Effects of Oil Field Development on Calf Production and Survival in the Central Arctic Herd

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Stephen M. Arthur
Patricia A. Del Vecchio

Alaska Department of Fish and Game
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Stephen M. Arthur

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AUTHORS: Stephen M. Arthur and Patricia A. Del Vecchio

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SUMMARY

We measured rates of survival, change in body mass, and skeletal growth of caribou (*Rangifer tarandus*) calves from the Central Arctic caribou herd (CAH) from June 2001 through March 2006 to study potential effects of anthropogenic disturbance during the calving period. Calves were captured and radiocollared during June of each year in the 2 main calving areas of the CAH, located east and west of the Sagavanirktok River in northern Alaska. The western calving area has been subject to increasing levels of disturbance since the late 1980s, whereas the eastern area is relatively less disturbed. Radiocollared calves were located at approximately 2–week intervals from June through October of their first year, then again in March and the following June, to estimate survival. Calves were again captured, weighed, and measured during September and March following their birth (ages 3 and 9 months). Summer distributions of calves from the 2 calving areas were assessed by modeling the 95% fixed kernel utilization distributions of locations from each radiotracking trip. Additionally, in March 2003, 2004, and 2005, a total of 58 caribou cows were captured and fitted with Global Positioning System (GPS)-equipped collars which were programmed to determine locations every 5 hours during May–October and every 2 days during November–April. Calves of these cows were captured and radiocollared in June of each year along with calves from uncollared cows to obtain annual samples of 60–65 calves.

Body mass was significantly greater for calves from the eastern area than the western area in June, September, and March (ANOVA, $P < 0.05$). Metatarsus lengths were greater for eastern calves in June and September ($P \leq 0.05$), but not different in March ($P > 0.26$). Seasonal changes in mass and metatarsus length were strongly affected by calf mass or size at the start of each season, and did not differ consistently between areas. Kaplan–Meier estimates of survival rates for female calves during summer (16 June–6 September) ranged from 0.77 to

0.97; annual postcalving season survival ranged from 0.53 to 0.87. Survival rates did not differ significantly between calving areas during most seasons and years. However, calves that were heavier in September were more likely to survive the following winter ($P < 0.0001$).

Distributions of calves from the 2 calving areas overlapped extensively during summer, and there was no evidence of segregation by calving area during winter. Calves from both calving areas used summer ranges east of the Sagavanirktok River, including the coastal plain of the Arctic National Wildlife Refuge, especially during periods of high insect activity. Winter ranges included areas both north and south of the crest of the Brooks Range, including parts of the Arctic National Wildlife Refuge and Gates of the Arctic National Park and Preserve.

Similarities in distributions of caribou calves from the 2 calving areas during most of the year (excluding the calving season) indicate differences in size and mass of calves may be largely influenced by effects of habitat quality on caribou cows during the calving period. Thus, displacement of caribou cows from preferred calving habitats may reduce fitness and survival of calves. Future plans for this project include collecting calf growth and survival data for the 2006 cohort, an analysis of habitat use by caribou calves during the calving and postcalving (summer) periods, and the development of detailed models of caribou movements in relation to oil field infrastructure using data from GPS collars. These models will be used to investigate potential effects of infrastructure on caribou movements and habitat use during summer, and how these effects may influence calf growth and survival.

Key words: calf growth and survival, caribou, Central Arctic herd, oil field impacts

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BACKGROUND

The Central Arctic caribou (*Rangifer tarandus*) herd (CAH) has been the subject of research aimed at assessing potential effects of industrial development since the herd was first identified during the 1970s (e.g., Cameron and Whitten 1979; Fancy 1983; Whitten and Cameron 1983*a*; Jakimchuk et al. 1987). This is largely because the calving and summer ranges of the CAH encompass the major oil fields near Prudhoe Bay and the lower reaches of the Kuparuk River on Alaska's Arctic coastal plain (Fig 1). Most research during the 1980s and 1990s focused on identifying effects of industrial infrastructure (pipelines, roads, drill pads, and related structures) and human activity on caribou movements, activity patterns, and calving distribution. Several studies suggested that during the calving season (late May–late June), pregnant caribou cows and those with newborn calves avoid areas of disturbance associated with oil exploration and extraction (Dau and Cameron 1986; Cameron et al. 1992; Nellemann and Cameron 1996). For example, during the 1990s, the area of greatest concentration of calving by the western segment of the CAH shifted southward as development of oil-related infrastructure occurred in what was originally a major calving area (Lawhead and Johnson 2000; Wolfe 2000). However, other studies indicated that caribou bulls and nonpregnant cows may tolerate some levels of oil field activity (Curatolo and Murphy 1986; Pollard et al. 1996), especially after the calving season (Cronin et al. 1998*a*). Furthermore, despite evidence of reduced reproductive success during some years (Cameron et al. 2005), the CAH increased from approximately 5,000 caribou in 1975 (Whitten and Cameron 1983*b*) to almost 32,000 in 2002 (Lenart 2003). Because of the observed increase in herd size, Cronin et al. (1998*b*, 2000) questioned whether disturbance due to industrial activity had any significant population-level effects on the CAH.

Caribou herds throughout northern Alaska evidently were well below carrying capacity when studies of the CAH began during the late 1970s, and 3 of the 4 Arctic caribou herds showed dramatic increases in numbers during the 1980s and 1990s (Griffith et al. 2002). Thus, population-level effects of disturbance on the CAH may have been masked by the herd's responses to weather, range conditions, insect activity, or other environmental factors. Theoretical connections between effects of disturbance on individual caribou and potential effects on the population have been described (Cameron 1983; Murphy and Curatolo 1987; Murphy et al. 2000, Cameron et al. 2005), and some effects of disturbance may be evident only when combined with other adverse environmental influences (National Research Council 2003). Thus, despite the increase shown by the CAH during the period of oil field development, continuing concerns about effects of anthropogenic disturbance on caribou populations have led to the establishment of mitigation measures to be included in oil field development plans (Cronin et al. 1994) and the exclusion of some areas from petroleum development (U.S. Bureau of Land Management 1998).

Beginning with development of the Meltwater oil prospect during 2001, the area of industrial activity within the range of the CAH has been extended southward along the western side of an area that was used extensively for calving during the 1990s (Fig. 1). Although the Meltwater project included a plan to mitigate disturbance to caribou, some displacement of caribou cows may occur during the calving and immediate postcalving periods. Other projects that are likely to occur may further extend development into the herd's intensive calving areas. In addition, exploration and extraction of oil in the range of the neighboring Teshekpuk caribou herd (TCH) has begun. Environmental permits for these and future developments will likely include stipulations for measures to reduce disturbance of caribou. These requirements will be based largely on studies of the CAH, although much remains to be learned about the effects of industrial development on this herd. Of particular importance are the needs to identify specific mechanisms through which disturbance might affect caribou population dynamics (e.g., by reducing body condition, reproductive success, and/or survival), and to evaluate the effectiveness of established mitigation measures.

OBJECTIVES

This study was designed to investigate how anthropogenic disturbance within caribou calving grounds might affect production, growth, survival, and movements of caribou calves during 2001–2006. The study focused on physical parameters of calves because these directly influence population growth rates, and are themselves influenced by habitat use and movements of adult caribou cows (Cameron et al. 1993; Crête and Huot 1993; Cameron and Ver Hoef 1994). Thus, if anthropogenic disturbance causes caribou cows to alter their activity patterns or use of habitats, those effects should be evident in differing rates of growth and survival of calves. Objectives of the study were to:

1 Estimate annual pregnancy and birth rates of caribou cows.

2 Estimate survival of caribou calves to yearling age class and determine causes of mortality.

3 Estimate rates of growth and weight gain by calves during summer and winter.

4 Assess changes in location, physiography, and vegetation of calving sites among years.

5 Monitor movements of caribou to determine winter and summer distributions.

6 Estimate size of the herd at 2–year intervals using a complete aerial photo census.

Our study design assumed that the birth site of a calf would have some influence on the calf's growth and survival, by affecting forage available to the calf's mother during lactation or habitats used by the calf during summer, and we hypothesized that anthropogenic disturbance might cause calving distributions to change. However, more subtle effects of disturbance might not be evident in the distribution of calving locations. Thus, in March 2003 we expanded the project by deploying collars equipped with Global Positioning System (GPS) receivers on caribou cows, to gather detailed data on movements of cow–calf pairs in summer. These data will be used to develop quantitative models of each pair's use of habitats and exposure to various levels and types of anthropogenic disturbance, weather, and other environmental conditions. Results of this work will be described in greater detail in a future report.

STUDY AREA

The study area encompasses the range of the Central Arctic caribou herd, extending from the Chandalar River drainage in the southern Brooks Range north to the Arctic coast and approximately from longitude 145 to 152° west (Fig. 1). Terrain is extremely variable: rugged mountains typical of the herd's winter range; low, flat, arctic tundra typical of calving areas; and coastal gravel bars and river deltas used for summer insect relief. The area is approximately bisected by the Dalton Highway and trans–Alaska Pipeline corridor. The northern section has undergone extensive industrial development associated with exploration and production of oil and gas resources in the Prudhoe Bay, Kuparuk, and associated oil fields. The remainder of the area is remote and relatively undisturbed by human activity, except for dispersed recreation (hiking, river floating, and hunting). The area includes lands administered by the State of Alaska, U.S. Bureau of Land Management, U.S. Fish and Wildlife Service (Arctic National Wildlife Refuge), and National Park Service (Gates of the Arctic National Park and Preserve).

METHODS

The Alaska Department of Fish and Game (ADF&G) maintains a sample of approximately 80 radiocollared adult (≥ 3 years old) caribou cows in the CAH. These cows were located repeatedly during the calving period (early June) each year to determine the proportion of cows that were pregnant and the proportion that produced calves. Parturition status of cows that were not observed with calves was assigned according to the presence or absence of hard antlers and distended udders (Whitten 1995). The distribution of calving caribou cows was determined each year as the 99% fixed kernel utilization distribution of radiocollared parturient cows (those accompanied by calves or judged to be pregnant) during the peak of the calving period. Areas of concentrated calving activity were identified as sections of the fixed kernel utilization distributions with greater than average density of parturient cows (Wolfe 2000; Griffith et al. 2002). We also investigated fidelity of caribou cows to the 2 main calving areas of the CAH, located east and west, respectively, of the western-most channel of the Sagavanirktok River (hereafter referred to as eastern and western calving areas). We assessed fidelity in 2 ways: First, we determined the proportion of years each cow was located in each calving area during the calving season, and we used the maximum of the 2 proportions (east or west) as the measure of fidelity for each cow. Thus, fidelity could range from 50–100%. We limited this analysis to cows that were located during ≥ 5 years, so as to limit variation due to small samples. We also determined the proportion of calving seasons when a cow was found in the same calving area as she had used the previous year. To maintain adequate sample size, we restricted this analysis to cows that were located during ≥ 4 pairs of consecutive years (i.e., including ≥ 5 individual years).

In March 2003, 26 caribou cows were captured and equipped with collars containing satellite-linked GPS receivers (model TGW3680, Telonics Inc., Mesa, AZ). These collars were programmed to determine an animal's position at intervals of 2 days during winter (November–April) and 5 hours during summer (May–October). Location data were stored on-board the collars and relayed by satellite uplink using the Argos system once per week during winter and daily during summer. In March 2004 we deployed an additional 27 GPS collars on caribou cows. These included 2 refurbished collars from the original set that were recovered after the caribou died and 25 new collars (model TGW3600) with identical programming except that they did not contain the Argos satellite data uplink transmitter (data were stored on-board the collars for later recovery). Due to a transmitter defect identified by the manufacturer (Telonics, Inc.), 26 caribou that had been captured in March 2004 were recaptured during September 2004 so that the faulty collars could be replaced with new GPS-Argos collars similar to the original set. At this time, we also captured and collared one new caribou cow to replace tracking of another cow that had died. In March 2005, 12 caribou cows that were originally collared during 2003 were recaptured and their collars replaced with new GPS-Argos collars. Four additional caribou cows were captured in March 2006 and equipped with GPS-Argos collars recovered from caribou that had died.

In June of each year, 60–65 neonatal calves (≤ 2 days old, as determined by mobility, posture, and presence and appearance of umbilicus) were captured by hand after a brief pursuit with a helicopter. Captures were divided equally between the 2 main calving areas (east and west of the Sagavanirktok River). Boundaries of the capture areas were determined by the distributions of parturient radiocollared cows in the 2 areas each year (Fig. 2). Only female calves were captured during 2001 and 2002. During 2003–2005 our objectives were modified to include both male and female calves of cows that had been equipped with GPS radio collars. Thus, 11, 16, and 13 male calves were included during 2003, 2004, and 2005, respectively. Calves of 17 GPS-equipped cows were captured during June 2003. These included 9 in the western area (5 M; 4 F) and 8 in the eastern area (6 M; 2 F). In June 2004 we captured calves of 40 GPS-equipped cows, including 24 from the western (9 M; 15 F) and 16 from the eastern (7 M; 9 F) calving areas. In June 2005 we captured 22 calves of GPS-equipped cows, including 16 western (9 M; 7 F) and 6 eastern calves (3 M; 3 F). During each of these years, we captured additional female calves to obtain annual totals of 60–65 calves.

