Recovery of the Chisana Caribou Herd in the Alaska/Yukon Borderlands: Captive-Rearing Trials

Prepared by
Chisana Caribou Recovery Team

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Cover Photo:
Chisana caribou cow and her young calf in the captive rearing pen at Big Boundary Lake, summer 2006 (photo by Kathi Egli).

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EXECUTIVE SUMMARY

We conducted trials to assess the efficacy of a captive-rearing approach to increase calf survival in the Chisana Caribou Herd (CCH), a small, declining population of woodland caribou (*Rangifer tarandus caribou*) in the Alaska/Yukon borderlands. From 2003 to 2006, pregnant caribou cows were captured in late-winter and transferred to a holding pen established within their natural range. In the pen they were protected from predators through the calving and neonatal periods and then released back into their natural range in mid-June. Over the 4 years, 146 caribou calves were born in captivity and 136 survived to be released from the pen. Radio-telemetry was used to monitor the survival of the calves raised in the pen, as well as 156 calves born to radio-collared females in the wild. Calf survival from birth through the neonatal period was about 3 times greater for caribou in the pen. After release from the pen, survival of captive-reared calves to 5 months of age was 35% greater than that of caribou born in the wild, even though both groups were subjected to the same conditions. Despite the success of captive-rearing in dramatically increasing survival of calves in the program, the contribution of captive-rearing to recovery of the CCH was limited by the relatively small proportion of pregnant females from the herd that could be reasonably maintained in the captive-rearing pen. Our results indicate that captive-rearing could be a useful management action to conserve small, at-risk populations of woodland caribou, primarily to provide time to address factors limiting population growth.

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INTRODUCTION

At the time of European settlement of North America, woodland caribou (*Rangifer tarandus caribou*) occurred in most conifer-dominated forested regions. Since then, the distribution of woodland caribou has contracted northward, with some populations becoming extirpated (Schaefer 2003). Many remaining populations of woodland caribou (*Rangifer tarandus caribou*) are in decline (e.g. Schaefer et al. 1999, McLoughlin et al. 2003, Stronen et al. 2007). Concordant with their decline, most populations of woodland caribou in Canada have been legally listed as at-risk under the Canadian *Species at Risk Act*.

Predation is a significant factor in the population dynamics of many caribou populations, particularly those that are relatively small in number and sedentary (Gasaway et al. 1983, 1992; Gauthier and Theberge 1985; Bergerud and Elliot 1986; Seip 1991, 1992; Dale et al. 1994; Adams et al. 1995*a*, Adams et al. 1995*b*; Bergerud and Elliot 1998). Predation of neonatal calves can be relatively high, particularly in the first 6 weeks after birth. For example, in Denali National Park an average of 46% of all caribou calves died within the first 15 days after birth, with annual survival rates ranging from 29% to 71% (Adams et al. 1995*a*, Adams et al. 1995*b*). Populations with consistently low calf survival and recruitment may decline markedly, unless factors limiting calf survival are addressed. Typically, in northern jurisdictions reducing predator populations is the most readily used management tool to increase caribou survival and stimulate population growth rates (Boertje et al. 1996; Hayes et al. 2003). The public, however, have charged wildlife managers to develop management prescriptions to increase ungulate populations without lethal control of predator populations (Yukon Department of Renewable Resources 1992; Hayes et al. 2003; Hayes and Couture 2004).

In response to concerns from local communities and First Nations over the fate of the Chisana Caribou Herd (CCH), a small declining population of woodland caribou, we developed and evaluated a novel captive-rearing approach as a means of increasing calf survival and stabilizing or increasing the population growth rate of a declining caribou population. We thought that if caribou calves were born and raised through the neonatal period in the protected confines of captivity, then we could increase the number of calves in the population and associated population growth rates. For example, similar approaches have been taken to increase productivity in fish (Carr et al. 2004), sea turtle (Pelletier et al. 2003), waterfowl (Pietz and Krapu 1994; LaGrange et al. 1995) and shorebird (Mabee and Estelle 2000) populations, usually by using predator exclosures to provide safe refuge during the nesting and brood-rearing stages.

