FINAL REPORT

MAMMAL SURVEYS IN THE GREATER KUPARUK AREA, NORTHERN ALASKA, 2010

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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 from late winter to fall 2010. Surveys were conducted in late winter (April), the calving season (early June), postcalving (late June), late summer (early and mid-August) and fall (mid-September). No surveys were scheduled during the insect season in July. Neither of two surveys scheduled in October could be conducted because of persistent inclement weather. 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 once in 2010, near the end of calving (8–9 June). Summary maps of caribou density were prepared to compare distribution and density in 2010 with long-term averages from regional calving surveys since 1993. A helicopter was used to sample age and sex composition on 11 June.
- The timing of snow melt was later than average in 2010. Snow depth was near record highs in mid-May at the Kuparuk airstrip, but the snow melted rapidly during fair weather in early June. Patchy snow remained during the calving survey on 8–9 June, but melted quickly during a week of clear, sunny weather. Temperatures were below average in late May and slightly above average in early June.
- On the calving survey (8–9 June), a total of 2,053 caribou were observed in the three calving survey areas, including 655 calves (32%), resulting in an expanded total estimate of 4,106 ± 421 caribou (adults and calves) and a mean density 1.26 ± 0.13 caribou/km². Adjusting the adult and yearling count for poor sightability due to patchy snow cover in the southern portion of the survey area produced an estimate of 4,854 ± 1,368 large caribou.
- The highest calving density in 2010 occurred southwest of the Kuparuk Oilfield, in the Colville East survey area. The highest densities of calving caribou were more strongly concentrated in the western portion of the survey area than has been observed in previous years.
- On 8 June, an estimated 126 caribou (including 30 calves) were present in the Kuparuk Field survey area, of which 78 caribou (including 16 calves) were north of the Spine Road and east of the Oliktok Point Road.
- Calf production by the western segment of the CAH was estimated at 76.8 calves:100 cows (*n* = 3,630 caribou) on 11 June 2010, slightly higher than the mean annual production estimated since 1978 (73.4 calves:100 cows). Calf production has exceeded the long-term mean in 13 of the last 15 years but has shown a slightly declining trend in recent years.
- Mean daily temperatures at the Kuparuk airstrip were lower than average in late June and were close to average in July. The mean daily air temperature reached a seasonal peak of 21º C (69º F) in early August. Temperature and wind-speed data for 2010 suggested that activity by mosquitoes and oestrid flies was low early in the summer (late June–early July), moderate in late July, and moderately high in early August.
- Outside of the calving season, the densities of caribou in the Colville East survey area were low in mid-April and August, moderate in mid-September, and high in late June during postcalving. No surveys could be conducted in October due to poor weather.
- Between April and August 2010, 24 sightings of muskoxen were recorded in the study area and surrounding region. The maximum count occurred on 8–9 June, when 42 individual muskoxen (30 adults and 12 calves) were observed in four groups. Five adults and one calf were along the Colville River, seven adults and four young were south of DS-2M, and 18 adults and seven young (in two groups) were near the mouth of the Kuparuk River.

- Twenty grizzly bear sightings, totaling 21 adults and 18 cubs, were recorded within 75 km of the coast in the Kuparuk–Colville region and northeastern NPRA during wildlife surveys in 2010.
- Twenty spotted seals were seen at a haulout on a sandbar in the Colville River in mid-August.

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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 differ in their use of calving, insect-relief, and winter 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 401,000 caribou in July 2009 (J. Dau, ADFG, pers. comm.), despite an 18% decline from the estimated peak of 490,000 in July 2003 (Dau 2007). WAH caribou calve in the Utukok uplands north of the western Brooks Range, then move into the Brooks Range during the insect season, and most animals in the herd migrate south long distances in the fall to winter in western Alaska (Dau 2007). The Teshekpuk Herd (TH) calves near Teshekpuk Lake, ~130 km (80 mi) west of Kuparuk, and uses coastal habitats as well as some inland sites for insect relief. The TH generally winters on the Arctic Coastal Plain (Person et al. 2007), although portions of the herd have 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; Parrett 2009; Lawhead et al. 2010). 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 2009a, 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 that occurs in the oilfield region on the central coastal plain, whereas the ranges of the TH and PH are located west and east of the oilfields, respectively. From the early 1970s to 2002, the CAH grew at an overall rate of 7% per year (Lenart 2003). The herd grew rapidly from ~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. A photocensus of the CAH was conducted by ADFG biologists on 9 July 2010 (L. Parrett, ADFG, pers. comm.), but the results are not yet available.

Similar to the CAH, the TH increased substantially in size from the mid-1970s to the early 1990s (Murphy and Lawhead 2000, Parrett 2009). 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 (Parrett 2009). In contrast to the other three 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 2007). After several years of trying, a photocensus of the PH was conducted successfully in early July 2010 (L. Parrett, ADFG pers. comm.), 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 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, and ADFG conducted two more transect surveys in June 1997 and June 2000. ABR has conducted similar transect surveys of the calving ground of the western segment of the CAH every year since 1993 (except 1994), and also conducted calving surveys in the region in 1983, 1984, and 1987.

The data from the surveys described in this report complement the data from telemetry studies by ADFG. 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 2009a, 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 2009a). Another 27 GPS collars were deployed in March 2004 and all but 4 collars were removed in March 2006 (Arthur and Del Vecchio 2009a). 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. 2010). In 2010, 12 more CAH females were outfitted with GPS collars by ADFG, with funding by 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 2010. Work was conducted primarily during the caribou calving season and secondarily during late winter and late summer–fall in the area between the Kuparuk Oilfield and the Colville River delta; the surveys in 2010 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 2010 study had four objectives:

- Document the distribution and abundance of caribou in the region between the Kuparuk and Colville rivers during the calving season (early to mid-June);
- Sample the sex and age composition of caribou in the Kuparuk–Colville region at the end of the calving season (mid-June) to 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 westernmost portion of the Prudhoe Bay Oilfield (west of the Kuparuk River). Aerial surveys of calving caribou were conducted in three survey areas: (1) the Kuparuk Field survey area (1,035 km²), including the Kuparuk and Milne Point

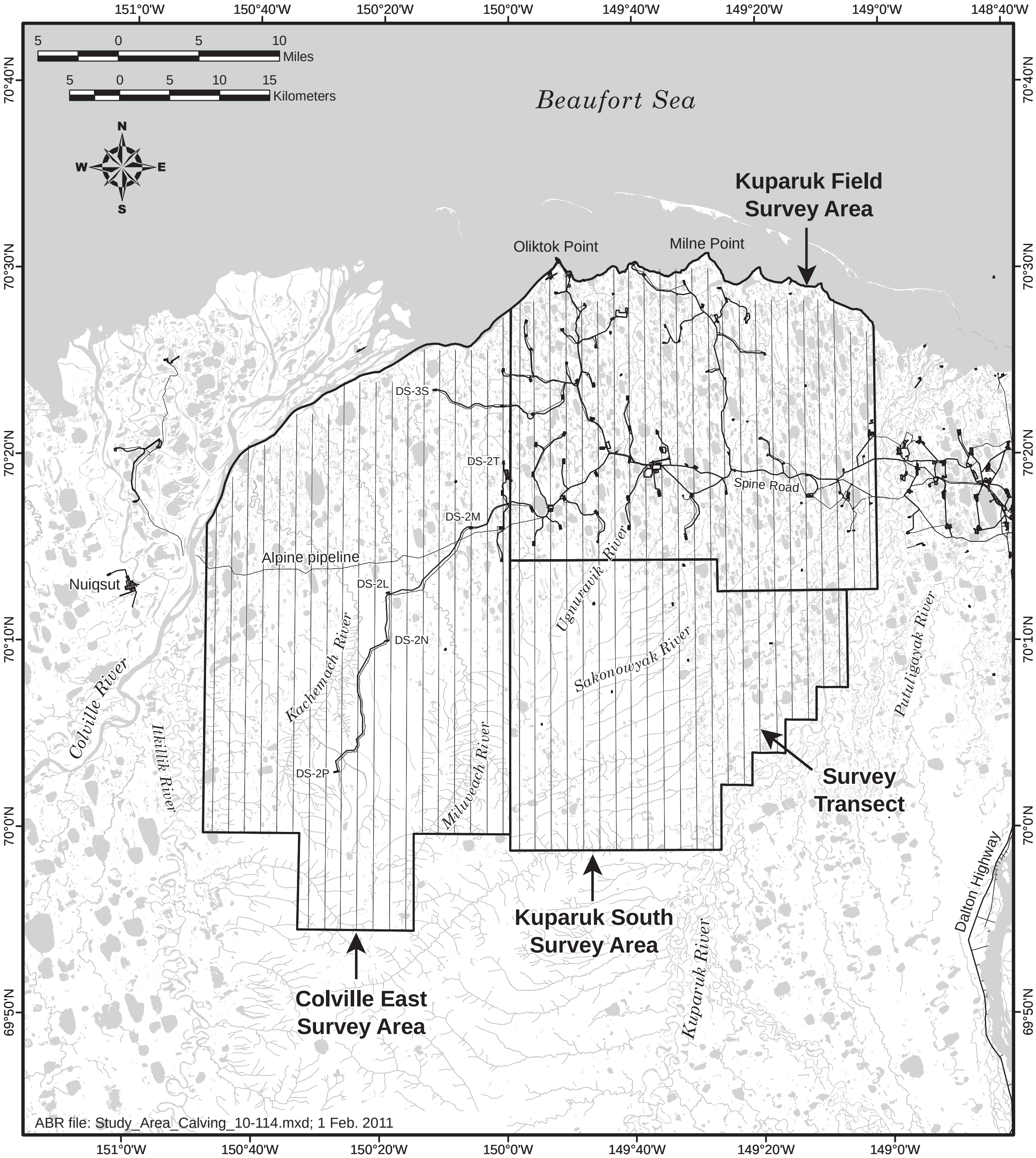

Figure 1. Survey areas and transect lines for systematic aerial surveys of caribou in the Kuparuk–Colville region, northern Alaska, during the 2010 calving season.

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.

These calving survey areas have been modified slightly over the years to optimize survey effort in areas of consistent high use by caribou. In 2002, the westernmost transect of the Colville East survey area and the two easternmost transects of the Kuparuk Field survey area were dropped and the Kuparuk South survey area was extended eastward to the Kuparuk River. The net result was an expansion of total coverage from 3,188 to 3,255 km². In mid-June 2009, we added two transects west of the Colville East survey area to assess caribou distribution along the Itkillik River for the ASDP caribou monitoring study (Lawhead et al. 2010).