Captured calves were weighed and fitted with expandable, breakaway radio collars (MOD-310 or 315, Telonics Inc.), and a metatarsus was measured. Locations where calves were captured during early June were photographed and classified according to general habitat characteristics (plant communities, percent snow cover). Calves born very early or late in the calving period were excluded because these represent a small proportion of each cohort and may have lower survival rates than calves born near the peak of calving (Adams et al. 1995). During early September and March, collared calves were again captured, weighed, and measured. September and March captures were accomplished using a net-gun fired from a helicopter.

We attempted to locate all collared calves by aerial radiotracking approximately twice per month during late June–October, then again during late February or March and early June of the following year. Deaths of collared calves were recorded based on intervals between radiotracking flights, and survival was estimated using the Kaplan–Meier staggered entry procedure of Pollock et al. (1989) for summer (16 June–6 September), winter (7 September–31 May), and for their first year (16 June–31 May). Because of our small samples of calves collared during the first half of each calving period, we estimated perinatal survival (1–15 June) by summing all captures and mortalities until 20 calves had been captured, then dividing the total deaths by the total captures for that period. If this point was reached before 15 June, then subsequent days were treated using the staggered entry procedure (Pollock et al. 1989). We did not include perinatal survival in our estimates of annual survival or in any other analyses because of potential biases due to variable sample sizes, timing of captures within the calving period, and the possibility of capture-related mortality. Whenever possible, carcasses of calves that died were examined and probable cause of death was determined. During July and August 2004, smoke from extensive wildfires across eastern Interior Alaska forced the cancellation of many scheduled radiotracking flights. Instead, we used data from 44 GPS collars deployed on caribou cows with calves to obtain comparable data. We estimated dates that calves died in 2004 by comparing locations where collared calves were found dead with movements of each calf's mother: we assumed that the date the mother was closest to the location where the dead calf was found was the date of the calf's death. We grouped these data into 2-week periods to estimate mortality rates.

Data on calf body mass and metatarsus length were compared between sexes, areas, and among years using analysis of variance (ANOVA). Effects of body mass and metatarsus length on rates of gain in these measures during summer (June–September) and winter (October–March) were also compared between areas using ANOVA. We tested the hypothesis that overwinter survival of female calves was related to their condition during fall using logistic regression, with survival as the response variable, and September body mass as the measure of calf condition. Survival during winter is likely to be affected by environmental conditions, which vary both geographically and among years. Thus, we included independent variables representing location of the calf's winter range (north or south of the crest of the Brooks Range) and winter severity. The index of winter severity we used was the cumulative precipitation from October–March of each winter, expressed as the percent of the mean from 1971–2000. For calves that wintered on the south side of the Brooks Range, we used the mean of precipitation measurements from Coldfoot and Chandalar Shelf, and for calves wintering north of the Brooks Range we used the mean of measurements from Atigun Camp and Imnavait Creek. Precipitation measurements were reported by the U.S. Department of Agriculture, Natural Resources Conservation Service (Alaska Snow Survey Reports, available at http://ambcs.org/aksnow/bor_ak.html).

We examined summer (postcalving season) distributions of calves from the 2 calving areas (eastern and western) using the 95% fixed kernel utilization distributions of locations obtained during each radiotracking trip. In addition, locations of radiocollared calves and cows during late February–March were used to identify wintering areas. To examine patterns of distribution during summer 2004 (when few radiotracking flights were possible), we selected dates similar to those when radiotracking flights were conducted during previous years. We then modeled distributions of GPS locations of collared caribou cows with calves on these dates using the fixed kernel models.

A complete photo census of the CAH was conducted in July 2002. The census used standard methods for censusing caribou herds in Alaska (Valkenburg et al. 1985); a small fixed-wing aircraft (Piper PA-18) located collared caribou while the herd was aggregated along the Arctic coast. The groups were then photographed using a 9-inch format aerial mapping camera (model RMK-A 15/23, Carl Zeiss AG, Oberkochen, Germany) mounted in a DeHavilland Beaver aircraft. Caribou in the photographs were counted and classified as either calves or adults. We planned to census the herd at intervals of 2 or 3 years, weather permitting. However, no census was possible in 2004 or 2005 because of smoke, cloudy weather, and failure of the caribou to aggregate sufficiently to be photographed.

RESULTS

We defined parturition rate as the proportion of radiocollared caribou cows ≥ 4 years old that were judged to be pregnant or to have given birth. Annual parturition rates were 91% (2001, n = 35), 92% (2002, n = 50), 96% (2003, n = 53), 90% (2004, n = 69), and 85% (2005, n = 60) (Lenart 2003; this study).

Snow cover was unusually widespread across the calving area in early June 2001. As a result, spring migration was delayed and calving occurred over a larger area than during most years (Fig. 2). The peak of calving in 2001 was approximately 9–10 June; several days later than during 2002–2005 when the peak of calving was approximately 4–6 June. The fixed kernel distribution model likely overestimated the calving distribution in 2001 because of the lateness of calving; some pregnant cows that were located south of the usual calving areas during the survey (3–9 June) may have moved north before giving birth. However, our observations in early June suggested that caribou cows with calves were more widespread in 2001 than during most years. During 2002–2005, much of the usual calving area was free of snow by the peak of calving. Calving distributions during these years were similar to other years with similar timing of snowmelt (Fig. 2).

We obtained locations during ≥ 5 calving seasons for 46 caribou cows ($\bar{x}$ = 5.7 seasons per cow, range = 5–8). Mean fidelity to a specific calving area was 92% (range = 50–100%, median = 100%). Caribou used the same calving area as the previous year during a mean of 88% of calving seasons (n = 41 cows located during ≥ 4 consecutive-year pairs, range = 40–100%, median = 100%).

Perinatal survival rates (birth–15 Jun) ranged from 0.81–1.0 and 0.89–1.0, respectively, for calves from the eastern and western calving areas (Fig. 3). Survival of calves during summer (16 June–6 September) ranged from 0.83–0.97 for eastern calves and from 0.77–0.97 for western calves (Fig. 4). Winter survival rates (7 September–31 May) ranged from 0.64–0.95 for eastern calves, and 0.46–0.90 for western calves (Fig. 5). Annual postcalving survival rates (16 June–31 May) ranged from 0.53–0.82 for eastern calves and from 0.38–0.87 for western calves (Fig. 6). Survival rates did not differ significantly ($P > 0.21$) between calving areas except for the June–September 2004 interval (eastern: 0.97, western: 0.77; $z = 2.45$; $P = 0.004$).

Body mass, metatarsus lengths, and growth of female calves captured during June and September 2001–2005 and March 2002–2006 are summarized in Tables 1–4. We excluded June data for 11 calves (10 females during 2002; 1 male during 2003) that were judged to be > 2 days old when captured, based on the absence of an umbilicus, appearance of hooves, and mobility. These calves were included in analyses of data for September and March. There was no difference between sexes in mass or metatarsus length in June (ANOVA, $P = 0.29$), but males weighed more and had longer metatarsi than females in September and March ($P \leq 0.01$). Because of these differences, and because annual samples of males were too small for other meaningful tests, we included only female calves in the remaining comparisons.

For females, body mass during June, September, and March, and metatarsus lengths during June and September were greater for calves from the eastern area ($P \leq 0.05$; Tables 5 and 6).

In both areas, calves that were heavier at birth gained more mass during summer (ANOVA, $P < 0.0001$; Fig. 7A). However, summer gain in body mass as a proportion of birth mass showed the opposite trend: calves that were lighter at birth gained proportionally more mass compared to heavier calves ($P < 0.0001$; Fig. 7B). Both absolute and proportional increases in metatarsus length during summer were greater for calves that were smaller at birth ($P < 0.0001$; Fig. 8). Absolute and proportional changes in both mass and metatarsus length between September and March were negatively related to September values of those measures ($P < 0.001$; Figs. 9 and 10). Seasonal changes in size and mass were similar between calving areas, except for metatarsus length during September–March. During this period, smaller calves from the western area grew more and larger calves less in comparison to similar-sized calves from the eastern area (Table 6; Fig. 10).

Probability of survival of female calves during winter was positively related to body mass during September (logistic regression, $P < 0.0001$) and negatively related to cumulative precipitation during winter (calculated as percent difference from the long-term mean; $P = 0.03$). Logistic regression considering data from all years did not show a significant effect of location of winter range (north or south of the Brooks Range) on survival ($P = 0.14$). However, comparing survival rates between wintering areas separately for each year indicated that survival was lower for caribou wintering on the south side of the Brooks Range during winter 2004–2005 (Fig. 11; south: s = 0.59, SD = 0.06; north: s = 0.83, SD = 0.10; $z = 2.08$, $P = 0.02$), but not during other years ($P > 0.60$). Thus, the effect of wintering area on survival was not consistent among years, probably due to differences in weather patterns among years.

Distributions of calves from the 2 calving areas overlapped extensively during July and August (Figs. 12–16). Caribou moved north to the Arctic coast during warm weather in late June and July, and moved inland during cooler weather. Despite the overlap in summer distributions, during most years the distribution of caribou that calved in the western area extended farther west then that of caribou that calved in the eastern area. However, during summer 2004 almost all caribou that calved in the western area moved east of the Sagavanirktok River in early July, and remained there until mid August (Fig. 15). Conversely, 3 collared caribou that calved in the eastern calving area moved into the western area during early July 2004, where they remained until September. Distributions of both groups during summer 2004 included areas farther east than during previous years, and encompassed much of the coastal plain (1002 Area) of the Arctic National Wildlife Refuge (Fig. 15). This pattern was less pronounced during 2003 and 2005, although much of the herd moved east of the Sagavanirktok River during July of both years (Figs. 14 and 16).

Winter radiotracking surveys were conducted during the last week of February or early March each year. Sixty percent of radiocollared cows and calves used wintering areas in the southern Brooks Range during winter 2001–2002; this proportion increased to 87% during 2002–2003. During 2003–2004 through 2005–2006, the proportions wintering in the southern Brooks Range were 68, 69, and 54%, respectively. Most caribou wintering on the south side of the Brooks Range were located along the southwestern boundary of the Arctic National Wildlife Refuge (Fig. 17). Smaller numbers of radiocollared caribou wintered in the eastern section of Gates of the Arctic National Park and Preserve during 2001–2002 and 2002–2003. Other areas of winter concentration were located in the northern foothills of the Brooks Range, and some caribou wintered on the Arctic coastal plain. There was no evidence of segregation by wintering area among caribou from the 2 calving areas ($\chi^2 = 1.15$, $P = 0.28$).

A complete photo census of the CAH was conducted on 16 July 2002, while the herd was aggregated in 9 large groups along the Arctic coast. A total of 31,857 caribou were counted on photographs taken during the census (Lenart 2003).

DISCUSSION

Concerns about displacement of caribou from preferred ranges during the calving period are based on the assumption that physical characteristics of areas used for calving have some influence on caribou reproductive success. Specifically, quality of habitat used during the first few weeks after calving might affect the rate at which a calf grows and gains body mass and the ability of the calf's mother to provide nutrition for her calf, maintain or improve her own body condition, and prepare for her next pregnancy (Cameron et al. 1993; Crête and Huot 1993). Also, exclusion from preferred calving areas might increase exposure to predators, and thus reduce calf survival (Griffith et al. 2002). However, calf growth and survival rates also are influenced by habitat conditions, weather, insect activity, and perhaps other processes that occur after the calving period (White 1983). The relative importance of seasonal differences in habitat use and quality are unknown.

