FINAL REPORT

MAMMAL SURVEYS IN THE GREATER KUPARUK AREA, NORTHERN ALASKA, 2008

BRIAN E. LAWHEAD
ALEXANDER K. PRICHARD

PREPARED FOR

CONOCOPHILLIPS ALASKA, INC.
ANCHORAGE, ALASKA

PREPARED BY

ABR, INC.–ENVIRONMENTAL RESEARCH & SERVICES
FAIRBANKS, ALASKA

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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 April–October 2008. 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 other species of large mammals were recorded during aerial surveys for caribou and for other species (mainly birds).
- A fixed-wing airplane was used to survey the calving distribution and abundance of caribou twice in 2008, around the peak of calving (2–4 June) and after most cows had calved (10–11 June). Summary maps of caribou density were prepared to compare distribution and density in 2008 with long-term averages from regional calving surveys since 1993. A helicopter was used to sample age and sex composition on 12 June. Additional aerial surveys of caribou distribution and abundance were conducted in late April, mid-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 slightly earlier than average in 2008. Snow depth was above average on 15 May at the Kuparuk airstrip, but the snow melted rapidly during late May and was largely gone during the first week of June. Temperatures were well above average in late May and early June.
- On the first calving survey (2–4 June), 3,615 caribou were observed, including 568 calves (16%), among the 3 calving survey areas. Expanding the counts to include the entire survey area resulted in a total estimate (± 80% confidence interval [CI]) of 7,230 ± 456 total caribou (adults and calves) and a mean density of 2.22 ± 0.14 caribou/km² among all 3 survey areas.
- On the second calving survey (10–11 June), 11,623 caribou were observed, including 2,269 calves (20%), among the 3 survey areas, resulting in an expanded total estimate of 23,246 ± 1,585 caribou (adults and calves) and a mean density of 7.14 ± 0.49 caribou/km², the highest recorded since surveys began in 1993. The highest calving density in 2008 occurred south of the Kuparuk Oilfield, in the Kuparuk South survey area.
- Calf production by the western segment of the CAH was estimated at 78.3 calves:100 cows (n = 7,728 caribou) on 12 June, higher than the mean annual production estimated during 1978–2008 (73.3 calves: 100 cows). Calf production has exceeded 70 calves:100 cows in 12 of the last 13 years.
- On 10 June 2008, 1,484 total caribou (including 284 calves) were estimated to be in the Kuparuk Field survey area, of which 782 caribou (including 156 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 above average in June and early July, close to average in late July, and below average in early August. Temperature and wind speed data for 2008 suggest that activity by mosquitoes and oestrid flies was higher than average early in the summer and lower than average in August.
- The densities of caribou in the Colville East survey area outside of the calving season were low to moderate in late April and mid-May, high in late June, low in August, and increased again in September and early October, before dropping again in late October. The mean density for April–October surveys in 2008 (0.40 caribou/km²; excluding June) was in the range of the densities observed during 2001–2007 (0.07–0.62 caribou/km²).
- Between early May and mid-October 2008, 28 sightings of muskoxen were recorded in the study area. A mixed-sex group numbering up to 13 animals was found near the Colville River. A large mixed-sex group totaling up to 26 animals was seen repeatedly near CPF-1 in May and early June. Up to 41 muskoxen were observed near the Kuparuk River and in the Milne Point area; a maximum of 9 calves were observed at one time with the Kuparuk River and Milne Point groups.

- Twenty grizzly bear sightings, totaling 20 adults and 16 cubs, were recorded within 75 km of the coast in the NPRA and Kuparuk–Colville region during the 2008 aerial surveys. Other large mammal sightings included a polar bear on the Colville River delta on 8 August; 28 spotted seals hauled out on a bar in the Colville River delta on 18 August; a gray wolf along the Miluveach River on 25 October; and a wolverine along Fish Creek in NPRA on 26 June.

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ACKNOWLEDGMENTS

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INTRODUCTION

Four herds of barren-ground caribou (*Rangifer tarandus granti*) inhabit Alaska north of the Brooks Range. The 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 377,000 caribou in July 2007 (Dau 2007), despite a 23% decline from the estimated peak of 490,000 in July 2003. 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, although a portion of the herd has shown a tendency to winter with the Central Arctic Herd (CAH) in recent years. The CAH typically 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 5,000 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 conducted in July 2008 by ADFG, but the results are not available at this writing.

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 from 1995 to its peak count of 45,166 in the most recent census in July 2002 (Carroll 2003). A photocensus was conducted in July 2008 by ADFG, but the results are not yet available.

In contrast to the other 3 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 was conducted in July 2008 by ADFG, but the results are not yet available.

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 the 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 spring 2008, 64 CAH females were outfitted with conventional VHF radio-collars (E. Lenart, ADFG, pers. comm.), including 53 adults (aged 2 years or older) and 11 1-yr-olds. No 3-yr-olds were collared. During 2001–2004, 60–65 newborn calves were outfitted annually with VHF collars by ADFG, supported in part 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. In early July 2008, four GPS collars were deployed on CAH females by ADFG with funding from CPAI.

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 2008. 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 2008 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 other large mammals as well, most notably muskoxen (*Ovibos moschatus*) and grizzly (brown) bears (*Ursus arctos*).

The 2008 study had 4 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 estimate 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 wildlife 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 3 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 2 easternmost transects of the Kuparuk

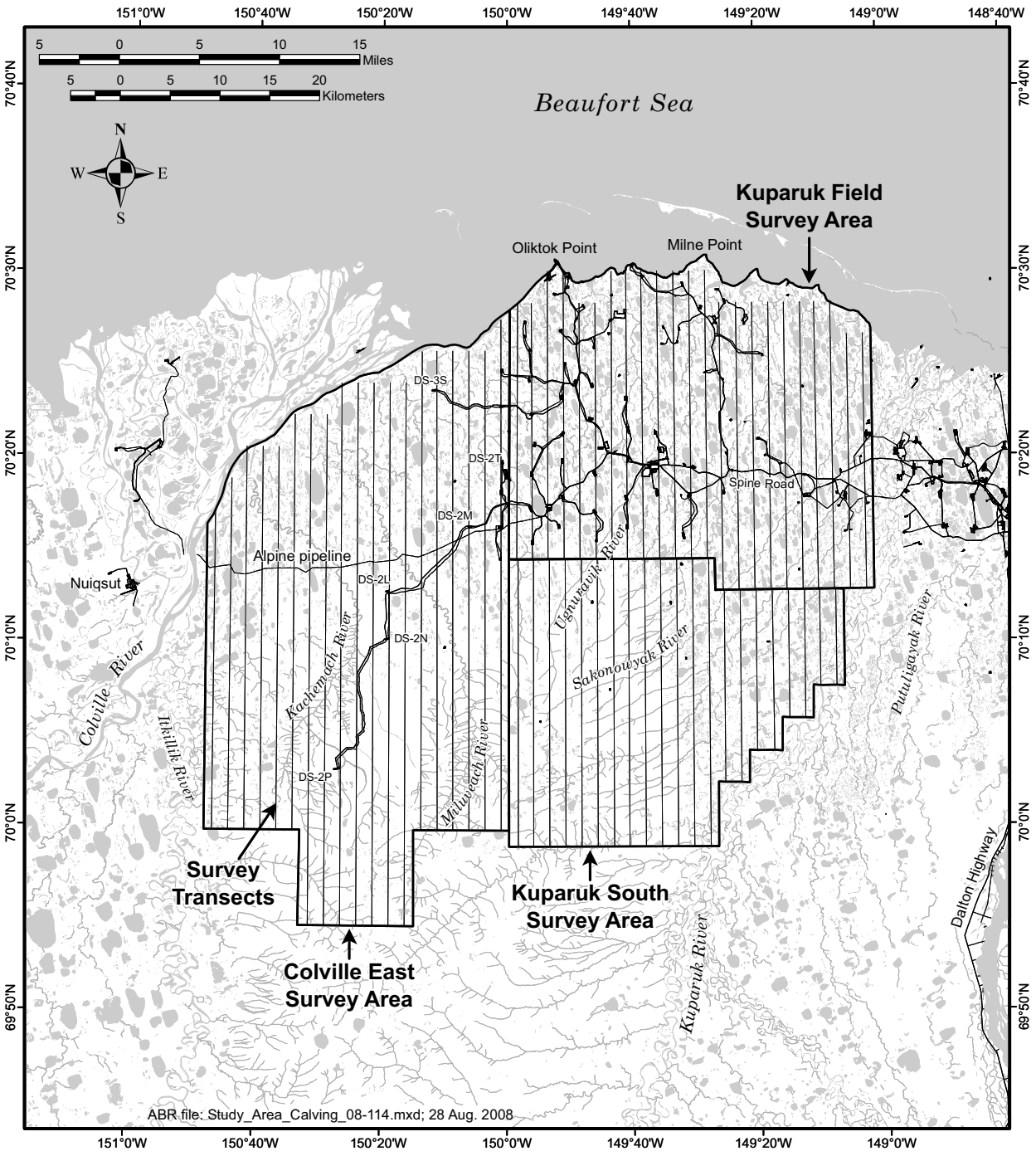

Figure 1. Survey areas and transect lines for systematic aerial surveys of caribou in the Kuparuk–Colville region, northern Alaska, during the 2008 calving season.

Field survey area were dropped and the Kuparuk South survey area was extended eastward to the Kuparuk River. The net result was an 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 for that survey period in the southwestern and southeastern corners to form a rectangle on the southern end (thereby expanding the survey area to 1,700 km²). The western border was extended farther west in fall 2008, for a total area of 1,938 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 2008 (Figure 1): one near the typical peak of calving (2–4 June) and one a week later (10–11 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 1995–2007). Caribou were counted by 2 observers looking on opposite sides of a Cessna 206 airplane; a third observer recorded data. In each survey area, the pilot navigated along north–south-oriented transect lines using route 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 4 100-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 2008) 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. Although patchy snow remained during the early calving season survey (2–4 June), the proportion of ground covered by snow was relatively low and sightability was high enough to make the use of the SCF unnecessary. By the time of our second calving survey (10–11 June), nearly all snow had melted and sightability was high.

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 3 survey areas on 12 June. 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 10–11 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 *ArcMap* GIS software (Environmental Systems Research Institute, Inc. [ESRI], Redlands, CA) to map caribou densities in 2008 and over all years (1993 and 1995–2008). 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 in late April, May, June, August, September, 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.

OTHER MAMMALS

Locations and numbers of large mammals other than caribou were noted and mapped as incidental observations during aerial surveys in the 3 calving survey areas and in the Colville East survey area during late summer–fall surveys. Additional sightings were obtained from observers conducting other wildlife surveys (mainly birds) and from CPAI employees.

RESULTS AND DISCUSSION

CARIBOU CALVING SEASON

HABITAT AND SURVEY CONDITIONS

The daily air temperatures in spring 2008 generally were above the long-term average (Appendices A and B). Snow depth was close to the long-term average in early April and slightly above average on 15 May. Snow had melted at the Kuparuk Airstrip by 30 May (Figure 2, Appendix A). The average daily air temperature at the Kuparuk airstrip did not exceed freezing in early June but the cumulative sum of thawing-degree days (TDD) was above average in late May and early June (Figure 2, Appendix A).

Patches of snow cover remained during the first calving survey on 2–4 June, but large areas were snow-free and we did not use the SCF for large caribou (Lawhead et al. 1994). Almost all of the snow cover in the survey areas had melted by the time of the second calving survey on 10–11 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.

