MAMMAL SURVEYS IN THE GREATER KUPARUK AREA, NORTHERN ALASKA, 2009

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FINAL REPORT

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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–August 2009. Surveys were conducted in spring, the calving season, postcalving, and late summer; no surveys were conducted during the insect season in July or in September and October due to weather and logistical problems. Incidental sightings of other species of large mammals were recorded during aerial surveys for caribou and other species (mainly birds).
- A fixed-wing airplane was used to survey the calving distribution and abundance of caribou twice in 2009, around the peak of calving (2–4 June) and near the end of calving (8–10 June). Summary maps of caribou density were prepared to compare distribution and density in 2009 with long-term averages from regional calving surveys since 1993. A helicopter was used to sample age and sex composition on 11 June. Additional aerial surveys of caribou distribution and abundance were conducted in mid-May, late June, early August, and late August 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 2009. Snow depth was about average in mid-May at the Kuparuk airstrip, but the snow melted rapidly during a warm spell in mid-May and was largely gone by the first week of June. Temperatures were well above average in late May and early June.
- On the first calving survey (2–4 June), 1,239 caribou were observed, including 206 calves (17%), 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 2,478 ± 178 total caribou (adults and calves) and a mean density of 0.76 ± 0.05 caribou/km² among all 3 survey areas. Adjusting the adult count for poor sightability due to patchy snow cover produced an estimate of 3,877 ± 1,041 adult caribou.
- On the second calving survey (8–10 June), 5,181 caribou were observed among the 3 survey areas, including 1,302 calves (25%), resulting in an expanded total estimate of 10,362 ± 724 caribou (adults and calves) and a mean density 3.18 ± 0.22 caribou/km². The highest calving density in 2009 occurred southwest of the Kuparuk Oilfield, in the Colville East survey area. The distribution of caribou in the survey area and the locations of radio-collared caribou tracked by the Alaska Department of Fish and Game (ADFG) indicated that many female caribou were south of the survey areas during calving.
- Calf production by the western segment of the CAH was estimated at 71.2 calves:100 cows (n = 3,615 caribou) on 11 June, slightly lower than the mean annual production estimated during 1978–2009 (73.3 calves: 100 cows). Calf production has exceeded 70 calves:100 cows in 13 of the last 14 years but has shown a slightly declining trend in recent years.
- On 8–9 June, 418 total caribou (including 62 calves) were estimated to be in the Kuparuk Field survey area, of which 170 caribou (including 22 calves) were north of the Spine Road and east of the Oliktok Point Road.
- Mean daily temperatures at the Kuparuk airstrip were lower than average in late June and were close to average in July. The air temperature reached a seasonal peak of 28º C (82º F) in mid-July. Temperature and wind-speed data for 2009 suggested that activity by mosquitoes and oestrid flies was low early in the summer (late June–early July), very high in mid-July, low in late July, and moderately high in early August.
- The densities of caribou in the Colville East survey area outside of the calving season were low in mid-May and August and high in late June during postcalving. No surveys could be conducted in September or October due to poor weather and logistical problems.
- Between early June and August 2009, 28 sightings of muskoxen were recorded in the study area and surrounding region. The maximum single-day count occurred on 9

June, when 61 individual muskoxen (47 adults and 14 calves) were observed in 8 groups: a group of 11 adults and 5 calves along the Colville River, 11 adults and 3 young near Milne Point, 13 adults and 4 young in two groups east of the Milne Point Road, and 12 adults and 2 calves in 4 groups near the Kuparuk River.

- Twenty-six grizzly bear sightings, totaling 29 adults and 11 cubs, were recorded within 75 km of the coast in the northeastern NPRA and Kuparuk–Colville region during various 2009 aerial surveys. Nine spotted seals were hauled out on a sandbar in the Colville River delta on 22 August.

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INTRODUCTION

Four herds of barren-ground caribou (*Rangifer tarandus granti*) inhabit Alaska north of the Brooks Range. The herds differ 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 most animals in the herd migrate south long distances in the fall to winter in western Alaska. The Teshekpuk Herd (TH) calves near Teshekpuk Lake, about 130 km (80 mi) west of Kuparuk, uses coastal habitats as well as some inland sites for insect relief, and generally winters on the Arctic Coastal Plain (Person et al. 2007), although some of the herd has shown a tendency to winter with the Central Arctic Herd (CAH) since 2004–2005 and unusual wintering excursions by large portions of the herd were made to the ranges of the Porcupine Herd (PH) in 2003–2004 and the WAH in 2008–2009 (Carroll 2007; Lawhead et al., in prep.). 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, primarily in the southern foothills in recent years (Arthur and Del Vecchio 2007, Lenart 2009a). The 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 (Lenart 2003). The herd grew rapidly from about 5,000 animals in the mid-1970s to the early 1990s, reaching a count of 23,444 caribou in July 1992 before declining 23% to 18,093 caribou in July 1995. By July 1997, the herd was estimated at 19,730 animals. The herd continued increasing, reaching 27,128 animals in July 2000 and 31,857 in July 2002. A total of 66,772 caribou were counted in July 2008 (Lenart 2009a), representing a mean annual increase of 13% since 2002.

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 64,106 in the most recent census in July 2008 (L. Parrett, ADFG, pers. comm.). In contrast to the other 3 herds, the PH has 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 photocensus in July 2001 (Griffith et al. 2002). On the basis of population modeling, survivorship analysis, and herd-composition surveys, the PH is thought to have declined further to ~110,000–115,000 caribou by 2006 (Lenart 2007a).

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 area between Bullen Point and the Staines River, 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 cows annually (Arthur and Del Vecchio 2007; Lenart 2009a). A small sample of 10-month-old CAH females is outfitted annually with conventional VHF radio-collars (Lenart 2009a).

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 all but 4 collars were removed in March 2006 (Arthur and Del Vecchio 2007). The last 4 collars released automatically in June 2006, so no GPS or satellite collars were active on CAH caribou from then until June 2008 (Lenart 2009a). In late June–early July 2008, 14 GPS collars were deployed by ADFG on CAH females, 4 of which were provided by CPAI. In late June 2009, 4 of the GPS collars were replaced and new GPS collars were placed on 2 other CAH females by ADFG, with funding from CPAI (Lawhead et al., in prep.).

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 2009. Work was conducted primarily during the caribou calving season and secondarily during late winter and late summer in the area between the Kuparuk Oilfield and the Colville River delta; the surveys in 2009 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 brown (hereafter, grizzly) bears (*Ursus arctos*).

The 2009 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 incidentally 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 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

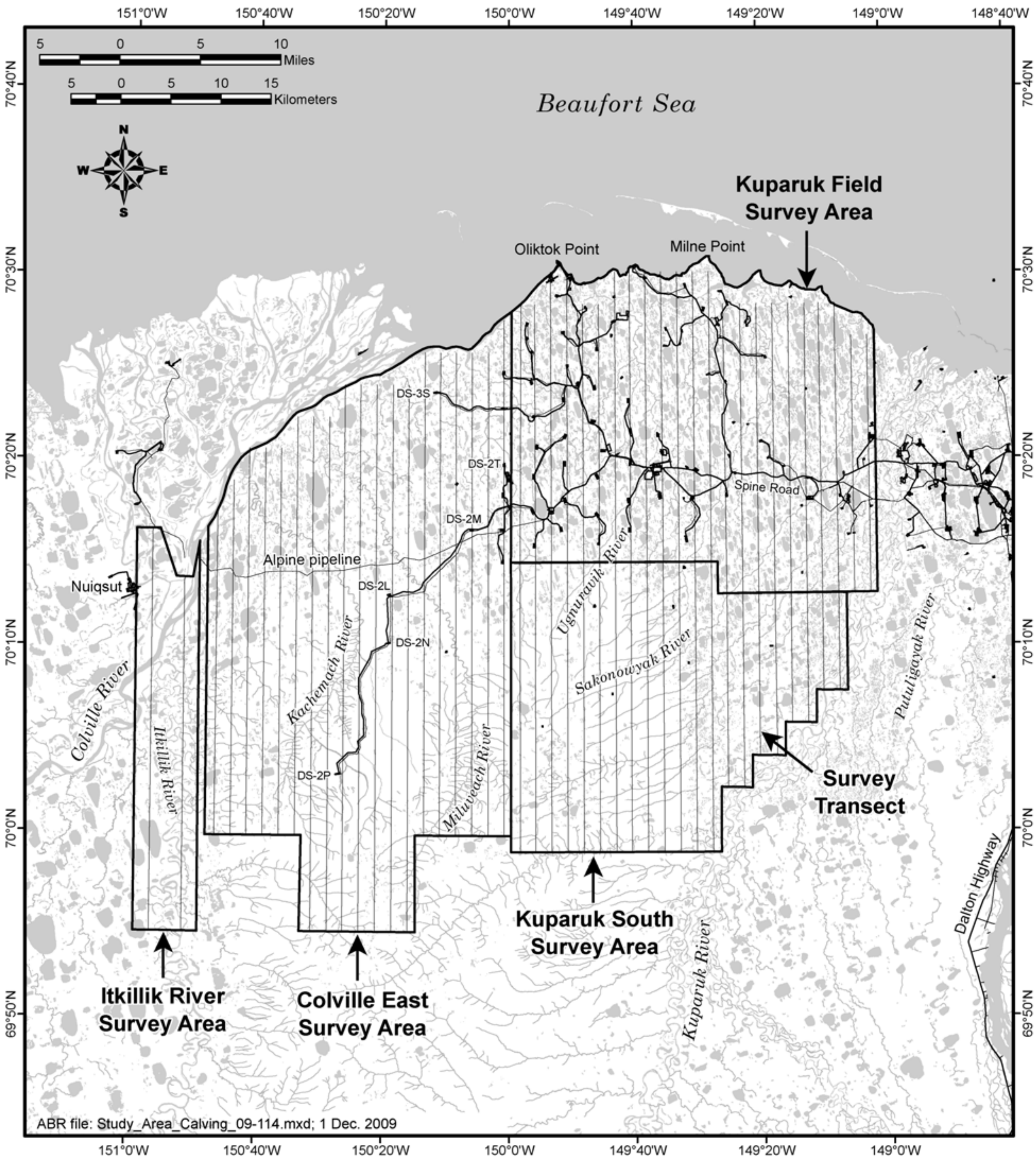

Figure 1. Survey areas and transect lines for systematic aerial surveys of caribou in the Kuparuk–Colville region, northern Alaska, during the 2009 calving season.

total coverage from 3,188 to 3,255 km². In mid-June 2009, we added two transects to the west of the Colville East survey area to assess caribou distribution along the Itkillik River for the ASDP caribou monitoring study (Lawhead et al., in prep.).

Surveys during spring, postcalving, and late summer covered the Colville East survey area, which was extended for those surveys 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 2009 (Figure 1): one near the typical peak of calving (2–4 June) and one a week later (8–10 June), after most females had calved. The surveys were scheduled during similar date ranges as those conducted in previous years in early and mid June (1–8 and 9–16 June, respectively, in 1993 and 1995–2008). 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-wide 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 2009) 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 surveys (Lawhead et al. 1994); no SCF was available for calf counts. Patchy snow remained during the early calving season survey (2–4 June), so the SCF was applied to the early calving counts. By the time of our second calving survey (8–10 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 11 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 8–10 June.

