E. Russell, R. G. White, R. D. Cameron, and K. R. Whitten. 2002. Section 3: The Porcupine caribou herd. Pages 8–37 *in* D. C. Douglas, P. E. Reynolds, and E. B. Rhode, editors. Arctic Refuge coastal plain terrestrial wildlife research summaries. U.S. Geological Survey, Biological Resources Division, Biological Science Report USGS/BRD/BSR-2002-0001.

Johnson, C. B., M. T. Jorgenson, R. M. Burgess, B. E. Lawhead, J. R. Rose, and A. A. Stickney. 1996. Wildlife studies on the Colville River delta, Alaska, 1995. Fourth annual report prepared for ARCO Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 154 p.

Johnson, C. B., B. E. Lawhead, J. R. Rose, A. A. Stickney, and A. M. Wildman. 1997. Wildlife studies on the Colville River delta, Alaska, 1996. Fifth annual report prepared for ARCO Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 139 p.

Johnson, C. B., B. E. Lawhead, J. R. Rose, M. D. Smith, A. A. Stickney, and A. M. Wildman. 1998. Wildlife studies on the Colville River delta, Alaska, 1997. Sixth annual report prepared for ARCO Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 144 p.

Lawhead, B. E. 1999. Caribou distribution, abundance, calf production, and movements in the Kuparuk Oilfield region during the 1998 calving and insect seasons. Report prepared for ARCO Alaska, Inc. and Kuparuk River Unit, Anchorage, by ABR, Inc., Fairbanks. 21 p.

Lawhead, B. E., and R. D. Cameron. 1988. Caribou distribution on the calving grounds of the Central Arctic Herd, 1987. Report prepared for ARCO Alaska, Inc. and the Kuparuk River Unit, Anchorage, by Alaska Biological Research, Inc., and Alaska Department of Fish and Game, Fairbanks. 59 p.

Lawhead, B. E., and C. B. Johnson. 2000. Surveys of caribou and muskoxen in the Kuparuk–Colville region, Alaska, 1999, with a summary of caribou calving distribution since 1993. Report prepared for PHILLIPS Alaska, Inc. and the Kuparuk River Unit, Anchorage, by ABR, Inc., Fairbanks. 30 p.

Lawhead, B. E., C. B. Johnson, and L. C. Byrne. 1994. Caribou surveys in the Kuparuk Oilfield during the 1993 calving and insect seasons. Report prepared for ARCO Alaska, Inc. and the Kuparuk River Unit, Anchorage, by Alaska Biological Research, Inc., Fairbanks. 38 p.

Lawhead, B. E., C. B. Johnson, A. M. Wildman, and J. R. Rose. 1997. Caribou distribution, abundance, and calf production in the Kuparuk Oilfield during the 1996 calving season. Report for ARCO Alaska, Inc. and the Kuparuk River Unit, Anchorage, by ABR, Inc., Fairbanks. 17 p.

Lawhead, B. E., C. B. Johnson, A. M. Wildman, and J. R. Rose. 1998. Caribou distribution, abundance, and calf production in the Kuparuk Oilfield during the 1997 calving season. Report prepared for ARCO Alaska, Inc. and the Kuparuk River Unit, Anchorage, by ABR, Inc., Fairbanks. 18 p.

Lawhead, B. E and A. K. Prichard. 2001. Surveys of caribou and muskoxen in the Kuparuk–Colville region, Alaska, 2000. Report prepared for PHILLIPS Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 39 p.

Lawhead, B. E and A. K. Prichard. 2002. Surveys of caribou and muskoxen in the Kuparuk–Colville region, Alaska, 2001. Report prepared for PHILLIPS Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 37 p.

Lawhead, B. E and A. K. Prichard. 2003a. Surveys of caribou and muskoxen in the Kuparuk–Colville region, Alaska, 2002. Report prepared for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 38 p.

Lawhead, B. E, and A. K. Prichard. 2003b. Mammal surveys in the Greater Kuparuk Area, northern Alaska, 2003. Report prepared for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 45 p.

Lawhead, B. E, and A. K. Prichard. 2005. Mammal surveys in the Greater Kuparuk Area, northern Alaska, 2004. Report prepared for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 39 p.

Lawhead, B. E, and A. K. Prichard. 2006. Mammal surveys in the Greater Kuparuk Area, northern Alaska, 2005. Report prepared for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 33 p.

Lawhead, B. E, and A. K. Prichard. 2007. Mammal surveys in the Greater Kuparuk Area, northern Alaska, 2006. Report prepared for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 34 p.