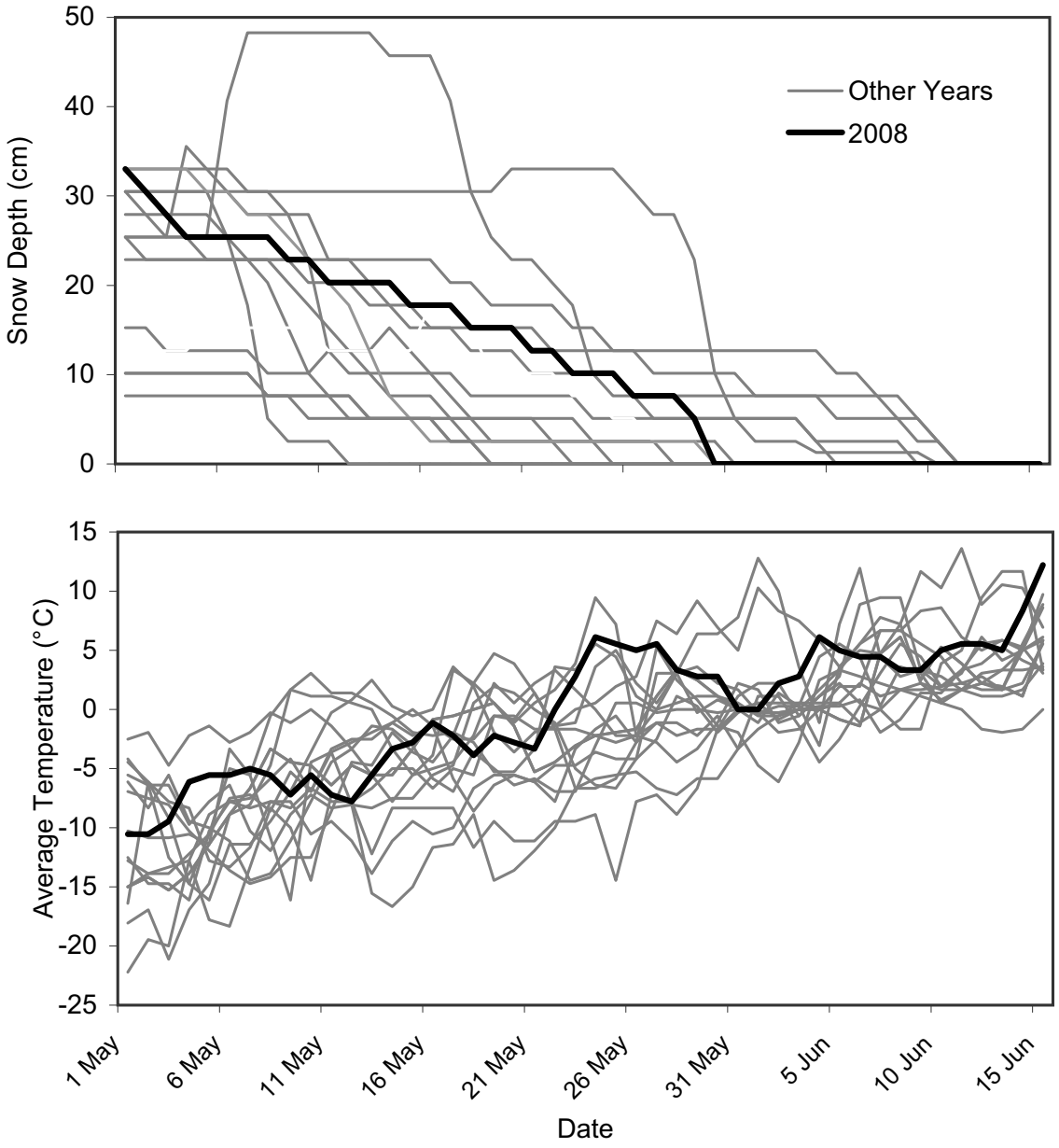

Figure 2. Snow depth (cm) and average daily temperature (° C) at the Kuparuk airstrip during 1 May–15 June 2008, compared with 1993 and 1995–2007.

DISTRIBUTION AND ABUNDANCE IN 2008

The number of caribou in the calving survey areas increased substantially between the early and mid-June surveys. During 2–4 June, we counted 3,615 caribou, including 568 calves (15.7%), in all 3 calving survey areas combined. During 10–11 June, we counted 11,623 caribou, including 2,269 calves (19.5%), in all 3 areas. Doubling our 50% sampling counts produced population estimates of 6,094 ± 368 large caribou and 1,136 ± 110 calves among all 3 survey areas in early June, compared with 18,708 ± 1,189 large caribou and 4,538 ± 437 calves in mid-June (Table 1).

The average densities among all 3 survey areas combined were 1.87 ± 0.11 large caribou/km² (2.22 ± 0.14 total caribou/km²) in early June and 5.75 ± 0.37 large caribou/km² (7.14 ± 0.49 total caribou/km²) in mid-June (Table 2). The density of caribou was highest near the border between the Colville East and Kuparuk South survey areas. The density of large caribou in Kuparuk South and Colville East on both surveys in 2008 was 5–10 times higher than in the Kuparuk Field survey area (Table 2, Figures 3–8).

Compared with previous years since these transect surveys began 1993, the overall number and density of caribou in mid-June 2008 were the highest on record in the Kuparuk South survey area and the second highest on record in the Colville East and Kuparuk Field survey areas (Table 3, Appendix C). The overall density for all areas combined was by far the greatest observed thus far during all transect surveys since 1993 (Table 2). The distribution of caribou in 2008 was typical of the pattern seen in most years since 1993, with the highest-density calving activity occurring in the Kuparuk South survey area.

In 2008, the density of caribou in the Kuparuk Field survey area during calving was the highest observed since 1996, even though it was much lower than the density in the other 2 areas (Table 3, Appendix C). On 10 June, 391 of the caribou (including 78 calves) counted in the Kuparuk Field survey area (53% of the total number and 55% 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. These proportions are close to the long-term averages. The proportions north and east of those roads averaged 50% of total caribou and 51% of calves between 1996 and 2007, 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, 2008). The area north and east of the Spine Road and the Oliktok Point Road, respectively, generally have shown consistent low-density use annually since the early 1990s by several hundred cows with average to high numbers of calves and fewer yearlings and bulls than in areas farther south.

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 1995–2008 (Johnson et al. 1996, 1997, 1998; Lawhead et al. 1997, 1998; Lawhead 1999; Lawhead and Johnson 2000; Lawhead and Prichard 2001, 2002, 2003a, 2003b, 2005, 2006, 2007, 2008, this study). These annual data were used to generate mean values over the entire 15-year 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 estimates of observable population and density in each area reveal the variability in numbers and densities among areas and years (Appendix C). 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). Within the Kuparuk Field survey area, caribou density was highest in areas away from roads (Figures 7 and 8). Although the density of calving caribou in the vicinity of the Milne Point Road (which passes through the center of the Kuparuk Field survey area) has generally declined since the 1980s (Noel et al. 2004), the density of caribou in the Kuparuk Field survey area was the second highest on record (Appendix C). In mid-June 2008, an estimated

Table 1. Estimated numbers of caribou (± 80% CI) during the 2008 calving season in the Colville East, Kuparuk South, and Kuparuk Field survey areas, Alaska.

Survey Area	Date	Total Area (km²)	Estimate [a]		
			Total	Large [b]	Calves
Colville East	June 3–4	1,432	3,810 ± 300	3,388 ± 259	422 ± 59
	June 11	1,432	10,148 ± 1,049	8,310 ± 740	1,838 ± 333
Kuparuk South	June 3–4	788	3,044 ± 301	2,366 ± 225	678 ± 85
	June 10–11	788	11,614 ± 1,022	9,198 ± 797	2,416 ± 252
Kuparuk Field	June 2–3	1,035	376 ± 45	340 ± 42	36 ± 8
	June 10	1,035	1,484 ± 200	1,200 ± 159	284 ± 50
Total	June 2–4	3,255	7,230 ± 456	6,094 ± 368	1,136 ± 110
	June 10–11	3,255	23,246 ± 1,585	18,708 ± 1,189	4,538 ± 437

[a] Estimates are actual counts multiplied by 2 to account for 50% sampling intensity.
[b] Adults + yearlings.

Table 2. Estimated density of caribou (number per km² ± 80% CI) in the Colville East, Kuparuk South, and Kuparuk Field survey areas, June 2008.

Survey Area	Date	Density		
		Total	Large [a]	Calves
Colville East	June 3–4	2.66 ± 0.21	2.37 ± 0.18	0.29 ± 0.04
	June 11	7.09 ± 0.73	5.80 ± 0.52	1.28 ± 0.23
Kuparuk South	June 3–4	3.86 ± 0.38	3.00 ± 0.29	0.86 ± 0.11
	June 10–11	14.74 ± 1.30	11.67 ± 1.01	3.07 ± 0.32
Kuparuk Field	June 2–3	0.36 ± 0.04	0.33 ± 0.04	0.03 ± 0.01
	June 10	1.43 ± 0.19	1.16 ± 0.15	0.27 ± 0.05
Total	June 2–4	2.22 ± 0.14	1.87 ± 0.11	0.35 ± 0.03
	June 10–11	7.14 ± 0.49	5.75 ± 0.37	1.39 ± 0.13

[a] Adults + yearlings.

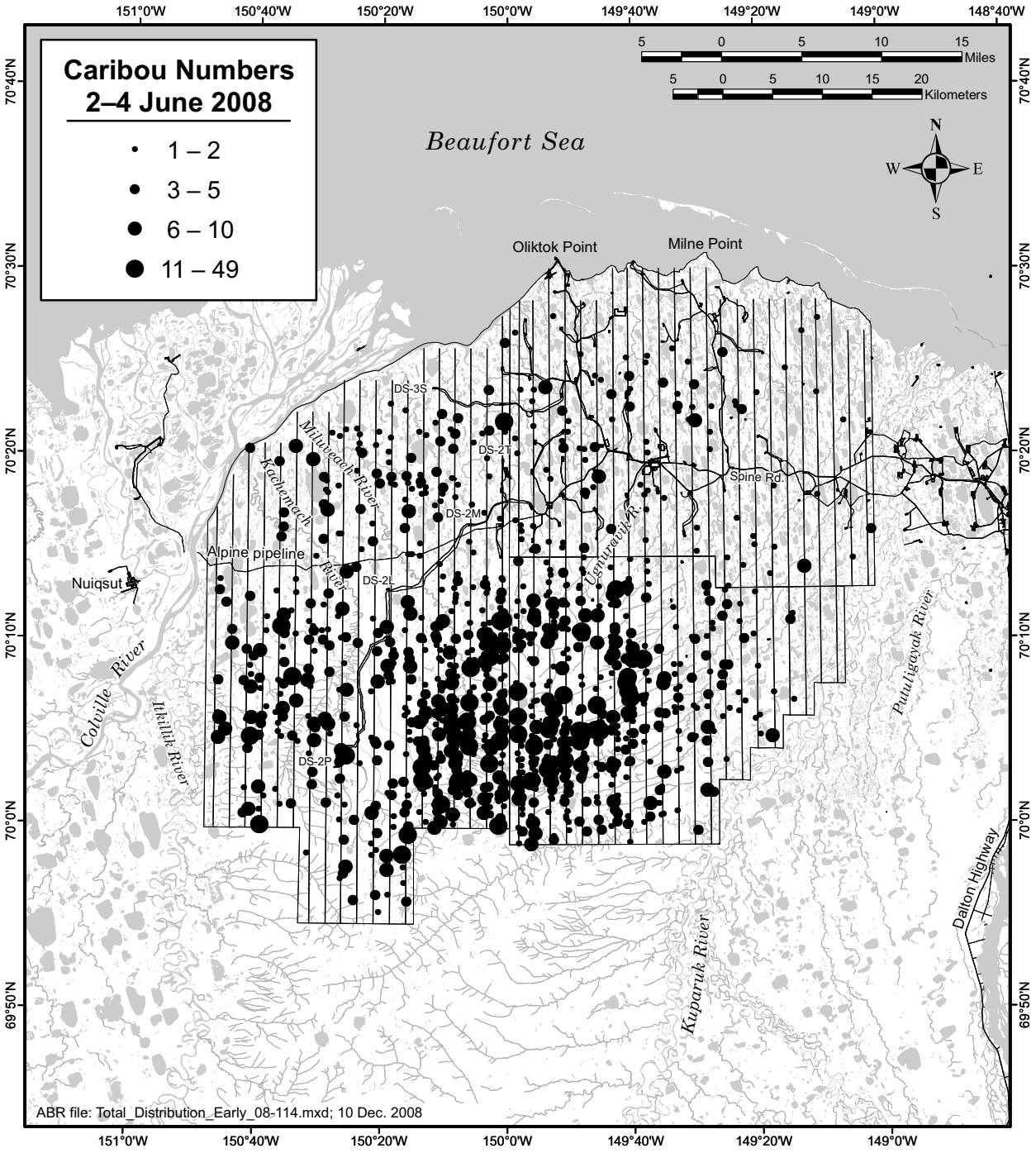

Figure 3. Distribution and group size of all caribou (adults and calves) in the Kuparuk–Colville calving survey areas, 2–4 June 2008.