Captive breeding for release back into the wild is a useful management tool for endangered species recovery, and for some species can make the difference between survival and extinction. Despite its important role for a few species, captive breeding techniques have fundamental limitations. Problems with achieving self-sustaining captive-bred populations, successful reintroductions,

progressive domestication and genetic erosion, susceptibility to disease, high cost, and continuity restrict its use to a limited number of endangered species where other viable alternatives are unavailable (Snyder et al. 1996). Alternatively captive rearing and release into the wild on the species' native range with natural fostering has potential to overcome many of these limitations and provides another approach. We believed that annual short-term (10 weeks) captive rearing in a semi-wild environment could increase the rate of recruitment to supplement populations by improving survival for neonates during the early, high-risk stages of life without the risks associated with long-term adaptation to captivity.

Our intent was to hold pregnant caribou and their calves during the late gestation and neonatal periods, after which they would be released from the pen. If feasible and successful, captive-rearing may hold promise for increasing population growth of other ungulate populations that are limited by neonatal predation. To evaluate the efficacy of our captive-rearing trials, we compared survival and body mass of captive-reared calves with a sample of those born in the wild.

METHODS

Study Population and Area

The CCH is a small herd that ranges along the borderlands of western Yukon and eastern Alaska, near the headwaters of the White River in the Nutzotin Mountains (Figure 1). Zittlau et al. (2000) used DNA analyses to demonstrate that the CCH is relatively genetically distinct from neighbouring caribou herds. During the 1990s, local outfitters and communities were concerned that the CCH was in rapid decline. Based on limited survey data, Farnell and Gardner (2002) estimated that the CCH declined from about 1900 caribou in 1988 to a low of about 400 in 2001, and that calf:cow and bull:cow ratios had also declined markedly (Figure 2). Further, there was evidence that the age structure of cows was skewed to older age-classes that were beyond their prime as a result of over a decade of poor calf recruitment (Farnell and Gardner 2002). Demographic data suggested that the CCH was much reduced in numbers, and that current calf recruitment would not sustain the herd in the long-term. Furthermore, nuclear DNA data does not indicate mixing with any neighbouring herds; thus demographic "rescue" from neighbouring herds was not likely (Farnell and Gardner 2002).

The study area was within the Alaska-St. Elias Range Tundra Ecoregion (Ricketts et al. 1999), south of Beaver Creek, Yukon (62.38° N, 140.88° W). The area is characterized by rugged and glaciated mountains with many peaks rising to 2500 m. The herd's range is drained by the Donjek, Generc, White, Chisana, and Nabesna rivers (Figure 1). Treeline generally occurs at 1,050–1,200 m. White spruce (*Picea glauca*) dominates well-drained soils, while stunted black spruce (*Picea mariana*) is common on poorly drained sites. White birch (*Betula papyrifera*), trembling aspen (*Populus tremuloides*), and balsam poplar (*P. balsamifera*) are found in warmer lowland areas. Willow (*Salix* spp.),

dwarf birch (*Betula* spp.), soapberry (*Shepherdia canadensis*), and ericaceous shrubs (e.g. *Vaccinium* spp., *Ledum* spp.) dominate understory, riparian, and subalpine regions. Sedge–tussock fields are common in poorly drained sites and gentle slopes. Steeper slopes give way to alpine forbs, ericaceous shrubs, grasses, and lichens. The CCH range is within the rain shadow of the St. Elias Mountains and is classified as a dry, cold, continental climate, receiving an average of 32 cm of annual precipitation. At Beaver Creek, annual snowfall averages approximately 132 cm, and mean annual temperature is –6.6°C.