Lawhead, B. E., A. K. Prichard, M. J. Macander, and M. Emers. 2002. Caribou mitigation monitoring study for the Meltwater Project, 2001. First annual report prepared for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 74 p.

Lawhead, B. E., A. K. Prichard, M. J. Macander, and M. Emers. 2003. Caribou mitigation monitoring study for the Meltwater Project, 2002. Second annual report prepared for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 85 p.

Lawhead, B. E., A. K. Prichard, M. J. Macander, and M. Emers. 2004. Caribou mitigation monitoring study for the Meltwater Project, 2003. Third annual report prepared for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 104 p.

Lawhead, B. E., A. K. Prichard, and M. J. Macander. 2008. Caribou monitoring study for the ASDP, 2007. Third annual report prepared for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks.

Lenart, E. A. 1999. GMU 26B and 26C, Central Arctic. Pages 265–286 *in* C. Healy, editor. Caribou management report of survey–Inventory activities, 1 July 1998–30 June 2000. Alaska Department of Fish and Game, Federal Aid in Wildlife Restoration Project 3.0. Division of Wildlife Conservation, Juneau.

Lenart, E. A. 2001. GMU 26B and 26C, Central Arctic. Pages 222–235 *in* M. V. Hicks, editor. Management report, survey–inventory activities, 1 July 1996–30 June 1998: Caribou. Alaska Department of Fish and Game, Federal Aid in Wildlife Restoration Grants W-24-5 and W-27-1, Study 3.0. Division of Wildlife Conservation, Juneau.

Lenart, E. A. 2003. GMU 26B and 26C, Central Arctic. Pages 304–326 *in* C. Healy, editor. Caribou management report of survey and inventory activities, 1 July 2000–30 June 2002. Alaska Department of Fish and Game, Division of Wildlife Conservation, Juneau.

Mörschel, F. M. 1999. Use of climatic data to model the presence of oestrid flies in caribou herds. Journal of Wildlife Management 63: 588–593.

Murphy, S. M., and B. E. Lawhead. 2000. Caribou. Chapter 4, pages 59–84 *in* J. Truett and S. R. Johnson, editors. The Natural History of an Arctic Oil Field: Development and the Biota. Academic Press, San Diego, CA.

Noel, L. E., K. Parker, and M. A. Cronin. 2004. Caribou distribution near an oilfield road on Alaska's North Slope, 1978–2001. Wildlife Society Bulletin 32: 757–771.

Pennycuick, C. J., and D. Western. 1972. An investigation of some sources of bias in aerial transect sampling of large mammal populations. East African Wildlife Journal 10: 175–191.

Reynolds, P. E., K. J. Wilson, and D. R. Klein. 2002. Section 7: Muskoxen. Pages 54–64 *in* D. C. Douglas, P. E. Reynolds, and E. B. Rhode, editors. Arctic Refuge coastal plain terrestrial wildlife research summaries. U.S. Geological Survey, Biological Resources Division, Biological Science Report USGS/BRD/BSR-2002-0001.

Russell, D. E., A. M. Martell, and W. A. C. Nixon. 1993. Range ecology of the Porcupine caribou herd in Canada. Rangifer, Special Issue No. 8. 167 p.

Shideler, R., P. Reynolds, S. Arthur, E. Lenart, and T. Paragi. 2007. Decline of eastern North Slope muskoxen. The Alaskan Wildlifer, August 2007: 5–6.

Smith, L. N., L. C. Byrne, C. B. Johnson, and A. A. Stickney. 1994. Wildlife studies on the Colville River delta, Alaska, 1993. Report for ARCO Alaska, Inc., Anchorage, by Alaska Biological Research, Inc., Fairbanks. 95 p.

Taylor, K. P. 1993. Region III caribou population and habitat management. Pages 11–21 *in* S. M. Abbott, editor. Annual performance report of survey–inventory activities, 1 July 1992–30 June 1993: Caribou. Volume 24, Part 11. Alaska Department of Fish and Game, Federal Aid in Wildlife Restoration Project W-24-1, Study 3.0. Division of Wildlife Conservation, Juneau.

Walker, D. A., K. R. Everett, P. J. Webber, and J. Brown. 1980. Geobotanical atlas of the Prudhoe Bay region, Alaska. U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory Report 80-14, Hanover, New Hampshire.

Walsh, N. E., S. G. Fancy, T. R. McCabe, and L. F. Pank. 1992. Habitat use by the Porcupine caribou herd during predicted insect harassment. Journal of Wildlife Management 56: 465–473.