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 landscape in the Kuparuk–Colville region slopes gently downward from upland, moist tussock tundra in the upper reaches of the Sakonowyak, Ugnuravik, Kalubik, Miluveach, and Kachemach drainages to moist and wet tundra near the sea 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

Surveys of the calving distribution of the western segment of the CAH in the GKA were conducted by ABR in 1993 and 1995–2010. In most previous years, we conducted two systematic aerial surveys of caribou distribution and numbers during calving. The early calving survey usually was conducted during June 1–8, near the typical peak of calving (2–4 June), and the late calving survey was conducted during 8–16 June, after most females had calved. In 2010, the early calving survey was canceled because of persistent inclement weather. Thus, a single late calving survey was conducted of the Kuparuk Field, Kuparuk South, and Colville East survey areas (Figure 1) during 8–9 June. Caribou were counted by two observers, looking on opposite sides of a Cessna 206 airplane, while a third observer recorded data. In each survey area, the pilot navigated along north–south-oriented transect lines using route coordinates loaded into a Global Positioning System (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), and width was verified by comparison with maps loaded into the observers' GPS receivers. 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 airplane location was recorded using a GPS receiver, the numbers of adults and calves were recorded, and the group was assigned to a distance category (one of four 100-m-wide zones) east or west of the airplane. 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 2010) 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. At the time of our calving survey in 2010 (8–9 June), patchy snow cover was present over the southern portions of the study areas, but not the northern portions. Therefore, we applied the SCF to the Kuparuk South survey area and the portion of the Colville East survey area south of the Alpine pipelines.

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

Because the transect survey method using fixed-wing aircraft tends to undercount calves, a helicopter (Bell 206-LIII "Long Ranger") was used to sample the sex and age composition (cows, calves, yearlings, and bulls) of caribou groups in portions of all three survey areas on 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 observed on 8–9 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 2010 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 estimated density of all caribou (large caribou plus 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 Colville East survey area in mid-April, late June, early and late August, and mid-September. Two surveys also were planned for October but had to be canceled this year because of inclement weather. 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 three calving survey areas and in the Colville East survey area during the winter, postcalving, oestrid fly, late summer, and fall surveys. Additional sightings were obtained from ABR observers conducting other wildlife surveys (mainly birds).

RESULTS AND DISCUSSION

CARIBOU CALVING SEASON

HABITAT AND SURVEY CONDITIONS

Daily air temperatures in spring 2010 were close to the long-term average with above average temperatures for several days near peak calving (6–12 June; Appendices A and B). Snow depth was close to the long-term maximum for most of May and then melted quickly in early June. Although inclement weather in the first week of June prevented aerial surveys, the weather was clear and sunny during the calving survey in the second week of June. Snow had melted at the Kuparuk Airstrip by 5 June (Figure 2, Appendix A), but large areas with extensive drifts of snow remained at the time of the calving survey on 8–9 June. The

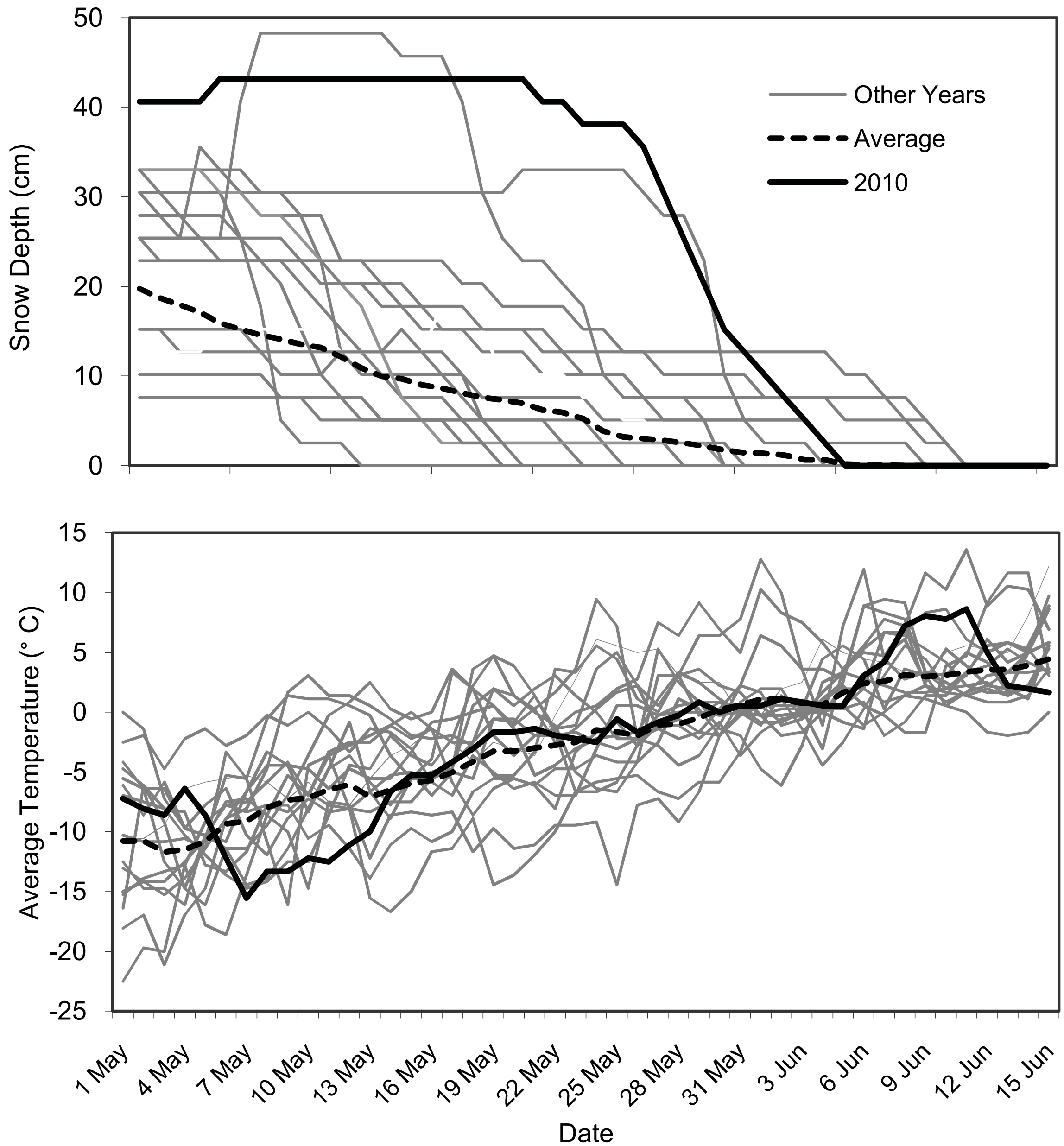

Figure 2. Snow depth (cm) and average daily temperature (° C) at the Kuparuk airstrip during 1 May–15 June 2010, compared with 1993 and 1995–2009.

cumulative sum of thawing-degree days (TDD) at the Kuparuk airstrip was below average in late May and slightly above average in early June (Figure 2, Appendix A).

Patches of snow cover remained in the southern portion of our study area during the calving survey on 8–9 June, so we applied the SCF for large caribou (Lawhead et al. 1994) to the transect counts in the Kuparuk South area and the Colville East survey area south of the Alpine pipelines.

DISTRIBUTION AND ABUNDANCE IN 2010

During 8–9 June, we counted 2,053 caribou, including 1,398 large caribou and 655 calves (31.9%), in all three survey areas combined. Doubling our 50% sample produced mid-June population estimates of 2,796 ± 275 large caribou and 1,310 ± 151 calves among all three areas (Table 1). After adjusting for low sightability, however, the estimate of large caribou increased to 4,854 ± 1,368 animals.

The mean estimated density (adjusted for sightability) for the combined survey areas was 1.49 ± 0.42 large caribou/km² (Table 2). Caribou were heavily concentrated in the Colville East survey area at the time of our calving survey (Figures 3–5). The density of large caribou in the Colville East survey areas in mid-June was more than 30 times higher than in the Kuparuk Field survey area (Table 2).

Compared with previous years since 1993, the overall number and density of caribou in mid-June 2010 were lower than the long-term averages, although the number of calves was similar to the long-term average (Table 3, Appendix C). The distribution of caribou in 2010 was concentrated in the western part of the area to a much greater degree than has been observed in previous years. Given the lower-than-average densities in all three survey areas, many CAH females likely were still south of the survey area. In years of late snow melt, such as 2010, calving typically tends to occur farther inland (Lawhead and Prichard 2001, 2002).

In 2010, the density of caribou in the Kuparuk Field survey area during calving was the second lowest density recorded on our surveys since 1993 (Table 3, Appendix C). On 8 June, 39 of the caribou (including 8 calves) counted in the Kuparuk Field survey area (61.9% of the total number and 53.3% 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. Although the total numbers were low, these proportions are higher than the long-term averages. The proportions north and east of those roads averaged 50% of total caribou and 50% of calves between 1996 and 2010, 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,

Table 1. Estimated numbers of caribou (± 80% CI) during the 2010 calving season in the Colville East, Kuparuk South, Kuparuk Field, and Itkillik River survey areas, Alaska.

Survey Area	Date	Total Area (km²)	Unadjusted Estimate[a]			SCF-adjusted (large only)[c]
			Total	Large[b]	Calves	
Colville East	June 9	1,432	3,742 ± 395	2,514 ± 257	1,228 ± 143	4,409 ± 1,169[d]
Kuparuk South	June 8–9	788	238 ± 32	186 ± 26	52 ± 10	349 ± 103
Kuparuk Field	June 8	1,035	126 ± 24	96 ± 19	30 ± 7	–
Total calving area	June 8–9	3,255	4,106 ± 421	2,796 ± 275	1,310 ± 151	4,854 ± 1,368

[a] Estimates are actual counts multiplied by 2 to adjust for 50% sampling intensity.
[b] Adults + yearlings.
[c] Applied sightability correction factor (SCF) of 1.88 (Lawhead et al. 1994).
[d] Applied SCF only to that portion south of the Alpine pipelines.

Table 2. Estimated density of caribou (number per km² ± 80% CI) in the Colville East, Kuparuk South, Kuparuk Field, and Itkillik River survey areas, June 2010.