To summarize calving distribution and abundance data from early and mid-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 2009 and over all years (1993 and 1995–2009). 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 and assigned to the centroid of the segment. The IDW interpolation technique calculated a density surface as the distance-weighted density of the 14 nearest centroids for each 200-m grid cell in the study area (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 May, late June, and August. Surveys also were planned for September and October but had to be canceled this year because of inclement weather and logistical problems. These 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 the spring, postcalving, and late summer 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

Daily air temperatures in spring 2009 generally were above the long-term average (Appendices A and B). Snow depth was close to the long-term maximum in early April, but was about average on 15 May. Snow had melted at the Kuparuk Airstrip by 20 May, after record high temperatures occurred on 18–19 May (Figure 2, Appendix A), but some remnant drifts persisted in the survey areas into early June. The average daily air temperature at the Kuparuk airstrip was above average in early June and 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, so we applied the SCF for large caribou (Lawhead et al. 1994) to our counts. Almost all of the snow cover in the survey areas had melted by the time of the second calving survey on 8–10 June. The snow remaining at that

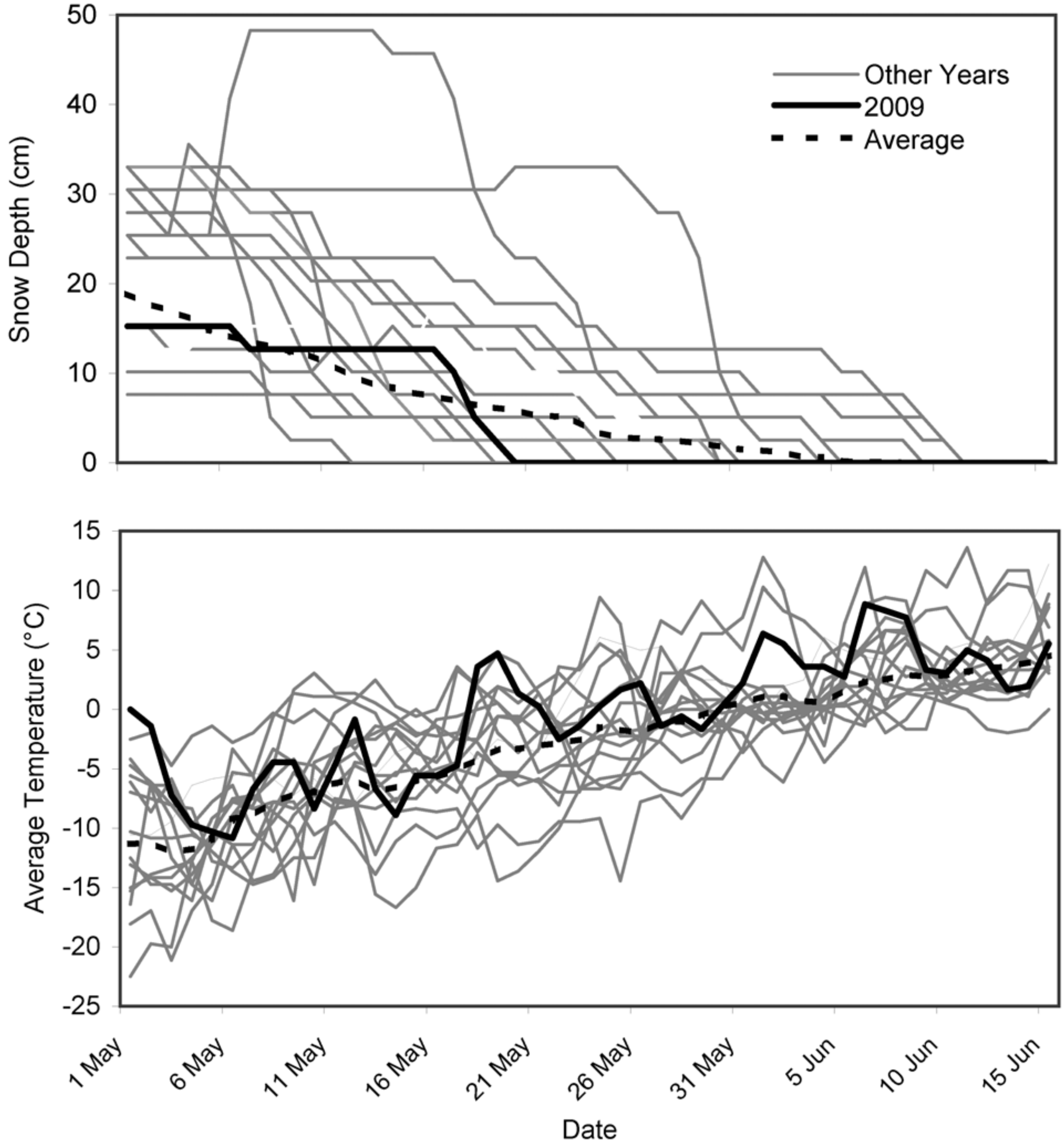

Figure 2. Snow depth (cm) and average daily temperature (° C) at the Kuparuk airstrip during 1 May–15 June 2009, compared with 1993 and 1995–2008.

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 2009

The number of caribou in the calving survey areas increased substantially between the early and mid-June surveys. During 2–4 June, we counted 1,239 caribou, including 206 calves (16.6%), in all 3 calving survey areas combined. During 8–10 June, we counted 5,181 caribou, including 1,302 calves (25.1%), in all 3 areas. Doubling our 50% sample counts produced population estimates of 2,066 ± 143 large caribou and 412 ± 47 calves among all 3 survey areas in early June, compared with 7,758 ± 506 large caribou and 2,604 ± 232 calves in mid-June (Table 1). After adjusting for low sightability during early June, however, the estimate of large caribou in all 3 areas combined increased to 3,877 ± 1,041 animals.

The mean estimated densities (adjusted for sightability) among all 3 survey areas combined were 1.19 ± 0.32 large caribou/km² in early June and 2.38 ± 0.16 large caribou/km² (3.18 ± 0.22 total caribou/km²) in mid-June (Table 2). The density of caribou was highest along the border between the Colville East and Kuparuk South survey areas (Figures 3–8). The density of large caribou in the Kuparuk South and Colville East survey areas in mid-June was 9–12 times higher than in the Kuparuk Field survey area (Table 2).

Compared with previous years since these transect surveys began 1993, the overall number and density of caribou in mid-June 2008 were higher than the long-term average but were lower than in the last 3 years (Table 3, Appendix C). The distribution of caribou in 2009 showed high densities along the border between the Kuparuk South and Colville East survey areas, with the highest densities occurring in the southern portions. That distribution suggested that many caribou still were south of the survey areas during calving in 2009, which was confirmed by the locations of radio-collared caribou tracked by ADFG during 1–4 June (E. Lenart, ADFG, pers. comm.). Based on ADFG maps of collared CAH caribou located west of the Dalton Highway at that time, 5 of 14 (36%) parturient females and 8 of 8 (100%) nonparturient females were located south of the GKA survey areas during the first round of calving surveys. Thus, only 9 of 22 (41%) collars, all parturient females, from the western segment of the CAH were estimated to be in the GKA study area during the first calving survey in 2009; 4 of the 5 parturient females outside the study area were located within 10 km and the other was ~13 km. In comparison, 20 of 22 (91%; including 2 just outside the border) collared females were in the GKA study area on June 2–3, 2008 and 22 of 32 (69%; including 3 just outside the border) were in the study area on June 3–6, 2007. Typically, calving tends to occur farther inland in years of late snow melt, but melt occurred earlier than normal in 2009 because of warm temperatures in May. Nonparturient females are more likely to occur farther from areas of concentrated calving, so the higher proportion of nonparturient caribou in the collared sample in 2009 may help to explain the inland distribution of collars.

In 2009, the density of caribou in the Kuparuk Field survey area during calving was below the long-term mean density and was only about 28% of the density observed in 2008 (Table 3, Appendix C). On 8–9 June, 82 of the caribou (including 11 calves) counted in the Kuparuk Field survey area (39.2% of the total number and 35.5% 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 lower than the long-term averages. The proportions north and east of those roads averaged 49% of total caribou and 50% of calves between 1996 and 2009, within a wide range (22–77% 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, 2009). 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 occurring there than 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 1995–2009

Table 1. Estimated numbers of caribou (± 80% CI) during the 2009 calving season in the Colville East, Kuparuk South, Kuparuk Field, and Itkillik River survey areas, Alaska.

Survey Area	Date	Total Area (km^2)	Unadjusted Estimate [a]			SCF-Adjusted (Large Only)[c]
			Total	Large [b]	Calves	
Colville East	June 3–4	1,432	2,030 ± 159	1,662 ± 126	368 ± 44	3,119 ± 843
	June 9–10	1,432	7,038 ± 626	5,196 ± 430	1,842 ± 207	
Kuparuk South	June 3	788	256 ± 29	264 ± 32	22 ± 6	439 ±125
	June 9	788	2,906 ± 278	2,206 ± 204	700 ± 84	
Kuparuk Field	June 2	1,035	192 ± 32	170 ± 28	22 ± 6	319 ± 98
	June 8–9	1,035	418 ± 57	356 ± 47	62 ± 15	
Total Calving Area	June 2–4	3,255	2,478 ± 178	2,066 ± 143	412 ± 47	3,877 ± 1,041
	June 8–10	3,255	10,362 ± 724	7,758 ± 506	2,604 ± 232	
Itkillik River	June 8	240	200 ± 49	200 ± 49	0	

[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 km^2 ± 80% CI) in the Colville East, Kuparuk South, Kuparuk Field, and Itkillik River survey areas, June 2009.

Survey Area	Date	Unadjusted Density			SCF-Adjusted (Large Only)[b]
		Total	Large [a]	Calves	
Colville East	June 3–4	1.42 ± 0.11	1.16 ± 0.09	0.26 ± 0.03	2.18 ± 0.59
	June 9–10	4.91 ± 0.44	3.63 ± 0.3	1.29 ± 0.14	
Kuparuk South	June 3	0.32 ± 0.04	0.34 ± 0.04	0.03 ± 0.01	0.56 ± 0.16
	June 9	3.69 ± 0.35	2.80 ± 0.26	0.89 ± 0.11	
Kuparuk Field	June 2	0.19 ± 0.03	0.16 ± 0.03	0.02 ± 0.01	0.31 ± 0.09
	June 8–9	0.40 ± 0.06	0.34 ± 0.05	0.06 ± 0.01	
Total Calving Area	June 2–4	0.76 ± 0.05	0.63 ± 0.04	0.13 ± 0.01	1.19 ± 0.32
	June 8–10	3.18 ± 0.22	2.38 ± 0.16	0.80 ± 0.07	
Itkillik River	June 8	0.83 ± 0.20	0.83 ± 0.20	0	