Previous studies have suggested that body condition of cows affects both birth rates and perinatal calf survival (Cameron et al. 1993, 2000, 2005; Cameron and Ver Hoef 1994; Gerhart et al. 1997). Furthermore, Wolfe (2000) concluded that the western calving area of the CAH was lower-quality habitat than the eastern area. Although we did not assess body condition of cows, the differences we observed in birth mass and metatarsus length between calves from the 2 calving areas suggest that cows that used the eastern area were in better condition than those that used the western area. Cows using the lower-quality calving range may have had reduced ability to replenish body reserves and prepare for a subsequent pregnancy, which could lead to lower pregnancy rates (Cameron et al. 2005), and reduced fitness of calves. Smaller calves may also require a longer nursing period, increasing the energetic cost to the mother and further reducing her ability to prepare for her next pregnancy (Gerhart et al. 1997; Russell and White 2000). Distributions of caribou cows and calves using the 2 calving areas differed during the calving season, but overlapped extensively during the remainder of the summer and were identical during winter. Furthermore, cows showed a strong tendency to return to the calving area they used during the previous year. Thus, differences in habitats used by caribou cows during the calving season likely were at least partly responsible for the differences we observed in calf size at birth. These results suggest that quality of habitats used during the calving period may affect body condition of caribou cows, which in turn may affect the ability of their calves to attain sufficient size and mass to survive their first winter. Thus, efforts to minimize displacement of caribou during the calving season should help reduce impacts of development within the range of the CAH.

The dramatic increase in population size shown by the CAH during the 1980s and 1990s also raises the possibility that density-dependent reduction of habitat quality may be important. If habitat conditions were limiting on winter ranges rather than on calving ranges, then density dependent effects should have been equally evident among caribou using both calving areas.

However, if calving habitat were to become scarce, demographic effects likely would first be evident in the western calving area, because some calving habitat there has been replaced by high-density industrial infrastructure. If the reduction in calf size we noted in the western area is primarily due to caribou density rather than the shift in calving distribution, then a similar reduction would be expected to occur in the near future on the eastern calving area, where high-quality habitat is presumably more abundant at present.

We did not find significant differences in survival rates between areas, despite the observed differences in calf size and the relationship between calf mass and survival. However, variances of our survival estimates were relatively large, especially during winter, when much of the mortality occurred and when effects of reduced body condition would likely be most important. Thus, these comparisons would be unable to detect small differences in survival rates, although among ungulates, such small differences in survival can have significant effects on population trends (Nelson and Peek 1984; Eberhardt 1985; Hern et al. 1990; Walsh et al. 1995; Crête et al. 1996; Arthur et al. 2003). Physical parameters, such as body condition, provide more sensitive measures with which to test for effects of disturbance and differences in habitat quality.

Because of other changes that occurred during the period of oil field development, it is not possible to determine whether the shift in calving distribution during the 1980s was a response to development or an effect of the increase in herd size or some other cause. Thus, the differences we noted between calves from the 2 calving areas do not necessarily imply effects of industrial activity. However, our results suggest that there is sufficient variability in habitat quality across the coastal plain to affect calf size, which may in turn affect calf recruitment. If further increases in levels of anthropogenic disturbance cause caribou to reduce their use of preferred habitats, it should be possible to detect effects of these changes by measuring birth weights and growth rates of calves. If similar changes do not occur in less-disturbed areas, then this may be taken as evidence of possible effects of disturbance.

FUTURE PLANS

Fieldwork for this project will conclude with the collection of calf growth and survival data for the 2006 cohort of calves of GPS-equipped cows. These cows will be recaptured during March 2007 and their collars recovered and replaced with conventional VHF radio collars. Additional data analyses will include investigating habitat use by caribou calves during the calving and postcalving (summer) periods by classifying calving locations (capture sites) and calving distributions (fixed kernel models of radiotracking data) using a digital map of vegetation communities (Muller et al. 1998; Wolfe 2000; Kelleyhouse 2001). In addition, data from the GPS collars will be used to assess patterns of movement and habitat use by caribou cows with calves during summer, and how these may be affected by industrial activity. If sufficient funding is obtained, we plan to support a graduate research project to develop detailed spatial models of caribou movements in relation to oil field infrastructure. These models will be used to investigate potential effects of infrastructure on caribou movements and habitat use during summer, and how these effects may influence calf growth and survival.

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PREPARED BY:

Stephen M. Arthur
Wildlife Biologist III

Patricia A. Del Vecchio
Wildlife Technician IV

SUBMITTED BY:

Mark E. McNay
Research Coordinator

Laura A. McCarthy
Publications Technician II

APPROVED BY:

Thomas W. Paul
Federal Aid Coordinator
Division of Wildlife Conservation

Matthew H. Robus, Director
Division of Wildlife Conservation

APPROVAL DATE: February 15, 2007

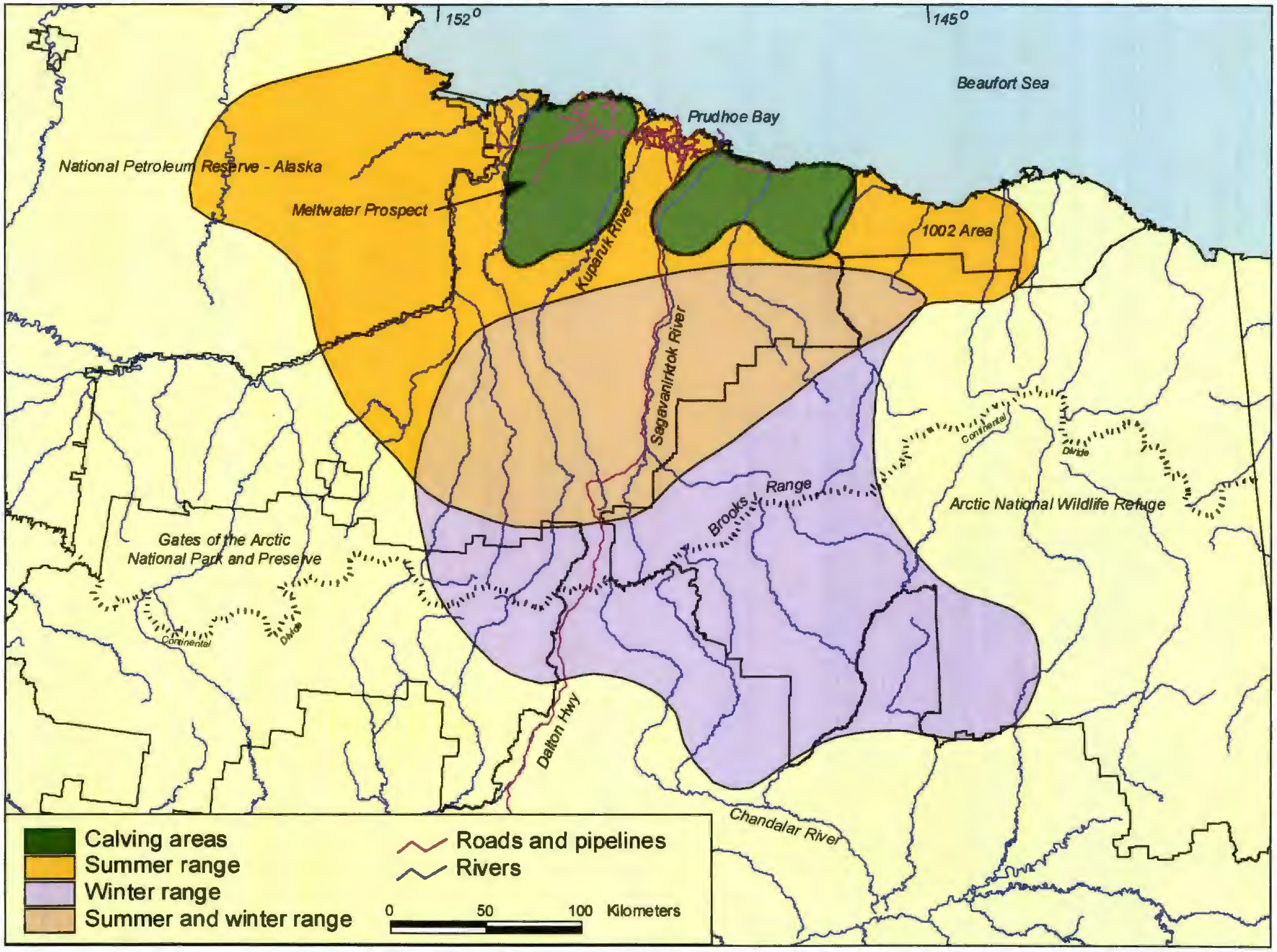

FIGURE 1 Seasonal ranges of the Central Arctic caribou herd

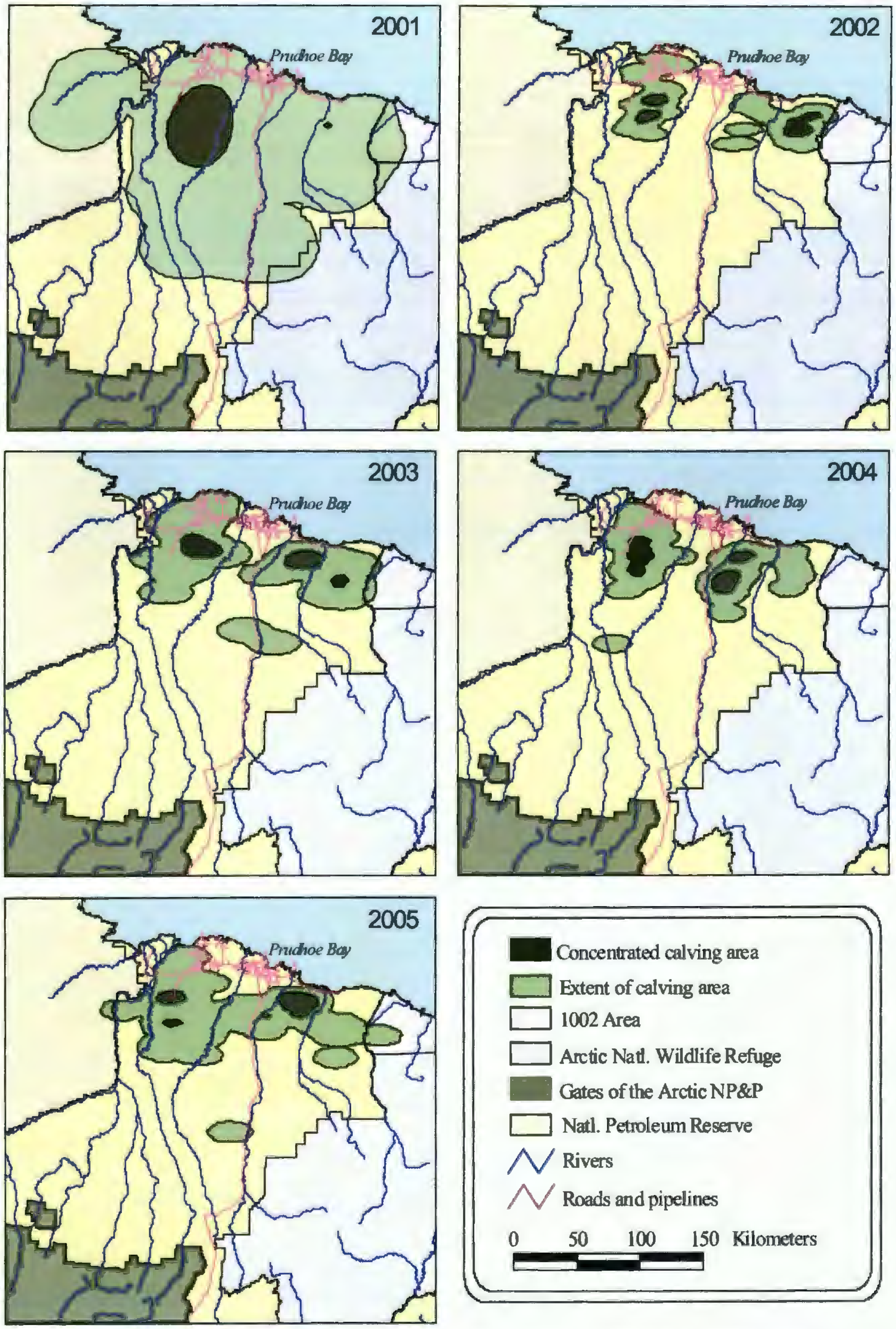

FIGURE 2 Distributions of parturient caribou cows during the peak of calving, 2001–2005. Extent of calving is defined by the 99% fixed kernel utilization distribution. Concentrated calving areas are those with greater than average density of calving caribou.