Whitten, K. R., and R. D. Cameron. 1985. Distribution of calving caribou in relation to the Prudhoe Bay oil field. Pages 35–39 *in* A. M. Martell and D. E. Russell, editors.

Caribou and human activity: Proceedings of the 1st North American Caribou Workshop. Canadian Wildlife Service Publication, Ottawa, Ontario.

Whitten, K. R., G. W. Garner, F. J. Mauer, and R. B. Harris. 1992. Productivity and early calf survival in the Porcupine caribou herd. Journal of Wildlife Management 56: 201–212.

Woolington, J. D. 1995. Central Arctic Herd. Pages 211–224 *in* M. V. Hicks, editor. Management report of survey–inventory activities, 1 July 1992–30 June 1994: Caribou. Alaska Department of Fish and Game, Federal Aid in Wildlife Restoration Projects W-24-2 and W-24-3, Study 3.0. Division of Wildlife Conservation, Juneau.

Appendix A. Snow depth (cm) and sum of thawing degree-days (TDD; °C above freezing) at the Kuparuk airstrip, April–June 1983–2007.

	Snow Depth (cm)			Sum of TDD (° C)		
Year	1 April	15 May	31 May	1–15 May	16–31 May	1–15 June
1983	10	5	0	0	3.6	53.8
1984	18	15	0	0	0	55.6
1985	10	8	0	0	10.3	18.6
1986	33	20	10	0	0	5.0
1987	15	8	3	0	0.6	6.7
1988	10	5	5	0	0	16.7
1989	33	–	10 [a]	0	5.6	20.6
1990	8	3	0	0	16.1	39.7
1991	23	8	3	0	7.8	14.4
1992	13	8	0	0.3	20.3	55.0
1993	13	5	0	0	8.6	33.6
1994	20	18	8	0	4.4	49.2
1995	18	5	0	0	1.1	59.4
1996	23	5	0	8.1	41.7	86.1
1997	28	18	8	0	20.8	36.1
1998	25	8	0	3.6	45.8	74.2
1999	28	15	10	0	1.4	30.3
2000	30	23	13	0	0	36.7
2001	23	30	5	0	1.1	53.3
2002	30	trace	0	4.4	31.1	59.4
2003	28	13	trace	0	10.8	23.6
2004	36	10	5	0	10.0	27.8
2005	23	13	0	0	3.3	16.1
2006	23	5	0	0	23.3	93.3
2007	25	46	5	0	0	46.4
Mean	22	12	3	0.7	10.7	40.5

[a] Value for 1 June.

Appendix B. Estimated numbers and densities of caribou in the Kuparuk Field, Kuparuk South, Colville East, Colville Inland, and Colville Delta survey areas, 1993 and 1995–2007.

Survey Area	Date	Total Area (km²)	Estimated Total Caribou [a]	Total Density (per km²)	Estimated Total Calves [a]	Calf Density (per km²)	Snow Cover
Kuparuk Field [bc]	4 June 1993	850	155	0.18	23	0.03	Patchy; SCF used
	15 June 1993	1202	786	0.65	188	0.16	None
	11 June 1996	1137	2458	2.16	897	0.79	None
	3 June 1997	1137	421	0.37	33	0.03	High; SCF not used
	11 June 1997	1137	320	0.28	81	0.07	Patchy; SCF used
	4–5 June 1998	1097	862	0.76	300	0.27	None
	14 June 1998	1107	688	0.62	202	0.18	None
	12–13 June 1999	1102	1284	1.17	456	0.41	Patchy; SCF not used
	14–15 June 2000	1107	402	0.36	102	0.09	Patchy; SCF used
	12 June 2001	1107	666	0.60	168	0.15	Patchy; SCF not used
	6, 8 June 2002	1035	1124	1.09	304	0.29	None
	12 June 2002	1035	886	0.86	226	0.22	None
	3, 5 June 2003	1035	692	0.67	79	0.08	Patchy; SCF used
	13 June 2003	1035	496	0.48	140	0.14	Low; SCF not used
	4 June 2004	397	90	0.23	15	0.04	Patchy; SCF used
	12, 16 June 2004	1035	580	0.56	174	0.17	None
	4–5 June 2005	1035	68	0.07	15	0.01	Patchy; SCF used
	9 June 2005	1035	54	0.05	18	0.02	Low; SCF not used
	2–3 June 2006	1035	49	0.05	8	0.01	Patchy; SCF used
	10 June 2006	1035	912	0.88	248	0.24	None
	3–4 June 2007	1035	120	0.12	8	0.01	Patchy; SCF used
	10 June 2007	1035	452	0.44	60	0.06	None
Kuparuk South [defg]	2 June 1993	825	328	0.40	16	0.02	Patchy; SCF used
	13 June 1995	548	2769	5.05	531	0.97	None
	4 June 1996	599	3573	5.96	1044	1.74	None
	9–10 June 1996	599	4344	7.25	1572	2.62	None
	2 June 1997	599	286	0.48	42	0.07	High; SCF not used
	12 June 1997	599	1437	2.40	415	0.69	Patchy; SCF used
	4 June 1998	603	3160	5.24	812	1.35	None
	12–13 June 1998	603	6162	10.22	2222	3.68	None
	12 June 1999	603	1964	3.26	622	1.03	Low; SCF not used
	12–13 June 2000	603	320	0.53	83	0.14	Patchy; SCF used
	7 June 2001	603	534	0.89	49	0.08	Patchy; SCF used
	11 June 2001	603	2132	3.54	608	1.01	Patchy; SCF not used
	7 June 2002	788	4256	5.40	1002	1.27	None
	11 June 2002	788	4778	6.06	1164	1.48	None
	4–5 June 2003	788	1530	1.94	180	0.23	Patchy; SCF used