Survey Area	Date	Unadjusted Density			SCF-adjusted (large only)[b]
		Total	Large[a]	Calves	
Colville East	June 9	2.61 ± 0.28	1.76 ± 0.18	0.86 ± 0.10	3.08 ± 0.82[c]
Kuparuk South	June 8–9	0.30 ± 0.04	0.24 ± 0.03	0.07 ± 0.01	0.44 ± 0.13
Kuparuk Field	June 8	0.12 ± 0.02	0.09 ± 0.02	0.03 ± 0.01	–
Total calving area	June 8–9	1.26 ± 0.13	0.86 ± 0.08	0.40 ± 0.05	1.49 ± 0.42

[a] Adults + yearlings.
[b] Applied sightability correction factor (SCF) of 1.88 (Lawhead et al. 1994).
[c] Applied SCF only to that portion south of the Alpine pipelines.

2007, 2008, 2009, 2010). 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. Thus, the estimated total of 78 total caribou in the area in 2010 is lower than the number observed in recent years.

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 1995–2010 (Johnson et al. 1996, 1997, 1998, 1999; Lawhead et al. 1997, 1998; Lawhead 1999; Lawhead and Johnson 2000; Lawhead and Prichard 2001, 2002, 2003a, 2003b, 2005, 2006, 2007, 2008, 2009, 2010, this study). These annual data were used to generate mean values over the entire 17-year period for each 3.2-km transect segment (Figure 5; 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 variability in numbers and densities among areas and years (Appendix C). The summary data since 1993 demonstrate that the areas of greatest calving activity (in terms of caribou distribution and density) consistently were located south or southwest of the Kuparuk Oilfield (Figure 5).

The proportion of caribou in the Colville East survey area in 2010 was the highest observed in that area since surveys began in 1993. The highest density of calving has occurred in Colville East in 8 of the 16 years since 1995, including 1997, 2000, 2003–2005, 2007, and 2009–2010 (Table 3). In the other half of the years since 1995, the mean density of caribou during calving was highest in the Kuparuk South survey area (Table 3). In 2010 and other recent years, caribou densities in the Colville East survey area were lower near the Tarn (DS-2N) and Meltwater (DS-2P) roads, consistent with localized avoidance of the area within 2–4 km of active roads during calving by maternal caribou (Lawhead et al. 2002, 2003, and 2004; Lawhead and Prichard 2005, 2006, 2007, 2010).

An area of locally high density in the Colville East survey area during the 2010 calving season was located northwest of CPF-2 and south of DS-3S (Figure 5), 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 2002–2010.

On 8 June 2010, 126 caribou were estimated in the Kuparuk Field survey area, of which 78 caribou (including 16 calves) were north of the Spine Road and east of the Oliktok Point Road; caribou density was highest in areas away from roads (Figure 5). By comparison, the estimated numbers in the Kuparuk Field survey area during our mid-June surveys in 1993 and 1995–2009 ranged from 54 to 2,458 caribou (Appendix C). The historically used Kuparuk–Milne concentration area was used at lower levels in 2010 than the range observed during 1979–1987

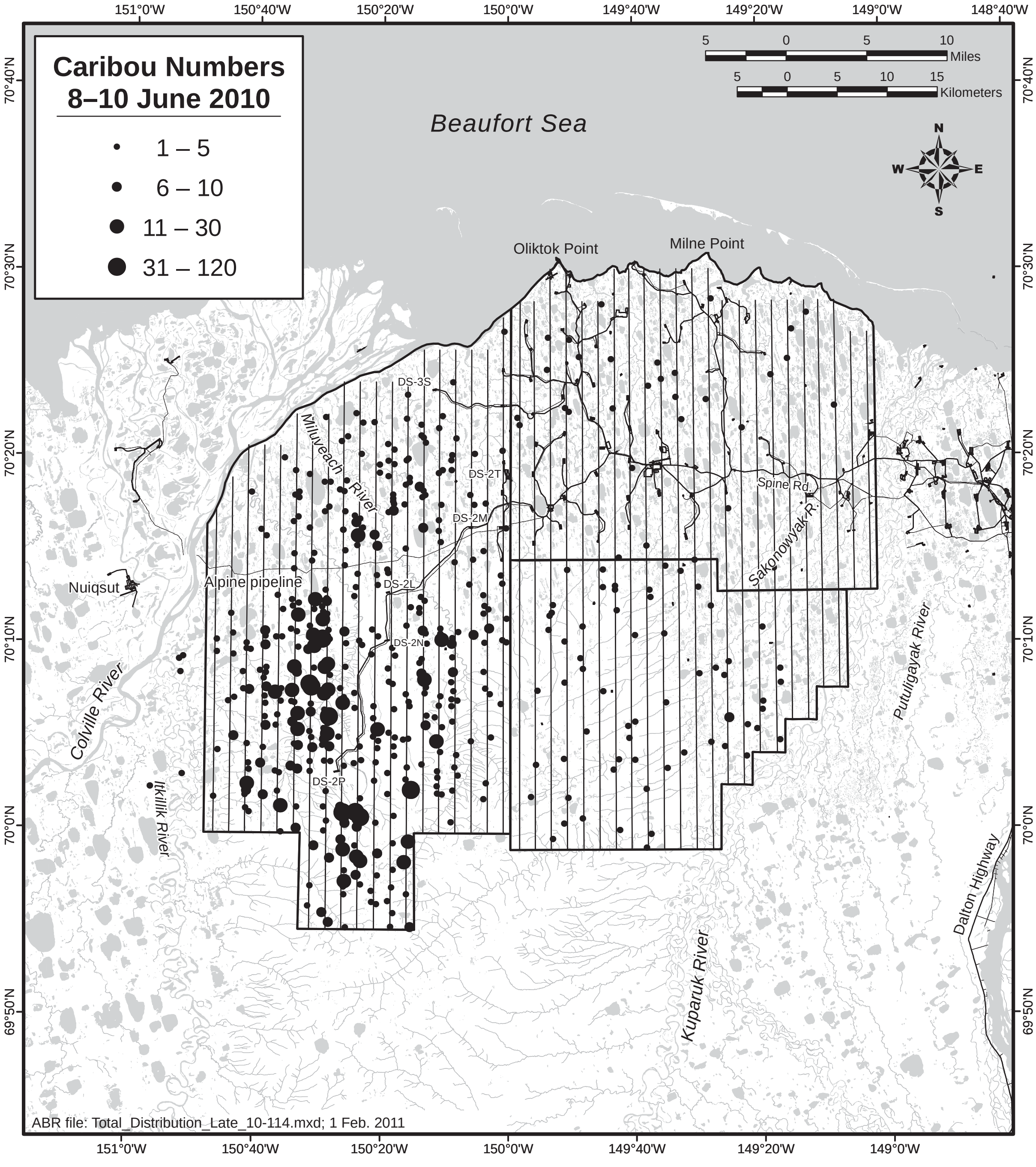

Figure 3. Distribution and group size of all caribou (adults and calves) in the Kuparuk–Colville and Itkillik River calving survey areas, 8–9 June 2010.

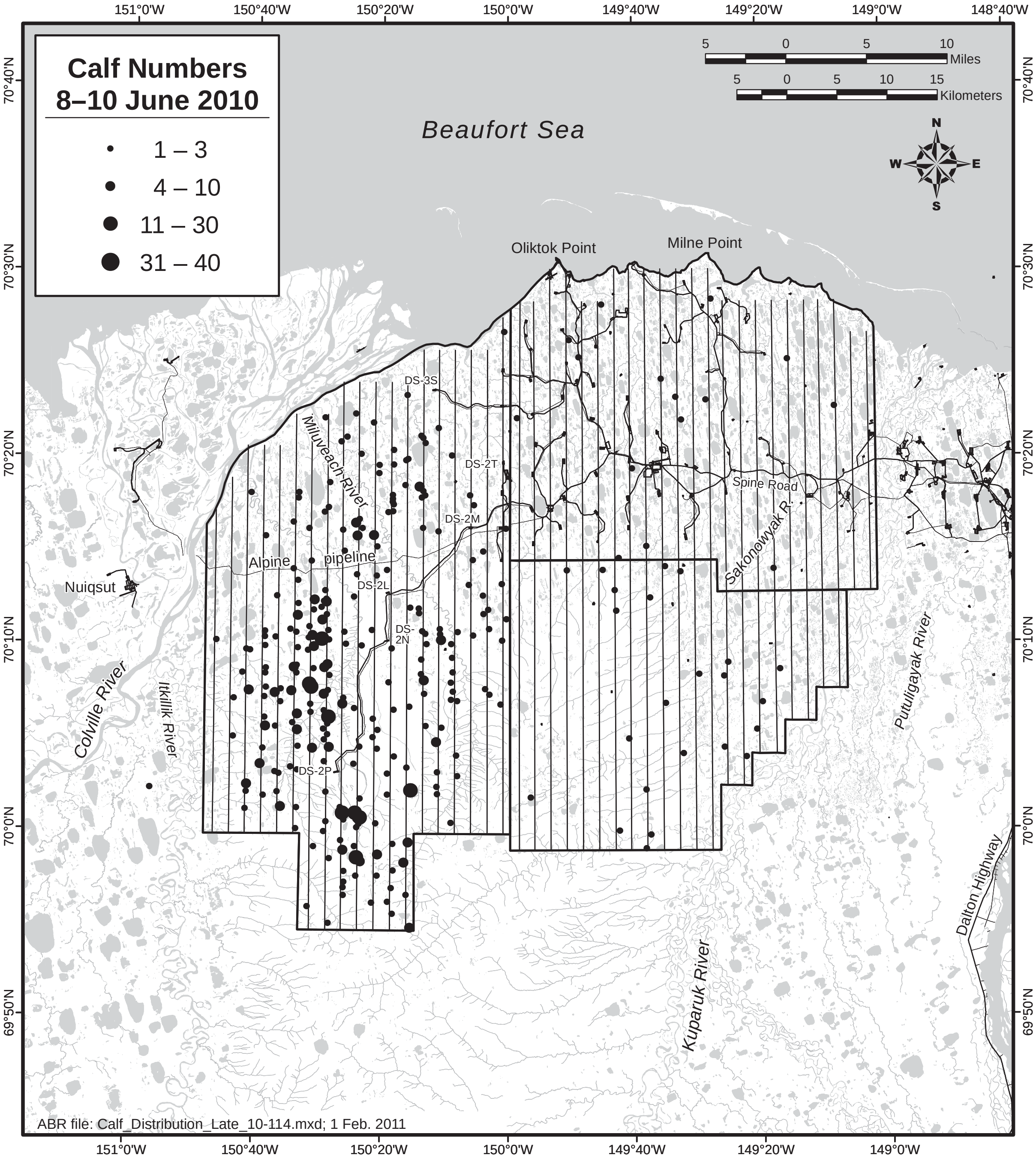

Figure 4. Distribution and number of calf caribou in the Kuparuk–Colville and Itkillik River calving survey areas, 8–9 June 2010.