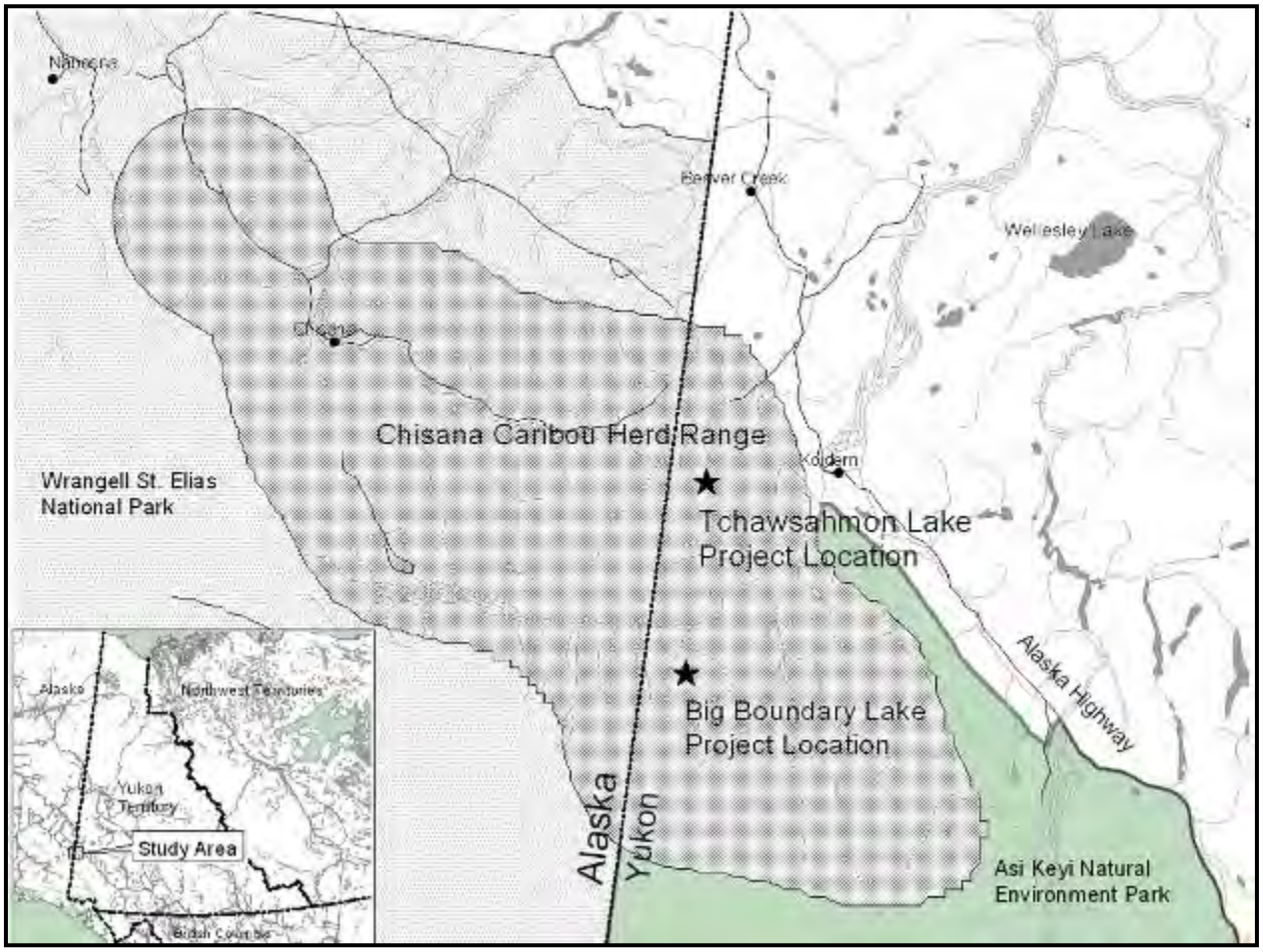


Figure 1. Range of the Chisana Caribou Herd in western Yukon and eastern Alaska, and location of the Tchawsahmon Lake and Big Boundary Lake project locations where captive-rearing pens were established in 2003 and 2004–2006, respectively.