Appendix B. Continued.

Survey Area	Date	Total Area (km²)	Estimated Total Caribou [a]	Total Density (per km²)	Estimated Total Calves [a]	Calf Density (per km²)	Snow Cover
Kuparuk South [defg]	12–13 June 2003	788	1334	1.69	366	0.46	Low; SCF not used
	4 June 2004	603	199	0.33	49	0.08	Patchy; SCF used
	16 June 2004	603	2188	3.63	640	1.06	None
	5 June 2005	788	308	0.39	41	0.05	Patchy; SCF used
	9–10 June 2005	788	314	0.40	88	0.11	Low; SCF not used
	4 June 2006	788	414	0.52	53	0.07	Patchy; SCF used
	10–11 June 2006	788	8360	10.61	2476	3.14	None
	4–5 June 2007	788	564	0.72	68	0.09	Patchy; SCF used
	10–11 June 2007	788	4900	6.22	1240	1.57	None
Colville Inland [h]	23 May 1993	1107	8	0.01	0	0.00	High; SCF not used
	28 May 1993	1107	224	0.20	15	0.01	Patchy; SCF used
	7 June 1993	1107	1186	1.07	64	0.06	Low; SCF not used
	10 June 1993	1107	1249	1.13	127	0.11	None
	5 June 1995	1107	321	0.29	30	0.03	Patchy; SCF used
Colville East [ijklm]	26 May 1993	650	60	0.09	0	0	High; SCF not used
	27 May 1993	1050	87	0.08	0	0	High; SCF not used
	3 June 1993	1050	542	0.52	0	0	Patchy; SCF used
	8 June 1993	709	914	1.29	148	0.21	Low; SCF not used
	11 June 1993	910	2181	2.40	558	0.61	None
	4–5 June 1995	1057	315	0.30	41	0.04	Patchy; SCF used
	12–13 June 1995	1349	2057	1.52	305	0.23	None
	3–4 June 1996	1362	800	0.59	159	0.12	None
	12–13 June 1996	1358	2670	1.97	786	0.58	None
	1–2 June 1997	1362	555	0.41	60	0.04	Patchy; SCF used
	10–12 June 1997	1321	4035	3.05	1214	0.92	Patchy; SCF used
	3 June 1998	1370	1840	1.34	284	0.21	None
	11–12 June 1998	1370	1902	1.39	310	0.23	None
	11 June 1999	1478	2166	1.47	544	0.37	Low; SCF not used
	11–12 June 2000	1478	966	0.65	192	0.13	Patchy; SCF used
	5–6 June 2001	1478	169	0.11	0	0	Patchy; SCF used
	10–11 June 2001	1478	1148	0.78	192	0.13	Patchy; SCF not used
	6–7 June 2002	1432	5584	3.90	830	0.58	None
	10–11 June 2002	1432	6232	4.35	1034	0.72	None
	3–4 June 2003	1432	1162	0.81	120	0.08	Patchy; SCF used
	10, 12 June 2003	1432	2790	1.95	614	0.43	Low; SCF not used
	5 June 2004	1262	1092	0.61	350	0.28	Patchy; SCF used
	16 June 2004	1323	6982	5.28	2286	1.73	None
	5–6 June 2005	1432	1387	0.97	297	0.21	Patchy; SCF used
	10–11 June 2005	1432	2746	1.92	726	0.51	Low; SCF not used
	3–5 June 2006	1432	395	0.28	53	0.04	Patchy; SCF used
	11–12 June 2006	1432	4056	2.83	1022	0.71	None
	2, 4–5 June 2007	1432	2290	1.60	192	0.13	Patchy; SCF used
	11–12 June 2007	1432	10,624	7.42	2596	1.81	None

Appendix B. Continued.