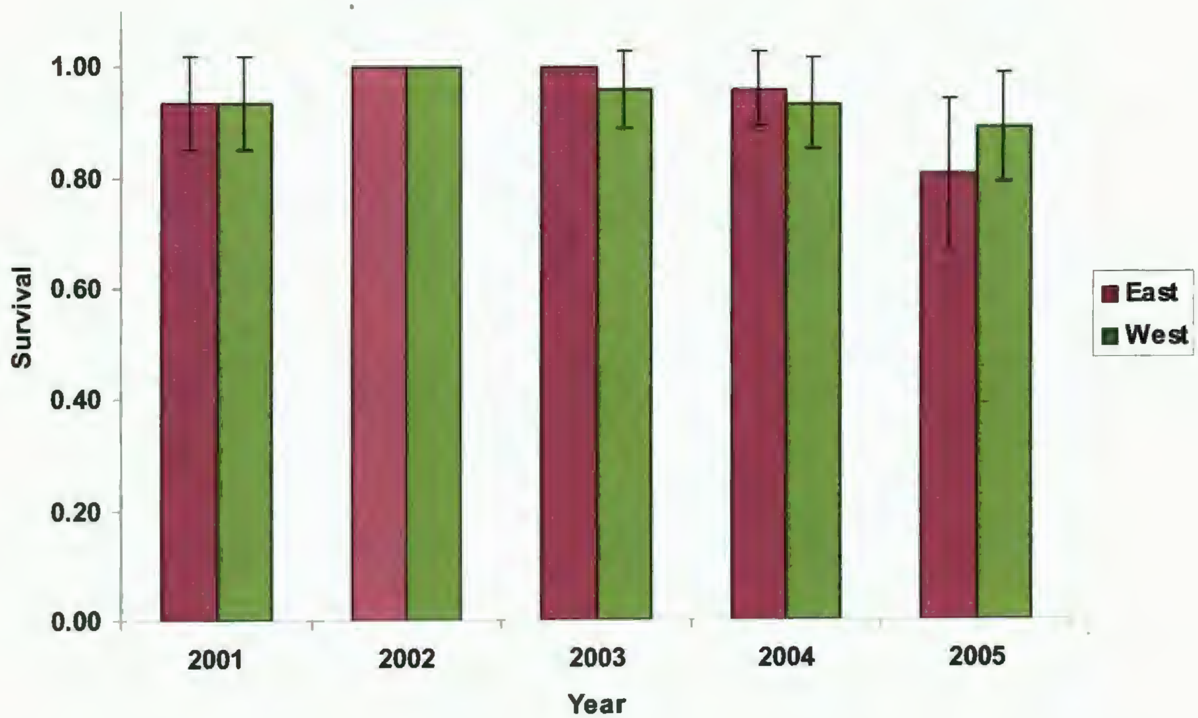

FIGURE 3 Perinatal survival rates of radiocollared Central Arctic caribou calves from calving areas either east or west of the Sagavanirktok River during 1–15 June 2001–2005. Vertical lines indicate 95% confidence intervals (no interval indicated when survival = 1.0).

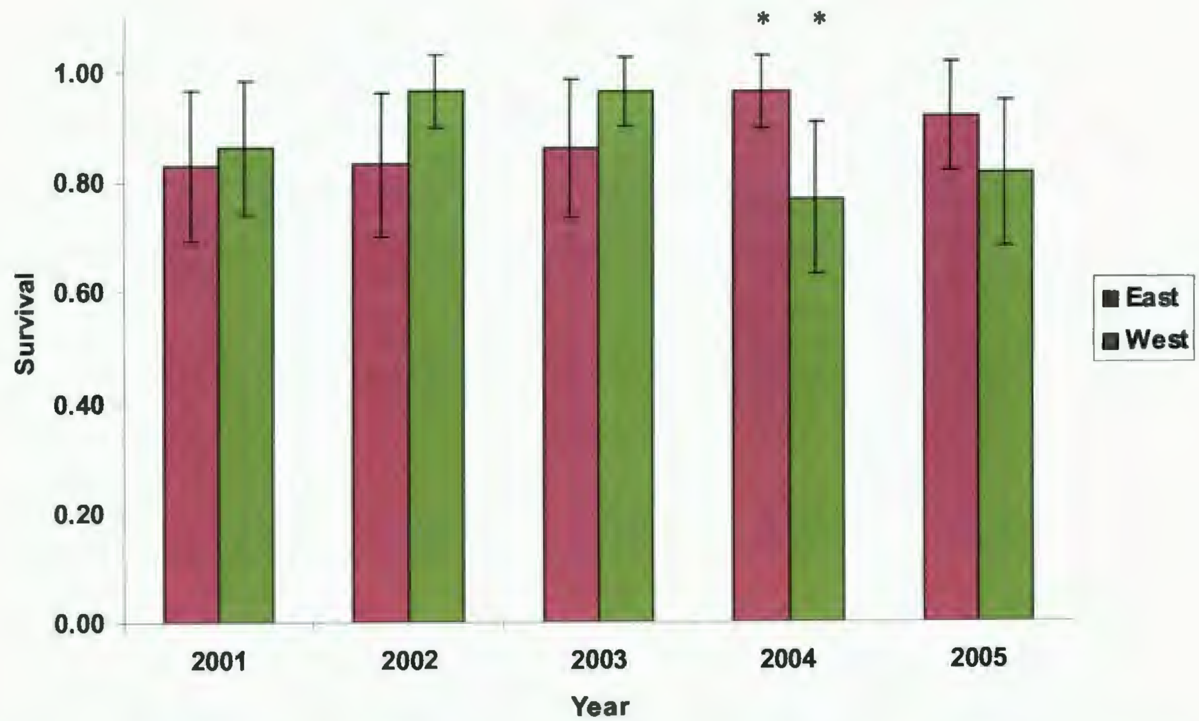

FIGURE 4 Summer survival rates of radiocollared Central Arctic caribou calves from calving areas either east or west of the Sagavanirktok River during 16 June–6 September 2001–2005. Vertical lines indicate 95% confidence intervals. Asterisks indicate significant difference between areas ($P < 0.01$).

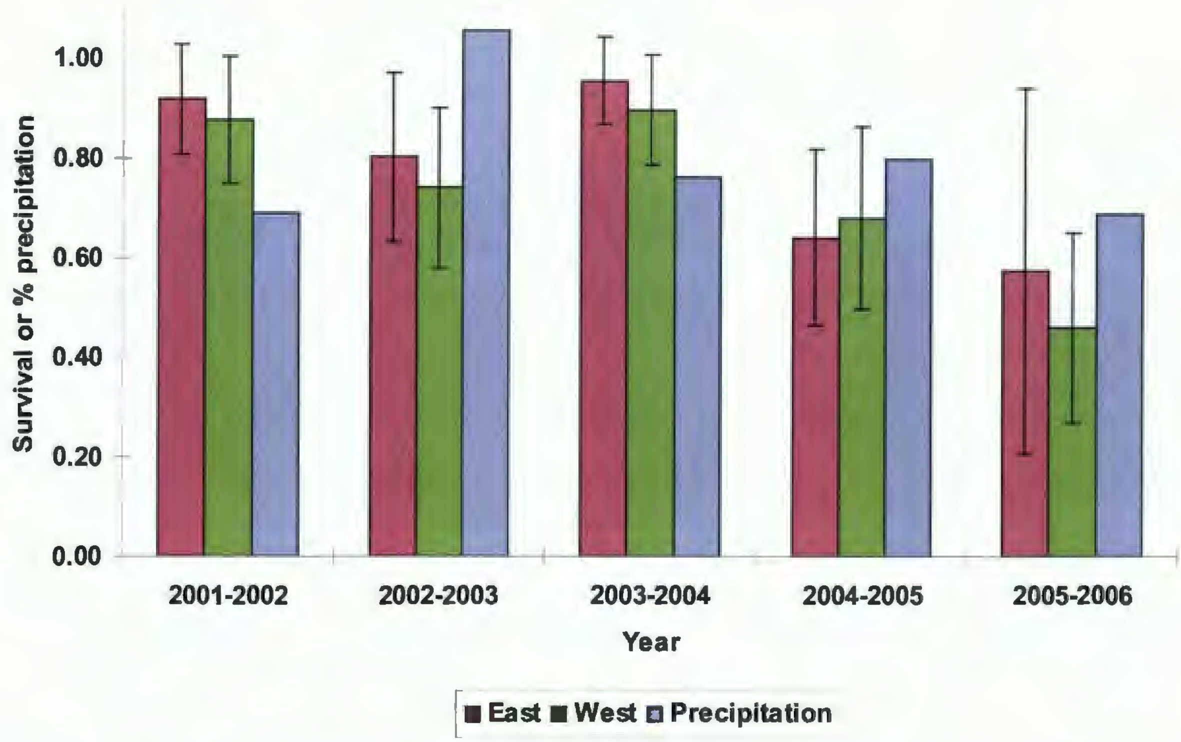

FIGURE 5 Relative amount of winter precipitation and overwinter survival rates of radiocollared Central Arctic caribou calves from calving areas either east or west of the Sagavanirktok River during 7 September–31 May 2001–2002 through 2005-2006. Vertical lines indicate 95% confidence intervals. Precipitation is the mean of cumulative precipitation from October–March each year, recorded at Coldfoot, Chandalar Shelf, Atigun Camp, and Imnaviat Creek, expressed as the percent of the mean from 1974–2000 (USDA, Natural Resources Conservation Service).

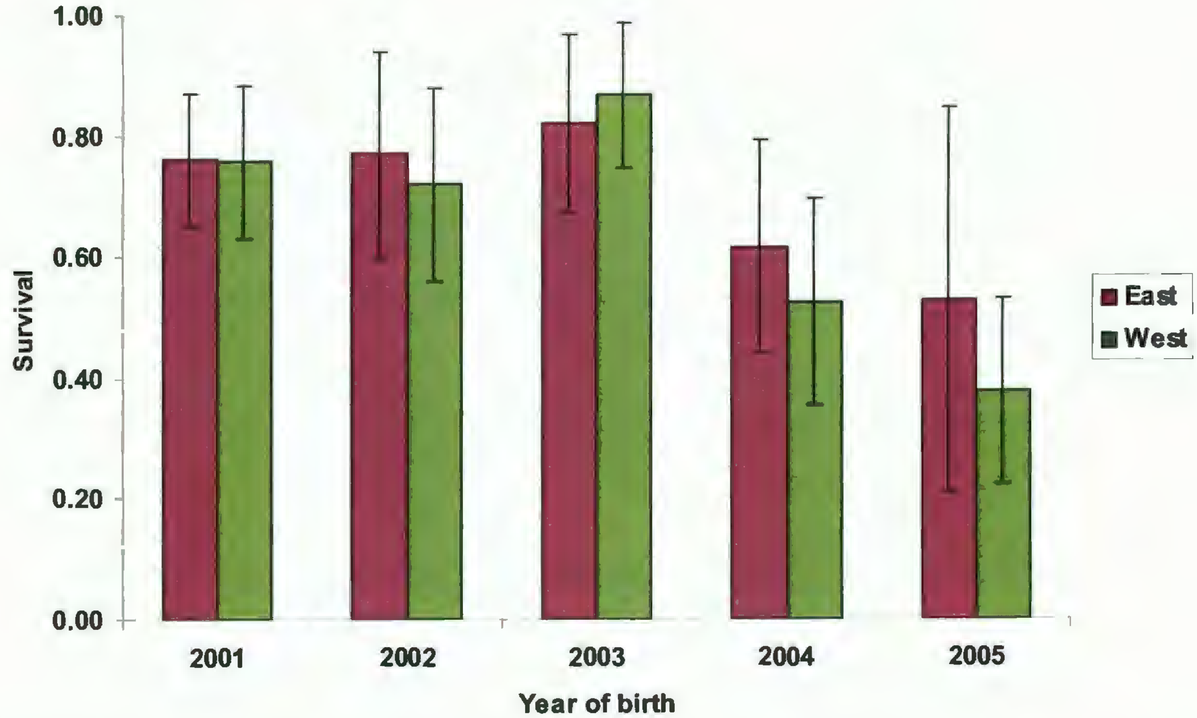

FIGURE 6 Annual (postcalving period) survival rates of radiocollared Central Arctic caribou calves from calving areas either east or west of the Sagavanirktok River beginning 16 June each year, 2001–2005. Vertical lines indicate 95% confidence intervals.