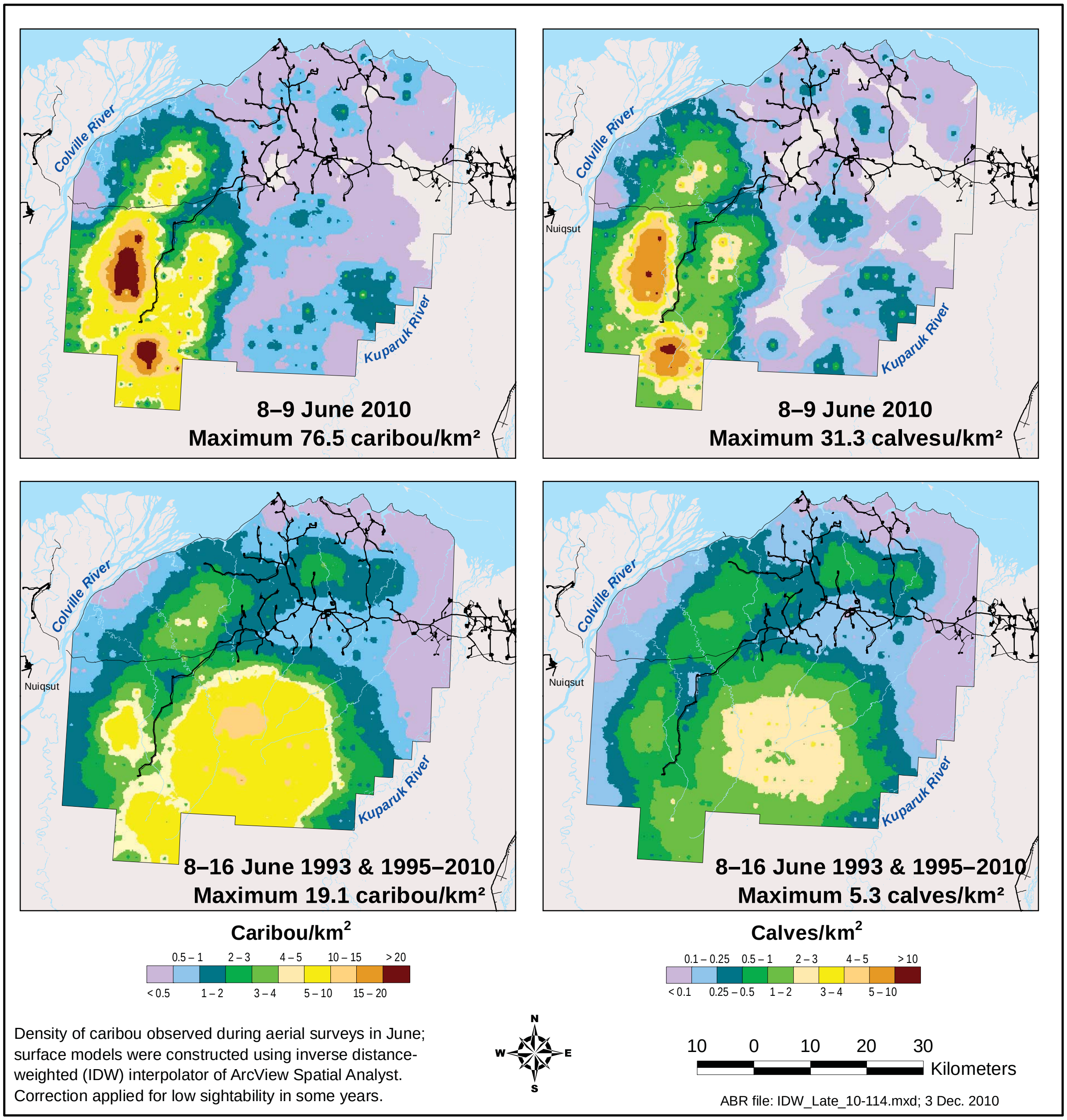

Figure 5. Distribution and density of all caribou and calf caribou in the Kuparuk–Colville calving survey areas during 8–9 June 2010 (top) and distribution and mean density of all caribou and calf caribou during mid-June in the Kuparuk–Colville calving survey areas, 1993 and 1995–2010 (bottom).

Table 3. Estimated density of caribou (number per km^2) in the Colville East, Kuparuk Field, and Kuparuk South survey areas in mid-June 1993 and 1995–2010.

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[a]	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[a]	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
2010[b]	4.61	1.52	0.12	0.03	0.57	0.12	2.21	0.71	Late
Mean	3.15	0.78	0.69	0.19	4.99	1.38	2.71	0.70	

[a] Applied sightability correction factor (SCF) of 1.88 (Lawhead et al. 1994).
[b] Applied SCF only to counts from the Kuparuk South survey area and southern portion of the Colville East survey area.

(~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). 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 declined since the 1980s (Noel et al. 2004, Joly et al. 2006).

SEX AND AGE COMPOSITION AT CALVING

During the age and sex composition survey on 11 June, we counted 3,630 caribou in portions of the Kuparuk Field, Kuparuk South, and Colville East survey areas (Figure 6). The sample comprised 2,024 cows, 1,555 calves, 49 yearlings, and 2 adult bulls (Table 4). Based on this count, our estimate of calf production in 2010 was 76.8 calves:100 cows for the western segment of the CAH. The calf:cow ratio in the Kuparuk Field survey area (41.2 calves:100 cows) was not significantly lower than that in the Kuparuk South survey area (78.2 calves:100 cows; $P = 0.215$, Fisher's Exact Test), but only 24 caribou were classified in the Kuparuk Field, as a result of the low density and dispersed distribution in that survey area. Yearlings composed 1.3% of the total composition sample, for an overall ratio of 2.4 yearlings:100 cows (Table 4).

Our estimate of calf production in 2010 by the western segment of the CAH was above the long-term average (73.4 calves:100 cows) for 1978–2010, for the thirteenth time in the last 15 years (Figure 7). After declining between the mid-1980s and the mid-1990s, calf production increased in 1996 (Figure 7); a slightly declining trend has been noted in recent years. Between 1996 and 2010, the calf:cow ratio has declined at an average rate of 0.45% per year and the decline was significantly less than zero ($P = 0.005$; generalized linear model with binomial distribution). Our 2010 estimate is substantially lower than ADFG's estimated parturition rate of 97% for adult cows ($n = 37$ on 2–5 June 2010). The estimated rate of early calf survival was 85 calves:100 cows ($n = 39$ on 22–23 June), based on radio-collared adult females aged 4 years and older (E. Lenart, ADFG, pers. comm.).

Our estimated calf:cow ratios have consistently been lower than those of ADFG (Figure 8), probably due to methodological differences. 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 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, our calf estimate would be less than the ADFG estimate, which was based on collared adults at least 4 years old. ADFG found that an average of 3.4% of 2-year-olds were parturient between 1994 and 2008 ($n = 87$; Lenart 2009a).

The ratio of 2.4 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) and lower than our estimates that ranged between 4.1 and 39.6 yearlings:100 cows during 1996–2009 (mean = 12.7, $n = 12$). These low ratios are unexpected because calf production has been consistently high in recent years (Figure 7) and overwinter calf survival was high during 2001–2003 and somewhat lower during 2004–2006 (Arthur and Del Vecchio 2009a). 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). Variation can result from annual differences in the migration and distribution patterns of yearlings, which often associate with barren adult females, or from changes in the proportion of nonreproductive 2-year-old cows (with small body size) in the population. Our composition surveys have tended to focus on the areas of the western calving grounds having the greatest density of calving animals, so yearlings may be underrepresented.

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) at Kuparuk in 2010 were the second lowest on record during late June, slightly above average in early July and well above average in July and August (Appendices D and E). Average daily temperatures dropped below average on 13 June and remained below average