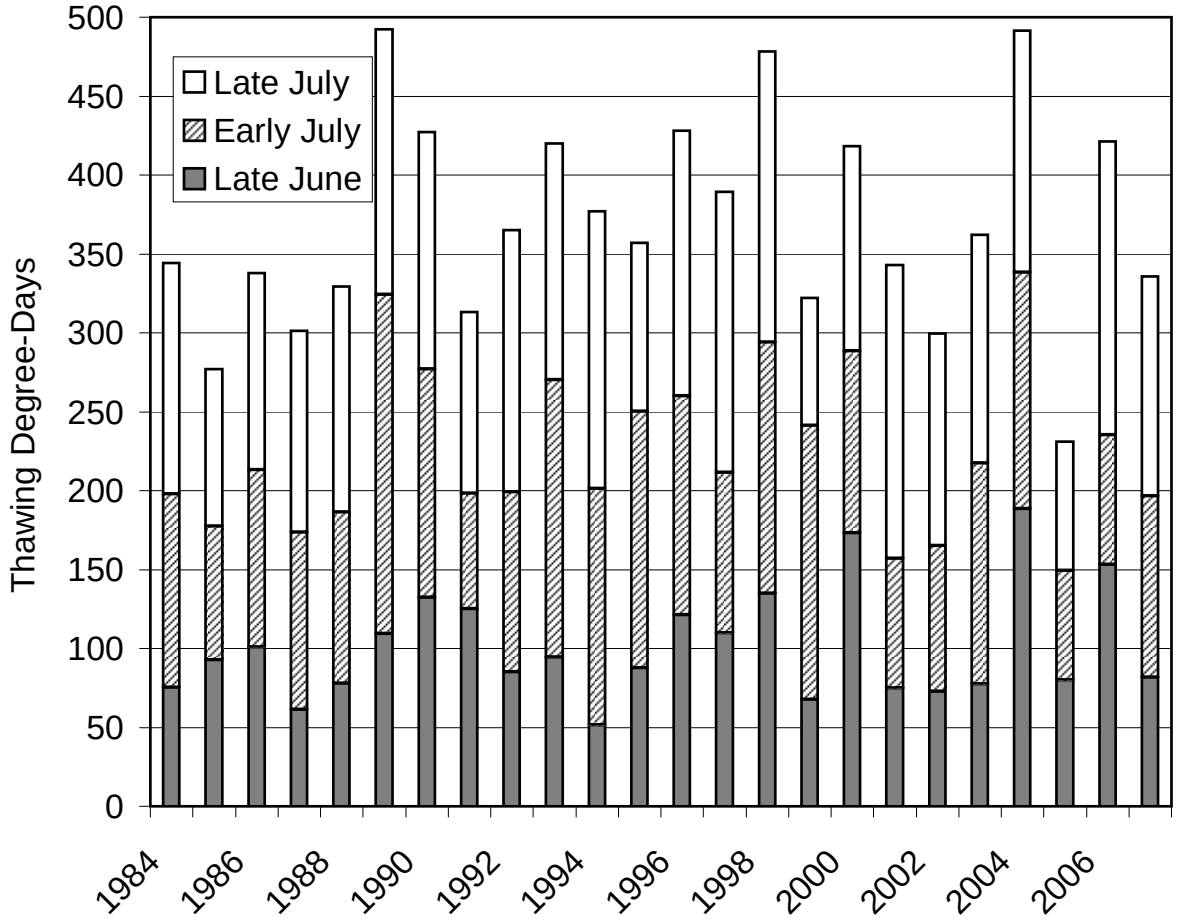
Survey Area	Date	Total Area (km²)	Estimated Total Caribou [a]	Total Density (per km²)	Estimated Total Calves [a]	Calf Density (per km²)	Snow Cover
Colville Delta	28 May 1993	637	27	0.04	0	0	High; SCF not used
	10 June 1993	637	0	0	0	0	Low; SCF not used
	3 June 1995	637	18	0.03	0	0	Low; SCF not used
	2 June 1996	637	58	0.09	0	0	None
	13 June 1996	637	10	0.02	1	<0.01	None
	1 June 1997	637	0	0	0	0	High; SCF not used
	12, 20 June 1997	637	0	0	0	0	Patchy; SCF used
	9 June 2006	637	6	0.01	1	<0.01	None