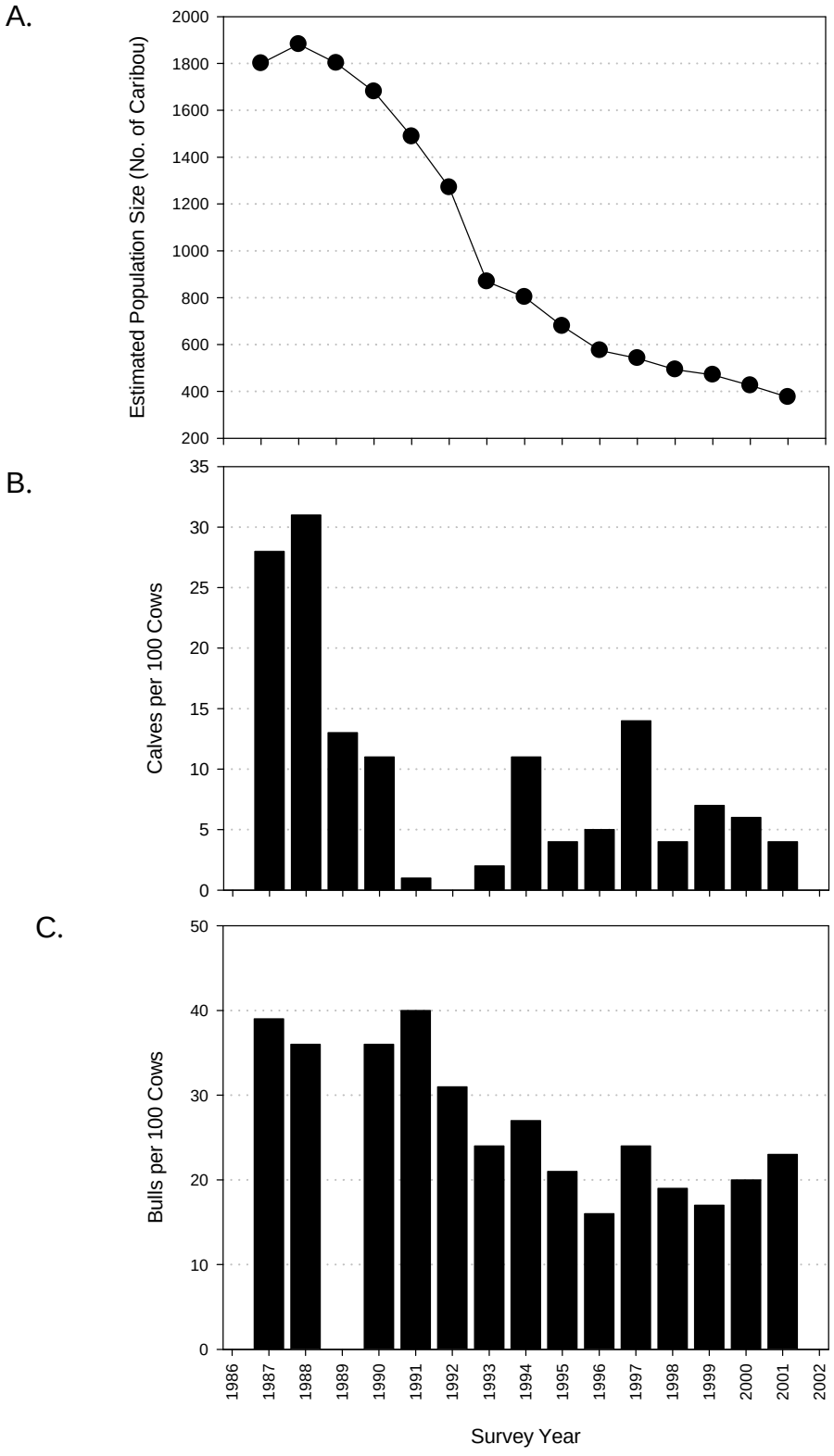


Figure 2. A) Estimated trend in population size of the Chisana Caribou Herd and B) calves per 100 cows and C) bulls per 100 cows for 1987–2001. Data from Farnell and Gardner (2003).