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

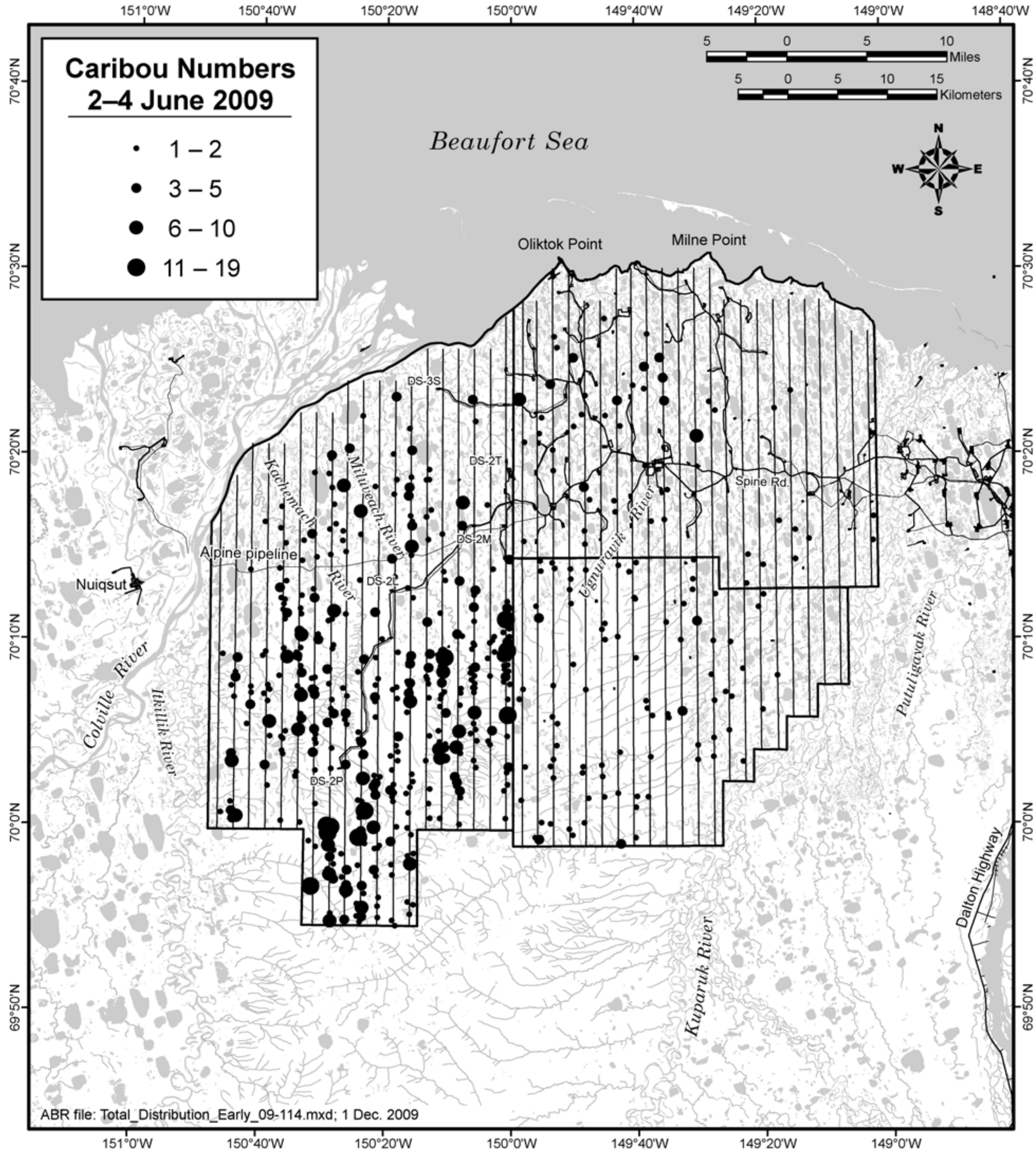

Figure 3. Distribution and group size of all caribou (adults and calves) in the Kuparuk–Colville calving survey areas, 2–4 June 2009.

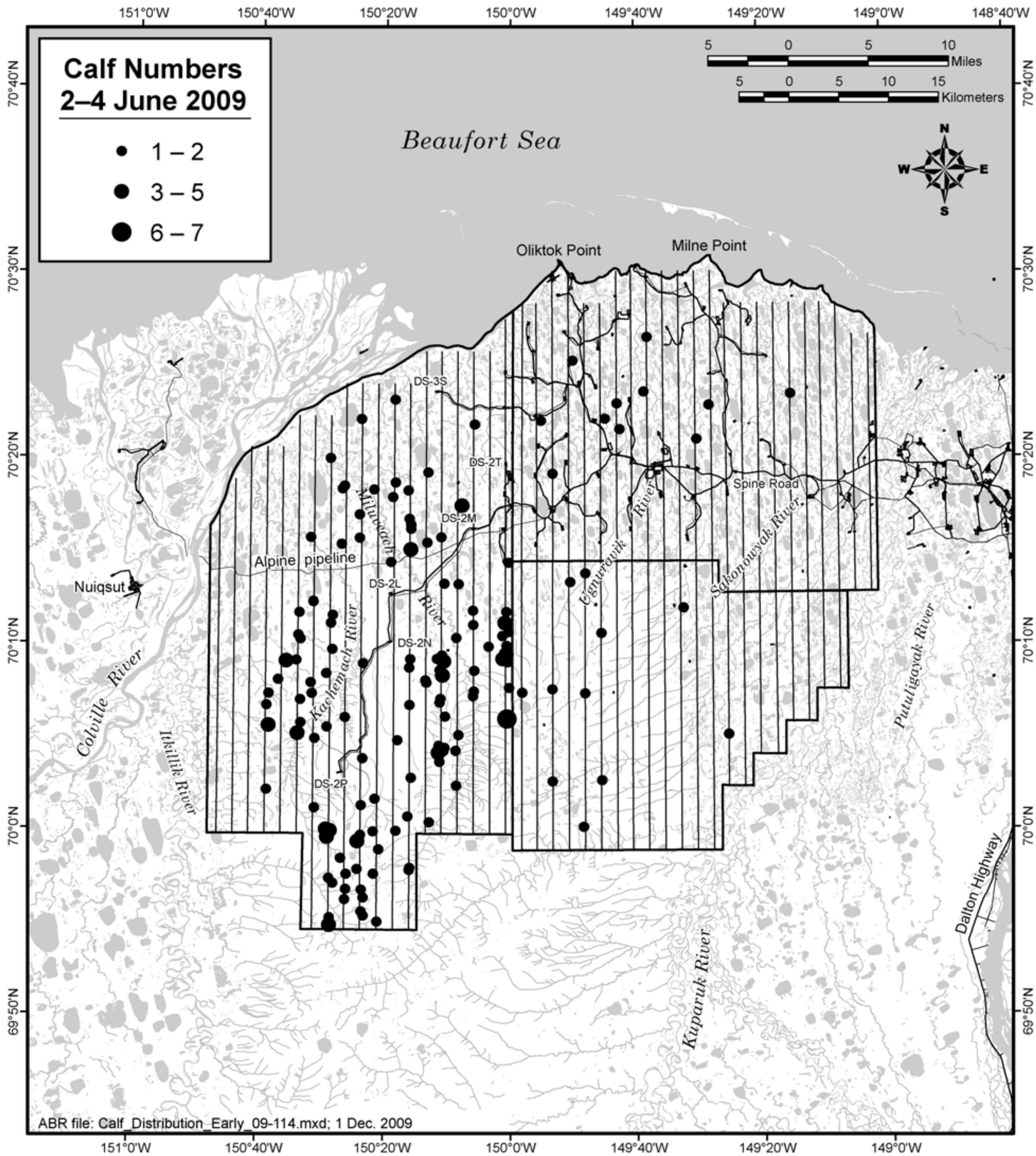

Figure 4. Distribution and number of calf caribou in the Kuparuk–Colville calving survey areas, 2–4 June 2009.

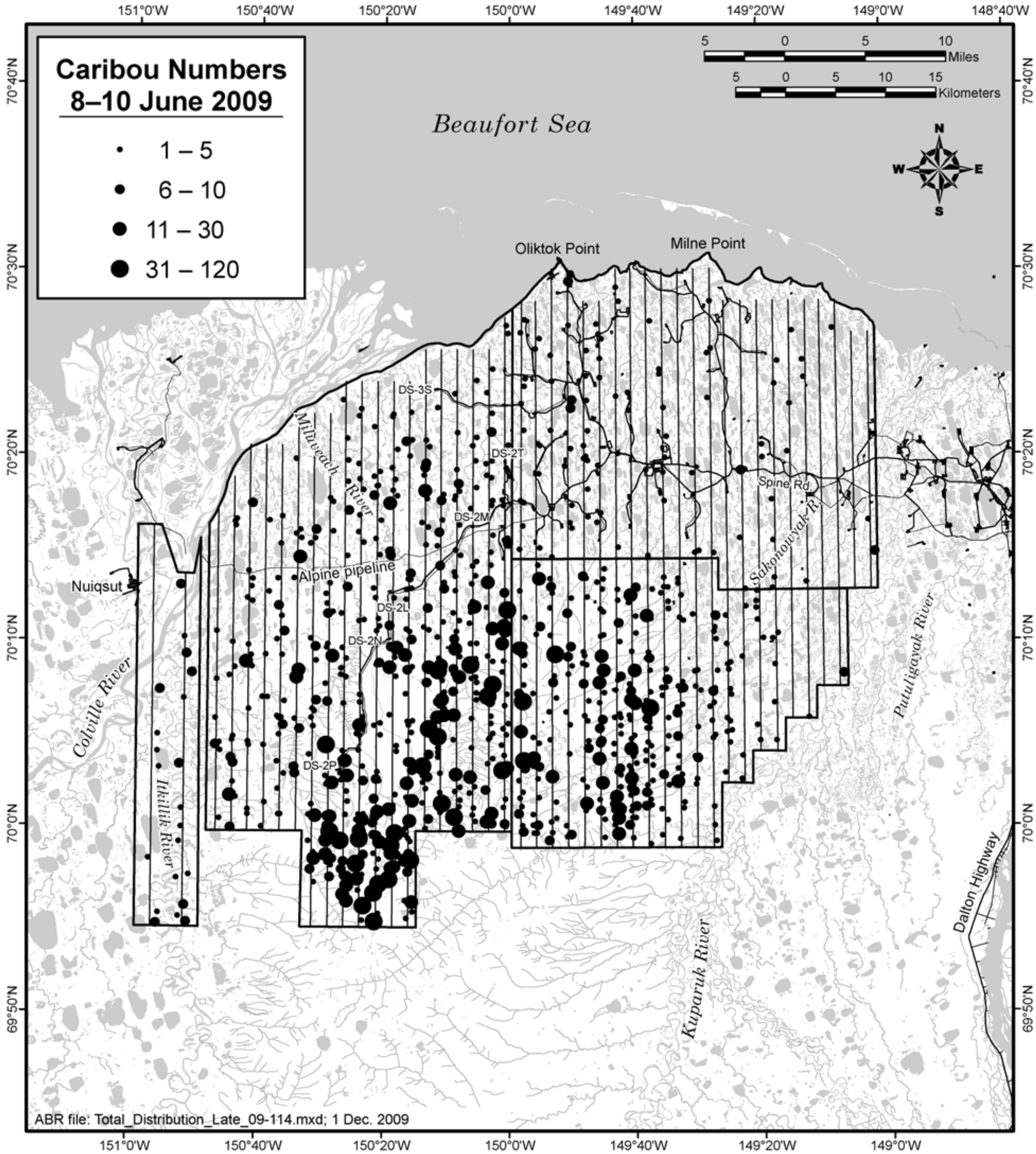

Figure 5. Distribution and group size of all caribou (adults and calves) in the Kuparuk–Colville calving survey areas, 8–10 June 2009.