[a] Incorporates Sightability Correction Factor (SCF) of 1.88 (Lawhead et al. 1994) where indicated.
[b] Dropped two easternmost transects in 2002.
[c] Unable to survey easternmost 14 transects on 4 June 2004.
[d] Kuparuk Inland survey area of 1993 and 1995.
[e] Shifted south 1.6 km in 1996 to eliminate overlap with Kuparuk Field survey area.
[f] Enlarged and extended east to Kuparuk River in 2002.
[g] Unable to survey easternmost 8 transects in 2004.
[h] Surveyed only in 1993; northern portion incorporated in Colville East survey area in 1995.
[i] Extended south to 70º N latitude in 1995, thus incorporating much of 1993 Colville Inland survey area.
[j] Extended south in 1999 to incorporate Meltwater South study area.
[k] Dropped westernmost transect in 2002.
[l] Unable to survey westernmost 3 transects on 5 June 2004.
[m] Unable to survey westernmost 2 transects on 16 June 2004.

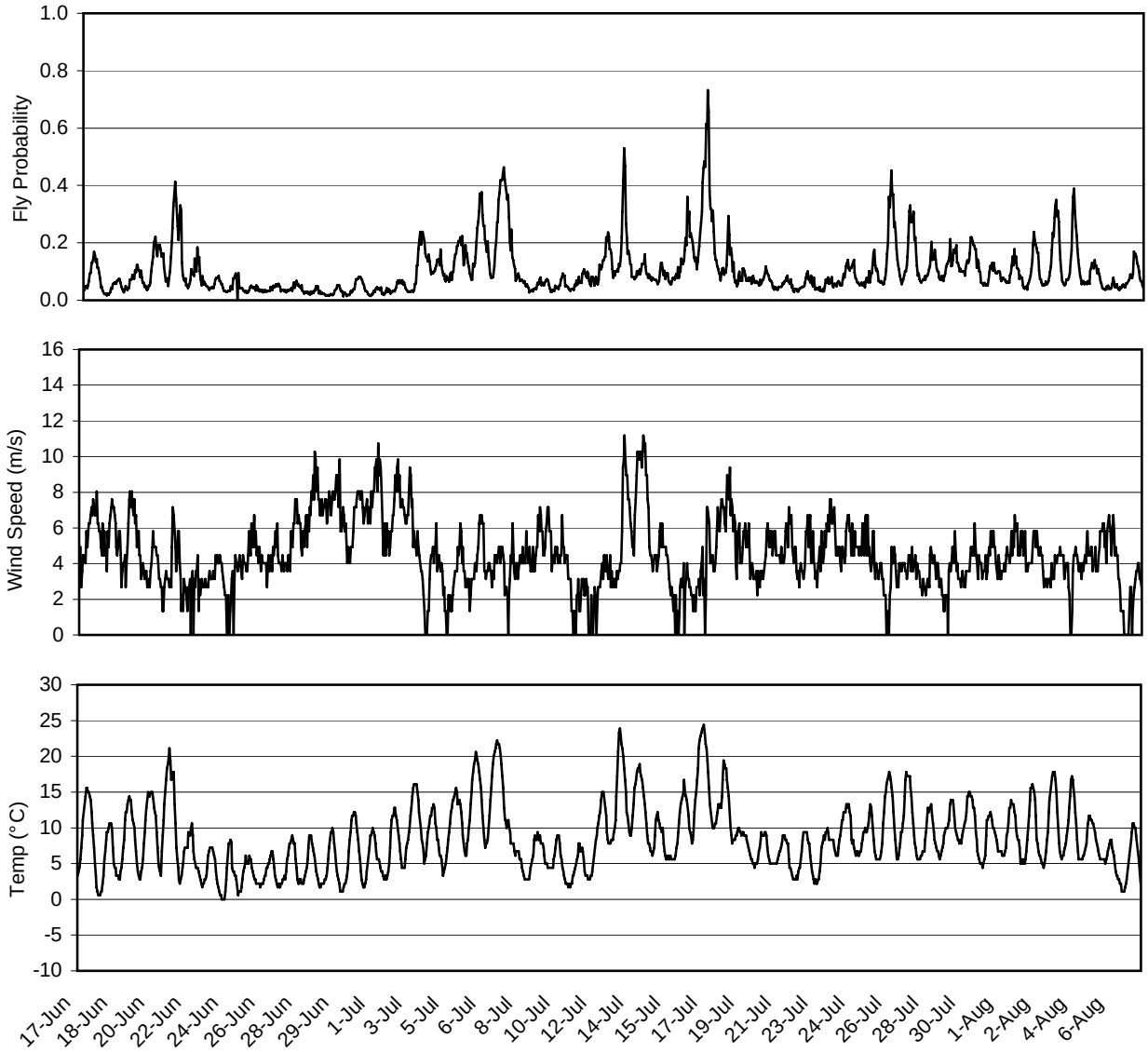
Appendix C. Sum of thawing degree-days (°C above freezing) at the Kuparuk airstrip during four periods of the insect season, mid-June to mid-August 1983–2007.