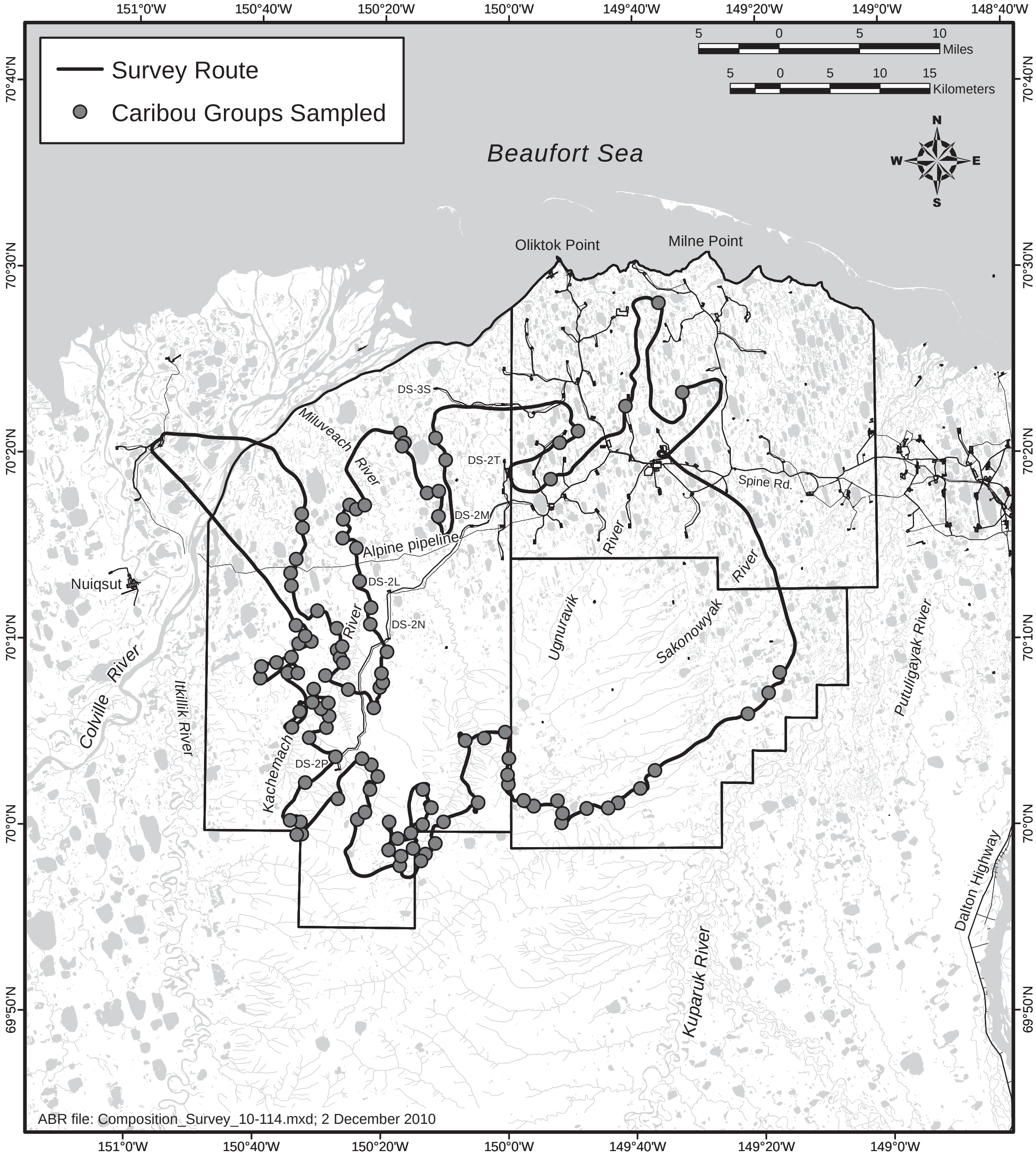

Figure 6. Route of aerial survey and location of groups sampled to quantify sex and age composition of caribou in the Kuparuk–Colville calving survey areas, 11 June 2010.

Table 4. Sex and age composition of caribou in the Kuparuk–Colville region, 11 June 2010.

Survey Area	No. of Groups	Total No.	Cows		Calves		Yearlings		Bulls		Calf Ratio [a]	Yrlg. Ratio [b]
			No.	%	No.	%	No.	%	No.	%		
Kuparuk Field	6	24	17	70.8	7	29.2	0	0	0	0	41.2	0
Kuparuk South	13	79	54	68.4	20	25.3	5	6.3	0	0	37.0	9.3
Colville East	88	3,527	1,953	55.4	1,528	43.3	44	1.2	2	0.1	78.2	2.3
Total	107	3,630	2,024	55.8	1,555	42.8	49	1.3	2	0.1	76.8	2.4

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

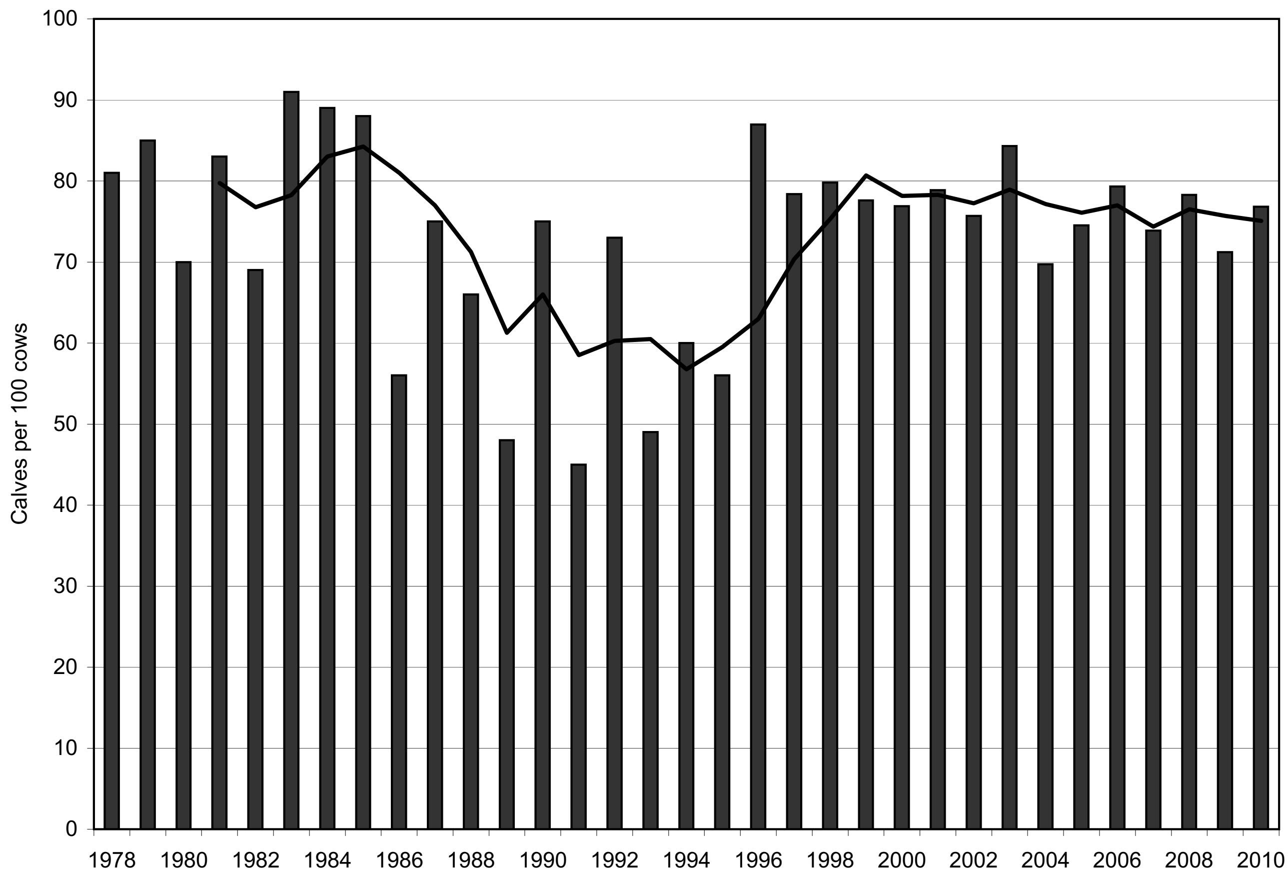

Figure 7. Estimated production of calf caribou (calf:cow ratio [bars] and 4-year moving average [line]) by the western segment of the Central Arctic Herd, based on aerial surveys in mid-June 1978–2010. Data sources: Fancy et al. (1992) for 1978–1990; Woolington (1995) for 1991–1992; Smith et al. (1994) 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, 2010, this study) for 2000–2010.

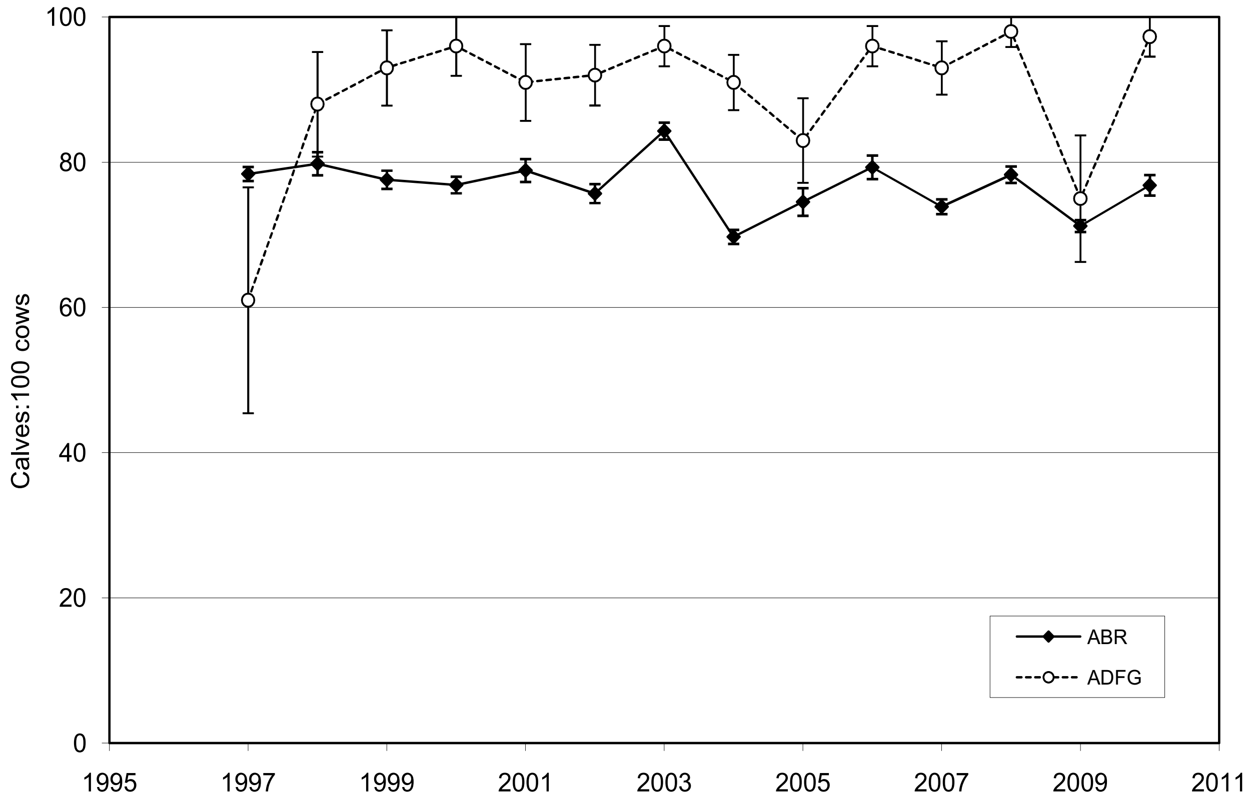

Figure 8. Estimated number (± SE) of calves:100 cows, based on estimates from radio-collared females by ADFG (aged ≥ 4 years old; Lenart 2009b, pers. comm.) and from aerial surveys by ABR (females aged ≥ 2 years old), 1997–2010.

until 4 July. Temperatures were briefly warm in early July, reaching 18°C (64°F) on 9 July. There was another warm spell in late July when temperatures were above average from 26 July–5 August before dropping below average for the next six days (Appendix B).