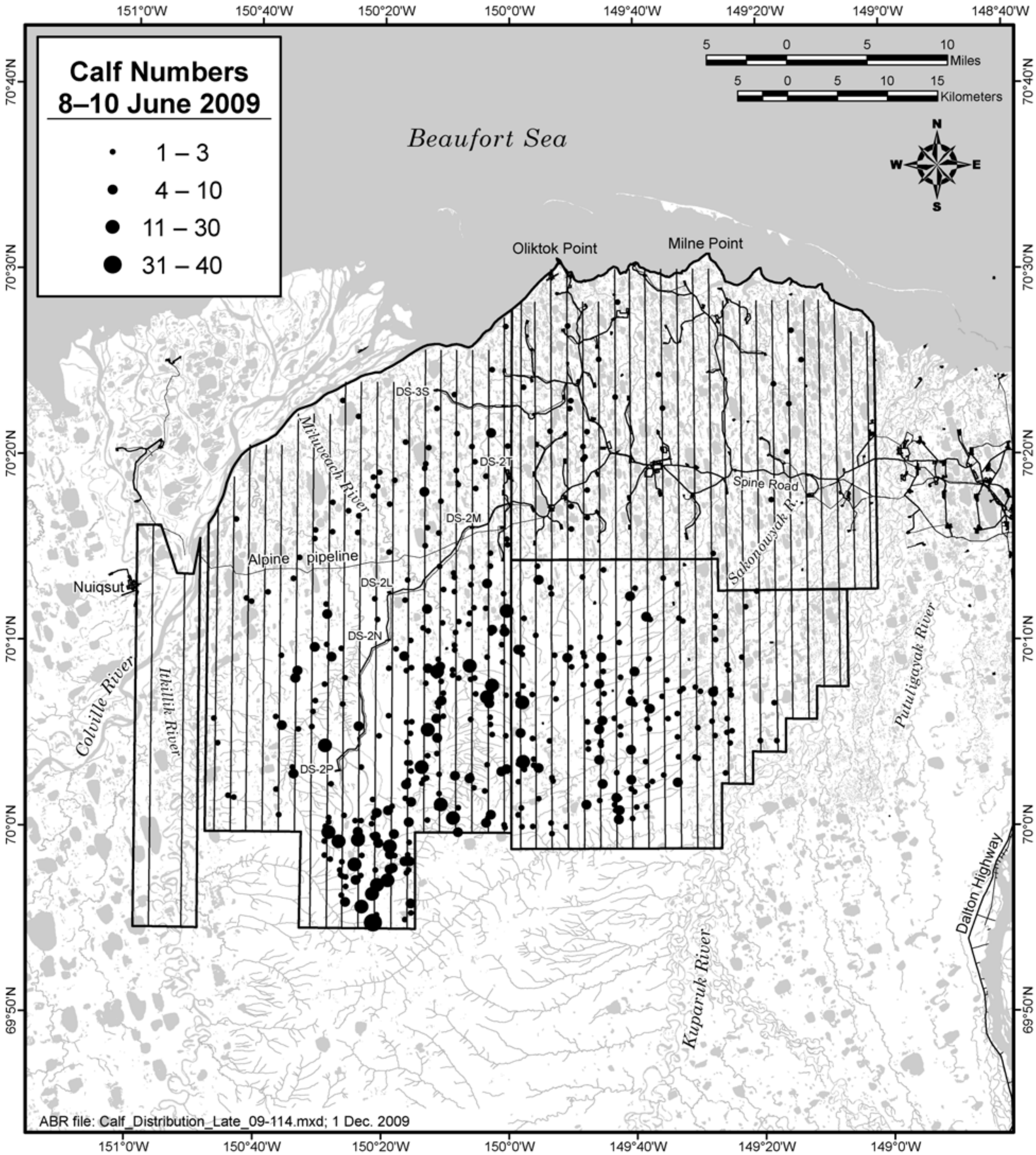

Figure 6. Distribution and number of calf caribou in the Kuparuk–Colville calving survey areas, 8–10 June 2009.

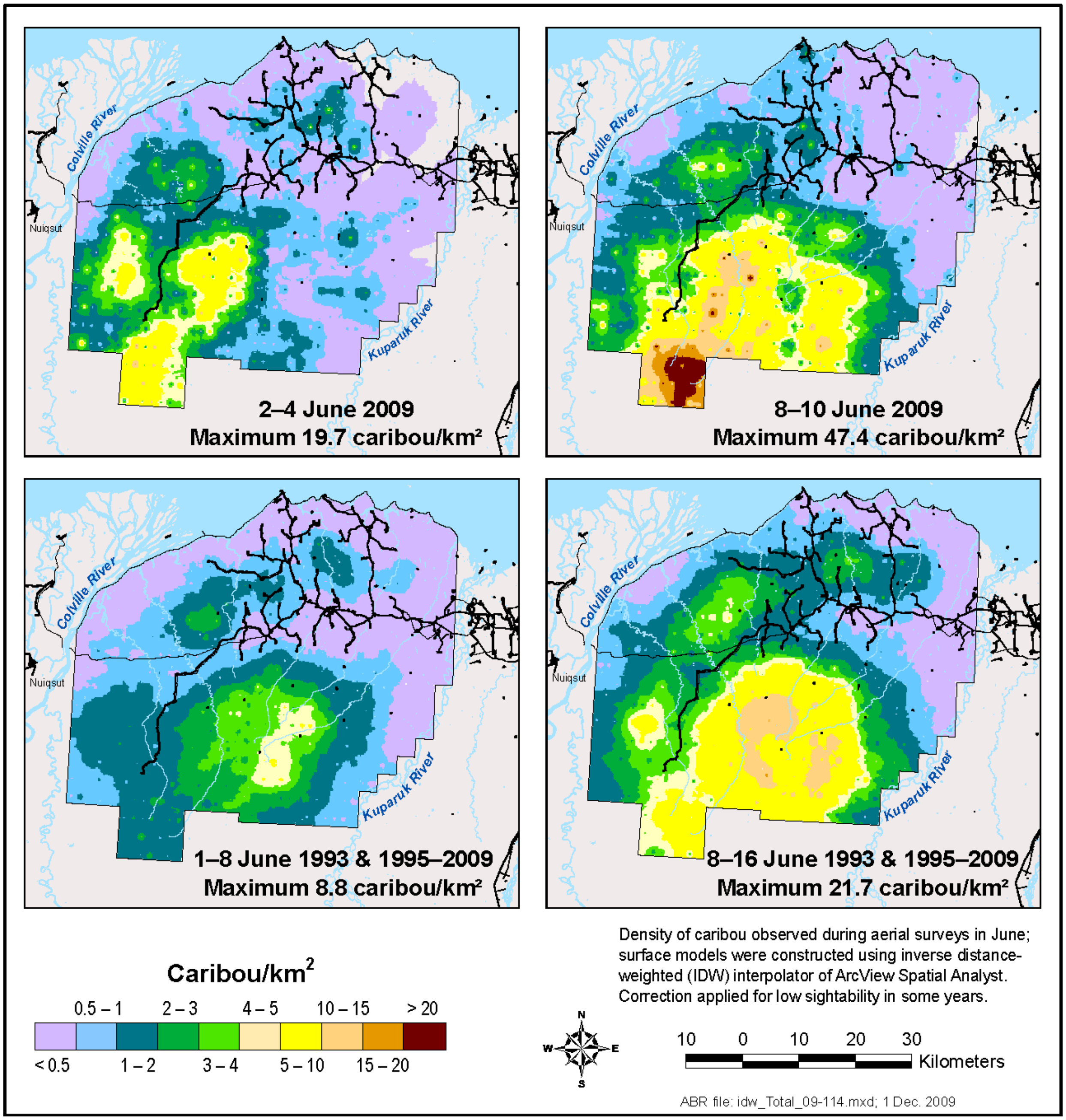

Figure 7. Distribution and density of all caribou in the Kuparuk–Colville calving survey areas during 2–4 June and 8–10 June 2009 (top) and distribution and mean density of all caribou during early June and mid-June in the Kuparuk–Colville calving survey areas, 1993 and 1995–2009 (bottom).

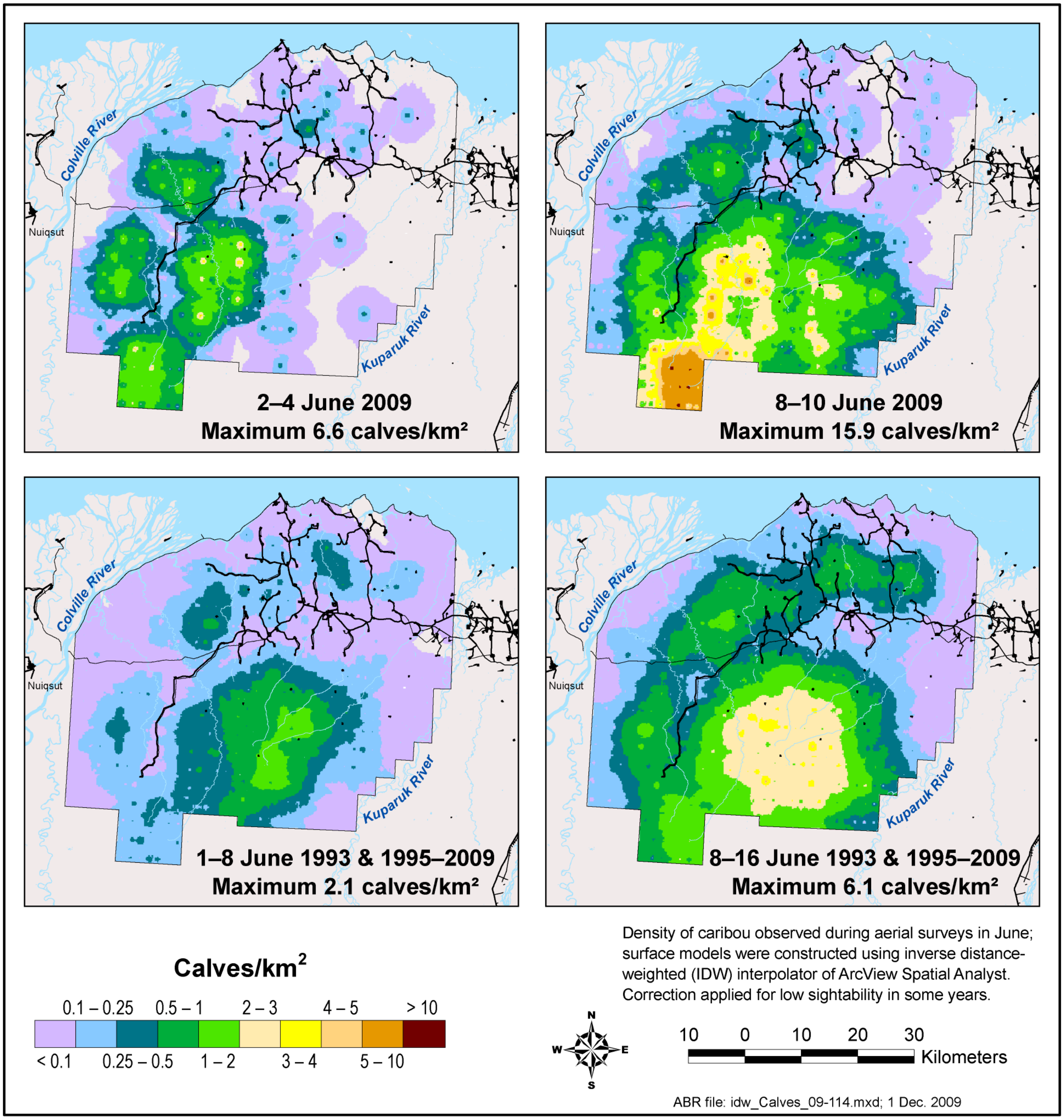

Figure 8. Distribution and density of calf caribou in the Kuparuk–Colville calving survey areas during 2–4 June and 8–10 June 2009 (top) and distribution and mean density of calf caribou during early June and mid-June in the Kuparuk–Colville calving survey areas, 1993 and 1995–2009 (bottom).

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 1995–2009.

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
2009	4.91	1.29	0.40	0.06	3.69	0.89	3.18	0.80	Early
Mean	3.06	0.73	0.73	0.20	5.28	1.46	2.74	0.70	

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

(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, 2009, this study). These annual data were used to generate mean values over the entire 16-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 about half the years since 1995, the mean density of caribou during calving has been highest in the Kuparuk South survey area; however, in several 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 7 of the 15 years since 1995, including 2003–2005 and 2007 (Table 3). In 2009 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).