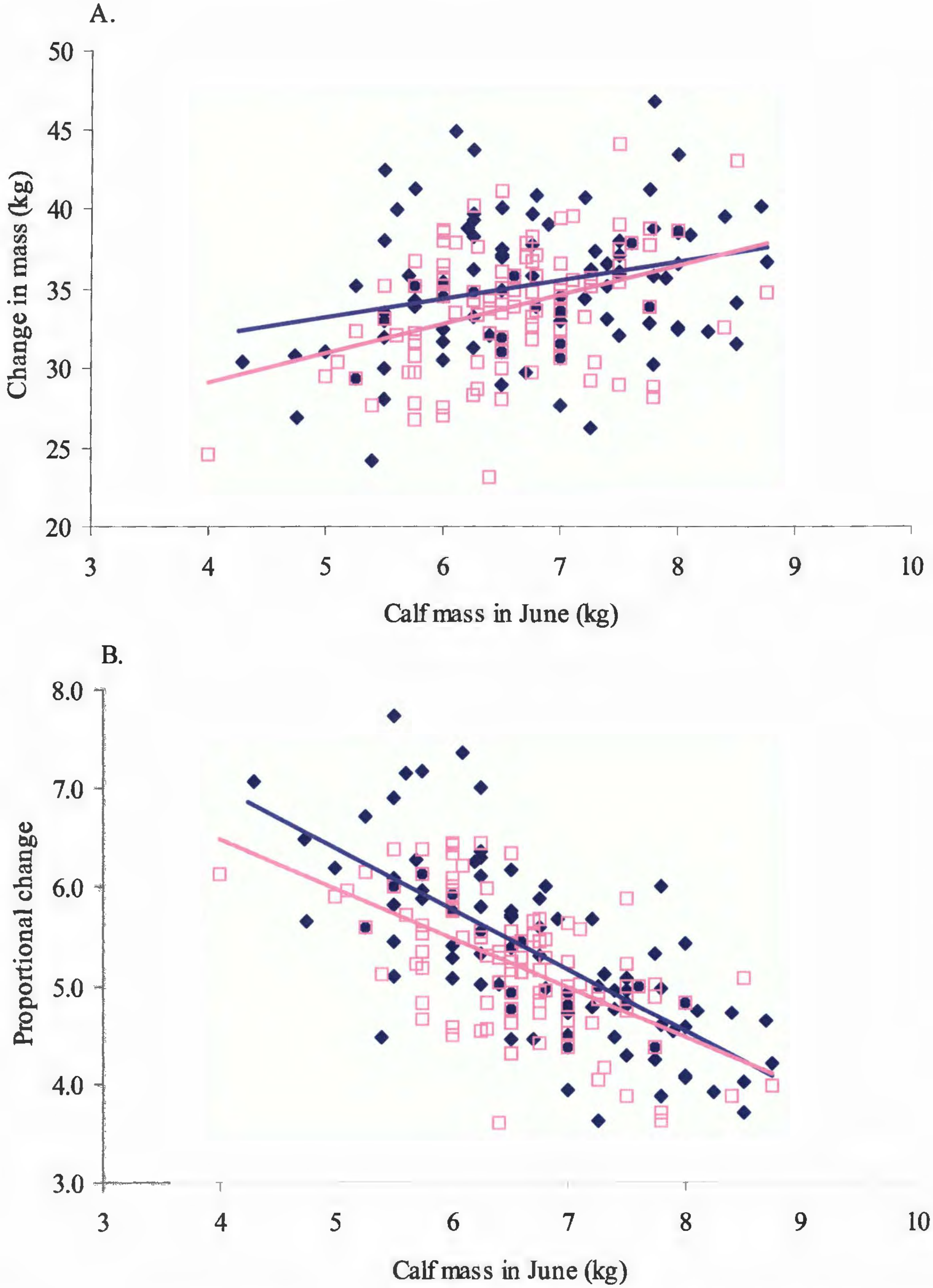

FIGURE 7 Absolute (A) and proportional (B) change in mass from early June–early September in comparison to June mass of calves from the Central Arctic caribou herd, 2001–2005. Calves were born either east (blue diamonds) or west (red squares) of the Sagavanirktok River, Alaska.

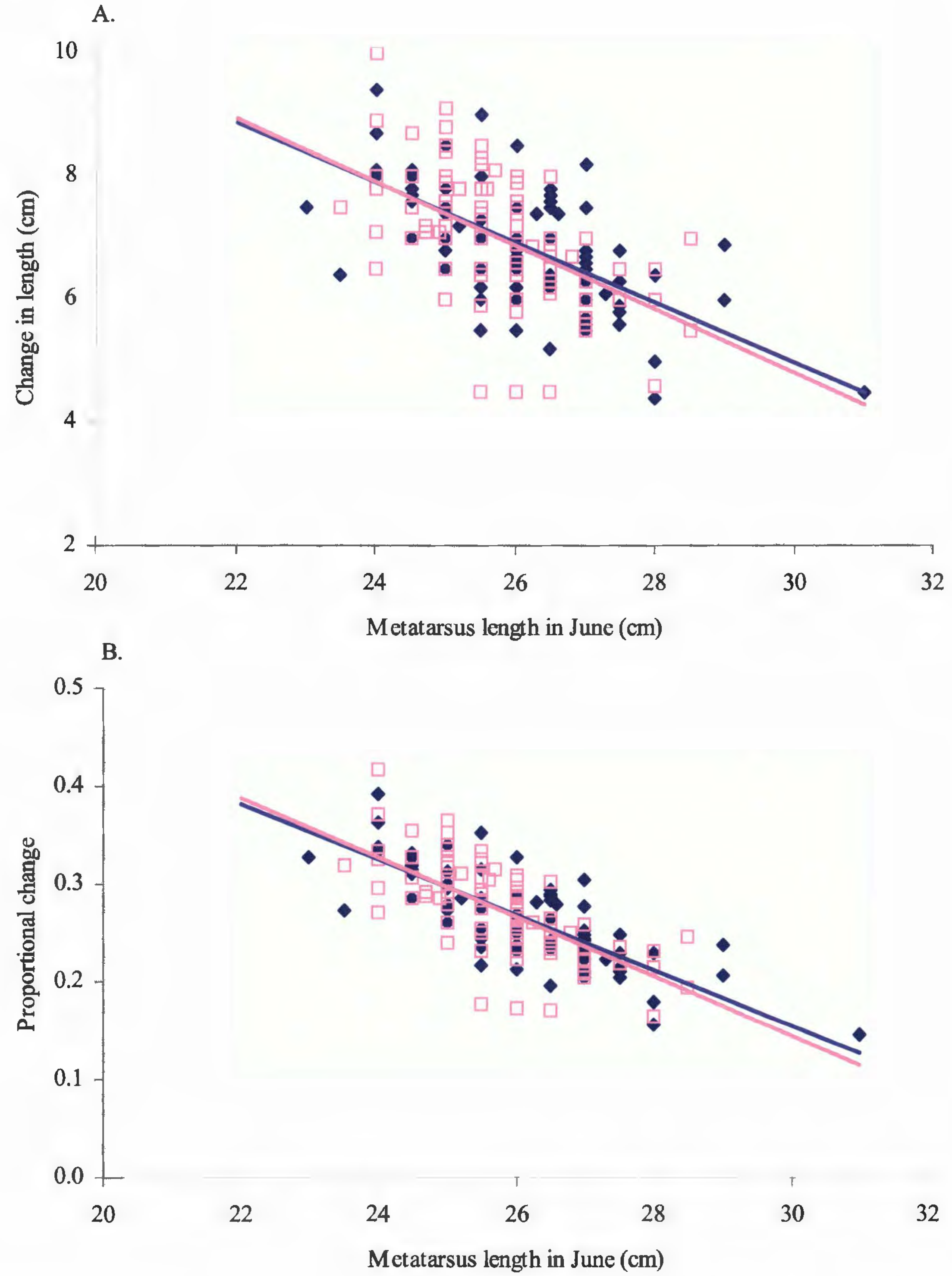

FIGURE 8 Absolute (A) and proportional (B) change in metatarsus length from early June–early September in comparison to June metatarsus length of calves from the Central Arctic caribou herd, 2001–2005. Calves were born either east (blue diamonds) or west (red squares) of the Sagavanirktok River, Alaska.

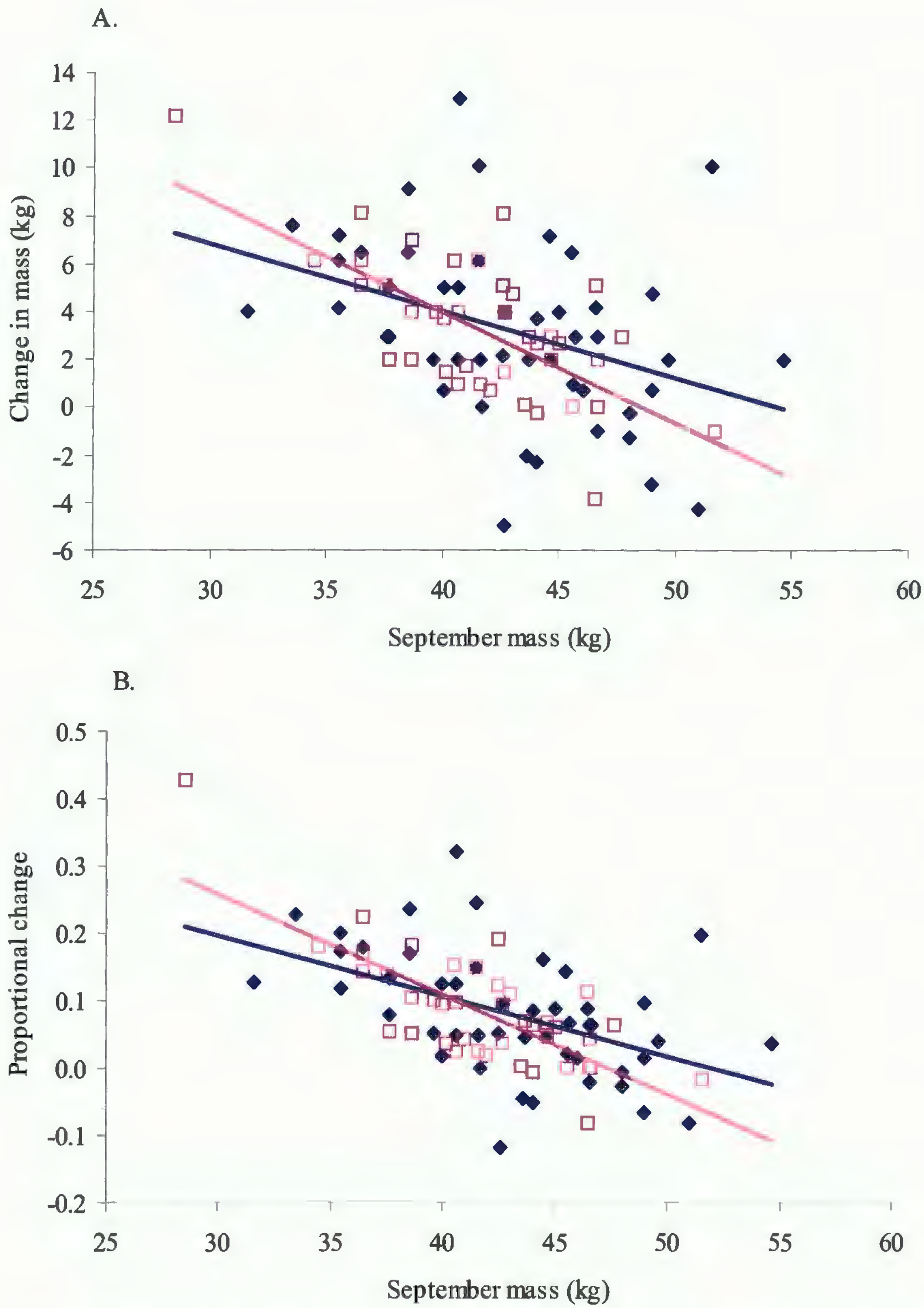

FIGURE 9 Absolute (A) and proportional (B) change in mass from September–March in comparison to September mass of calves from the Central Arctic caribou herd, 2001–2005. Calves were born either east (blue diamonds) or west (red squares) of the Sagavanirktok River,Alaska.