Weather conditions can be used to predict the occurrence of harassment by mosquitoes (*Aedes* spp.) and oestrid flies (*Hypoderma tarandi* and *Cephenemyia trompe*) (White et al. 1975, Fancy 1983, Dau 1984, Russell et al. 1993, Mörschel 1999). The estimated probabilities of insect activity based on daily maximum temperatures at the Kuparuk airstrip (but ignoring wind speed; Russell et al. 1993) were near record lows for the second year in a row 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 the Kuparuk airstrip, exceeded 50% on one day between 15 June and 6 August 2010 (3 August; Appendix H). The peak fly-harassment probability was 61% on the evening of 3 August, when the daily mean air temperature reached 21º C (69º F) 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 were relatively low during most of July and early August. 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 caribou aggregate and 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 for this study during the insect season in 2010, but collared CAH females moved far east of the Kuparuk and Prudhoe Bay oilfields in July and remained there for the rest of the insect season, a movement pattern that has become more common in the last six years. CAH females outfitted with GPS collars east of the Sagavanirktok River in late June 2010 returned to the west by mid-July, when several collared animals moved into the area near the Colville River delta before returning to the east (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, the cooler-than-normal temperatures in the second half of June suggest that it occurred relatively late in the season. ABR biologists conducting bird surveys during 20–26 June on the Colville River delta reported little or no mosquito harassment, but numerous mosquitoes were reported by field observers working on other projects in early July.

CARIBOU SURVEYS IN LATE WINTER AND LATE SUMMER–FALL

Late winter and late summer–fall surveys of the Colville East survey area were hindered by persistent poor weather in 2010. Only the westernmost transects and the northern third of the Colville East survey area could be surveyed in mid-April because of poor weather. Complete surveys of the Colville East survey area were flown in late June, early August, mid-August, and mid-September (Table 5; Figure 9), but the two surveys scheduled for October had to be canceled.

Very few caribou (0.04 caribou/km²) were observed in the limited area that could be surveyed in mid-April. The density of caribou in the survey area was fairly high during the postcalving survey on 21–22 June (2.46 caribou/km²; Table 5), but was below the peak density recorded during the second calving survey in mid-June (2.61 caribou/km² unadjusted for low sightability; Table 2). Densities were low in early August (0.04 caribou/km²), slightly higher in mid-August (0.06 caribou/km²), and considerably higher in mid-September (0.04 caribou/km²; Table 5).

The overall mean density of caribou in the Colville East survey area during late winter and late summer–fall 2010 (excluding calving and postcalving) was 0.10 caribou/km² (Table 5), similar to the density observed for those periods in other recent years (0.05–0.62 caribou/km² in 2001–2010; Lawhead and Prichard 2002, 2003a, 2003b, 2005, 2006, 2007, 2008, 2009, 2010). These densities are highly influenced by the date of the surveys. In 2010, densities were low outside of the calving, postcalving, and fall surveys.

OTHER MAMMALS

MUSKOX

Muskox sightings were recorded 24 times between 18 April and 18 August 2010 in three

Table 5. Number and density of caribou in the Colville East survey area, April–September 2010 (excluding calving surveys).

Date	Area Surveyed [a] (km²)	Total Counted	Estimated Total	Density (caribou/km²)	Number of Groups	Average Group Size
April 18–20 [b]	424	17	34	0.04	5	3.4
June 21–22	970	2,389	4,778	2.46	96	24.9
August 5	850	35	70	0.04	6	5.8
August 18–20	850	52	104	0.06	5	10.4
September 16	850	222	444	0.26	13	17.1
Total	3,944	2,715	5,430	0.69	191	21.7

[a] 50% coverage of survey area.
[b] Only northern third of Colville East survey surveyed.
[c] Only two westernmost transects were surveyed due to fog in other areas.

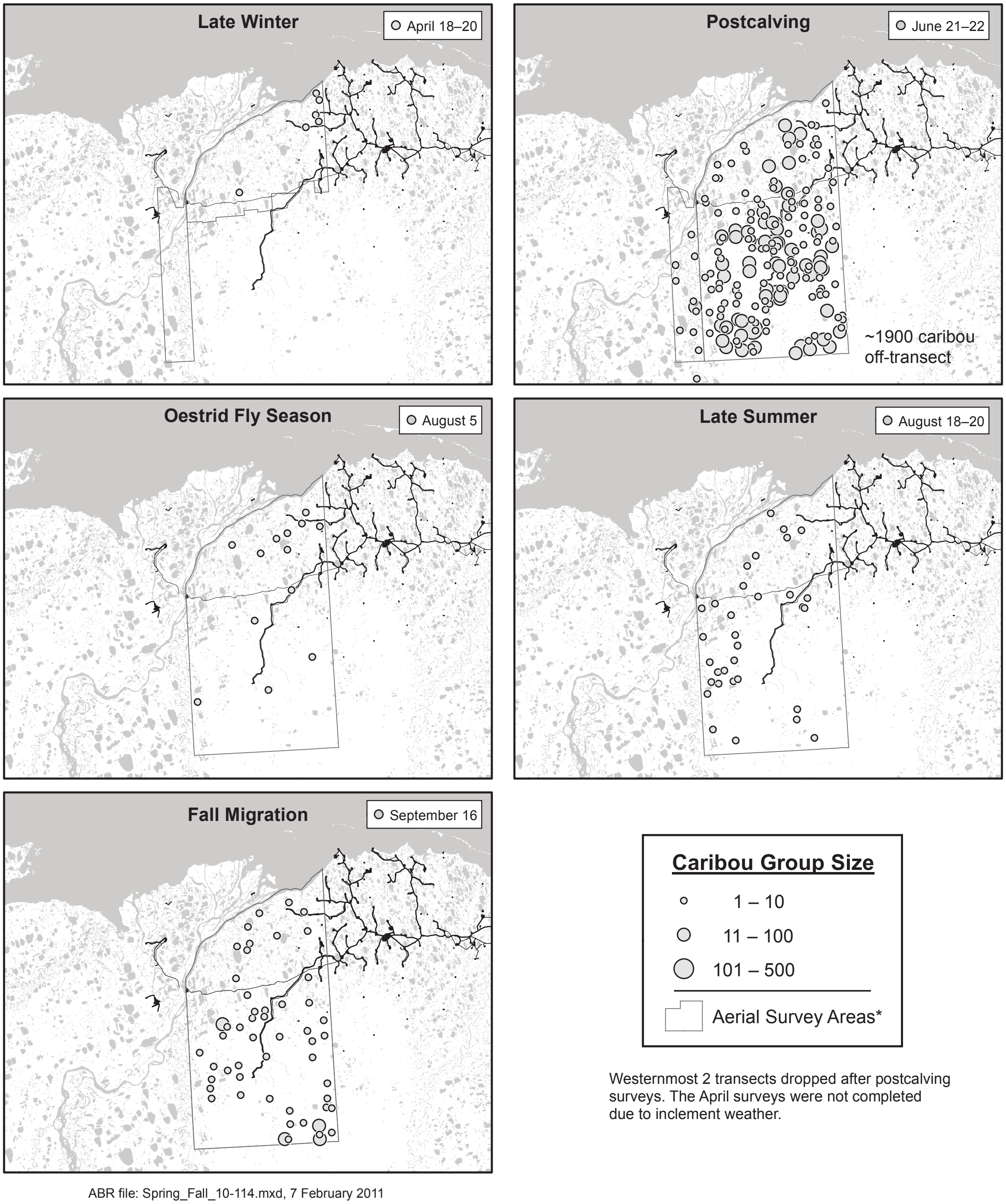

Figure 9. Distribution and size of caribou groups in the Colville East survey area, April–September 2010.

portions of the Kuparuk–Colville region: along the Colville River and Colville River delta, in the central GKA (near Kuparuk CPF-2 and CPF-3), and along the Kuparuk River and coastline west to Beechey Point (Table 6, Figure 10). Because individual muskoxen could not be identified, we were unable to distinguish specific groups reliably on successive surveys. The numbers observed in various locations indicated that at least three different groups were present. On 8–9 June, 42 individual muskoxen (30 adults and 12 calves) were observed in four groups. Five adults and one calf were seen along the Colville River, seven adults and four young were south of DS-2M, and 18 adults and seven young in two groups were observed near the mouth of the Kuparuk River (Table 6, Figure 10).

In past years, two mixed-sex groups of muskoxen generally were seen in the study area, one near the Colville River delta and the other near the Kuparuk River delta. Near the Kuparuk River in 2010, we observed 25 muskoxen (18 adults and 7 calves) in early June, 18 adults in mid-June, and at least 21 muskoxen (17 adults and 4 calves) in mid-August. A total of 22 muskoxen (17 adults and 5 calves in 3 groups) also were observed on the Colville River delta in mid-August. A group of 11 muskoxen (7 adults and 4 calves) was observed moving northeast through the Kuparuk oilfield on 9, 12, and 15 June; it is possible that those may have been some of the animals observed on the Colville delta in August (Table 6).

The muskox population on the North Slope of Alaska has declined within the last decade, evidently due to a combination of predation by grizzly bears, disease, and unusual mortality events such as drowning (Reynolds et al. 2002a, 2002b; Reynolds 2006; Shideler et al. 2007; Arthur and Del Vecchio 2009b; Lenart 2009b; Beckmen 2009). The decline first was reported in ANWR but later was noted farther west on the central coastal plain. 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 2009b). 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 radio-collars on 20–27 muskoxen annually (Arthur and Del Vecchio 2009b). Disease monitoring also has increased (Beckmen 2009).

GRIZZLY BEAR

Twenty grizzly bear sightings, totaling 21 adults and 18 cubs, were recorded within 75 km of the coast in the Kuparuk–Colville region during aerial surveys in 2010 (Table 6, Figure 10). Some of those observations were likely the same individuals observed multiple times, but individual identification is seldom possible from visual observations, even for the ear-tagged, radio-collared bears being studied by ADFG (Shideler 2009).

Grizzly bears were recorded at widely scattered locations throughout the GKA and adjacent areas in 2010. Six adult bears and six cubs were recorded on the Colville River delta and five adults and ten cubs were observed in the oilfield area during June–August (Table 6). The latter included a sow with three large (assumed to be 2-yr-old) cubs seen on 9 June and 21 June; those two sightings likely were the same family group. Three single bears were observed along the Kuparuk River on 8 June and a bear den was found on 5 August east of DS-2P on a west-facing stream bank.