Woodland caribou in this area are important to local First Nations, both culturally and as a food source. The CCH is also an important component of the area's ecosystem. Together with moose (*Alces americanus*), thinhorn sheep (*Ovis dalli*), and smaller prey such as snowshoe hare (*Lepus americanus*), they support a diverse mix of predators and scavengers, including wolves (*Canis lupus;* 5.6/1000 km^2; R. Farnell & C. Gardner, unpublished data), brown bears (*Ursus arctos;* 16–18/1000 km^2; C. Gardner, unpublished data), American black bears (*Ursus americana*), Canada lynx (*Lynx canadensis*), coyotes (*Canis latrans*), wolverines (*Gulo gulo*), and golden eagles (*Aquila chrysaetos*). Moose and sheep are likely the common alternate prey species in the CCH range. Moose density was estimated at 230/1000 km^2 in 1998 (C. Gardner, unpublished data) and sheep density was 1.05/km^2 of habitable sheep range (Sumanik 1987).

Caribou Captures

From 2003 to 2006 we captured adult female caribou in late-March to early-April to stock the captive rearing pen. A fixed-wing aircraft was used to search for caribou with radio-telemetry and in areas identified through previous field surveys and local knowledge. Caribou were captured via a net-gun fired from a Bell 206B helicopter (Barret et al. 1982). In all years, captured caribou were blind-folded, their legs were bound and they were restrained in bag for transport (Plate 1). We also sawed off a portion of their antlers in 2004–2006 to reduce risk of injury to handlers and damage to helicopters. Caribou were transported inside a helicopter to the capture pen (see below; Plate 1). In the second year of the project (2004), we experimented with using a chemical sedative to reduce the stress on animals (and their handlers), subjecting half of the animals to the chemical sedation using an intranasal administration of medetomidine at a dosage of 10–13 mg/caribou. Results from this trial demonstrated that sedated caribou were easier to handle and less stressed than non-sedated caribou (M. Oakley et al., unpublished data); thus in the last 2 years of the program (2005–2006) all caribou transported from the capture site to the pen were sedated after capture by net gun. Only cows determined pregnant by ultrasound were placed in the pen, although in 2003, 3 nonproductive cows were kept based on unclear ultrasound results. Once at the pen facility, all cows were thoroughly examined; various physiological, morphological, and body condition measures were recorded; biological samples (e.g. blood, feces, teeth, etc.) were taken; and each animal was fitted with a radio-collar, plastic ear tag, and uniquely numbered visibility band (see Plates 2 and 3). Sedated animals were given the appropriate antagonist (atipamezole at 30–40 mg/caribou) and pregnant individuals were released into the pen.

Captive-Rearing

Establishment and Layout of Pens

Pens were established in late-winter prior to captures, and were located at remote sites within the herd's winter range (Plate 4). Sites for constructing

the pens were selected to ensure that they had enough large trees to both act as fence posts and to provide cover for caribou to give birth, rest, and shelter from inclement weather; were open enough to provide visibility so that the penned animals could be adequately monitored; and provided access to water and natural forage. In 2003, we established a pen at Tchawsahmon Lake, about 45 km south of Beaver Creek, Yukon (62.38º N, 140.88º W); to reduce transportation time of captured caribou, we located the pen at Boundary Lake in 2004–2006, about 80 km south of Beaver Creek, Yukon (Figure 1). The later location was within the core winter and early summer range, which reduced transport times to the pen for captured animals, and put penned caribou closer to where the rest of their herd normally would be at the time of release from the pen. Pen sizes for 2003–2006 were 6.0, 9.5, 12.0, and 12.2 ha, respectively.