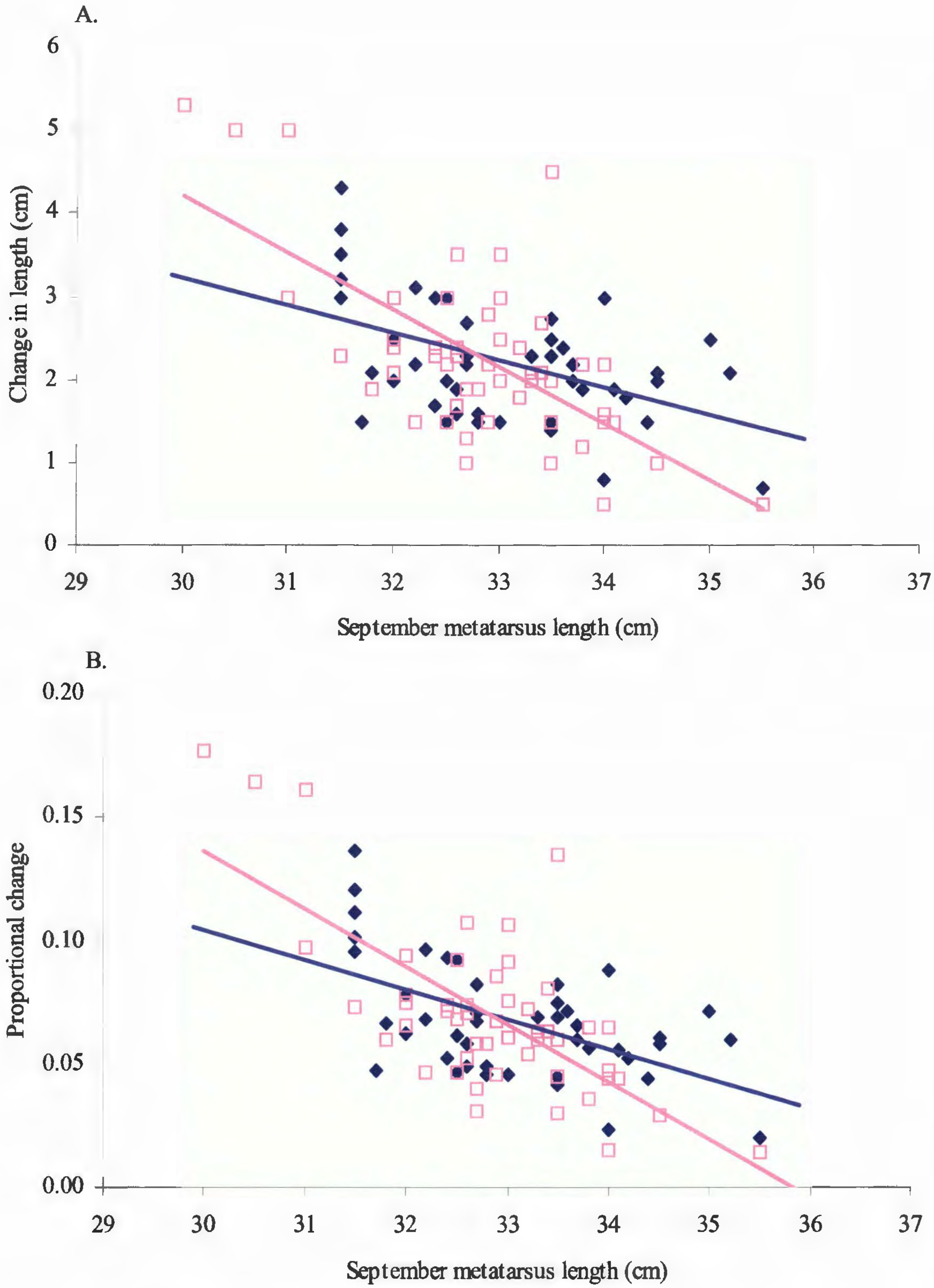

FIGURE 10 Absolute (A) and proportional (B) change in metatarsus length from September–March in comparison to September metatarsus length of calves from the Central Arctic caribou herd, 2001–2005. Calves were born either east (blue diamonds) or west (red squares) of the Sagavanirktok River, Alaska.

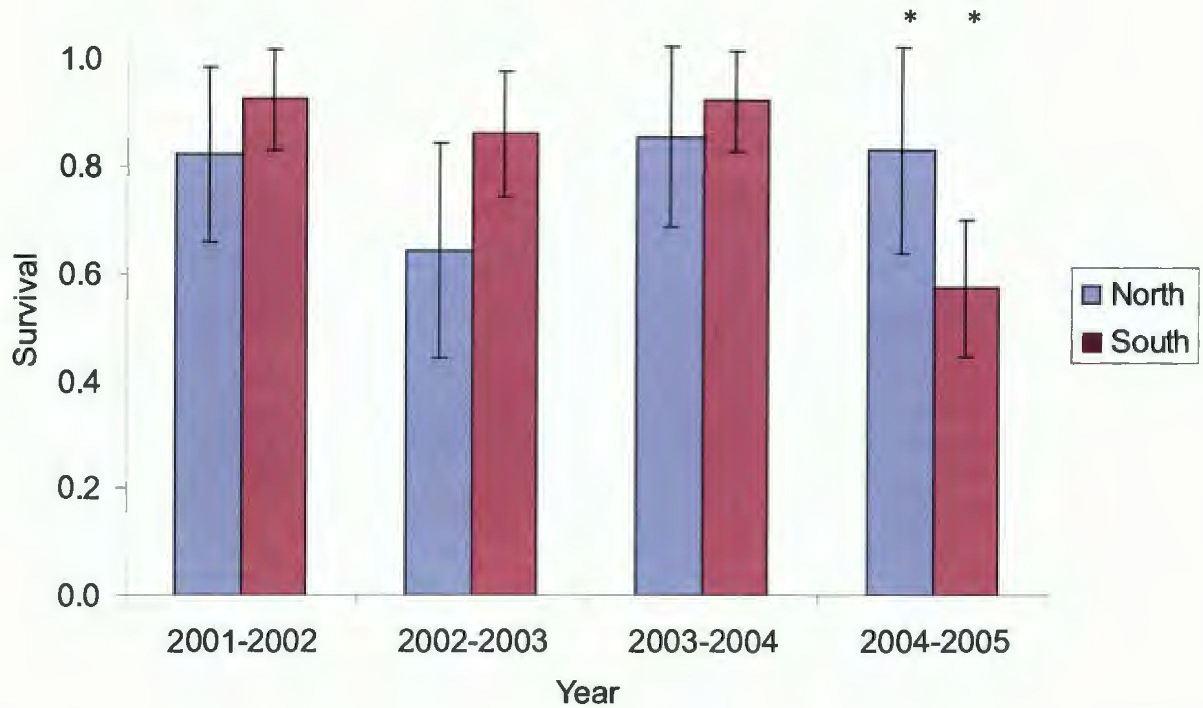

FIGURE 11 Overwinter survival rates (October–June) of radiocollared Central Arctic caribou calves using winter ranges either north or south of the crest of the Brooks Range, 2001–2002 through 2004-2005. Vertical lines indicate 95% confidence intervals. Asterisks indicate a significant difference between winter ranges for that year ($P < 0.05$)

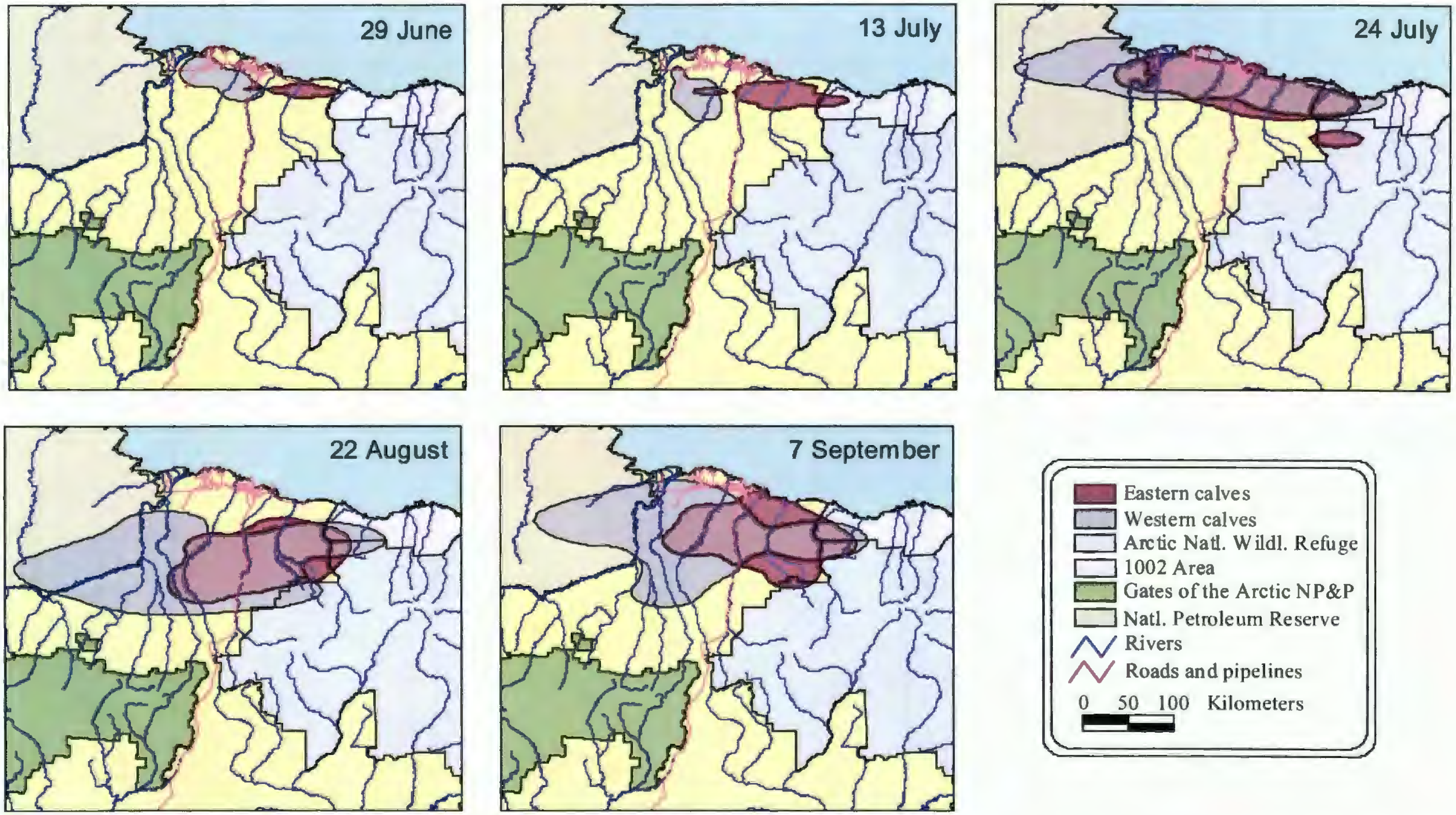

FIGURE 12 Distributions of radiocollared Central Arctic caribou calves during summer 2001. Colors indicate whether calves were born east or west of the Sagavanirktok River. Distributions are based on the 95% fixed kernel utilization distributions of calf locations each day.

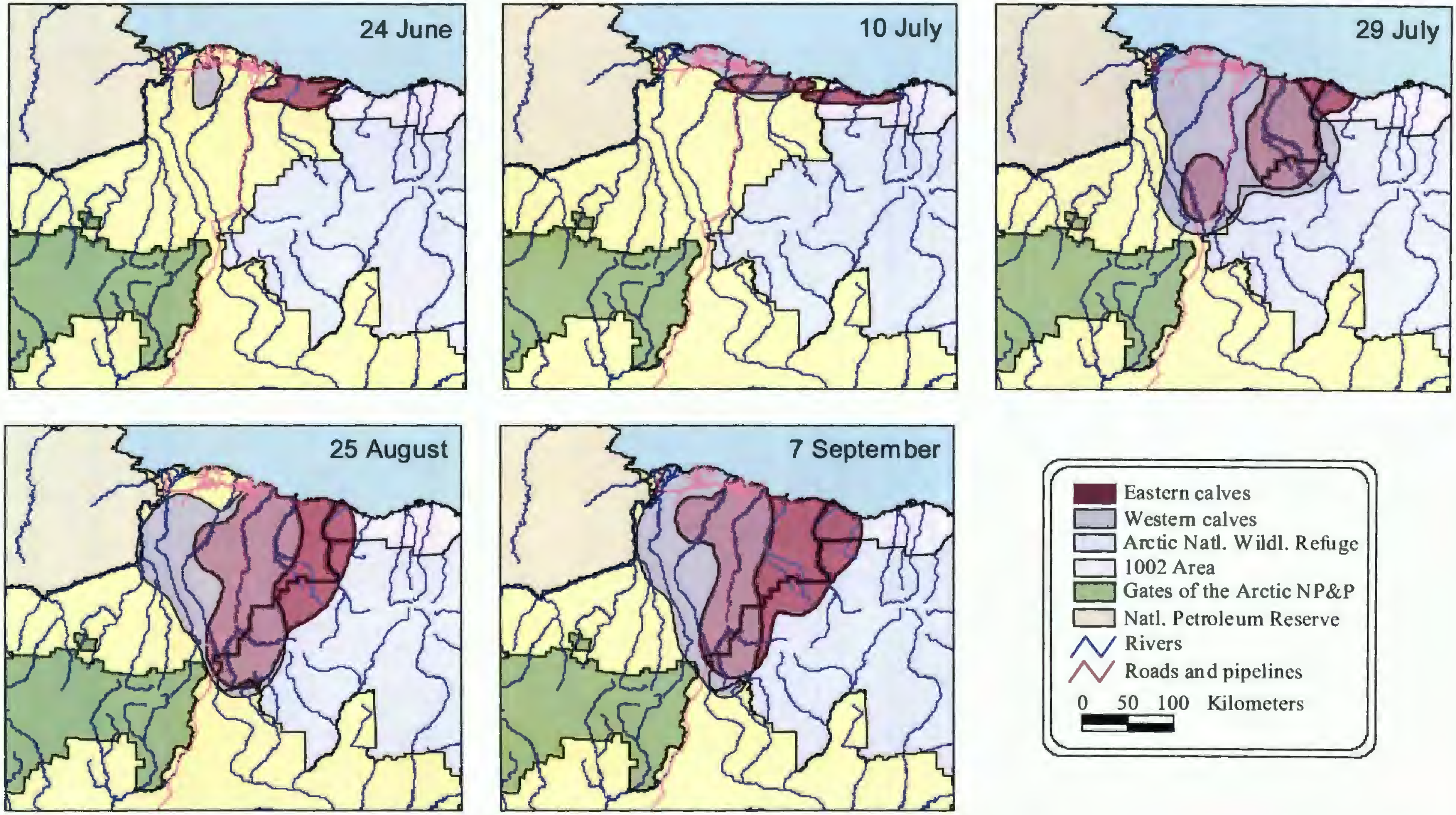

FIGURE 13 Distributions of radiocollared Central Arctic caribou calves during summer 2002. Colors indicate whether calves were born east or west of the Sagavanirktok River. Distributions are based on the 95% fixed kernel utilization distributions of calf locations each day.