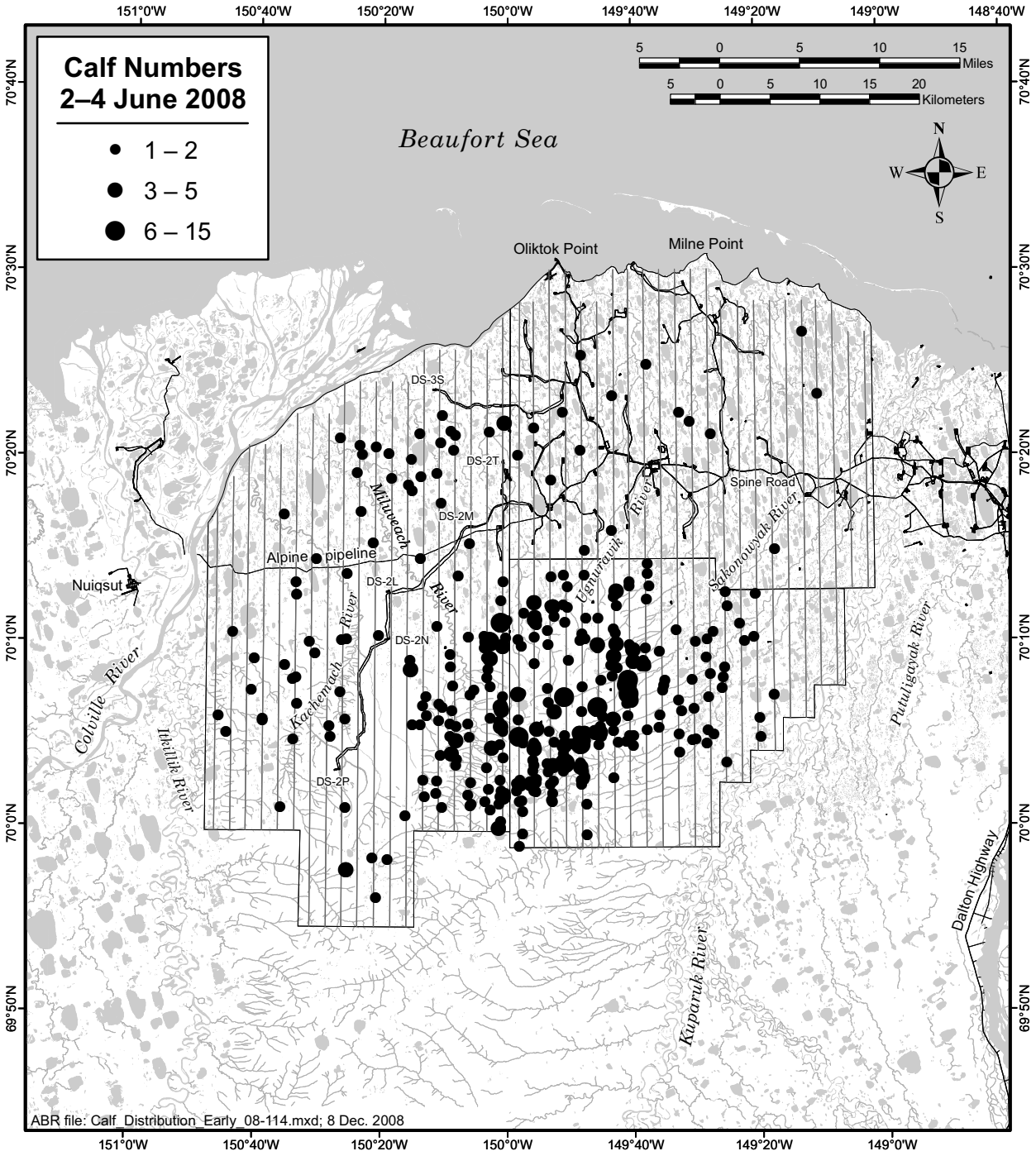

Figure 4. Distribution and number of calf caribou in the Kuparuk–Colville calving survey areas, 2–4 June 2008.

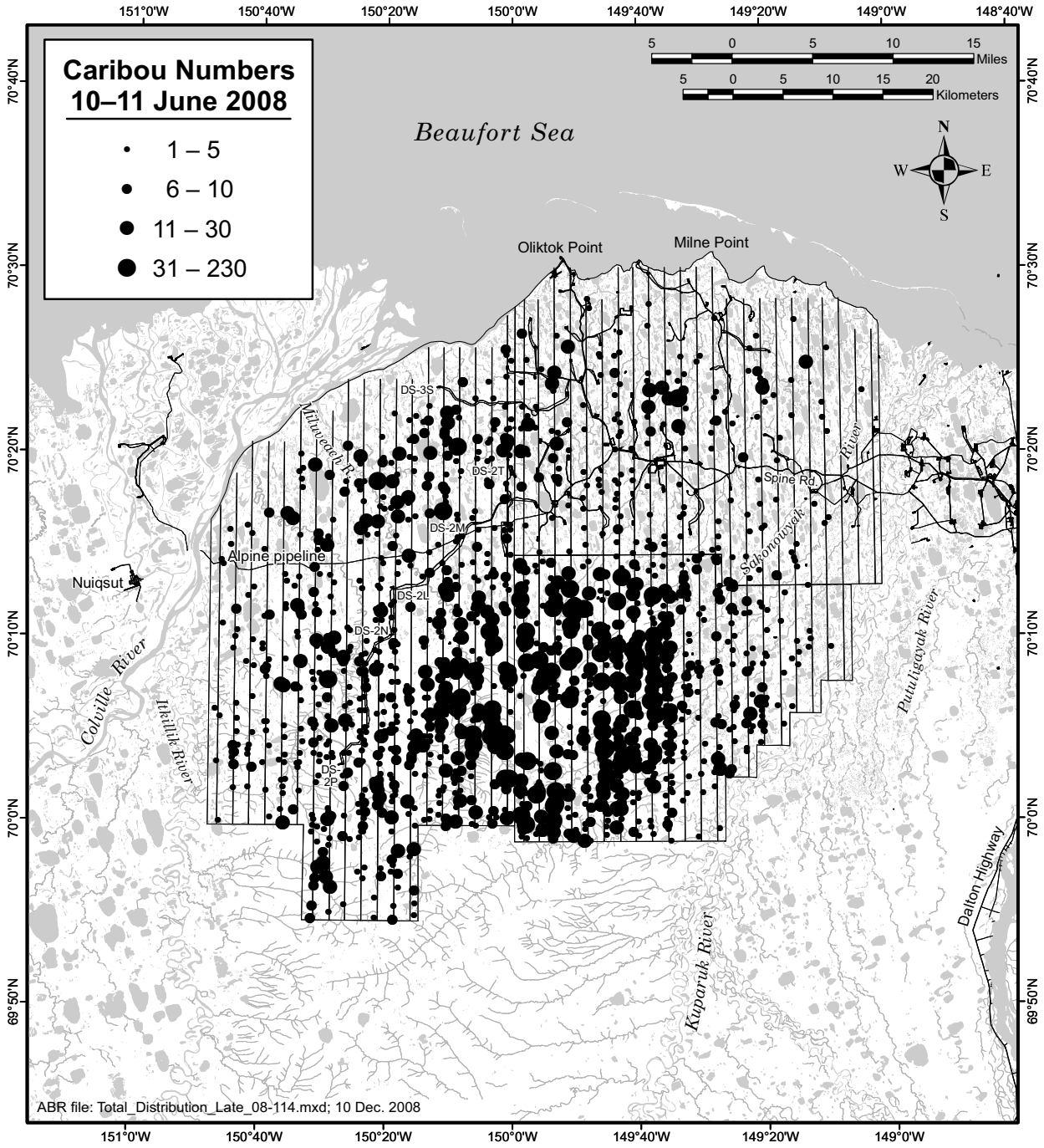

Figure 5. Distribution and group size of all caribou (adults and calves) in the Kuparuk–Colville calving survey areas, 10–11 June 2008.

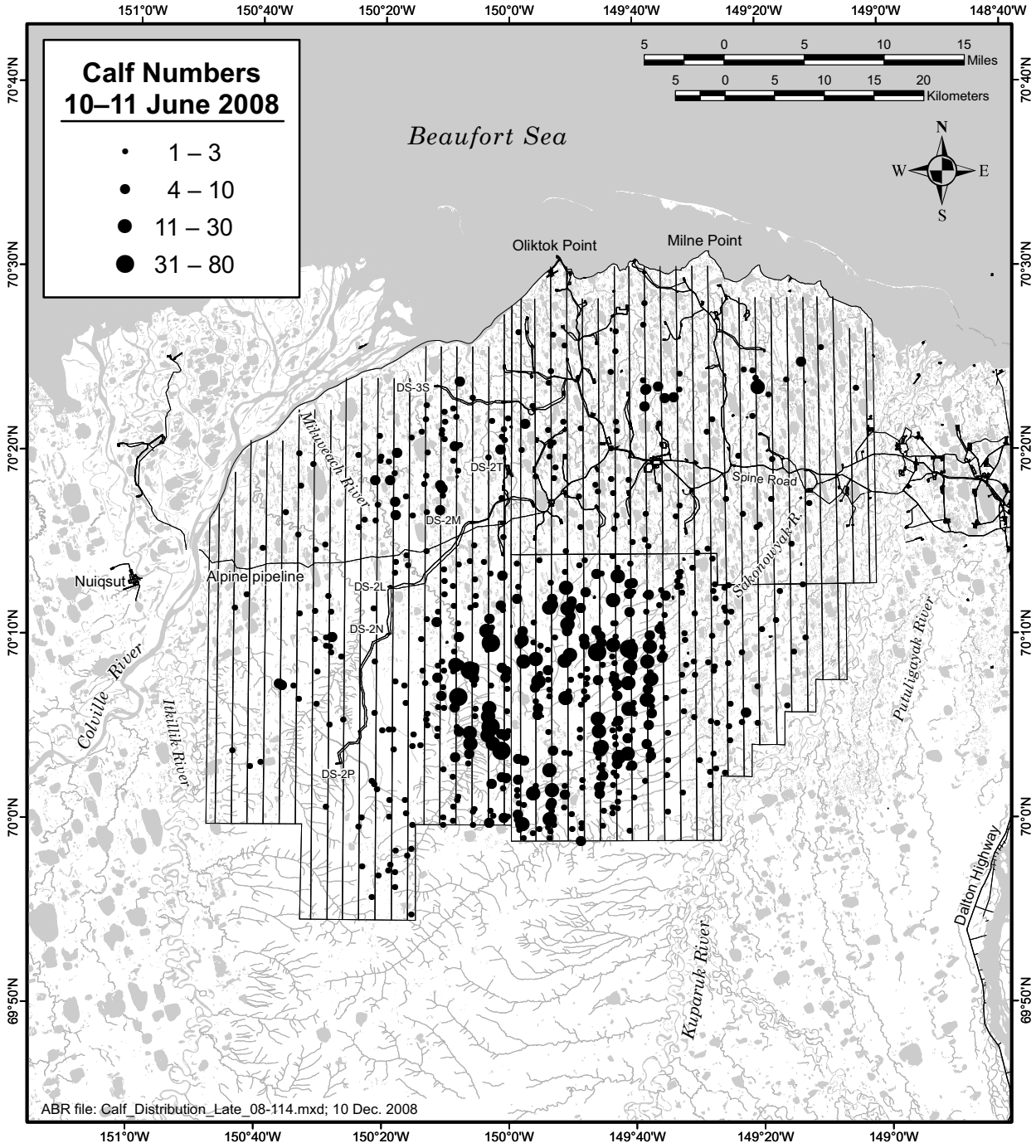

Figure 6. Distribution and number of calf caribou in the Kuparuk–Colville calving survey areas, 10–11 June 2008.