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, Joly et al. 2006). Within the Kuparuk Field survey area, caribou density was highest in areas away from roads (Figures 7 and 8). In mid-June 2009, an estimated 418 caribou were present in the Kuparuk Field survey area, of which an estimated 170 caribou (including 22 calves) were north of the Spine Road and east of the Oliktok Point Road. By 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). The historically used Kuparuk–Milne concentration area was used at lower levels in 2009 than the range observed during 1979–1987 (~300–2,100 caribou north of the Spine Road; Figure 6 in Cameron 1994), although the numbers show a large amount of annual fluctuation (Appendix C).

An area of locally high density during the 2009 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 2002–2009.

SEX AND AGE COMPOSITION AT CALVING

During the age and sex composition survey on 11 June, we counted 3,615 caribou in portions of the Kuparuk Field, Kuparuk South, and Colville East survey areas (Figure 9). The sample comprised 2,030 cows, 1,446 calves, 136 yearlings, and 3 adult bulls (Table 4). Based on this count, our estimate of calf production in 2009 was 71.2 calves:100 cows for the western segment of the CAH. The calf:cow ratio in the Kuparuk Field survey area (50.7 calves:100 cows) was significantly lower than that in the Kuparuk South survey area (81.6 calves:100 cows; $P = 0.035$, Fisher's Exact Test). Yearlings composed 3.8% of the total sample, for an overall ratio of 6.7 yearlings:100 cows (Table 4).

At 71.2 calves:100 cows, our estimate of calf production by the western segment of the CAH in 2009 was below the long-term average (73.3 calves:100 cows) for 1978–2009, for only the second time in the last 14 years (Figure 10). The other exception occurred in 2004, when some TH caribou also were present in the study area during the calving season (Lawhead and Prichard 2005). After declining from the mid-1980s to the mid-1990s, calf production increased in 1996, but has shown a slight declining trend in recent years (Figure 10). Our 2009 estimate is slightly less than ADFG's preliminary estimated parturition rate of 75% for adult cows ($n = 44$ on 1–3 June). The late June survival estimate of 52 calves:100 cows ($n = 42$ on 23–24 June), based on radio-collared adult females aged 4 years and older (E. Lenart, ADFG, pers. comm.). Both of these ADFG estimates were below the 1994–2009 average.

Our estimated calf:cow ratios have consistently been lower than those of ADFG (probably due to methodological differences), but their 2009 estimate showed a more pronounced

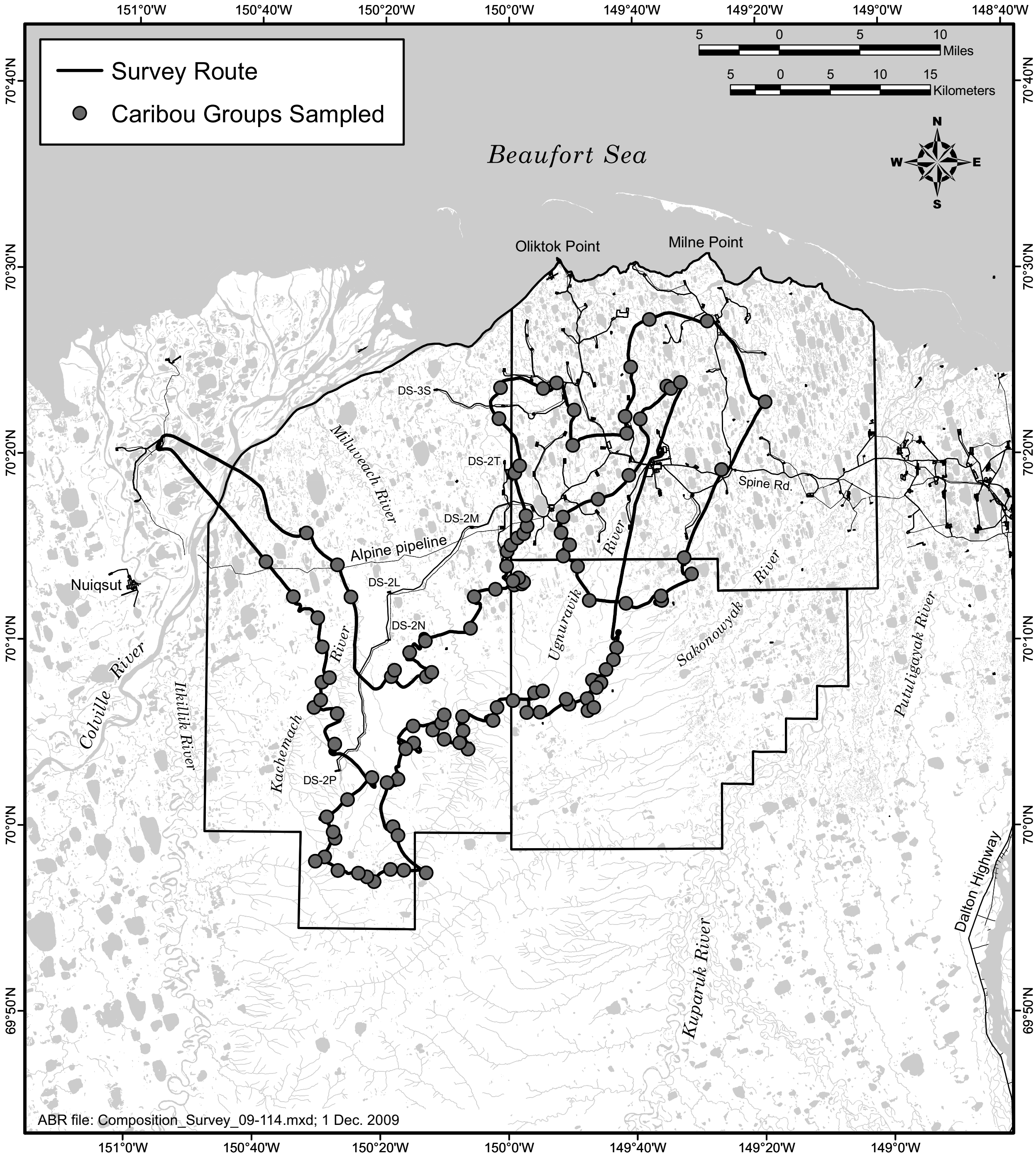

Figure 9. Route of aerial survey and location of groups sampled to quantify sex and age composition of caribou in the Kuparuk–Colville calving survey areas, 11 June 2009.

Table 4. Sex and age composition of caribou in the Kuparuk–Colville region, 11 June 2009.

Survey Area	No. of Groups	Total No.	Cows		Calves		Yearlings		Bulls		Calf Ratio [a]	Yrlg. Ratio [b]
			No.	%	No.	%	No.	%	No.	%		
Kuparuk Field	28	113	71	62.8	36	31.9	5	4.4	1	0.9	50.7	7.0
Kuparuk South	27	677	369	54.5	301	44.5	7	1.0	0	0	81.6	1.9
Colville East	58	2,825	1,590	56.3	1,109	39.3	124	4.4	2	0.1	69.7	7.8
Total	113	3,615	2,030	56.2	1,446	40.0	136	3.8	3	0.1	71.2	6.7

[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 1978–2009. 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, 2009, this study) for 2000–2009.

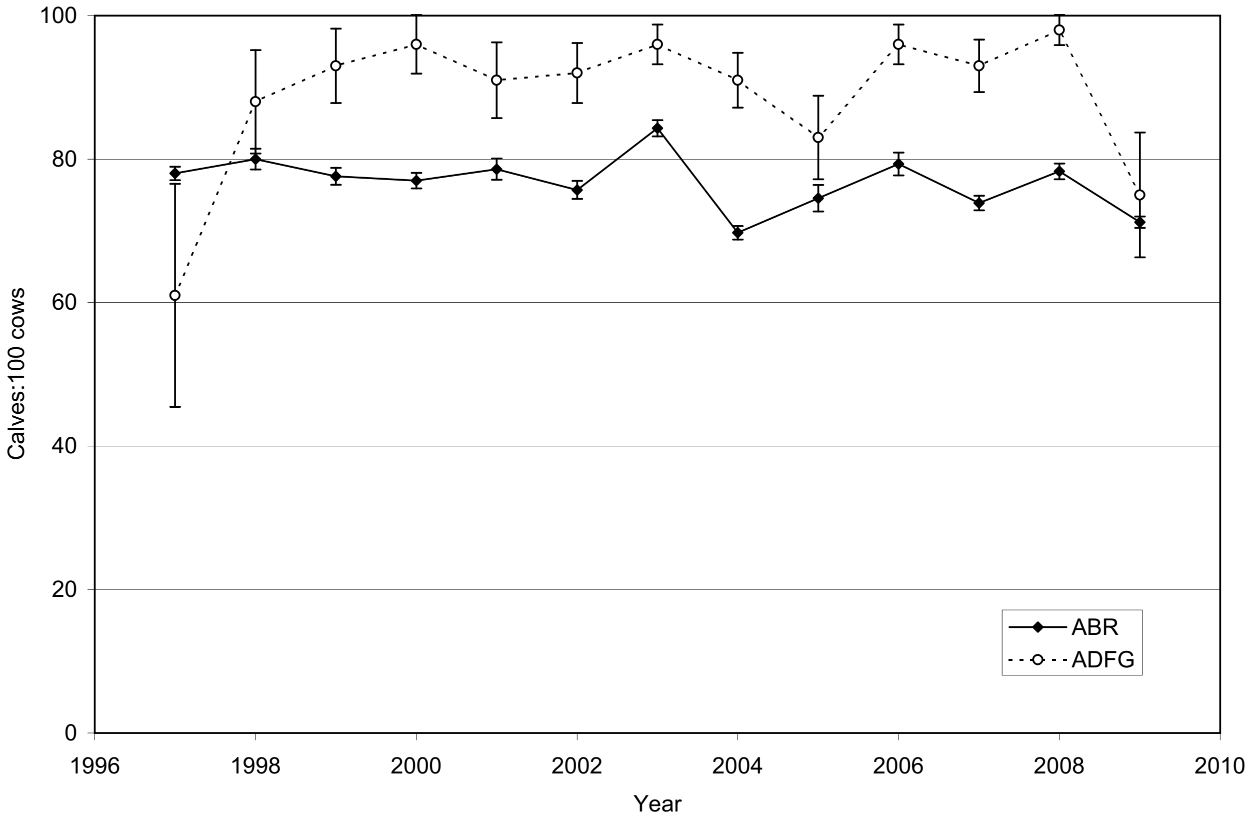

Figure 11. Estimated number (± SE) of calves:100 cows, based on estimates from radio-collared females by ADFG (aged ≥ 4 years old; Lenart 2007, 2009a) and from aerial surveys by ABR (females aged ≥ 2 years old), 1997–2009.

decline in parturition rate than did our estimate (Figure 11). Our estimate was obtained about a week after the typical peak of calving in the first week of June, so some mortality of young calves would have occurred between the ADFG and ABR counts. In addition, our classification of cows included 2- and 3-year-old females. Because those age classes have lower rates of parturition, we would expect our calf estimate to be less than the ADFG estimate, which was based on collared adults at least 4 years old. ADFG found that an average of 3.7% of 2-year-olds were parturient between 1994–2006 (n = 81; Lenart 2007b).

The ratio of 6.7 yearlings:100 cows in our composition sample was lower than 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 1996–2008 (mean = 13.3, n = 11). 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, which often associate with barren adult females, 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 of occurrence and severity of insect harassment. The sums of thawing degree-days (TDD) at Kuparuk were the lowest on record during late June, slightly above average in early July and slightly below average in late July (Appendices D and E; Kuparuk weather data for August were not yet available at the time this draft was written). Average daily temperatures dropped below average on 16 June and remained there for the rest of the month. Average temperatures dropped to just above freezing on 20 June, 7.4º C below the average temperature for that date.