Pens were fenced using a 2.29 m tall black geotextile cloth (LP 200, Layfield Geosynthetics & Industrial Fabrics Ltd., Edmonton, Alberta; Plate 4), which acted primarily as a psychological barrier to caribou and potential predators (e.g. Musiani et al. 2003), rather than an impermeable physical barrier (such as standard game or livestock fencing). The geotextile cloth was hung on cables tightly stretched between suitable trees, or 2.43 m tall rough fence posts, spaced approximately 20 m apart. We tried to route the fenceline along the top of ridgelines to make the fence appear higher and more formidable, and to limit the possibilities of either caribou or predators looking over the fence. A 3–4 wire electric fence (Margo Supplies Ltd., High River, Alberta) surrounded the geotextile fence to provide further predator deterrence.

We built 1 or 2 tree stands about 3–5 m above the ground and in or immediately adjacent to the pen to increase our ability to view and monitor penned caribou (Plate 5). Tree stands were located on high spots within the pen to maximize their effectiveness in covering the large enclosures. Wooden feeding troughs were placed in easy view from the tree stands to facilitate monitoring of caribou in the pen.

Caribou Husbandry

Penned caribou remained in captivity from late-March until mid-June each year. While in the pen, they were fed terrestrial lichens, a commercial pellet ration specifically for caribou, and foraged on native vegetation within the fence line. Terrestrial lichens (e.g. *Cladina stellaris, C. mitis, C. arbuscula*) were transported to the pen, after being picked the previous fall (often by local school children; see Plate 6), and placed in dry storage. Lichen and pellets were distributed twice daily at 12 hour intervals in feeding troughs. Pellets were introduced within the first week of captivity and increased gradually to avoid digestive problems. Inspection of fresh fecal piles in the pen and visual observation of caribou during daily monitoring provided guidance on how well animals were adapting to pellet feed. Beginning in 2005, we used electronic platform scales (Bassano et al. 2003) placed near feeding troughs to weigh caribou. During the last week of captivity, prior to release, the proportion of lichen fed was increased in preparation for the transition to a natural diet. Supplemental salt and other micronutrients (e.g. selenium) were provided by

placing standard 20 kg salt blocks in the pen. After snow melt, in cases where a natural water source was not available in the pen, water was provided in open containers or from a water line with continuous flow.

Penned caribou were monitored at least twice a day, usually via visual observations from the tree stands (Plate 5) or fence perimeter. In cases where individuals could not be located visually, we used radio-telemetry to ensure they were indeed in the pen and alive. Additionally, the perimeter of the pen was checked at least twice daily to ensure the integrity of the geotextile cloth and to look for signs of potential predators (Plate 7). Regular human presence around the fenceline was also believed to help deter bears and wolves from approaching the pen.

Evaluation: Captive-Reared vs. Free-Ranging Calves

Caribou Monitoring

We assessed the efficacy of captive-rearing in producing healthy calves that survive beyond the neonatal period by comparing survival and body mass of calves born in the pen with a sample of calves born to free-ranging cows. Calves born in the pen were captured by hand and examined (see Plate 8), generally within a day of birth. Calves were weighed (± 0.1 kg) using a spring scale and affixed with a VHF radio-transmitter on an expandable collar. Their status was checked daily, both visually and with ground-based telemetry. Once released, pen-reared calves were located periodically via aerial telemetry to assess their survival.

A comparable sample of free-ranging calves were captured and weighed as described by Adams et al. (1995*b*). Radio-collared cows ≥ 2 years old in the free-ranging population were observed from helicopters shortly after the peak of calving (≈ 20 May) to determine whether they were pregnant or not based on the presence of a calf at heel, a distended udder, and/or hard antler (Whitten 1995). To assess calf survival in the wild, each cow that was deemed parturient was located periodically throughout the summer and fall to determine if it was accompanied by a calf.