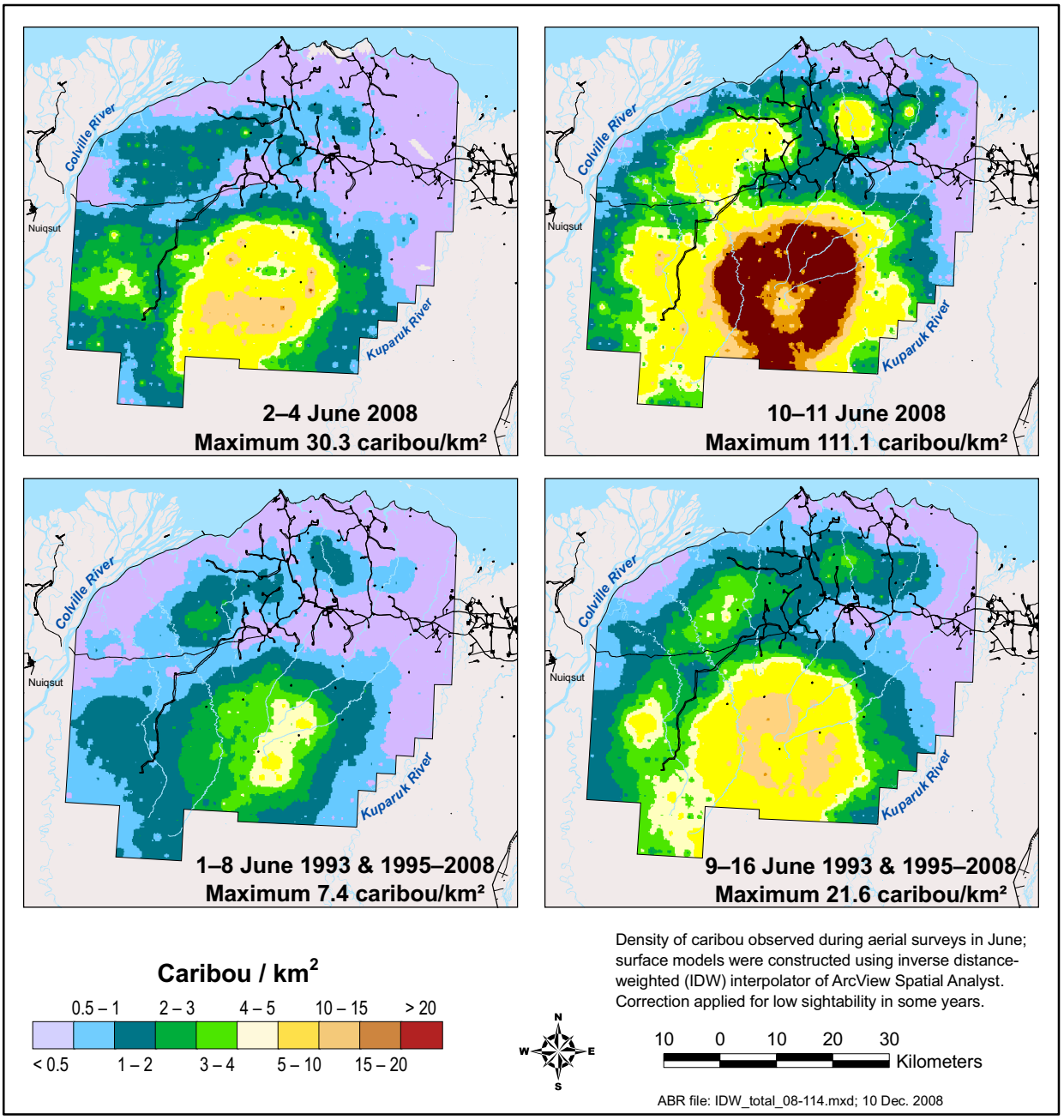

Figure 7. Distribution and density of all caribou in the Kuparuk–Colville calving survey areas during 2–4 June and 10–11 June 2008 (top) and distribution and mean density of all caribou during early June and mid-June in the Kuparuk–Colville calving survey areas, 1993 and 1995–2008 (bottom).

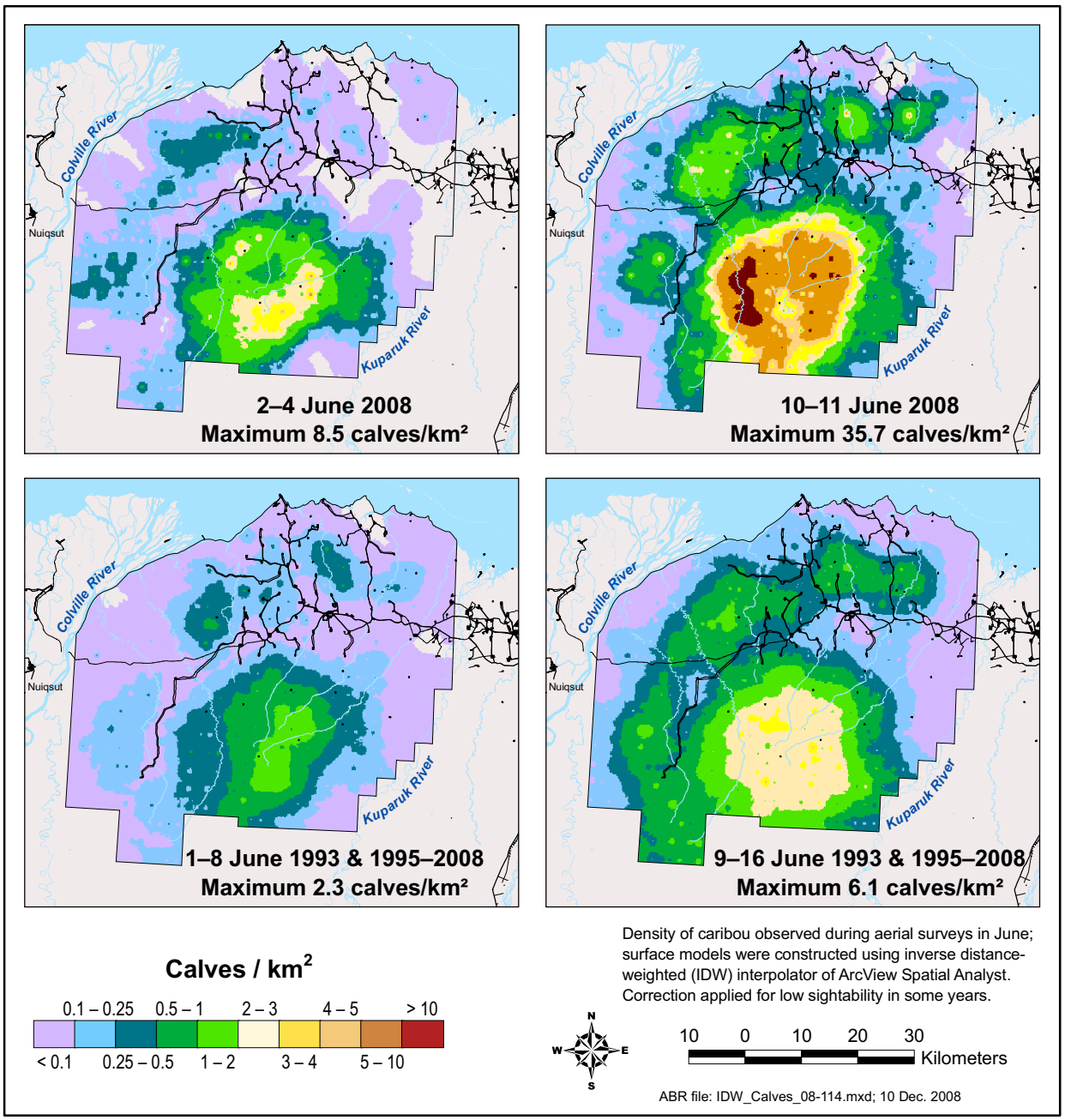

Figure 8. Distribution and density of calf caribou in the Kuparuk–Colville calving survey areas during 2–4 June and 10–11 June 2008 (top) and distribution and mean density of calf caribou during early June and mid-June in the Kuparuk–Colville calving survey areas, 1993 and 1995–2008 (bottom).

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 1995–2008.

Year	Colville East		Kuparuk Field		Kuparuk South		Total		Timing of Snow Melt
	Total	Calves	Total	Calves	Total	Calves	Total	Calves	
1993	2.40	0.61	0.65	0.16	–	–	1.40	0.35	Intermediate
1995	1.52	0.23	–	–	5.05	0.97	2.54	0.44	Intermediate
1996	1.97	0.58	2.16	0.79	7.25	2.62	3.08	1.06	Early
1997*	3.05	0.92	0.28	0.07	2.40	0.69	1.91	0.56	Late
1998	1.39	0.23	0.62	0.18	10.22	3.68	2.84	0.89	Early
1999	1.47	0.37	1.17	0.41	3.26	1.03	1.70	0.51	Late
2000*	0.65	0.13	0.36	0.09	0.53	0.14	0.53	0.12	Late
2001	0.78	0.13	0.60	0.15	3.54	1.01	1.24	0.30	Late
2002	4.35	0.72	0.86	0.22	6.06	1.48	3.65	0.74	Early
2003	1.95	0.43	0.48	0.14	1.69	0.46	1.42	0.34	Intermediate
2004	5.28	1.73	0.56	0.17	3.63	1.06	3.29	1.05	Intermediate
2005	1.92	0.51	0.07	0.02	0.30	0.09	0.94	0.25	Intermediate
2006	2.83	0.71	0.88	0.24	10.61	3.14	4.09	1.15	Intermediate
2007	7.42	1.81	0.44	0.06	6.22	1.57	4.91	1.20	Intermediate
2008	7.09	1.28	1.43	0.27	14.74	3.07	7.14	1.39	Intermediate
Mean	2.94	0.69	0.75	0.21	5.38	1.50	2.71	0.69	

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

1,484 caribou were present in the Kuparuk Field survey area. In comparison, the estimated numbers in the Kuparuk Field survey area during our mid-June surveys in 1993 and 1995–2008 ranged from 54 to 2,458 caribou (Appendix C).

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 2002–2008.

In most years since 1995, the mean density of caribou during calving has been highest in the Kuparuk South survey area; however, in 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 14 years since 1995, including 2003–2005 and 2007 (Table 3). In 2008 and other recent years, caribou densities were low in the area directly adjacent to the Tarn (DS-2N) and Meltwater (DS-2P) roads, 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 12 June 2008, we counted 7,728 caribou in portions of the Kuparuk Field, Kuparuk South, and Colville East survey areas (Figure 9). The sample comprised 4,160 cows, 3,257 calves, 290 yearlings, and 21 adult bulls (Table 4). Based on this count, our estimate of calf production in 2008 was 78.3 calves:100 cows for the western segment of the CAH. The calf:cow ratio in the Kuparuk Field survey area (78.7 calves:100 cows) was not significantly lower than that in the Kuparuk South survey area (80.5 calves:100 cows; $P = 0.797$, Fisher's Exact Test). Yearlings composed 3.8% of the total sample, for an overall ratio of 7.0 yearlings:100 cows (Table 4).

At 78.3 calves:100 cows, our estimate of calf production by the western segment of the CAH in 2008 was above the long-term average (73.3 calves:100 cows) for 1978–2008 (Figure 10). After declining from the mid-1980s to the mid-1990s, calf production increased in 1996 (Figure 10) and calf production has exceeded the long-term average in 12 of the last 13 years. Although calf production has declined slightly since 1996, it 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 2008 estimate is lower than ADFG's preliminary estimated parturition rate of 98% for adult cows ($n = 46$ on 2–4 June) and the late June survival count of 91 calves:100 cows ($n = 46$ on 23–24 June), based on radio-collared adult females aged 4 years and older (E. Lenart, ADFG, pers. comm.). Our estimated calf:cow ratio was obtained about a week and a half after the typical peak of calving in the first week of June. Our classification of cows also included 2- and 3-year-old females. Because 2-year-olds have low rates of parturition, our calf estimate would be expected to be lower than the ADFG estimate, which was based on adult caribou at least 4 years old. ADFG found that no 2-year-olds had calves in 2006 ($n = 6$).