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 insect activity based on daily maximum temperatures at the Kuparuk airstrip (but ignoring wind speed; Russell et al. 1993) were at record lows in late June and were close to average in July (Appendices F and G). The estimated probability of oestrid-fly activity (Mörschel 1999), based on average hourly wind speeds and temperatures recorded at Nuiqsut, exceeded 50% on 7 days between 17 June and 6 August 2009 (12–14, 28, 30 July and 3–4 August; Appendix H). The peak fly-harassment probability was 82% on the afternoon of 13 July, when the air temperature reached 28 ºC (82 ºF) with only a light breeze. Thus, the available weather data indicate that the levels of insect activity and resulting harassment of caribou in the Kuparuk area was very high during mid-July and fairly high in early August, but was low earlier in the summer. Harassment by mosquitoes and oestrid flies typically ceases by mid-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. No field observations were conducted during the insect season in 2009, but collared CAH females moved far east of the Kuparuk and Prudhoe Bay oilfields early in July and remained there for the rest of the insect season, a movement pattern that has become more common in the last 5 years. The CAH females outfitted with GPS collars in late June 2009 went as far east as Kaktovik in July and remained east of the Sagavanirktok River throughout the rest of 2009 (Lawhead et al. in prep.; E. Lenart, ADFG, pers. comm.). Although ABR biologists were not present to record the date of mosquito emergence in the study area, it appears to have occurred late in 2009 due to cooler-than-normal temperatures. Biologists conducting bird surveys on the Colville River delta during 22 June–6 July 2009 reported no mosquito harassment until 30 June, severe mosquito harassment on 1 July, mild or no mosquitoes on 2–4 July, and severe harassment again on 5 July.

CARIBOU SURVEYS IN SPRING AND LATE SUMMER–FALL

Spring and late summer–fall surveys of the Colville East survey area were hindered by persistent poor weather and logistical constraints in 2009. Only the 4 westernmost transects could be surveyed in mid-May because of poor weather, only the 2 westernmost transects were surveyed in early August before wildfire smoke from interior Alaska ended the survey, and no surveys could be completed in September or October because of logistical problems and persistent poor weather (Table 5; Figure 12). Very few caribou were observed in mid-May (0.03 caribou/km²), The mean density of caribou in the Colville East survey area was fairly high during the postcalving survey on 22–23 June (2.80 caribou/km²; Table 5) but was below the peak density recorded during the second calving survey in mid-June (4.91 caribou/km²; Table 2). No caribou were observed on the 2 transects surveyed in early August and only 24 caribou were observed during a complete survey conducted on 22–23 August (Table 5).

The overall mean density of caribou in the Colville East survey area during spring and late summer–fall 2009 (excluding calving and postcalving) was 0.05 caribou/km² (Table 5), the lowest mean density observed for those periods in other recent years (0.07–0.62 caribou/km² in 2001–2008; Lawhead and Prichard 2002, 2003a, 2003b, 2005, 2006, 2007, 2008, 2009). This density estimate probably was influenced by the smaller number of surveys in 2009 than usually are conducted.

Table 5. Number and density of caribou in the Colville East survey area (including the Itkillik River area), May–October 2009 (excluding calving surveys).

Date	Area Surveyed [a] (km²)	Total Counted	Estimated Total	Density (caribou/km²)	Number of Groups	Average Group Size
May 13 [b]	388	7	26	0.03	2	3.5
June 22–23	970	2,719	5,438	2.80	165	16.5
August 3 [c]	120	0	0	0	0	–
August 21–22	970	24	48	0.05	24	1.0
Total	2,448	2,750	5,512	1.13	191	12.8

[a] 50% coverage of survey area.
[b] Only four westernmost transects were surveyed due to fog in other areas. Sightability Correction Factor of 1.88 applied due to patchy snow; southeastern portion not surveyed due to fog
[c] Only two westernmost transects were surveyed due to fog in other areas.

OTHER MAMMALS

MUSKOX

Muskox sightings were recorded 28 times between 2 June and 22 August 2009 in 4 portions of the Kuparuk–Colville region: along the Colville River and Colville River delta, in the central GKA (near Kuparuk CPF-1), near Milne Point or Oliktok Point, and along the Kuparuk River (Table 6, Figure 13). In addition to the muskoxen in our study area, a total of 46 muskoxen (39 adults and 7 calves) were observed in 3 groups in the Prudhoe Bay oilfield near the Sagavanirktok River on 27 May.

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 9 June, when 61 individual muskoxen (47 adults and 14 calves) were observed in 8 groups: 11 adults and 5 calves along the Colville River, 11 adults and 3 young near Milne Point, 13 adults and 4 young in 2 groups east of the Milne Point Road, and 12 adults and 2 calves in 4 groups near the Kuparuk River.

In past years, 2 mixed-sex groups of muskoxen generally were seen in the study area near the Colville River delta and near the Kuparuk River delta. In 2009, more than 2 mixed-sex groups were seen and group sizes varied among surveys. Between 3 and 16 muskoxen were observed at several points along the Colville River and larger mixed-sex groups were seen near Milne Point and the Kuparuk River. A total of 29 muskoxen (26 adults and 3 calves) in 4 groups were observed near Milne Point on 2 June and 20 muskoxen in 3 groups (16 adults and 4 calves) were observed along the coast near Oliktok Point and Milne Point on 18 August. Near the Kuparuk River, 14 muskoxen (12 adults and 2 calves) were observed on 9 June, 15 muskoxen (10 adults and 5 calves) were observed on 20 June, and 23 muskoxen (19 adults and 4 calves) were observed there on 18–19 August.

The muskoxen population on the eastern North Slope of Alaska has declined within the last decade, due largely to predation by grizzly bears but also to disease and unusual mortality events such as drowning (Reynolds et al. 2002a, 2002b; Reynolds 2006; Shideler et al. 2007; Arthur and Del Vecchio 2009; Lenart 2009b; Beckmen 2009). The decline was seen first in ANWR but later was noted west of there. A population survey in April 2009 found 196 muskoxen on the central North Slope in GMU 26B, between the Colville and Canning rivers (Arthur and Del Vecchio 2009). Because of the population decline, ADFG increased monitoring of the North Slope population in 2007 and is conducting an intensive telemetry study to investigate distribution, movements, and survival, maintaining

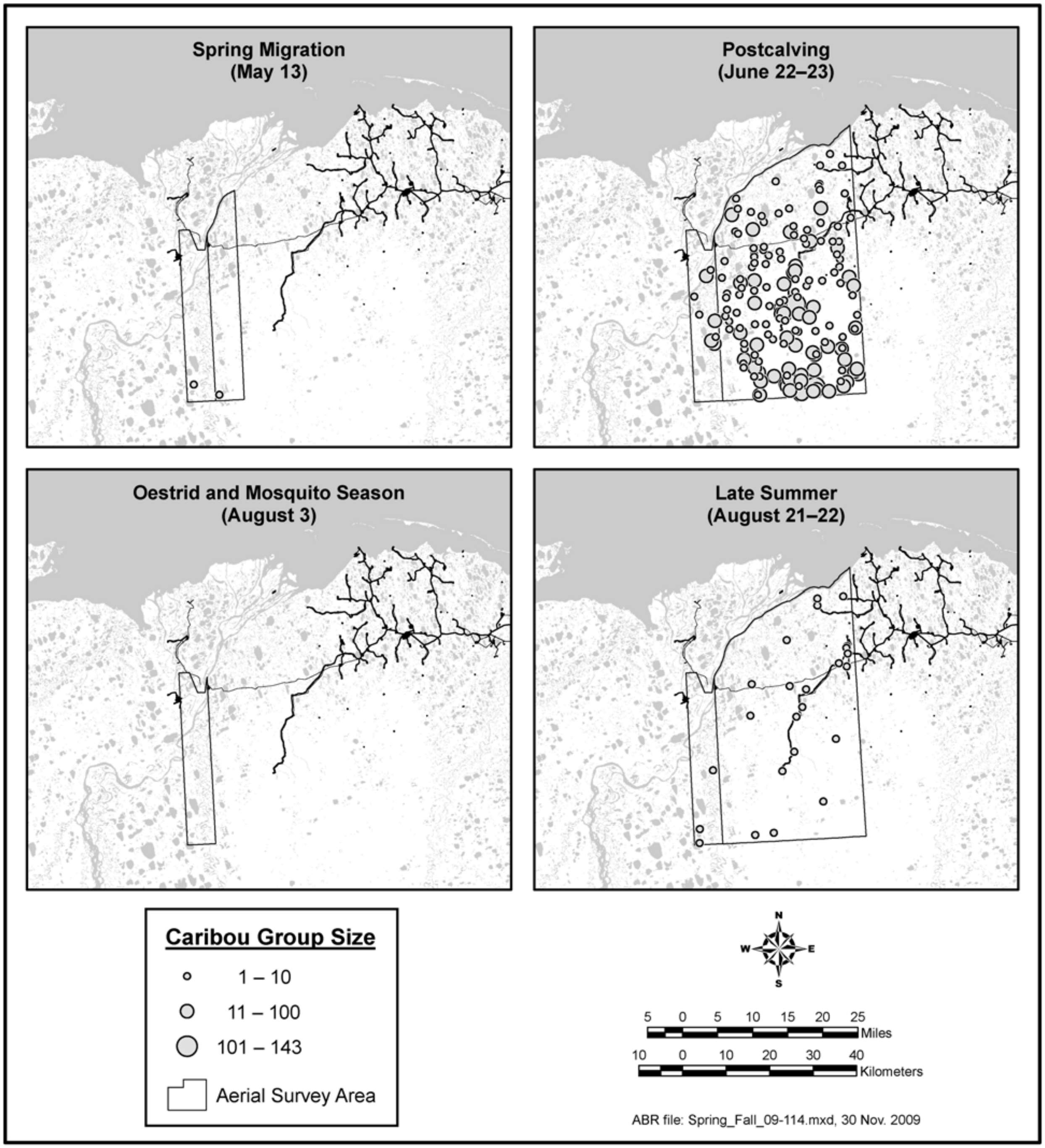

Figure 12. Distribution and size of caribou groups in the Colville East survey area during different seasons, May–August 2009.

Table 6. Locations and number of other large mammals observed during aerial or road surveys in the Kuparuk–Colville region, May–August 2009.