Bear sightings generally were distributed uniformly across the study area, except that eight bears in three groups were observed near DS-2P on 9 June in an area with high densities of calving caribou. Grizzly bears prey on caribou calves (Whitten et al. 1992, Shideler and Hechtel 2000) 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.

Six groups of bears were observed in the NPRA survey area in 2010: four in June, one in July, and one in August. Two single adult bears, one pair of adults, and one sow with two cubs were observed in NPRA in June. Single adults were seen in July and August (Table 6).

SPOTTED SEAL

On 17 August 2010, a group of 20 spotted seals (*Phoca largha*) was hauled out on a sandbar off the main channel of the Colville River (Table 6, Figure 10) that is known to be a preferred haulout

Table 6. Locations and number of other large mammals observed during aerial or road surveys in the Kuparuk–Colville region, April–September 2010.

Species	General Location	Date	Adults	Young	Total	Specific Location
Muskox	Colville R. delta	June 9	5	1	6	Miluveach R. mouth
		June 10	1	0	1	NE Colville delta
		June 13	5	1	6	SE Colville delta
		June 13	1	0	1	SE Colville delta
		August 5	1	0	1	SE Colville delta
		August 5	1	0	1	SE Colville delta
		August 5	6	1	7	SE Colville delta
		August 7	1	1	2	NE Colville delta
		August 17	10	3	13	E of Nuiqsut
		August 18	6	1	7	SE Colville delta
		August 18	1	1	2	Northern Colville delta
	Oilfield area	April 18	5	0	5	S of Alpine pipelines
		June 9	7	4	11	S of DS-2M
		June 12	7	4	11	DS-2M
		June 15	7	4	11	E of DS-3S
	Kuparuk River	June 8	9	4	13	Beechey Pt.
		June 8	9	3	12	Kuparuk R. mouth
		June 20	3	0	3	Near Spine Rd.
		June 22	6	0	6	S of Spine Rd.
		June 22	3	0	3	Near Spine Rd.
		June 22	9	0	9	Near Spine Rd.
		August 16	7	3	10	Kuparuk R. mouth
		August 17	10	1	11	S of Spine Rd.
		August 18	5	2	7	Near Spine Rd.
Grizzly bear	NPRA	June 11	1	0	1	W of Fish Creek
		June 12	1	2	3	S of Fish Creek
		June 13	2	0	2	SW of Fish Creek
		June 22	1	0	1	W of Fish Creek
		July 14	1	0	1	Fish Creek
		August 4	1	0	1	W of Fish Creek
	Colville R. delta	June 13	1	2	3	SE of Alpine
		June 26	1	2	3	NW Colville delta
		July 13	1	0	1	Eastern Colville delta
		August 3	1	0	1	SW of Alpine
		August 19	1	0	1	Eastern Colville delta
		August 19	1	2	3	N of Nuiqsut
	Oilfield area	June 9	1	2	3	E of DS-2P
		June 9	1	0	1	E of DS-2P
		June 9	1	3	4	E of DS-2P
		June 21	1	3	4	SW of DS-2P
		August 18	1	2	3	N of DS-2L
	Kuparuk River	June 8	1	0	1	S of Spine Rd.
		June 8	1	0	1	W of Kuparuk R.
		June 8	1	0	1	W of Upper Kuparuk R.
Spotted seal	Colville R. delta	August 17	20	0	20	Eastern delta

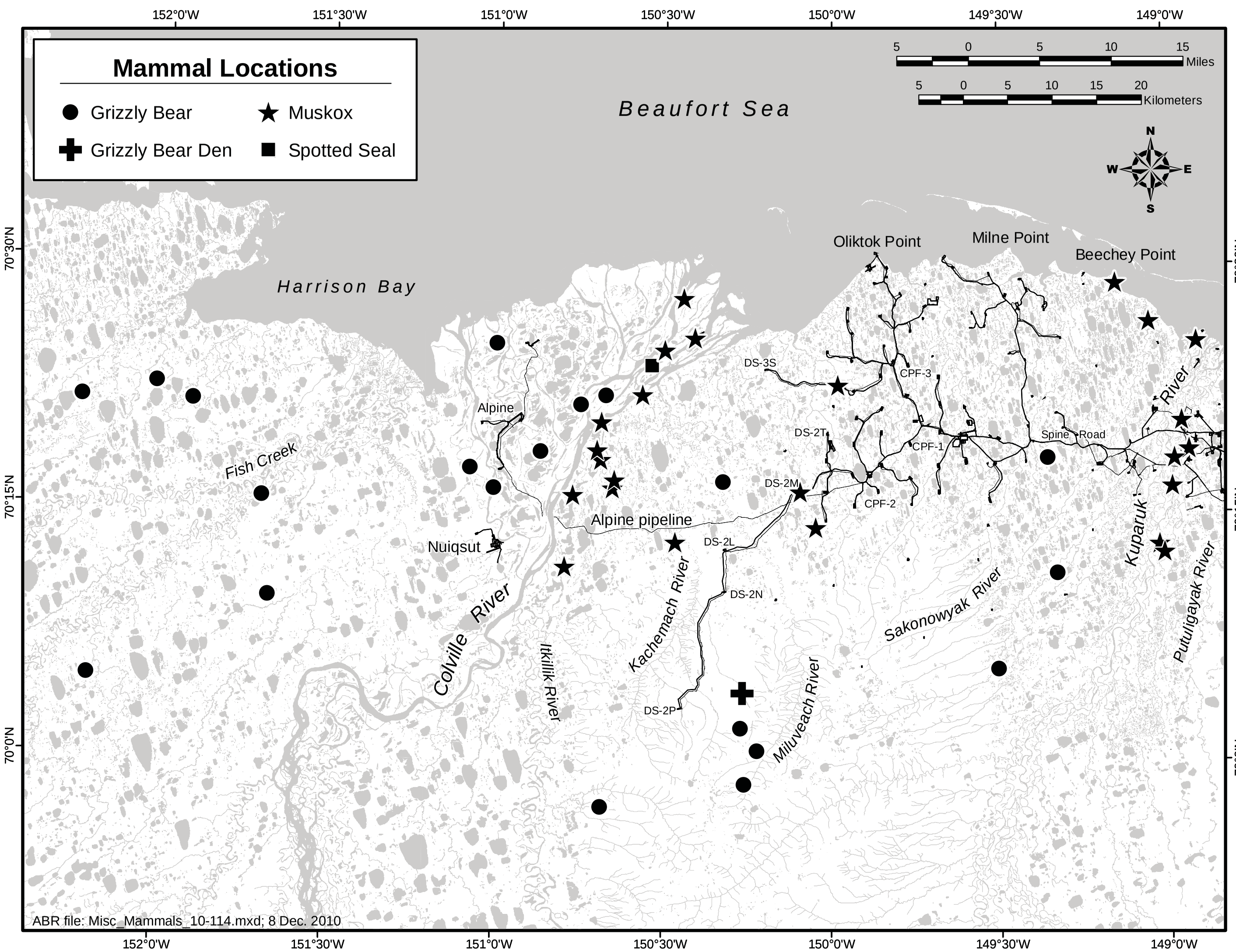

Figure 10. Distribution of large mammals (other than caribou) observed during aerial and road surveys in northeastern NPRA, the Colville River delta, and the Greater Kuparuk Area, April–September 2010.

site for spotted seals. Nine seals were hauled out there in August 2009 (Lawhead and Prichard 2010) and seals were recorded repeatedly in the same area in late summer during more intensive surveys of the Colville delta in the 1990s (Johnson et al. 1999).

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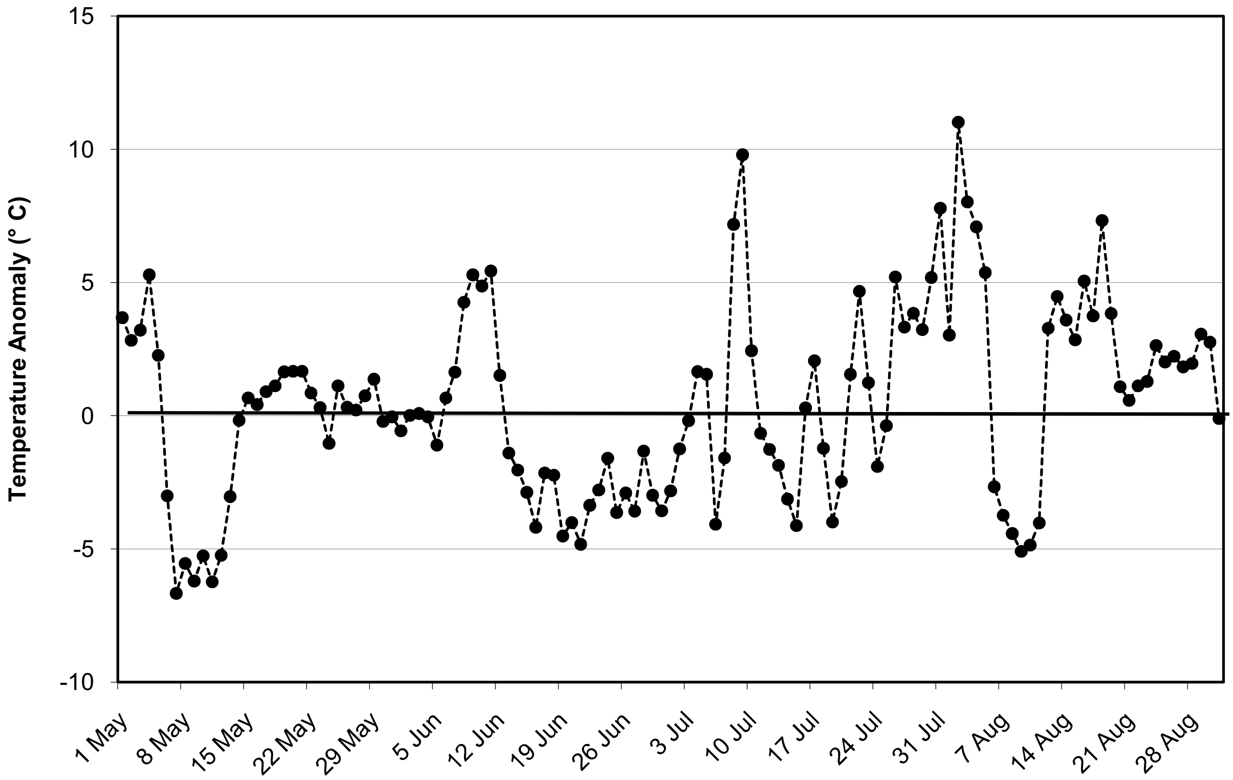
Appendix A. Snow depth (cm) and sum of thawing degree-days (TDD; º C above freezing) at the Kuparuk airstrip, April–June 1983–2010. Some values changed from previous reports due to different rounding error in average temperature calculations.