The ratio of 7.0 yearlings:100 cows in our composition sample was near the low end of the range of estimates reported for 1979–2000 for the CAH (8–48; mean 25.3; $n = 14$) (Lenart 2003). Our estimate ranged between 4.1 and 39.6 yearlings:100 cows during 1996–2007 (mean = 13.9, $n = 10$). 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 likely frequency of occurrence and severity of insect harassment. The sums of thawing degree-days (TDD) were above the long-term average during late June and

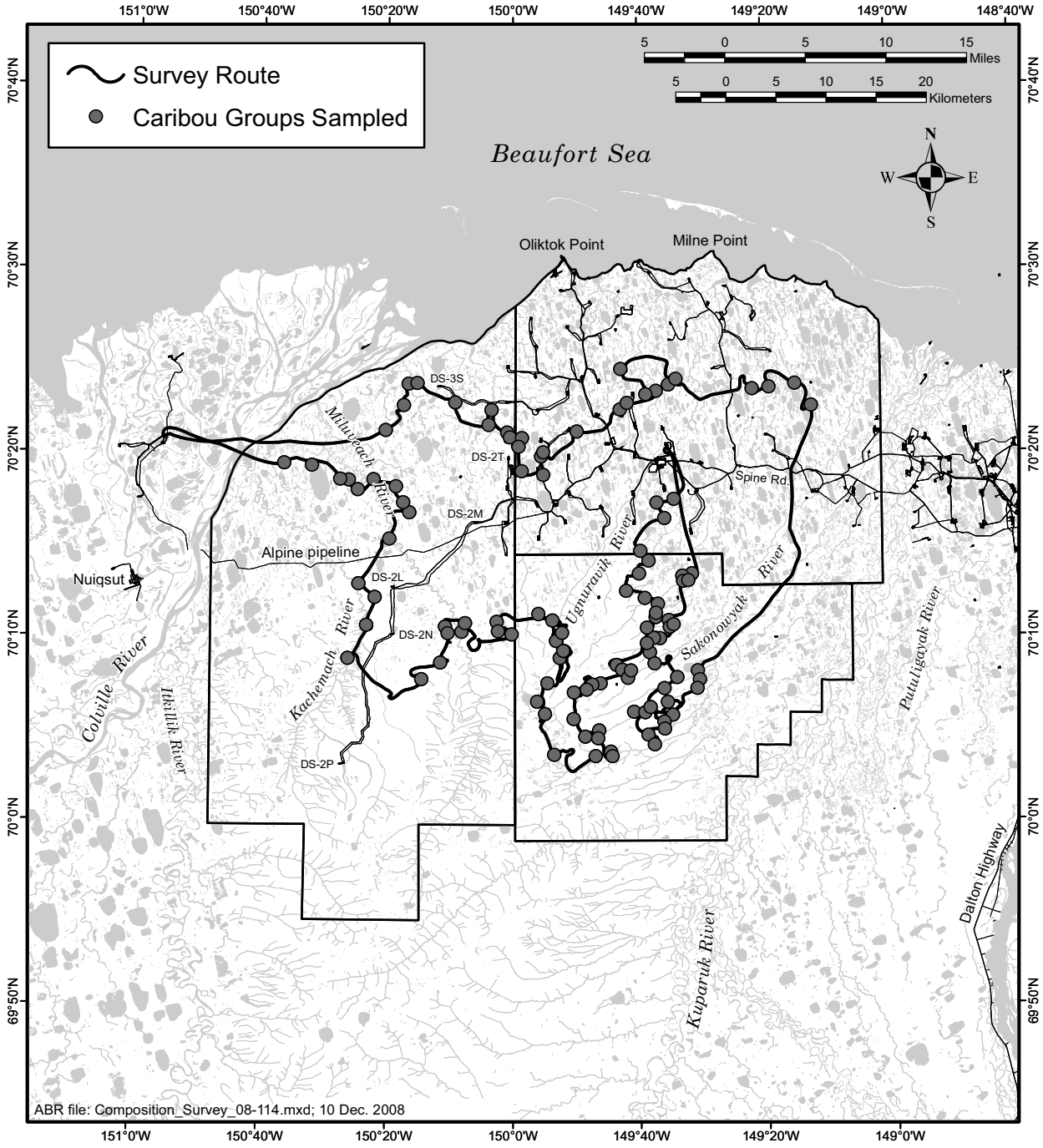

Figure 9. Route of aerial survey and location of groups sampled to quantify sex and age composition of caribou in the Kuparuk–Colville calving survey areas, 12 June 2008.

Table 4. Sex and age composition of caribou in the Kuparuk–Colville region on 12 June 2008.

Survey Area	No. of Groups	Total No.	Cows		Calves		Yearlings		Bulls		Calf Ratio [a]	Yrlg. Ratio [b]
			No.	%	No.	%	No.	%	No.	%		
Kuparuk Field	22	636	342	53.8	269	42.3	23	3.6	2	0.3	78.7	6.7
Kuparuk South	60	5,519	2,951	53.5	2,376	43.1	191	3.5	1	0.0	80.5	6.5
Colville East	32	1,573	867	55.1	612	38.9	76	4.8	18	1.1	70.6	8.8
Total	114	7,728	4,160	53.8	3,257	42.1	290	3.8	21	0.3	78.3	7.0

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

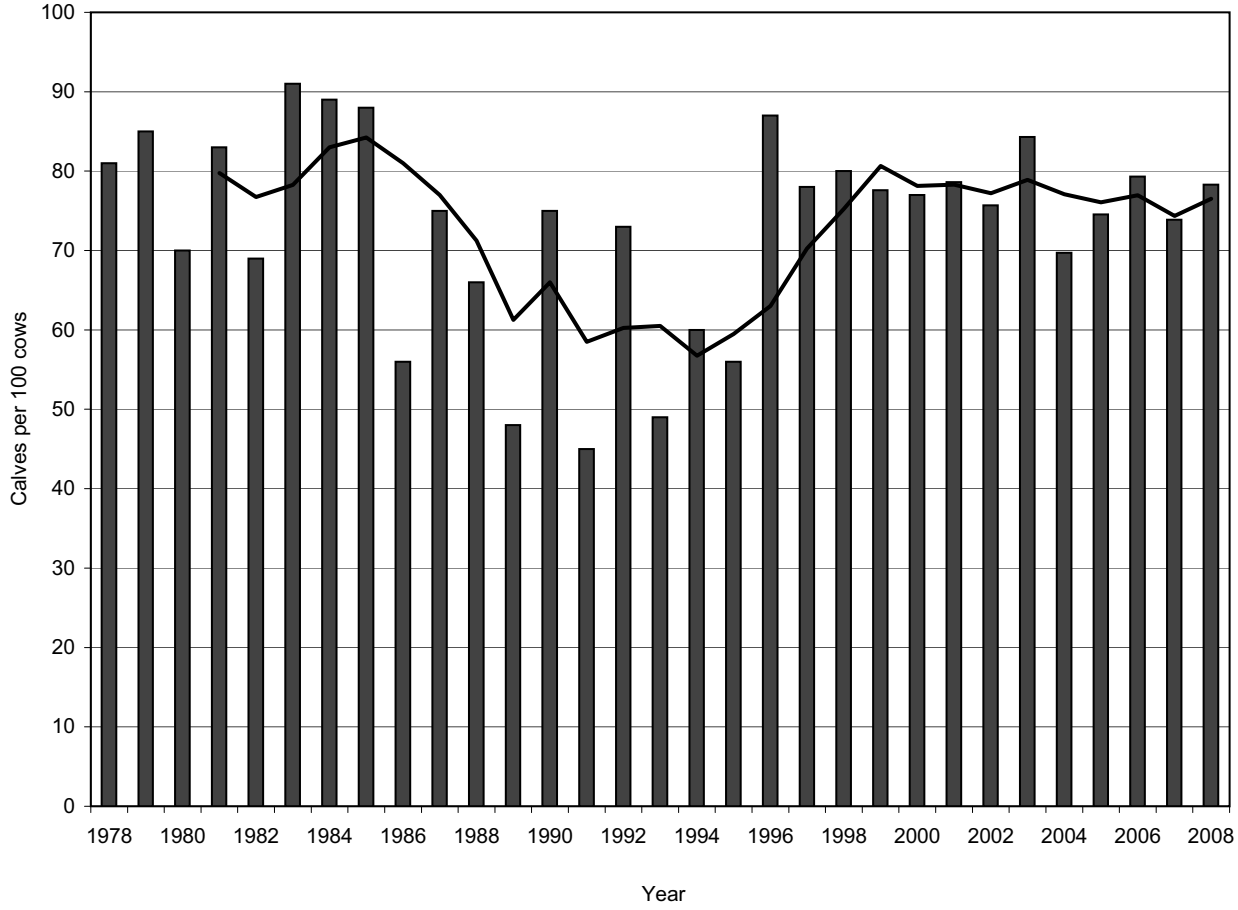

Figure 10. Estimated production of calf caribou (calf:cow ratio [bars] and 4-year moving average [line]) by the western segment of the Central Arctic Herd, based on aerial surveys in mid-June 1978–2008. Data sources: Fancy et al. (1992) for 1978–1990; Woolington (1995) for 1991–1992; Smith et al. (1994) 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, 2008, this study) for 2000–2008.

early July, were slightly below average in late July, and were well below average in early August, indicating cooler-than-normal temperatures late in the season (Appendices D and E).

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 and oestrid flies activity based on daily maximum temperatures at the Kuparuk airstrip (but ignoring wind speed; Russell et al. 1993) were above average in June and early July, close to average in late July, and well below average in August (Appendix F and G). The estimated probability of oestrid fly activity (Mörschel 1999), based on average hourly wind speeds and temperatures recorded at Nuiqsut, was >50% on 7 days between 17 June and 6 August 2008 (Appendix H): 2 days in June (20, 30 June), 5 days in July (7–9, 5, 28 July), and none in August. Thus, the available weather data indicate that the levels of insect activity and resulting harassment of caribou were fairly high in late June and early July, but were low in late July and 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 moderate in late April and mid-May (0.52–0.99 caribou/km²; Table 5; Figure 11), but was far below the peak density recorded during the second calving survey in mid-June (7.09 caribou/km²; Table 2). Caribou density declined but remained high on the postcalving survey on 19 June (3.21 caribou/km²; Table 5, Figure 11), when many caribou were found in large postcalving aggregations, especially in the southeastern corner of the survey area. An additional ~1,900 caribou were observed that day in 2 large groups east of the survey area along the "Rubar Fork," a tributary of the Kuparuk River. Those aggregations suggested that mosquitoes had begun to emerge farther inland. Although ABR biologists were not present to record the date of mosquito emergence in the study area, it appears to have occurred between 19 and 23 June, which is relatively early, judging from our experience since the early 1980s. Biologists conducting bird surveys on the Colville River delta in 2008 reported high levels of mosquito harassment on 23–24 June on the delta. Three

Table 5. Number and density of caribou in the Colville East survey area, April–October 2008 (excluding calving surveys).

Date	Area Surveyed [a] (km²)	Total Counted	Estimated Total	Density (caribou/km²)	Groups	Average Group Size
April 29–30 [b]	429	251	502	0.59	57	4.4
May 19 [c]	663	348	1,308	0.99	44	7.9
June 19	850	2,727	5,454	3.21	144	18.9
August 21	850	119	238	0.14	79	1.5
September 25 [d]	969	482	964	0.50	147	3.3
October 7–9 [e]	311	106	212	0.34	9	11.8
October 24–25	969	60	120	0.06	14	4.3
Total	5,041	4,093	8,798	0.87	494	8.3

[a] 50% coverage of survey area.
[b] Only southwestern and eastern portions were surveyed due to fog in other areas.
[c] Sightability Correction Factor of 1.88 applied due to patchy snow; southeastern portion not surveyed due to fog.
[d] Added two transects to western side for this survey and subsequent surveys.
[e] Only western portion and part of one eastern transect were surveyed due to fog.