Statistical Analyses

Contingency table analysis was used to compare survival of captive-reared calves and wild-born calves a) from birth to release from the pen (approximately 15 May – 15 June - the neonatal period); b) from release until mid-fall (approximately 15 October – 3 months since release); and c) both time periods combined. High mortality rates of wild-born calves resulted in sample sizes too small for statistical analyses within each year; therefore, we pooled samples across years. Body mass was compared among year and treatment (captive-reared or wild-born calves) using a factorial analysis (e.g. ANOVA).

Evaluation: Population Dynamics

The number of calves recruited into the population at 5 months of age (mid-October) was used to assess the relative contribution of captive-rearing to the demography of the population. Fall calf:cow ratios from 1987 to 2002 were

summarized by Farnell and Gardner (2002). Additional fall composition counts were conducted from a Robinson R-44 helicopter in October 2003–2006 to derive calf:cow ratios and other demographic data. Data were tabulated to assess the percent of calves present in fall that were captive-reared or wild-born.

RESULTS

Captive-Rearing

In 2003–2006, 175 adult female caribou were captured for possible transfer to the pen (Table 1). Five cows died from capture-related causes, including 3 that died immediately following capture (1 in 2003, 2 in 2004), and 2 that died within a few days following capture (1 in 2004, 1 in 2005), probably as a result of stress-induced capture myopathy (Chalmers and Barrett 1982). Sedation of caribou in 2004–2006 noticeably reduced stress to animals during transport and handling (M. Oakley et al., unpublished data), and presumably reduced the risk of capture myopathy.

Table 1. Summary data for Chisana caribou captured and captive-reared, western Yukon / eastern Alaska, 2003–2006.

Variable	Year			
	2003	**2004**	**2005**	**2006**
Number of Cows Captured	22 [A]	37 [B]	58 [C]	58 [D]
Number of Cows in the Pen	20 [E]	29	50	50
Number of Pregnant Cows in the Pen	17	29	50	50
Number of Calves Born in the Pen	17	29	50	50
Number of Calves Released from the Pen	17	29	45	45

[A] 1 cow died during capture operations and was not transported to the pen.
[B] 6 cows were not pregnant and were released; 2 cows died from capture-related causes.
[C] 7 cows were not pregnant and were released; 1 cow died following capture from capture myopathy.
[D] 8 cows were not pregnant.
[E] Pregnancy determination via ultrasound were equivocal for 3 cows placed in the pen; they did not produce calves.

We captured and cared for 20, 29, 50, and 50 adult caribou in the pen in 2003–2006, respectively (Table 1). Cows appeared to adjust well to captivity and the mixture of natural and commercial feed, as they gained 10% and 6% in body mass in 2005 and 2006, respectively, between capture and 30 April (L. Adams, unpublished data), a period of late winter when wild caribou were probably losing body mass. With the exception of 3 cows in 2003 that were not pregnant, all of the penned cows gave birth (Table 1). Captive rearing in 2003–2006 resulted in 146 calves being born in the pen (Table 1). Calving occurred as early as 7 May and continued as late as 8 June, but most cows in the pen were relatively synchronous, with a strong peak in calving occurring 16–20 May in each year (Figure 3).