Species	General Location	Date	Adults	Young	Total	Specific Location
Muskox	Colville River	June 9	11	5	16	N of Alpine Pipelines
		August 22	3	0	3	mouth of Itkillik R.
	Oilfield area	June 4	1	0	1	near DS-2N
		June 9	8	1	9	E of Milne Point Rd.
		June 9	5	3	8	E of Milne Point Rd.
	Kuparuk River	June 2	2	0	2	near Spine Rd.
		June 9	4	1	5	N of Spine Rd.
		June 9	1	0	1	near Spine Rd.
		June 9	1	0	1	near Spine Rd.
		June 9	6	1	7	12 km S of Spine Rd.
		June 20	3	2	5	N of Spine Rd.
		June 20	7	3	10	near Spine Rd.
		June 23	3	2	5	S of Spine Rd.
		June 24	4	0	4	near Spine Rd.
		August 18	1	1	2	N of Spine Rd.
		August 19	5	1	6	near Spine Rd.
		August 19	5	0	5	near Spine Rd.
		August 19	2	1	3	near Spine Rd.
		August 19	4	1	5	near Spine Rd.
		August 19	2	0	2	S of Spine Rd.
	Oliktok/Milne Point	June 2	12	3	15	E of Milne Point Rd.
		June 2	2	0	2	E of Milne Point Rd.
		June 2	8	0	8	E of Milne Point Rd.
		June 2	4	0	4	E of Milne Point Rd.
		June 9	11	3	14	E of Milne Point Rd.
		August 18	3	3	6	E of Oliktok Point Rd.
		August 18	3	0	3	E of Milne Point Rd.
		August 18	10	1	11	E of Oliktok Point Rd.
Grizzly bear	NPRA	June 8	1	0	1	W of Fish Creek
		June 9	1	0	1	Fish Creek delta
		June 10	1	2	3	N of Fish Creek
		June 11	1	0	1	E of Fish Creek
		June 13	1	1	2	S of Fish Creek
		June 22	1	1	2	Judy Creek
		June 22	1	2	3	S of Fish Creek
		June 26	1	0	1	Fish Creek delta
		August 24	1	0	1	N of Fish Creek
	Colville River delta	June 8	1	0	1	E of Colville R. delta along coast
		June 9	1	0	1	Central delta
		June 9	1	0	1	E of Colville R. delta
		June 10	1	0	1	E of Colville R. delta
		June 20	1	0	1	N of Alpine pipelines
		June 22	2	0	2	Near Itkillik R.
		June 26	1	0	1	Central delta
		June 29	1	0	1	N of Alpine
		August 22	1	2	3	Near Itkillik R.
	Oilfield area	June 3	1	0	1	E of DS-2P
		June 9	2	0	2	S of CPF-1
		June 9	1	0	1	NE of DS-2P
		June 10	1	3	4	SE of DS-2P
		June 11	2	0	2	S of CPF-1
		June 20	1	0	1	N of Spine Rd.
		August 20	1	0	1	N of DS-2T
	Kuparuk River	August 20	1	0	1	S of Spine Rd.
Spotted seal	Colville River delta	August 22	9	9	0	Eastern delta

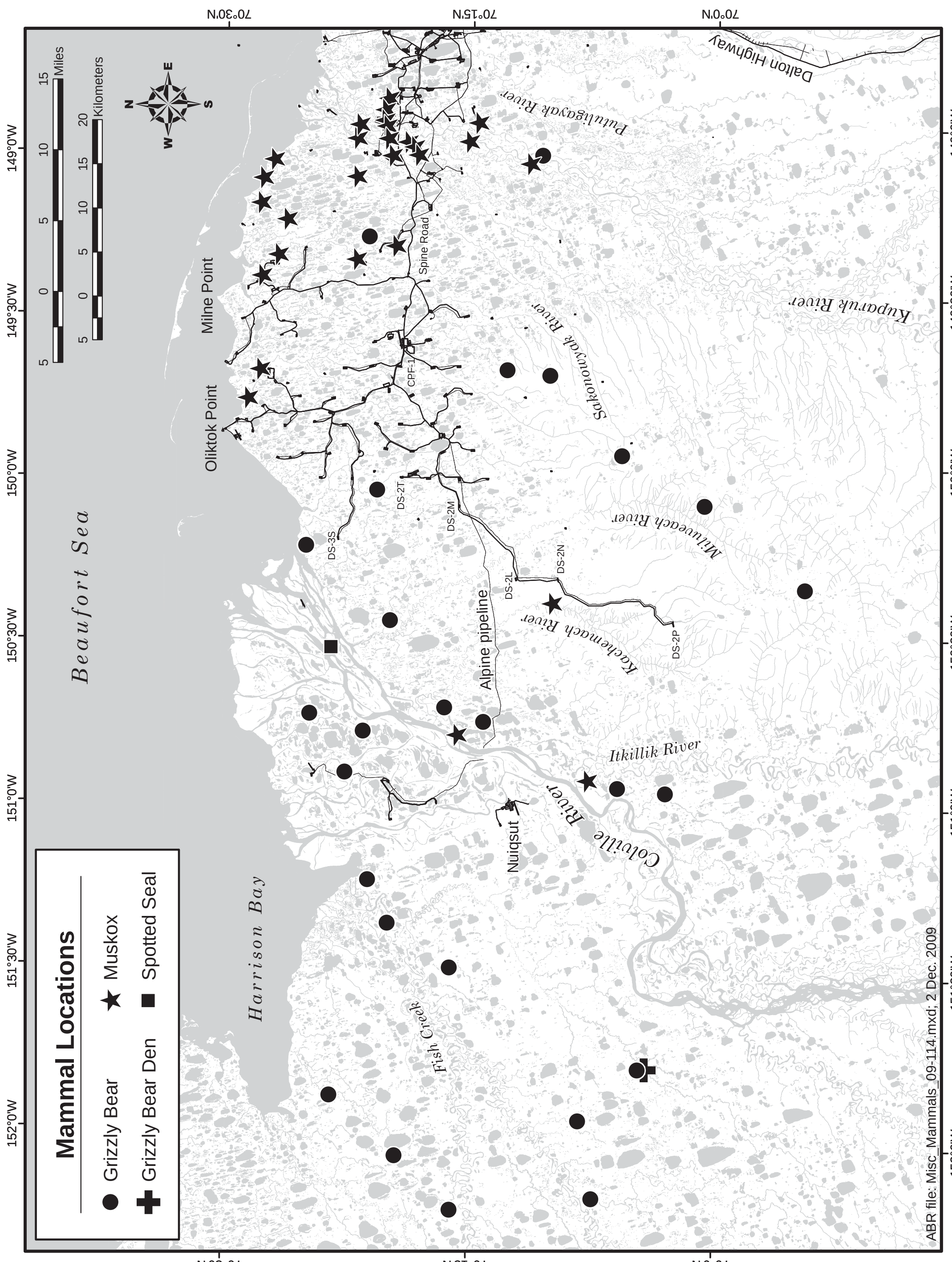

Figure 13. Distribution of large mammals (other than caribou) observed during aerial and road surveys in northeastern NPRA, the Colville River delta, and the Greater Kuparuk Area, May–August 2009.

radio-collars on 20–27 muskoxen annually (Arthur and Del Vecchio 2009). Disease monitoring also has increased (Beckmen 2009).

GRIZZLY BEAR

Twenty-six grizzly bear sightings, totaling 29 adults and 11 cubs, were recorded within 75 km of the coast in the Kuparuk–Colville region during aerial surveys in 2009 (Table 6, Figure 13). Eight bear groups, consisting of 2 sows with 2 cubs each and 2 sows with one cub and 4 single adults, were observed in the NPRA survey area in June and a single adult was observed in August. Some of these observations were likely the same individuals observed multiple times, but individual identification is seldom possible using visual observation, even for the radio-collared, ear-tagged bears being studied by ADFG (Shideler 2009).

Grizzly bears were seen at widely scattered locations throughout the GKA in 2009. Ten adult bears and 2 cubs in 9 groups were recorded on the Colville River delta and 11 adults and 3 cubs were observed in 9 groups in the oilfield area during June and August; the latter included a sow with 3 cubs observed on 10 June. A single bear was observed along the Kuparuk River on 20 August.

Similar to 2008, bears were distributed more uniformly 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 and 2009 likely was due to random variability and is an artifact of the timing of observations, rather than representing a fundamental shift in distribution.

SPOTTED SEAL

On 22 August 2009, a group of 9 spotted seals (*Phoca largha*) was hauled out on a sandbar off the main channel of the Colville River (Table 6, Figure 13). The species was recorded repeatedly in this area in late summer during more intensive surveys of the delta in the 1990s (Johnson et al. 1999).

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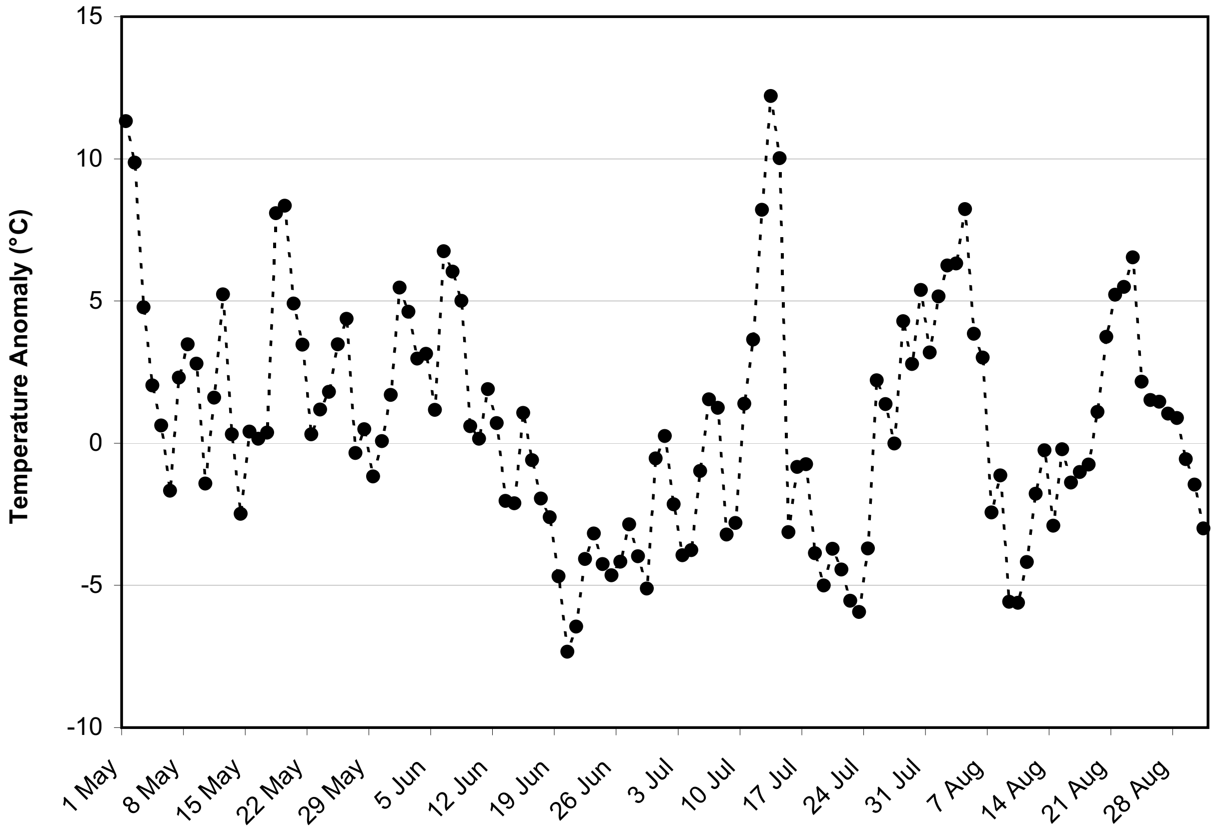
Appendix A. Snow depth (cm) and sum of thawing degree-days (TDD; º C above freezing) at the Kuparuk airstrip, April–June 1983–2009. Some values changed from previous reports due to different rounding error in average temperature calculations.

	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	0.8	51.9
2002	30	trace	0	4.2	30.3	57.8
2003	28	13	trace	0	10.8	23.6
2004	36	10	5	0	8.9	26.4
2005	23	13	0	0	2.5	14.2
2006	23	5	0	0	23.3	93.3
2007	25	46	5	0	0	46.4
2008	20	18	0	0	32.8	71.7
2009	36	13	0	0	16.7	71.7
Mean	22	13	3	0.6	11.6	42.5

[a] Value for 1 June.



Appendix B. Daily temperature anomalies (2009 temperature minus the average daily temperature for 1983–2008) recorded at the Kuparuk airstrip during spring and summer 2009.

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 1995–2009.