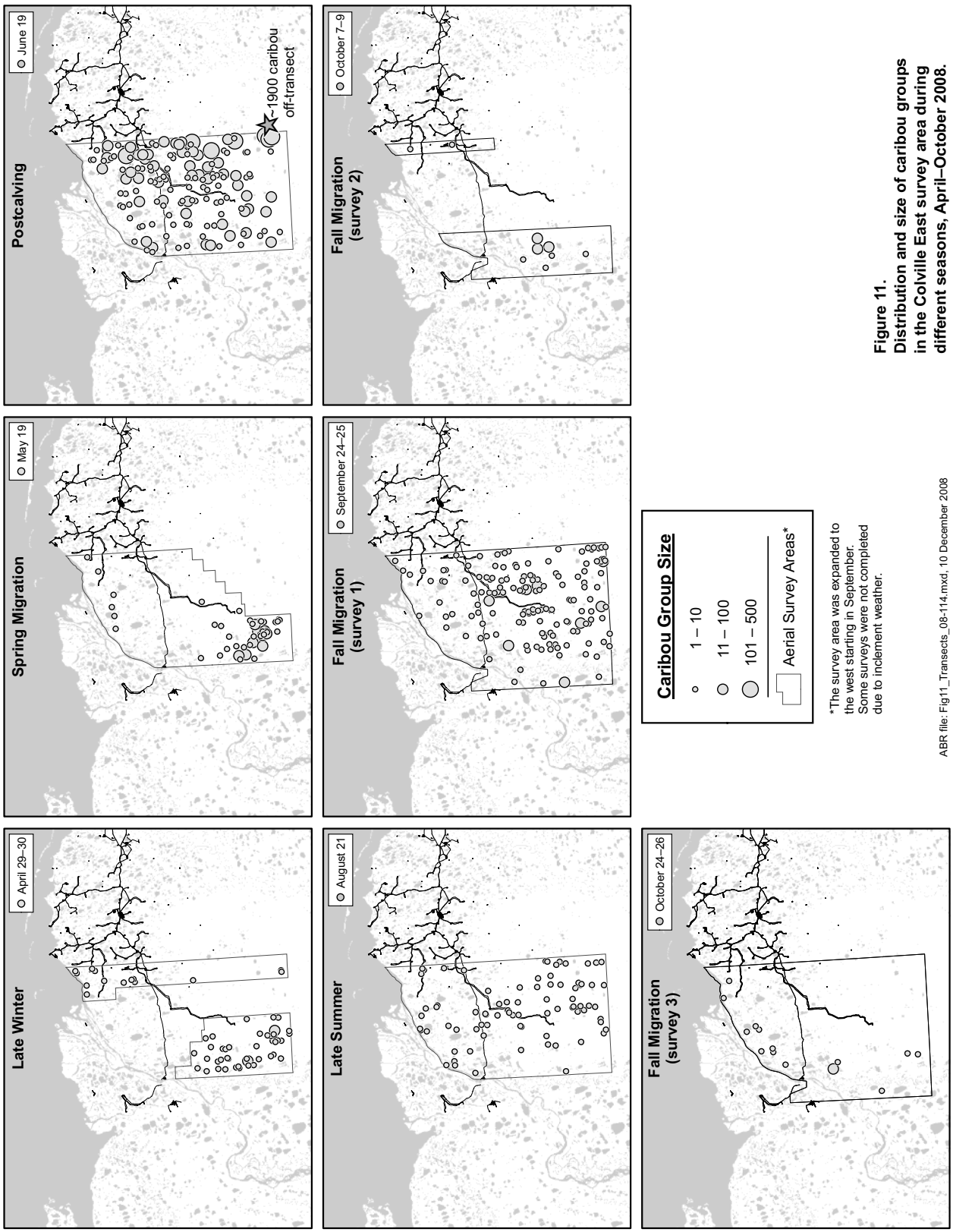

Figure 11.
Distribution and size of caribou groups in the Colville East survey area during different seasons, April–October 2008.

CAH radio-collars were found in the area between Milne Point and the Kuparuk River delta on 23–24 June, at a time when most of the CAH radio-collars were east of the Sagavanirktok River (E. Lenart, ADFG, pers. comm.), and several thousand caribou were observed by ABR bird biologists near Milne Point on 25 June 2008.

Few caribou were present in the study area on 21 August (0.14 caribou/km², Table 5, Figure 11). The number of caribou increased slightly in late September and early October but was very low in late October. Although caribou groups were observed throughout the survey area, the highest densities were generally 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 2008 (excluding calving and postcalving) was 0.40 caribou/km², in the middle of the range of mean densities observed for those periods in other recent years (0.07–0.62 caribou/km² in 2001–2007; Lawhead and Prichard 2002, 2003a, 2003b, 2005, 2006, 2007, 2008).

OTHER MAMMALS

MUSKOX

Muskox sightings were recorded 28 times between 29 April and 26 October 2008 in 4 general areas in the Kuparuk–Colville region: along the Colville River and Colville River delta, in the central GKA (near Kuparuk CPF-1), near Milne Point, and along the Kuparuk River (Table 6, Figure 12). Another group of 9 adults and calves was seen outside of the GKA study area near the Deadhorse airport on 2 June and reportedly had been in the area for several weeks.

Because individual muskoxen could not be identified, we were unable to distinguish specific groups reliably on successive surveys. The observed numbers and locations suggest that there was considerable interchange between groups and locations throughout the summer. The maximum single-day count was on 10 June when 67 individual muskoxen (55 adults and 12 calves) were observed in 4 groups: a group of 22 adults and 4 calves near CPF-1, 7 adults and 3 young in 2 groups near Milne Point, and 26 adults and 5 young in one group near the Kuparuk River.

In past years, 2 mixed-sex groups of muskoxen were seen in the study area: a group near the Colville River delta and a larger group near the Kuparuk River delta. In 2008, there appeared to be at least 2 large mixed-sex groups, which were not as consistent in their use of specific areas as in past years. Between 2 and 13 muskoxen were observed at various points along the Colville River. A group of up to 22 adults and 4 calves was recorded in the Kuparuk Oilfield near CPF-1 on 5 occasions between 19 May and 10 June. Two observations of 26 and 10 muskoxen were recorded near Milne Point during the early June and mid-June calving surveys, respectively. Near the Kuparuk River, a total of 31 muskoxen (26 adult and 5 calves) were observed on 10 June and 34 muskoxen (25 adults and 9 calves) were observed there on 24 June.

The muskoxen population on the eastern North Slope of Alaska has declined rapidly in recent years, due largely to predation by grizzly bears but also by disease and unusual mortality events such as drowning (Reynolds et al. 2002, Shideler et al. 2007, Lenart 2007, Arthur 2008). At least 11 adult females were killed by bears on the central North Slope in April–May 2008 (L. Parrett, ADFG, pers. comm.). Because of the recent population decline, ADFG increased monitoring of the central North Slope population in 2007 and is conducting an intensive telemetry study to investigate distribution, movements, and survival (Arthur 2008).

MOOSE

A drill-site operator in the western Prudhoe Bay field saw a single moose (*Alces alces*) near W pad on 7 July 2008 (A. Stickney, ABR, pers. comm.), but no moose were seen during ABR wildlife surveys in 2008. During ABR surveys since 1997, 12 moose were observed within 75 km of the coast. Most of those were seen near the Colville River delta, although 2 were in NPRA and 2 were along the Kuparuk River.

GRIZZLY BEAR

Twenty grizzly bear sightings, totaling 20 adults and 16 cubs, were recorded within 75 km of the coast in the Kuparuk–Colville region during aerial surveys in 2008 (Table 6, Figure 12). Three bear groups, consisting of 2 sows with 2 cubs each and a single adult, were observed in the NPRA

Table 6. Locations and number of muskoxen, grizzly bears, polar bears, seals, wolves, and wolverines observed during aerial or road surveys in the Kuparuk–Colville region, April–October 2008.

Species	General Location	Date	Total	Adults	Young	Specific Location
Muskox	Colville River	April 29	12	10	2	E of Nuiqsut
		June 4	3	2	1	N of DS-3S
		September 25	2	2	0	Mouth of Miluveach River
		October 25	11	9	2	E of Nuiqsut
		October 25–26	2	2	0	Mouth of Kachemach River
	Central GKA	May 19	26	22	4	SE of CPF-1
		June 2	26	22	4	E of CPF-1
		June 5	25	21	4	E of CPF-1
		June 7	25	21	4	E of CPF-1
		June 10	26	22	4	S of CPF-1
		June 18	7	5	2	N of Spine Rd., E of Milne Pt. Rd.
		June 19	7	5	2	W of Kuparuk River
	Milne Point	June 2	1	1	0	Milne Point
		June 2	11	11	0	E of Milne Point Road
		June 2	14	12	2	E of Milne Point Road
		June 10	9	6	3	E of Milne Point Road
		June 10	1	1	0	E of Milne Point Road
		August 18	3	3	0	E of Milne Point Road
	Kuparuk River	June 10	31	26	5	N of Spine Road
		June 24	6	4	2	S of Spine Road
		June 24	7	5	2	S of Spine Road
		June 24	11	8	3	N of Spine Road
		June 24	1	1	0	N of Spine Road
		June 24	9	7	2	N of Spine Road
		July 2	>7	>6	1	Near Spine Road
		August 19	10	8	2	N of Spine Road
		August 20	1	1	0	N of Spine Road
		September 25	4	3	1	S of Spine Road
Grizzly bear	NPRA	June 9	3	1	2	Upper Fish Creek
		June 9	1	1	0	Upper Judy Creek
		June 9	3	1	2	Lower Fish Creek
		June 10	3	1	2	Upper Fish Creek
		June 25	3	1	2	Lower Fish Creek
		August 18	3	1	2	Lower Fish Creek
	Colville River delta	June 24	1	1	0	Outer Colville delta
		August 19	1	1	0	E of CD-4
	Upper Colville River	May 18	2	1	1	E of Colville River
		October 7	1	1	0	Colville River
	Western Kuparuk Area	June 4	4	1	3	Upper Sakonowyak River
		June 11	1	1	0	Upper Miluveach River
		June 19	1	1	0	Lower Miluveach River
		June 19	1	1	0	S of DS-2M
		June 19	1	1	0	Upper Miluveach River
		September 25	1	1	0	Lower Kachemach River
		September 25	1	1	0	Upper Miluveach River
	Eastern Kuparuk Area	June 10	1	1	0	S of CPF-1
		June 10	3	1	2	E of Milne Point Road
		August 19	1	1	0	Kuparuk River
Polar bear	Colville River delta	August 8	1	1	0	At Colville Village
Spotted seal	Colville River delta	August 18	28	28	0	Eastern Colville delta
Wolf	Western Kuparuk Area	October 25	1	1	0	Miluveach River
Wolverine	NPRA	June 26	1	1	0	Fish Creek

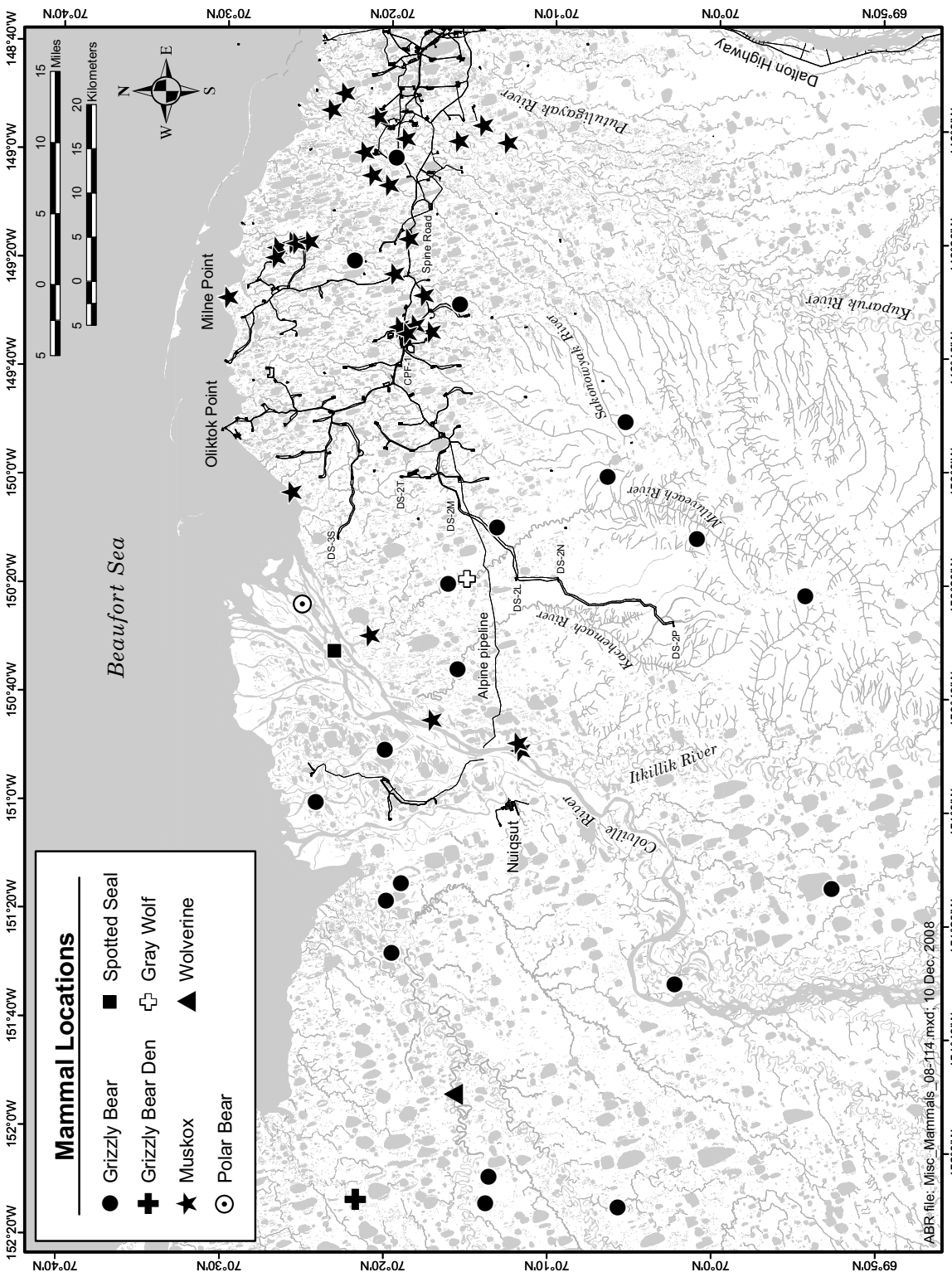

Figure 12. Distribution of large mammals other than caribou observed during aerial and road surveys in the NPRA and Kuparuk–Colville region, April–October 2008.

survey area on 9 June. Sows with 2 cubs were seen on 3 subsequent surveys in that area. Two sightings of single bears were recorded on the Colville River delta. Two bear groups were observed near the Colville River upstream from the delta. Seven groups, including a sow with 3 yearling cubs, were observed in the western Kuparuk area near the Miluveach, Kachemach, and upper Sakonowyak rivers. Three groups, including a sow with 2 cubs, were observed in the eastern Kuparuk area.