	Thawing Degree-Days				
Year	16–30 June	1–15 July	16–31 July	1–15 August	Total
1983 [a]	73.4	74.7	103.8	100.3	352.1
1984	75.3	122.8	146.4	99.5	444.0
1985	92.8	84.7	99.4	100.0	376.9
1986	100.8	112.2	124.7	109.4	447.2
1987	61.4	112.2	127.8	93.1	394.4
1988	78.1	108.3	143.1	137.5	466.9
1989	109.4	214.7	168.1	215.8	708.1
1990	132.2	145.0	150.0	82.5	509.7
1991	125.0	73.3	115.0	70.6	383.9
1992	85.3	113.9	166.1	104.2	469.4
1993	94.4	175.8	149.7	96.1	516.1
1994	51.7	149.7	175.8	222.2	599.4
1995	87.5	162.8	106.9	83.3	440.6
1996	121.1	138.9	168.1	95.8	523.9
1997	109.7	101.7	177.8	194.2	583.3
1998	135.0	158.9	184.4	174.4	652.8
1999	67.8	173.3	81.1	177.5	499.7
2000	173.3	115.0	130.0	120.6	538.9
2001	75.0	82.2	185.6	135.0	477.8
2002	72.8	92.2	134.4	106.1	405.6
2003	77.5	140.0	144.7	91.9	454.2
2004	188.3	150.0	153.3	155.0	646.7
2005	80.0	69.4	81.7	178.9	410.0
2006	153.1	82.2	186.1	109.7	531.1
2007	81.7	115.0	138.9	134.4	470.0
Mean	100.1	122.8	141.7	127.5	492.1

[a] Some missing values estimated by interpolation.



Appendix D. Index of annual insect-season severity (expressed as cumulative thawing degree-days in °C above freezing, from mid-June through July), 1984–2007.



Appendix E. Probability of oestrid fly activity (Mörschel 1999) in summer 2007, based on wind speed and temperature data recorded at Nuiqsut.

Appendix F. Average index values of mosquito activity (adapted from Russell et al. 1993) during June–August 1983–2007, based on daily maximum temperatures at the Kuparuk airstrip.

Average Mosquito Index = if daily Tmax <6 then zero; if Tmax >18 then 1; else 1–((18–Tmax)/13))