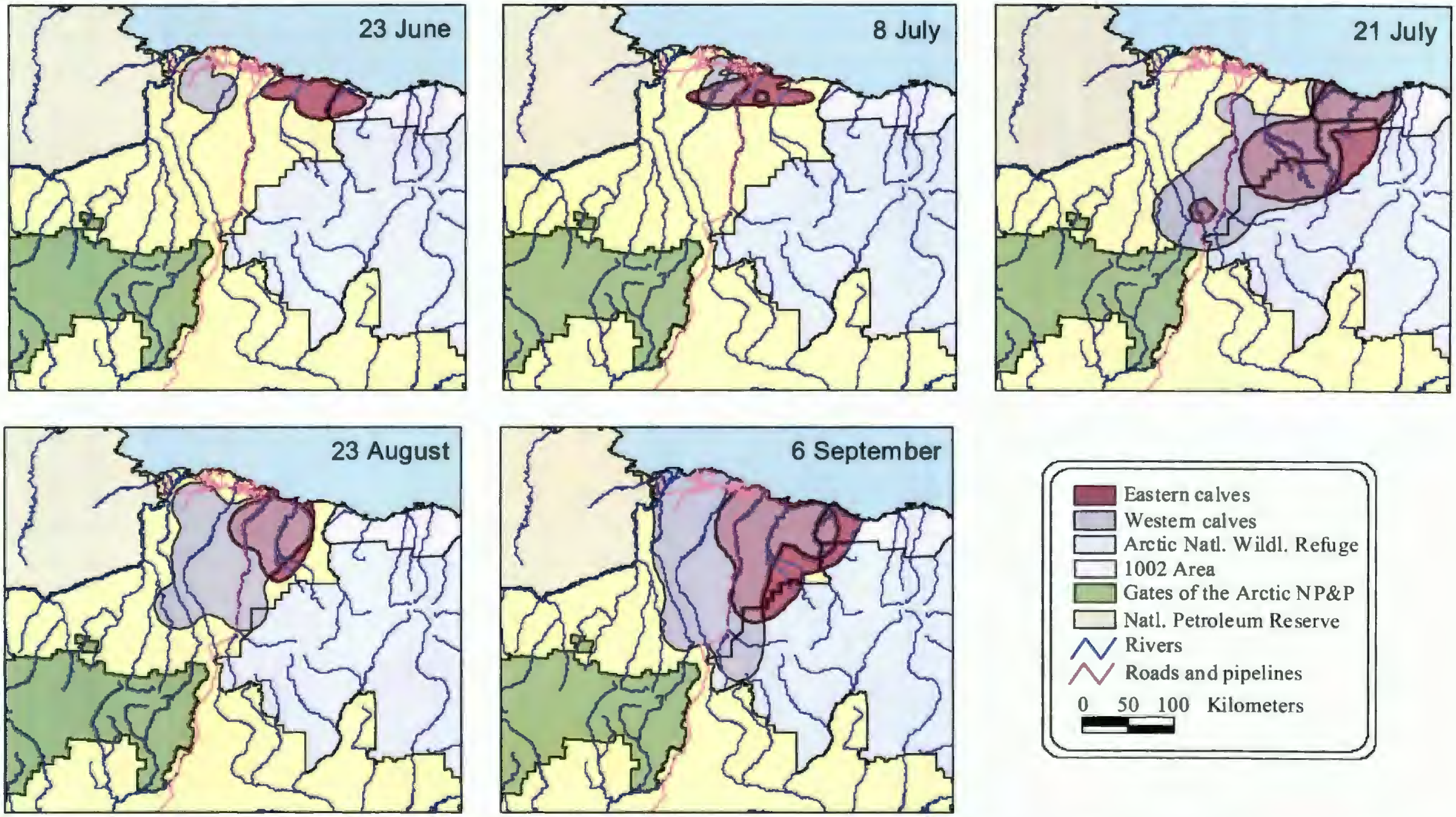

FIGURE 14 Distributions of radiocollared Central Arctic caribou calves during summer 2003. Colors indicate whether calves were born east or west of the Sagavanirktok River. Distributions are based on the 95% fixed kernel utilization distributions of calf locations each day.

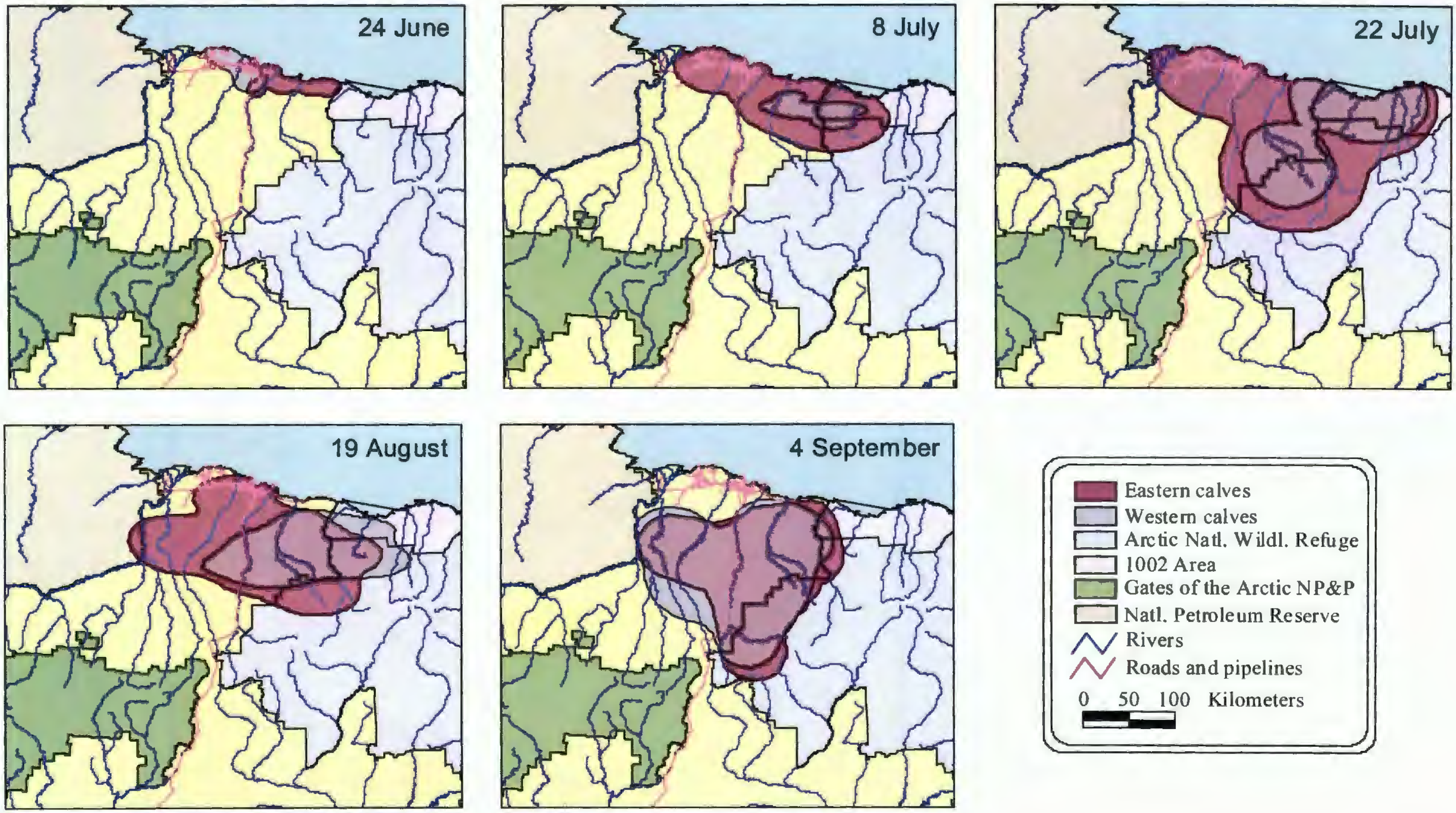

FIGURE 15 Distributions of radiocollared Central Arctic caribou calves during summer 2004. Colors indicate whether calves were born east or west of the Sagavanirktok River. Distributions are based on the 95% fixed kernel utilization distributions of calf locations each day.

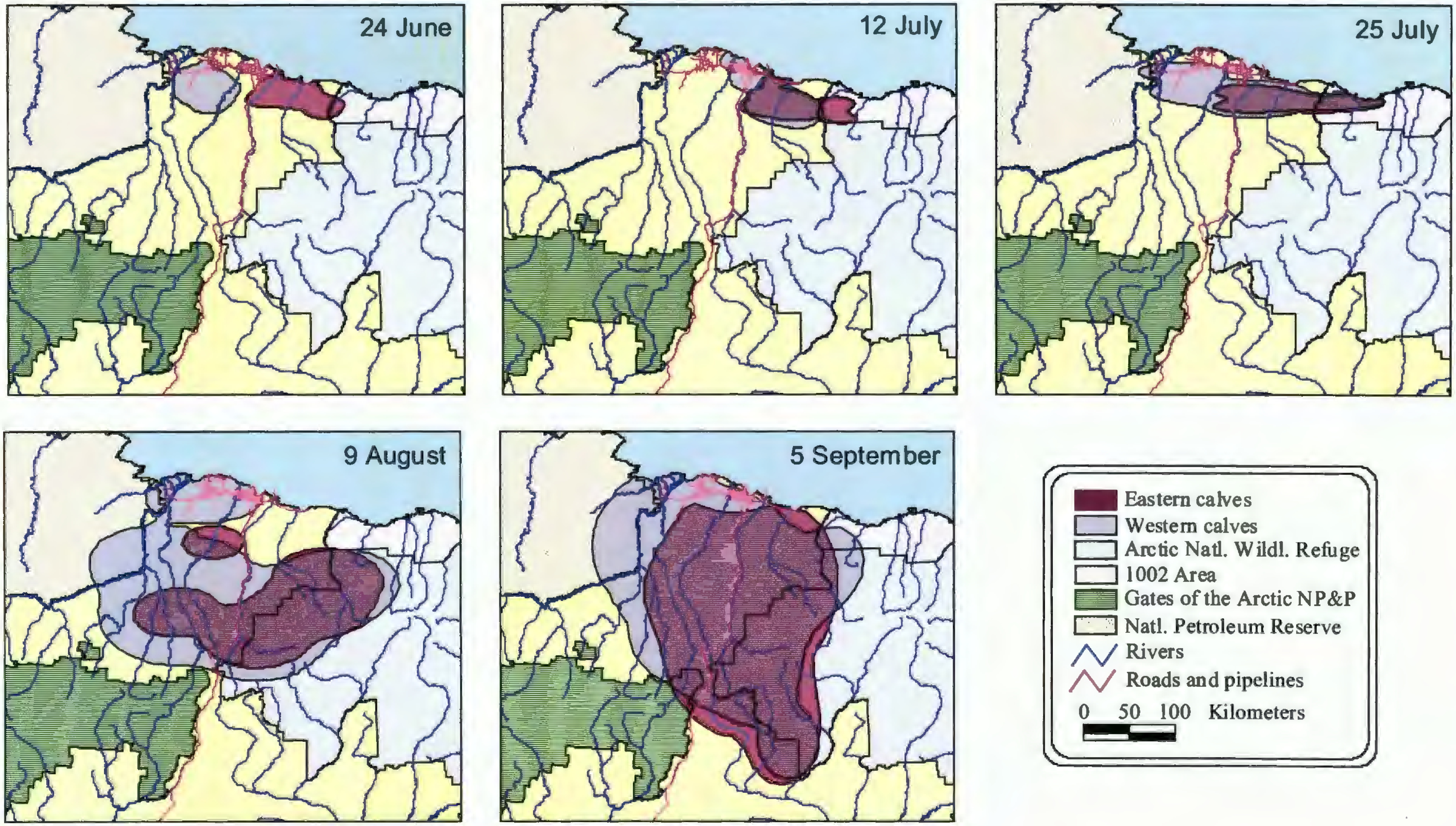

FIGURE 16 Distributions of radiocollared Central Arctic caribou calves during summer 2005. Colors indicate whether calves were born east or west of the Sagavanirktok River. Distributions are based on the 95% fixed kernel utilization distributions of calf locations each day.