Grizzly bears were seen at widely scattered locations throughout the GKA in 2008, in a more uniform pattern than in most previous years, when most bears were seen south of the Kuparuk Oilfield in June in the area of high-density calving by caribou (Lawhead and Prichard 2003b). Grizzly bears prey on caribou calves (Whitten et al. 1992), and the area south of the Kuparuk Oilfield includes abundant high-quality upland and riparian foraging habitats, so the concentration of bear sightings in high-density calving areas is not unexpected. The more uniform distribution of bear sightings in 2008 is likely due to random variability and is an artifact of the timing of observations, rather than representing a fundamental shift in distribution.

POLAR BEAR

One polar bear (*Ursus maritimus*) was observed on 8 August by an ABR observer staying at Colville Village (Table 6, Figure 12). Although polar bears occur annually in and near the Kuparuk Oilfield during winter, their occurrence during summer has been unusual. In 2007, however, 9 polar bears were observed in 5 groups in the Kuparuk-Colville area on 21 August (Lawhead and Prichard 2008). Only one other polar bear was recorded in the Kuparuk area during summer aerial surveys by ABR before 2007: a single bear was observed on 24–26 June 1998 near Mine Site D. With declining sea ice in fall, more polar bears are expected to occur on the mainland and barrier islands in the Beaufort Sea during the fall open-water season (Schliebe et al. 2008).

SPOTTED SEAL

On 18 August 2008, a group of 28 spotted seals (*Phoca largha*) was hauled out on a bar off the main channel of the Colville River (Table 6, Figure 12). The site was between 2 consistently used haulout sites where the species was recorded repeatedly in late summer during more intensive surveys of the delta in the 1990s (Johnson et al. 1999).

GRAY WOLF

One wolf (*Canis lupus*) was observed along the Miluveach River during a caribou survey on 25 October (Table 6, Figure 12). Only 2 wolves were recorded previously on ABR aerial surveys. Single wolves were observed in July 1997 along the Kachemach River and in July 2003 near Nuiqsut. An additional wolf was photographed under DS-2L by CPAI employees in July 2004.

WOLVERINE

One wolverine (*Gulo gulo*) was observed on 26 June 2008 along Fish Creek in NPRA (Table 6, Figure 12). Wolverines have been observed rarely during ABR aerial surveys in the Kuparuk area; that was the eighth sighting since 1993. Four of the past sightings occurred in the month of June, one in September, and 3 in October. The frequency of wolverine observations is heavily influenced by survey timing and conditions. Our survey efforts were concentrated in June, but the sightability of wolverines is higher in late fall when snow covers the ground. A drill-site operator in the western Prudhoe Bay field reported seeing a wolverine between N and P pads on 7 July 2008 (A. Stickney, ABR, pers. comm.).

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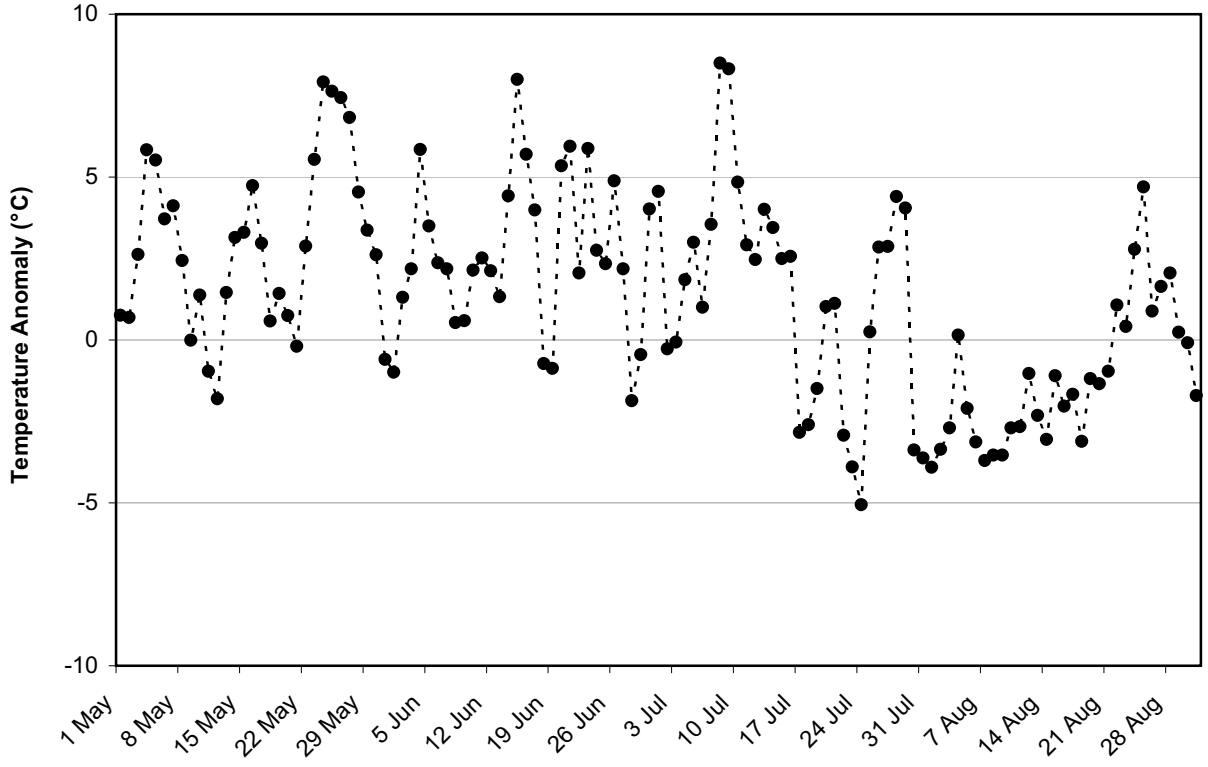
Appendix A. Snow depth (cm) and sum of thawing degree-days (TDD; º C above freezing) at the Kuparuk airstrip, April–June 1983–2008.

	Snow Depth (cm)			Sum of TDD (º 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	48.3
2008	20	18	0	0	33.9	73.3
Mean	22	12	3	0.6	11.6	41.8

[a] Value for 1 June.



Appendix B. Daily temperature anomalies (2008 temperature minus the daily average temperature for 1983–2007) during spring and summer 2008 at the Kuparuk airstrip.

Appendix C. Estimated numbers and densities of caribou in the Kuparuk Field, Kuparuk South, Colville East, Colville Inland, and Colville Delta survey areas, 1993 and 1995–2008.

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	1,202	786	0.65	188	0.16	None
	11 June 1996	1,137	2,458	2.16	897	0.79	None
	3 June 1997	1,137	421	0.37	33	0.03	High; SCF not used
	11 June 1997	1,137	320	0.28	81	0.07	Patchy; SCF used
	4–5 June 1998	1,097	862	0.76	300	0.27	None
	14 June 1998	1,107	688	0.62	202	0.18	None
	12–13 June 1999	1,102	1,284	1.17	456	0.41	Patchy; SCF not used
	14–15 June 2000	1,107	402	0.36	102	0.09	Patchy; SCF used
	12 June 2001	1,107	666	0.60	168	0.15	Patchy; SCF not used
	6, 8 June 2002	1,035	1,124	1.09	304	0.29	None
	12 June 2002	1,035	886	0.86	226	0.22	None
	3, 5 June 2003	1,035	692	0.67	79	0.08	Patchy; SCF used
	13 June 2003	1,035	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	1,035	580	0.56	174	0.17	None
	4–5 June 2005	1,035	68	0.07	15	0.01	Patchy; SCF used
	9 June 2005	1,035	54	0.05	18	0.02	Low; SCF not used
	2–3 June 2006	1,035	49	0.05	8	0.01	Patchy; SCF used
	10 June 2006	1,035	912	0.88	248	0.24	None
	3–4 June 2007	1,035	120	0.12	8	0.01	Patchy; SCF used
	10 June 2007	1,035	452	0.44	60	0.06	None
	2–3 June 2008	1,035	376	0.36	36	0.03	Low; SCF not used
	10 June 2008	1,035	1,484	1.43	284	0.27	None
Kuparuk South [defg]	2 June 1993	825	328	0.40	16	0.02	Patchy; SCF used
	13 June 1995	548	2,769	5.05	531	0.97	None
	4 June 1996	599	3,573	5.96	1,044	1.74	None
	9–10 June 1996	599	4,344	7.25	1,572	2.62	None
	2 June 1997	599	286	0.48	42	0.07	High; SCF not used
	12 June 1997	599	1,437	2.40	415	0.69	Patchy; SCF used
	4 June 1998	603	3,160	5.24	812	1.35	None
	12–13 June 1998	603	6,162	10.22	2,222	3.68	None
	12 June 1999	603	1,964	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	2,132	3.54	608	1.01	Patchy; SCF not used
	7 June 2002	788	4,256	5.40	1,002	1.27	None
	11 June 2002	788	4,778	6.06	1,164	1.48	None
	4–5 June 2003	788	1,530	1.94	180	0.23	Patchy; SCF used

Appendix C. 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	1,334	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	2,188	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	8,360	10.61	2,476	3.14	None
	4–5 June 2007	788	564	0.72	68	0.09	Patchy; SCF used
	10–11 June 2007	788	4,900	6.22	1,240	1.57	None
	3–4 June 2008	788	3,044	3.86	678	0.86	Low; SCF not used
	10–11 June 2008	788	11,614	14.74	2,416	3.07	None
Colville Inland [h]	23 May 1993	1,107	8	0.01	0	0.00	High; SCF not used
	28 May 1993	1,107	224	0.20	15	0.01	Patchy; SCF used
	7 June 1993	1,107	1,186	1.07	64	0.06	Low; SCF not used
	10 June 1993	1,107	1,249	1.13	127	0.11	None
	5 June 1995	1,107	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	1,050	87	0.08	0	0	High; SCF not used
	3 June 1993	1,050	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	2,181	2.40	558	0.61	None
	4–5 June 1995	1,057	315	0.30	41	0.04	Patchy; SCF used
	12–13 June 1995	1,349	2,057	1.52	305	0.23	None
	3–4 June 1996	1,362	800	0.59	159	0.12	None
	12–13 June 1996	1,358	2,670	1.97	786	0.58	None
	1–2 June 1997	1,362	555	0.41	60	0.04	Patchy; SCF used
	10–12 June 1997	1,321	4,035	3.05	1,214	0.92	Patchy; SCF used
	3 June 1998	1,370	1,840	1.34	284	0.21	None
	11–12 June 1998	1,370	1,902	1.39	310	0.23	None
	11 June 1999	1,478	2,166	1.47	544	0.37	Low; SCF not used
	11–12 June 2000	1,478	966	0.65	192	0.13	Patchy; SCF used
	5–6 June 2001	1,478	169	0.11	0	0	Patchy; SCF used
	10–11 June 2001	1,478	1,148	0.78	192	0.13	Patchy; SCF not used
	6–7 June 2002	1,432	5,584	3.90	830	0.58	None
	10–11 June 2002	1,432	6,232	4.35	1,034	0.72	None
	3–4 June 2003	1,432	1,162	0.81	120	0.08	Patchy; SCF used
	10, 12 June 2003	1,432	2,790	1.95	614	0.43	Low; SCF not used
	5 June 2004	1,262	1,092	0.61	350	0.28	Patchy; SCF used
	16 June 2004	1,323	6,982	5.28	2,286	1.73	None
	5–6 June 2005	1,432	1,387	0.97	297	0.21	Patchy; SCF used
	10–11 June 2005	1,432	2,746	1.92	726	0.51	Low; SCF not used
	3–5 June 2006	1,432	395	0.28	53	0.04	Patchy; SCF used
	11–12 June 2006	1,432	4,056	2.83	1,022	0.71	None

Appendix C. Continued.