	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
2010	41	43	13	0	1.4	53.3
Mean	23.0	13.6	3.5	0.6	11.3	42.9

[a] Value for 1 June.



Appendix B. Daily temperature anomalies (2010 temperature minus the average daily temperature for 1983–2009) recorded at the Kuparuk airstrip during spring and summer 2010.

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 1995–2010.

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
	8 June 2010	1,035	126	0.12	30	0.03	Low; SCF not used
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	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
	8–9 June 2010	788	474	0.60	98	0.12	Patchy; SCF used
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
	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

Appendix C. Continued.

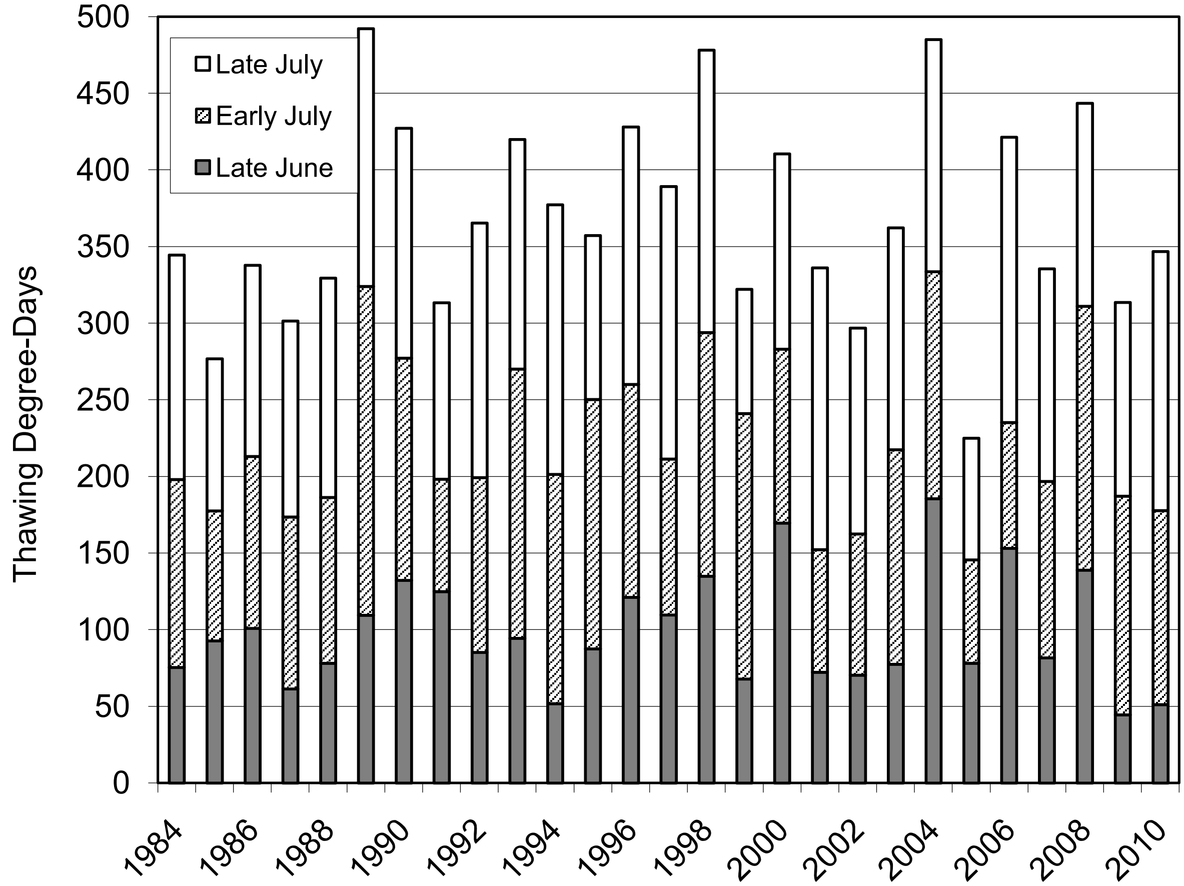
Survey Area	Date	Total Area (km²)	Estimated Total Caribou [a]	Total Density (per km²)	Estimated Total Calves [a]	Calf Density (per km²)	Snow Cover
	3–5 June 2006	1,432	395	0.28	53	0.04	Patchy; SCF used
	11–12 June 2006	1,432	4,056	2.83	1,022	0.71	None
	2, 4–5 June 2007	1,432	2,290	1.60	192	0.13	Patchy; 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
	9 June 2010	1,432	6,606	4.61	2,173	1.52	SCF used southern half
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
	7 June 2010	491	0	0	0	0	Low; SCF not used

[a] Incorporates sightability correction factor (SCF) of 1.88 (Lawhead et al. 1994) where indicated.
[b] Dropped 2 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 1983–2010.

	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
2010	51.1	126.7	168.9	149.2	115.2	611.1
Mean	97.3	125.1	141.5	126.7	77.1	567.7

[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 1984–2010.

Appendix F. Average index values of mosquito activity* (adapted from Russell et al. 1993) during June–August 1983–2010, based on daily maximum temperatures at the Kuparuk airstrip.

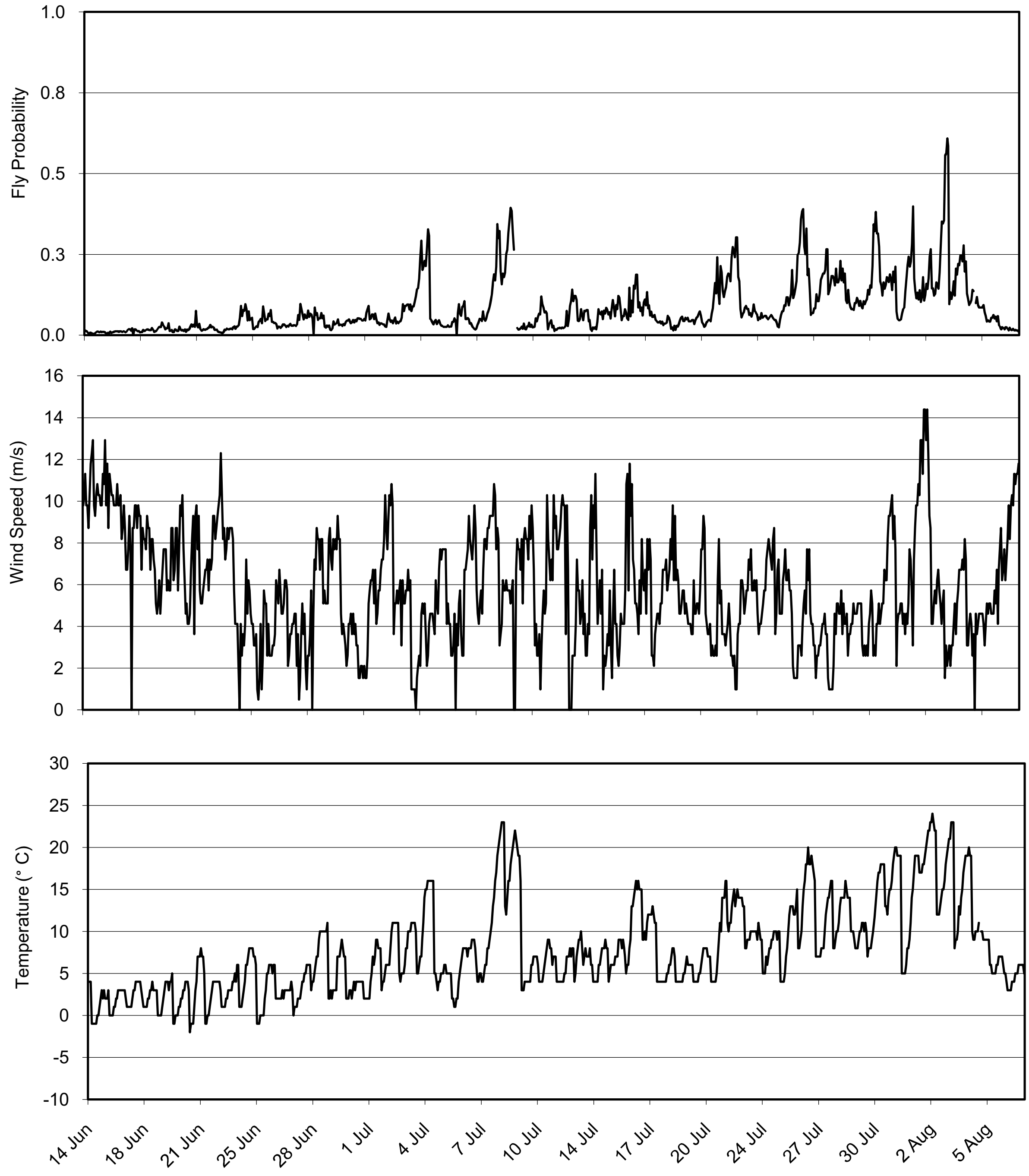
	June			July			August		
Year	Early	Late	Total	Early	Late	Total	Early	Late	Total
1983	0.28	0.31	0.30	0.28	0.40	0.34	0.43	0.15	0.29
1984	0.26	0.37	0.31	0.60	0.68	0.64	0.46	0.21	0.33
1985	0.09	0.48	0.28	0.42	0.45	0.44	0.52	0.31	0.41
1986	0.01	0.46	0.24	0.62	0.54	0.58	0.53	0.21	0.36
1987	0.00	0.22	0.11	0.52	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
2010	0.22	0.14	0.18	0.56	0.74	0.65	0.62	0.43	0.52
Mean	0.18	0.44	0.31	0.58	0.60	0.59	0.55	0.28	0.41

* Average Mosquito Index: if daily maximum temperature <6° C, then 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* (adapted from Russell et al. 1993) during June–August 1983–2010, 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
2010	0.13	0.01	0.07	0.34	0.60	0.47	0.54	0.20	0.36
Mean	0.09	0.30	0.19	0.43	0.46	0.44	0.41	0.15	0.28

* Average Fly Index: if daily maximum temperature <10° C, then 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 2010, based on hourly wind speed and temperature data recorded at the Kuparuk airstrip.