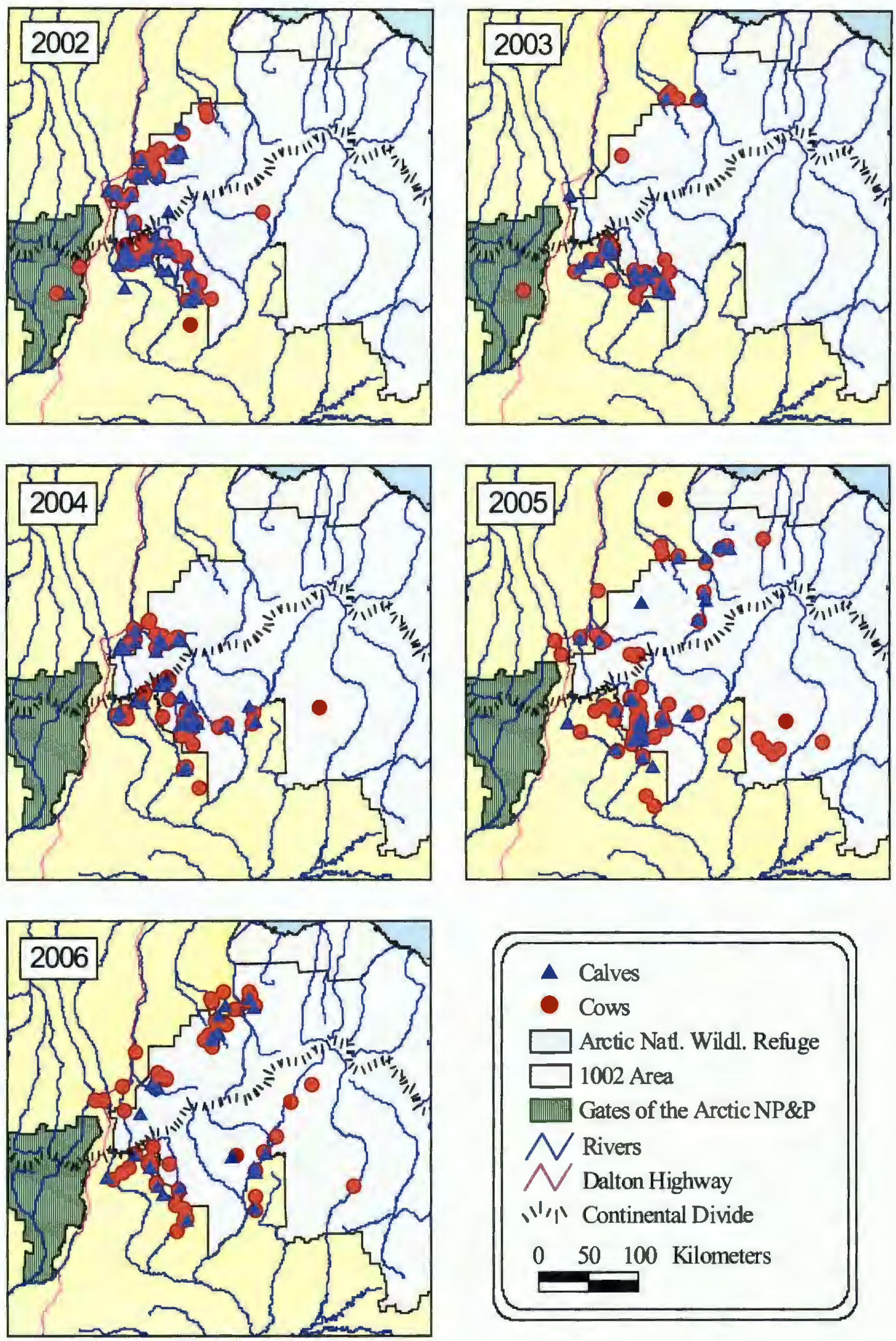

FIGURE 17 Distribution of radiocollared caribou from the Central Arctic herd, February–March 2002–2006.

TABLE 1 Body mass (kg) of female calves from the Central Arctic caribou herd, June 2001–March 2006

		June			September			March		
Area[b]	Cohort	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s	n
East	2001	6.1	0.9	33	40.9	4.3	24	47.3	6.4	11
	2002	7.0	1.0	20[c]	43.7	4.1	24	47.0	4.9	10
	2003	6.7	1.1	23	45.3	3.9	19	46.8	3.7	10
	2004	7.0	0.9	23	41.1	4.1	20	43.8	5.0	12
	2005	6.7	1.0	29	39.8	4.1	19	45.8	4.0	6
West	2001	6.3	0.9	32	39.0	4.3	24	44.6	3.7	14
	2002	6.6	0.8	30	42.3	4.2	25	44.9	3.5	15
	2003	6.5	0.8	26	41.1	3.9	18	44.0	2.8	11
	2004	6.5	0.8	24	40.6	3.7	17	44.4	2.6	8
	2005	6.4	0.8	26	38.4	4.2	17	43.9	4.2	13

[a] March data were from the year following birth of each cohort.

[b] Sample areas were located either east or west of the Sagavanirktok River.

[c] Excluding 10 calves that were not considered neonatal based on the absence of umbilicus and appearance of hooves.

TABLE 2 Change in body mass (kg) of female calves from the Central Arctic caribou herd, June 2001–March 2006

		June–September			September–March[a]			June–March[a]		
Area[b]	Cohort	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s	n
East	2001	34.6	3.9	24	6.7	2.6	11	40.9	5.8	11
	2002	36.3	4.2	16[c]	2.9	1.5	10	38.8	5.2	7[c]
	2003	38.6	3.7	19	-0.1	2.9	10	39.8	3.2	10
	2004	34.2	3.7	20	2.0	4.3	12	37.1	4.7	12
	2005	33.0	3.6	19	5.7	1.2	5	39.0	4.2	6
West	2001	32.6	3.9	24	5.4	3.8	13	38.0	3.5	14
	2002	35.6	3.9	25	2.2	1.5	14	38.3	3.3	15
	2003	34.5	3.6	18	2.3	1.7	7	37.0	2.8	11
	2004	33.9	3.3	17	1.9	2.5	8	37.3	2.2	8
	2005	32.0	3.9	17	4.1	3.1	10	37.2	4.0	13

[a] March data were from the year following birth of each cohort.

[b] Sample areas were located either east or west of the Sagavanirktok River.

[c] Excluding 10 calves that were not considered neonatal based on the absence of umbilicus and appearance of hooves.

TABLE 3 Metatarsus lengths (cm) of female calves from the Central Arctic caribou herd, June 2001–March 2006

		June			September			March[a]		
Area[b]	Cohort	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s	n
East	2001	25.9	1.2	33	33.0	1.0	24	35.4	1.2	11
	2002	25.6	1.7	20[c]	33.1	1.4	24	35.4	0.9	10
	2003	26.0	1.2	23	33.1	0.8	19	35.6	0.8	10
	2004	26.4	1.1	23	33.0	0.7	20	34.7	0.9	12
	2005	26.5	1.2	28	33.0	1.2	19	35.0	0.8	6
West	2001	25.6	1.6	32	32.7	1.2	24	35.3	1.3	14
	2002	25.4	0.9	30	32.7	1.2	25	35.0	0.7	15
	2003	25.3	0.8	26	32.9	0.8	18	34.9	0.5	11
	2004	25.7	1.0	24	32.6	0.9	17	35.0	0.8	8
	2005	26.0	1.1	26	32.8	0.7	17	34.9	0.8	13

[a] March data were from the year following birth of each cohort.
[b] Sample areas were located either east or west of the Sagavanirktok River.
[c] Excluding 10 calves that were not considered neonatal based on the absence of umbilicus and appearance of hooves.

TABLE 4 Change in metatarsus lengths (cm) of female calves from the Central Arctic caribou herd, June 2001–March 2006

		June–September			September–March[a]			June–March[a]		
Area[b]	Cohort	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s	n
East	2001	6.9	1.0	24	2.5	0.7	11	9.1	1.1	11
	2002	7.0	1.2	16[c]	2.5	1.1	10	9.5	0.9	7[c]
	2003	7.1	1.0	19	2.1	0.6	10	9.2	1.2	10
	2004	6.6	0.9	20	1.8	0.3	12	8.3	0.9	12
	2005	6.6	0.9	18	2.3	0.5	5	8.6	0.8	6
West	2001	6.8	1.2	24	2.7	1.6	13	9.2	1.7	14
	2002	7.2	1.0	26	2.3	1.0	14	9.4	0.6	15
	2003	7.5	0.8	18	2.1	0.6	7	9.4	0.9	11
	2004	6.9	0.8	17	2.0	0.7	8	9.0	0.7	8
	2005	6.6	1.1	17	2.0	0.4	10	8.6	1.4	13

[a] March data were from the year following birth of each cohort.
[b] Sample areas were located either east or west of the Sagavanirktok River.
[c] Excluding 10 calves that were not considered neonatal based on the absence of umbilicus and appearance of hooves.

TABLE 5 Results of ANOVA tests for effects of calving area and year on body mass and metatarsus lengths of female calves from the Central Arctic caribou herd, June 2001–March 2006

Variable:	June		September		March	
Effect	*F*	*P*	*F*	*P*	*F*	*P*
Mass:						
Calving area	4.05	0.0452	10.49	0.0014	4.59	0.0346
Year	4.16	0.0028	8.05	<0.0001	0.73	0.5745
Area*year	1.19	0.3177	1.07	0.3748	0.54	0.7099
Metatarsus:						
Calving area	10.14	0.0016	3.79	0.0529	1.28	0.2600
Year	3.07	0.0170	0.25	0.9104	1.03	0.3960
Area*year	0.58	0.6746	0.09	0.9855	0.60	0.6603

TABLE 6 Results of ANOVA tests for effects of initial values, calving area, and year on absolute and percent changes in body mass and metatarsus lengths between sampling periods for female calves from the Central Arctic caribou herd, June 2001–March 2006. Percent change is calculated in relation to the initial mass or length at the start of each period.

Variable:	June–September		September–March		June–March	
Effect	*F*	*P*	*F*	*P*	*F*	*P*
Mass (kg):						
Initial mass	20.46	<0.0001	12.47	0.0006	3.98	0.0487
Calving area	1.92	0.1678	0.60	0.4392	0.40	0.5303
Year	7.01	<0.0001	7.09	<0.0001	1.32	0.2697
Initial*area	1.09	0.2972	0.81	0.3694	0.80	0.3734
Mass (%):						
Initial mass	168.4	<0.0001	28.24	<0.0001	128.77	<0.0001
Calving area	2.69	0.1024	1.47	0.2289	0.97	0.3281
Year	7.58	<0.0001	7.32	<0.0001	1.94	0.1090
Initial*area	1.51	0.2205	1.83	0.1794	1.62	0.2057
Metatarsus (cm):						
Initial length	79.64	<0.0001	52.25	<0.0001	61.53	<0.0001
Calving area	0.02	0.8920	6.08	0.0156	1.38	0.2430
Year	1.60	0.1759	2.56	0.0439	1.63	0.1729
Initial*area	0.02	0.8812	6.18	0.0147	1.42	0.2367
Metatarsus (%):						
Initial length	185.3	<0.0001	71.92	<0.0001	143.52	<0.0001
Calving area	0.23	0.6302	6.75	0.0109	1.44	0.2336
Year	1.61	0.1723	2.29	0.0652	1.62	0.1746
Initial*area	0.25	0.6180	6.87	0.0103	1.48	0.2273

The Federal Aid in Wildlife Restoration Program consists of funds from a 10% to 11% manufacturer's excise tax collected from the sales of handguns, sporting rifles, shotguns, ammunition and archery equipment. The Federal Aid program allots funds back to states through a formula based on each state's geographic area and number of paid hunting license holders. Alaska receives a maximum 5% of revenues collected each year. The Alaska Department of Fish and Game uses federal aid funds to help restore, conserve and manage wild birds and mammals to benefit the public. These funds are also used to educate hunters to develop the skills, knowledge and attitudes for responsible hunting. Seventy-five percent of the funds for this report are from Federal Aid.

Stephen M. Arthur

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