	June			July			August[a]		
Year	Early	Late	Total	Early	Late	Total	Early	Late	Total
1983	0.28	0.31	0.30	0.28	0.41	0.35	0.44	0.15	0.28
1984	0.26	0.37	0.31	0.60	0.68	0.64	0.46	0.21	0.34
1985	0.09	0.48	0.28	0.42	0.45	0.44	0.52	0.31	0.41
1986	0.01	0.46	0.24	0.62	0.54	0.58	0.53	0.21	0.36
1987	0	0.22	0.11	0.52	0.47	0.49	0.34	0.42	0.38
1988	0.04	0.32	0.18	0.50	0.64	0.57	0.73	0.19	0.45
1989	0.01	0.58	0.29	0.90	0.74	0.82	0.84	0.59	0.71
1990	0.17	0.69	0.43	0.68	0.62	0.65	0.30	0.21	0.25
1991	0.01	0.58	0.30	0.35	0.48	0.42	0.27	0.27	0.27
1992	0.29	0.36	0.33	0.49	0.77	0.64	0.48	0.42	0.45
1993	0.13	0.43	0.28	0.80	0.66	0.73	0.37	0.26	0.31
1994	0.23	0.18	0.21	0.73	0.77	0.75	0.97	0.37	0.66
1995	0.28	0.36	0.32	0.83	0.35	0.58	0.30	0.36	0.33
1996	0.44	0.55	0.49	0.72	0.69	0.70	0.46	0.14	0.30
1997	0.07	0.50	0.28	0.41	0.82	0.62	0.84	0.33	0.58
1998	0.30	0.55	0.43	0.72	0.81	0.77	0.71	0.46	0.58
1999	0.11	0.28	0.20	0.84	0.29	0.56	0.82	0.20	0.50
2000	0.11	0.82	0.47	0.50	0.47	0.49	0.59	0.27	0.42
2001	0.25	0.33	0.29	0.32	0.75	0.54	0.60	0.05	0.31
2002	0.25	0.30	0.28	0.43	0.61	0.52	0.40	0.36	0.38
2003	0.10	0.39	0.24	0.65	0.58	0.62	0.46	0.09	0.27
2004	0.05	0.89	0.47	0.72	0.65	0.68	0.70	0.44	0.57
2005	0.01	0.34	0.18	0.28	0.28	0.28	0.82	0.11	0.45
2006	0.49	0.73	0.61	0.32	0.81	0.57	0.50	0.06	0.27
2007	0.14	0.38	0.26	0.57	0.55	0.56	0.60	0.41	0.50
Mean	0.16	0.46	0.31	0.57	0.60	0.58	0.56	0.28	0.41

Appendix G. Average index values of oestrid fly activity (adapted from Russell et al. 1993) during June–August 1983–2007, based on daily maximum temperatures at the Kuparuk airstrip.

Average Fly Index = if daily Tmax <10 then zero; if Tmax >18 then 1; else 1–((18–Tmax)/8))									
	June			July			August[a]		
Year	Early	Late	Total	Early	Late	Total	Early	Late	Total
1983	0.10	0.16	0.13	0.04	0.35	0.19	0.26	0.02	0.13
1984	0.14	0.14	0.14	0.40	0.59	0.50	0.34	0.09	0.22
1985	0.03	0.26	0.15	0.29	0.27	0.28	0.36	0.21	0.28
1986	0	0.33	0.17	0.49	0.35	0.41	0.38	0.08	0.23
1987	0	0.05	0.03	0.29	0.33	0.31	0.09	0.23	0.16
1988	0	0.10	0.05	0.26	0.48	0.37	0.60	0.14	0.36
1989	0	0.40	0.20	0.85	0.63	0.74	0.75	0.49	0.62
1990	0.04	0.52	0.28	0.62	0.50	0.56	0.09	0.06	0.07
1991	0	0.49	0.24	0.21	0.32	0.27	0.17	0.14	0.16
1992	0.20	0.19	0.20	0.33	0.63	0.49	0.36	0.26	0.31
1993	0.02	0.35	0.18	0.69	0.47	0.58	0.24	0.16	0.20
1994	0.06	0.10	0.08	0.58	0.70	0.64	0.95	0.24	0.58
1995	0.16	0.18	0.17	0.73	0.24	0.48	0.11	0.21	0.16
1996	0.31	0.46	0.38	0.63	0.57	0.60	0.34	0.03	0.18
1997	0	0.28	0.14	0.32	0.72	0.53	0.74	0.16	0.44
1998	0.16	0.42	0.29	0.55	0.69	0.62	0.52	0.23	0.37
1999	0.01	0.10	0.06	0.74	0.17	0.44	0.70	0.08	0.38
2000	0.04	0.75	0.39	0.39	0.28	0.34	0.49	0.20	0.34
2001	0.19	0.10	0.15	0.24	0.63	0.44	0.41	0.01	0.20
2002	0.18	0.18	0.18	0.23	0.49	0.36	0.30	0.24	0.27
2003	0	0.22	0.11	0.45	0.44	0.44	0.34	0.00	0.17
2004	0	0.83	0.41	0.57	0.50	0.53	0.62	0.31	0.46
2005	0	0.23	0.12	0.11	0.05	0.08	0.75	0.03	0.38
2006	0.39	0.61	0.50	0.15	0.71	0.44	0.29	0.03	0.15
2007	0.01	0.21	0.11	0.39	0.34	0.36	0.38	0.13	0.25
Mean	0.08	0.31	0.19	0.42	0.46	0.44	0.42	0.15	0.28