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	105	0.26	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
	2 June 2009	1,035	361	0.35	41	0.04	Patchy; SCF used
	8–9 June 2009	1,035	418	0.40	62	0.06	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

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	248	0.41	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
	3 June 2009	788	481	0.61	41	0.05	Patchy; SCF used
	9 June 2009	788	2,906	3.69	700	0.89	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 not 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	1,444	1.14	350	0.28	Patchy; SCF used
	16 June 2004	1,323	6,982	5.28	2,286	1.73	None

Appendix C. Continued.

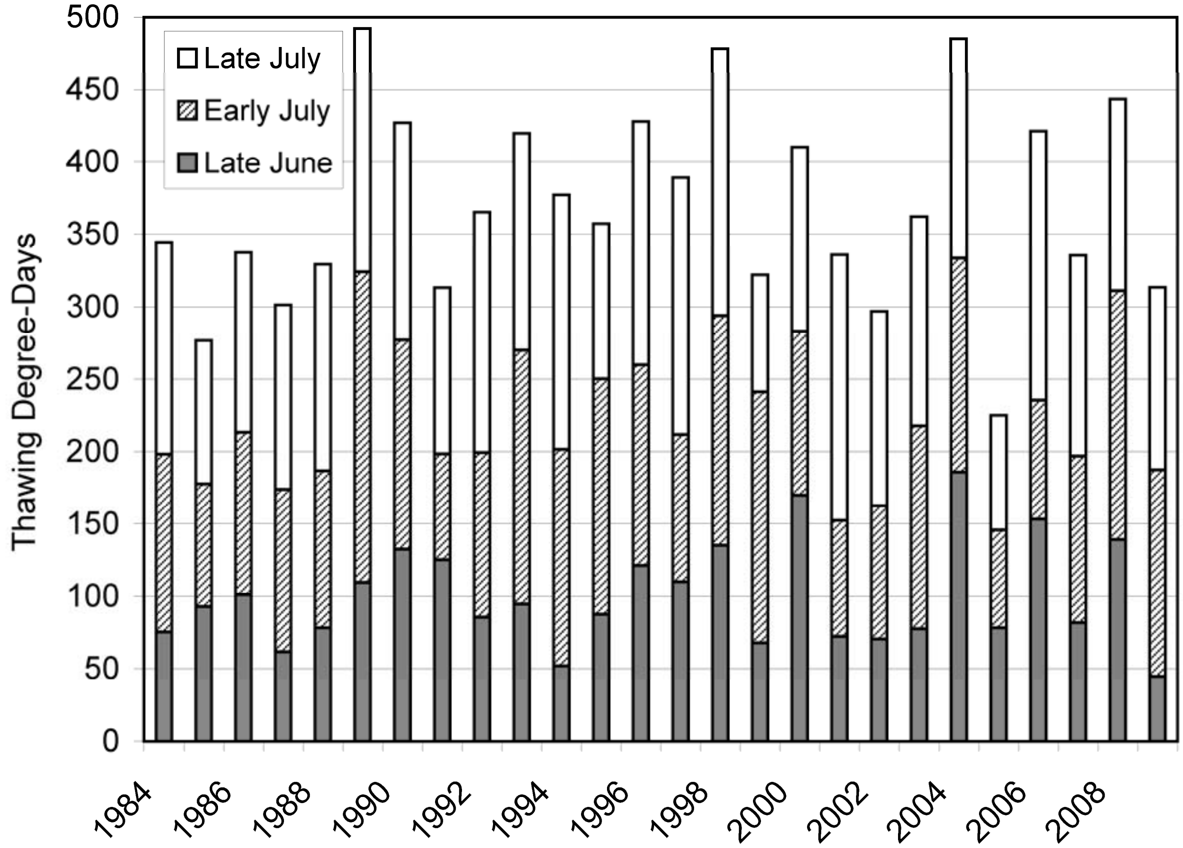
Survey Area	Date	Total Area (km²)	Estimated Total Caribou [a]	Total Density (per km²)	Estimated Total Calves [a]	Calf Density (per km²)	Snow Cover
	10–11 June 2005	1,432	2,746	1.92	726	0.51	Low; SCF not used
	3–5 June 2006	1,432	395	0.28	53	0.04	Patchy; SCF used
	11–12 June 2006	1,432	4,056	2.83	1,022	0.71	None
	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
	3–4 June 2009	1,432	3,816	2.66	736	0.51	Patchy; SCF used
	9–10 June 2009	1,432	7,038	4.91	1,842	1.29	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
	8 June 2009	491	14	0.03	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 1983–2009. Some values differ slightly from previous reports because of changes in rounding error in average temperatures.

	Thawing Degree-Days					
Year	16–30 June	1–15 July	16–31 July	1–15 August	16–31 August	Total
1983 [a]	73.3	74.7	103.8	100.3	50.7	402.9
1984	75.3	122.8	146.4	99.5	59.9	503.9
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	169.7	113.3	127.5	118.6	53.6	582.8
2001	72.2	80.0	183.9	131.7	32.5	500.3
2002	70.3	92.2	134.4	106.1	90.6	493.6
2003	77.5	140.0	144.7	91.9	55.0	509.2
2004	185.6	148.1	151.4	153.3	123.1	761.4
2005	78.1	67.5	79.4	176.7	44.4	446.1
2006	153.1	82.2	186.1	109.7	36.9	568.1
2007	81.7	115.0	138.9	134.4	103.6	573.6
2008	138.9	172.2	132.5	86.1	73.9	603.6
2009	44.4	142.8	126.4	133.6	95.0	542.2
Mean	99.0	125.0	140.5	125.9	75.6	566.1

[a] Some missing values estimated by interpolation.



Appendix E. Index of annual insect-season severity (expressed as cumulative thawing degree-days in º C above freezing) from mid-June through July 1984–2009.

Appendix F. Average index values of mosquito activity [a] (adapted from Russell et al. 1993) during June–August 1983–2009, based on daily maximum temperatures at the Kuparuk airstrip.

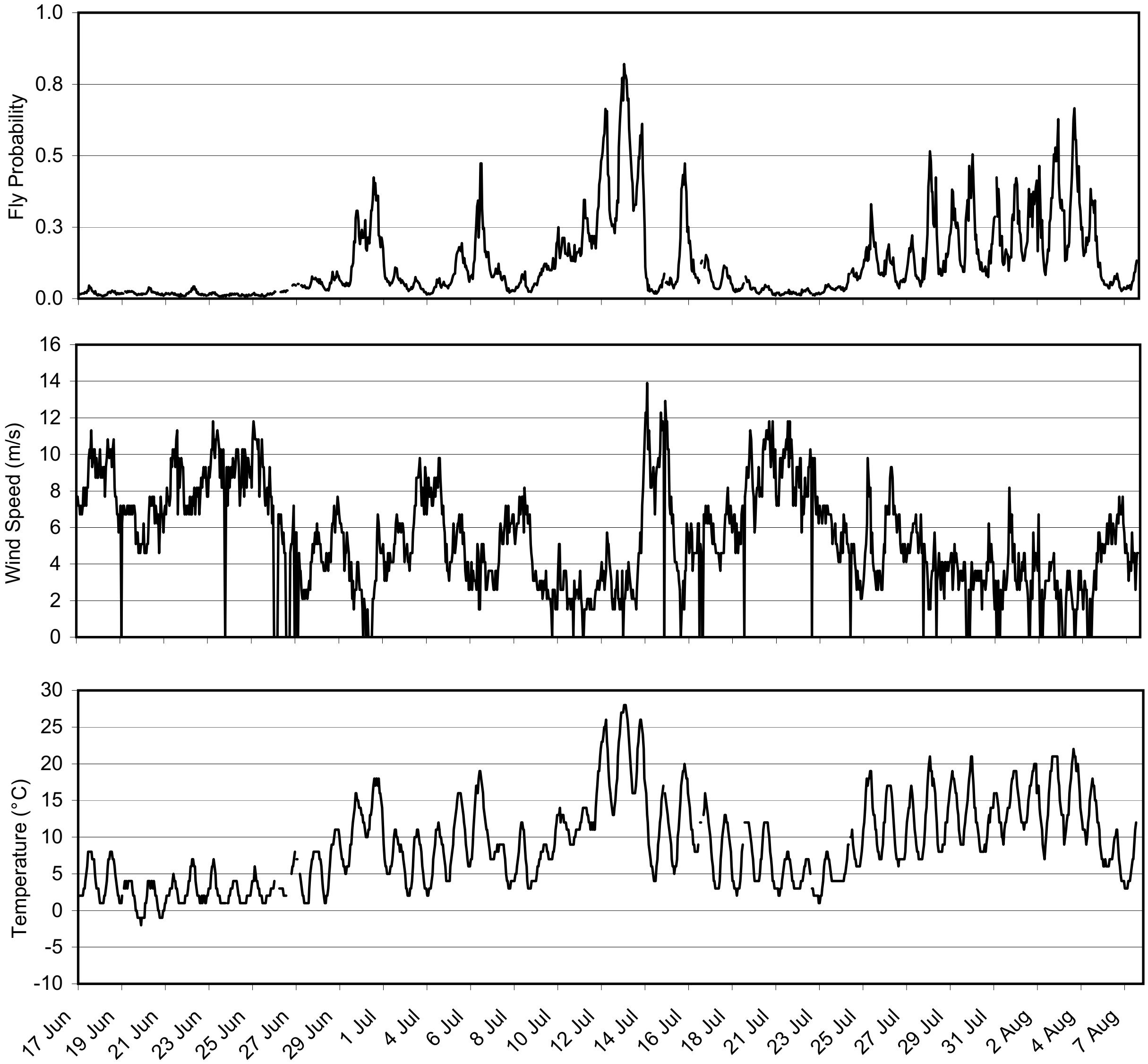
	June			July			August		
Year	Early	Late	Total	Early	Late	Total	Early	Late	Total
1983	0.28	0.31	0.30	0.28	0.40	0.34	0.43	0.15	0.29
1984	0.26	0.37	0.31	0.60	0.68	0.64	0.46	0.21	0.33
1985	0.09	0.48	0.28	0.42	0.45	0.44	0.52	0.31	0.41
1986	0.01	0.46	0.24	0.62	0.54	0.58	0.53	0.21	0.36
1987	0.00	0.22	0.11	0.52	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	0.22	0.22
2009	0.32	0.11	0.22	0.60	0.53	0.56	0.56	0.36	0.46
Mean	0.18	0.45	0.32	0.58	0.59	0.59	0.55	0.28	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)).

Appendix G. Average index values of oestrid fly activity [a] (adapted from Russell et al. 1993) during June–August 1983–2009, 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	0.15	0.12	0.04	0.33	0.19	0.25	0.02	0.13
1984	0.14	0.14	0.14	0.40	0.59	0.50	0.34	0.09	0.21
1985	0.03	0.26	0.15	0.29	0.27	0.28	0.36	0.21	0.28
1986	0.00	0.33	0.17	0.49	0.35	0.41	0.38	0.08	0.23
1987	0.00	0.05	0.03	0.29	0.33	0.31	0.09	0.23	0.16
1988	0.00	0.10	0.05	0.26	0.48	0.37	0.60	0.14	0.36
1989	0.00	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	0.00	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	0.00	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	0.00	0.22	0.11	0.45	0.44	0.44	0.34	0.00	0.17
2004	0.00	0.83	0.41	0.57	0.50	0.53	0.62	0.31	0.46
2005	0.00	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	0.05	0.03
2009	0.14	0.03	0.09	0.41	0.39	0.40	0.42	0.21	0.31
Mean	0.09	0.30	0.20	0.43	0.45	0.44	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)).



Appendix H. Probability of oestrid fly activity (Mörschel 1999) in summer 2009, based on wind speed and temperature data recorded at Nuiqsut.