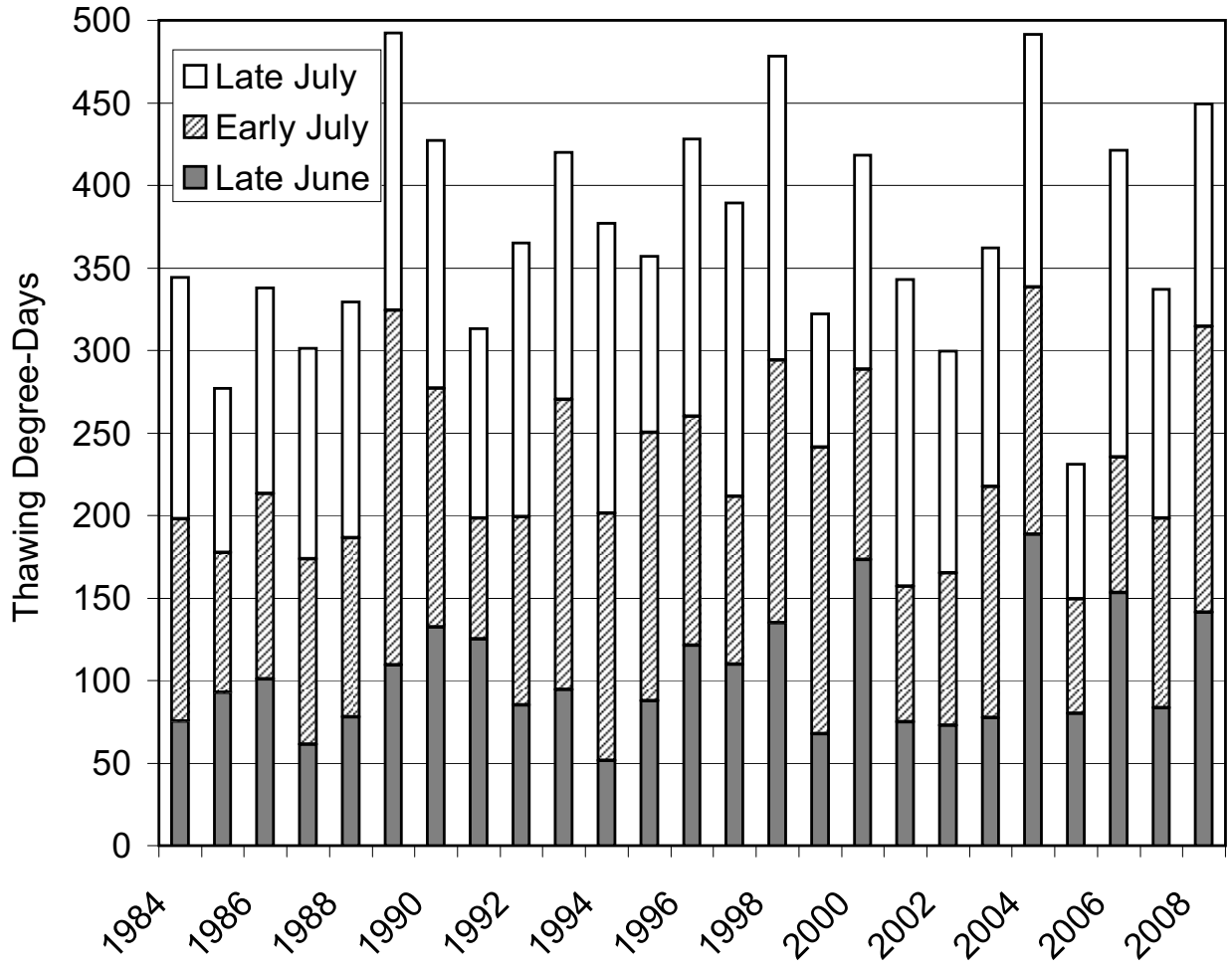
Survey Area	Date	Total Area (km²)	Estimated Total Caribou [a]	Total Density (per km²)	Estimated Total Calves [a]	Calf Density (per km²)	Snow Cover
	2, 4–5 June 2007	1,432	2,290	1.60	192	0.13	Patchy; SCF used
	11–12 June 2007	1,432	10,624	7.42	2,596	1.81	None
	3–4 June 2008	1,432	3,810	2.66	422	0.29	Low; SCF not used
	11 June 2008	1,432	10,148	7.09	1,838	1.28	None
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
	11 June 2005	491	2	<0.01	0	0	None
	9 June 2006	491	6	0.01	1	<0.01	None
	12 June 2008	491	30	0.06	2	<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 and early June 1995; northern quarter incorporated in Colville East survey area thereafter.
[i] Extended south to 70º N latitude in 1995, thus incorporating northern quarter of 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 D. Sum of thawing degree-days (º C above freezing) at the Kuparuk airstrip during 5 periods of the insect season, mid-June to August 1983–2008.

	Thawing Degree-Days					
Year	16–30 June	1–15 July	16–31 July	1–15 August	16–31 August	Total
1983 [a]	73.4	74.7	103.8	100.3	50.7	402.9
1984	75.3	122.8	146.4	99.5	59.9	503.8
1985	92.8	84.7	99.4	100.0	70.8	447.8
1986	100.8	112.2	124.7	109.4	54.4	501.7
1987	61.4	112.2	127.8	93.1	109.4	503.9
1988	78.1	108.3	143.1	137.5	52.2	519.2
1989	109.4	214.7	168.1	215.8	133.9	841.9
1990	132.2	145.0	150.0	82.5	72.8	582.5
1991	125.0	73.3	115.0	70.6	54.4	438.3
1992	85.3	113.9	166.1	104.2	96.1	565.6
1993	94.4	175.8	149.7	96.1	78.1	594.2
1994	51.7	149.7	175.8	222.2	92.2	691.7
1995	87.5	162.8	106.9	83.3	83.6	524.2
1996	121.1	138.9	168.1	95.8	34.7	558.6
1997	109.7	101.7	177.8	194.2	97.8	681.1
1998	135.0	158.9	184.4	174.4	123.1	775.8
1999	67.8	173.3	81.1	177.5	69.7	569.4
2000	173.3	115.0	130.0	120.6	55.6	594.4
2001	75.0	82.2	185.6	135.0	33.9	511.7
2002	72.8	92.2	134.4	106.1	90.6	496.1
2003	77.5	140.0	144.7	91.9	55.0	509.2
2004	188.3	150.0	153.3	155.0	126.1	772.8
2005	80.0	69.4	81.7	178.9	46.1	456.1
2006	153.1	82.2	186.1	109.7	36.9	568.0
2007	83.3	115.0	138.9	134.4	103.6	575.3
2008	141.1	173.3	135.0	88.3[b]	76.1 [b]	613.9
Mean	101.7	124.7	141.5	126.0	75.3	569.2

[a] Some missing values estimated by interpolation.
[b] Preliminary data.



Appendix E. Index of annual insect-season severity (expressed as cumulative thawing degree-days in º C above freezing) from mid-June through July 1984–2008.

Appendix F. Average index values of mosquito activity[a] (adapted from Russell et al. 1993) during June–August 1983–2008, based on daily maximum temperatures at the Kuparuk airstrip.

	June			July			August		
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
2008	0.31	0.71	0.51	0.85	0.59	0.71	0.22[b]	0.22[b]	0.22[b]
Mean	0.17	0.47	0.32	0.58	0.60	0.59	0.55	0.27	0.41

[a] Average Mosquito Index: if daily maximum temperature <6° C, index = 0; if daily maximum temperature >18° C, then index = 1; otherwise, index = 1–((18–daily maximum temperature)/13)).

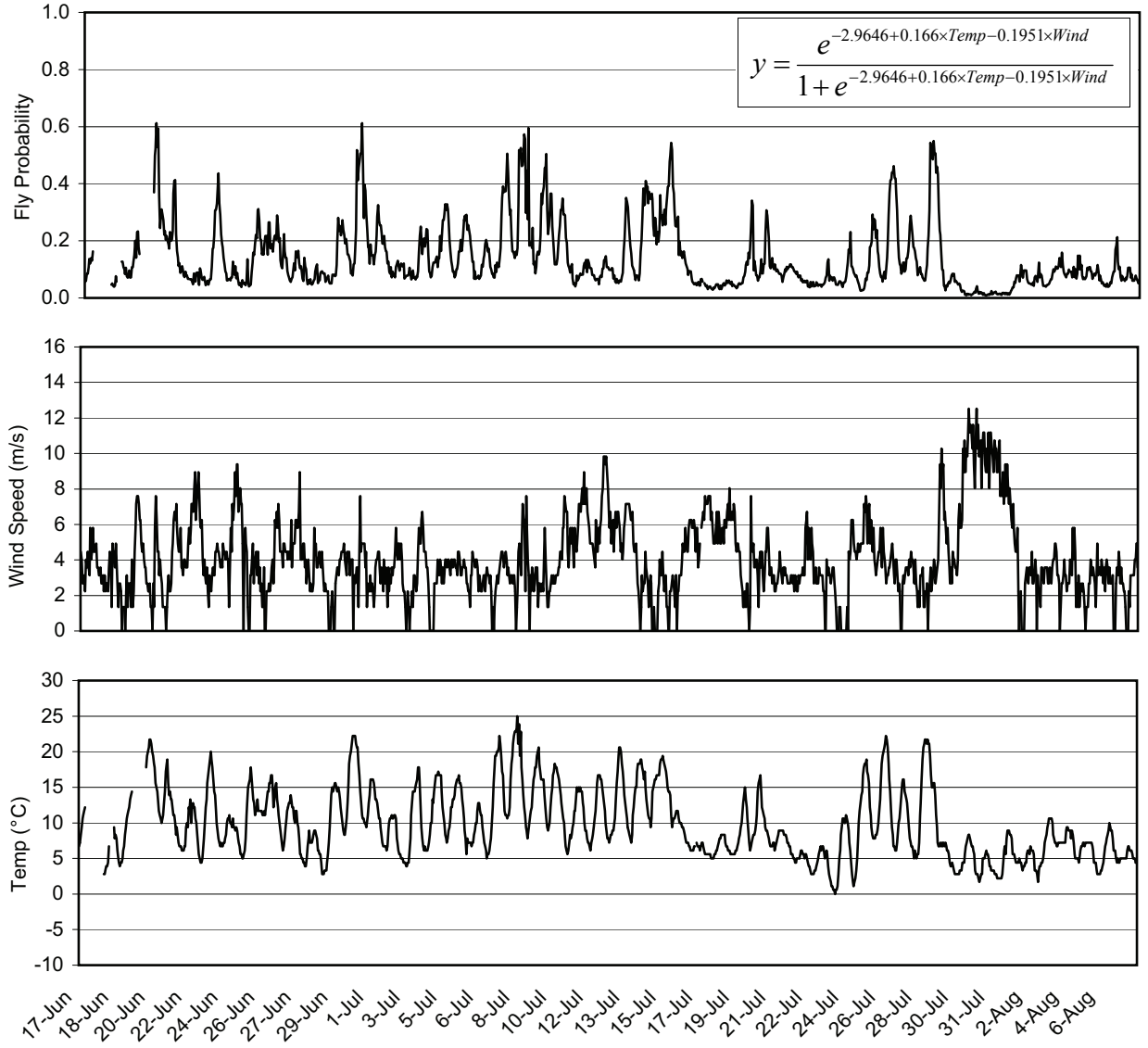
[b] Preliminary data.

Appendix G. Average index values of oestrid fly activity [a] (adapted from Russell et al. 1993) during June–August 1983–2008, based on daily maximum temperatures at the Kuparuk airstrip.

	June			July			August		
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
2008	0.12	0.55	0.34	0.75	0.43	0.59	0.00[b]	0.05[b]	0.03[b]
Mean	0.08	0.32	0.20	0.43	0.46	0.45	0.41	0.15	0.27

[a] Average Fly Index: if daily maximum temperature <10° C, index = 0; if daily maximum temperature >18° C, then index = 1; otherwise, index = 1–((18–daily maximum temperature)/8)).

[b] Preliminary data.



Appendix H. Probability of oestrid fly activity (Mörschel 1999) in summer 2008 based on wind speed and temperature data recorded at Nuiqsut.