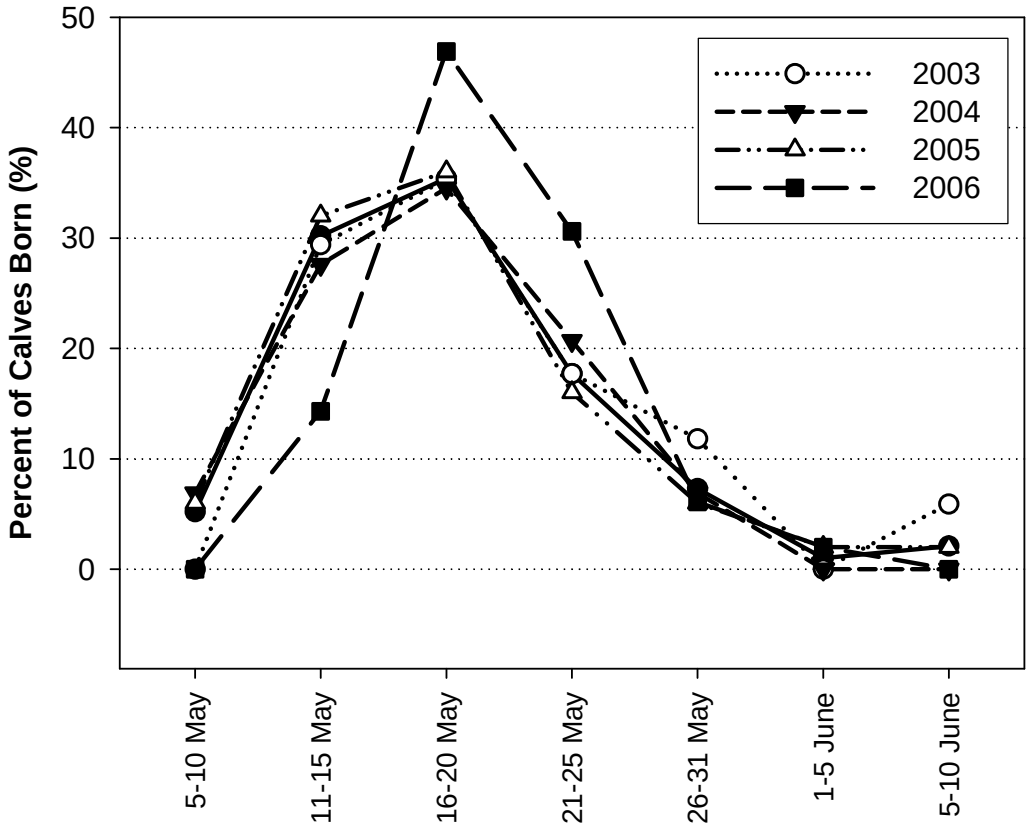


Figure 3. Percent of calves born in the pen during 5-day intervals in 2003 (*n* = 17), 2004 (*n* = 29), 2005 (*n* = 50), and 2006 (*n* = 49) during captive-rearing trails.

The geocloth and electronic fence formed an adequate pen and, with 1 exception, caribou did not escape during the 4 years of captive-rearing trials. In June 2006, 1 calf escaped from the pen and its mother was released from the pen to care for it. There was limited evidence of predators being attracted to the pen in most years. However, in 2003, we deterred 1 grizzly bear, while in 2004 we deterred 7 grizzly bears and 1 wolf, and in 2005, 1 golden eagle was deterred. In 2006, a black bear got into the pen and was shot and killed after killing a calf. However, there may have been a number of other instances for which predators were deterred but not detected. Ravens (*Corvus corax*), bald eagles (*Haliaeetus leucocephalus*), marten (*Martes americana*) and red fox (*Vulpes vulpes*) were observed feeding on placentas shed by caribou in the pen. Marten and red fox were also observed feeding on caribou that had recently died from other causes in the pen.

Body Mass of Calves

The estimated birth masses of calves differed among male and female calves ($F_{1,216} = 20.17$, $P < 0.001$), with females being about 15% lighter than males, and varied among years with calves born in 2005 lighter than other years (15% and 6% lighter for males and females, respectively; $F_{2,216} = 26.14$, $P < 0.001$). We did not detect any differences in mass at birth between captive-reared and wild-born calves ($F_{1,216} = 2.65$, $P = 0.105$; Table 2).

Table 2. Birth mass (kg) of calves born in the captive-rearing facilities and free-ranging calves of the Chisana Caribou Herd, Alaska-Yukon borderlands, 2004 – 2006.

	Pen						Wild					
	Male			Female			Male			Female		
	$\bar{x}$	*n*	SD	$\bar{x}$	*n*	SD	$\bar{x}$	*n*	SD	$\bar{x}$	*n*	SD
2004	9.5	11	1.33	8.0	16	1.15	9.6	12	1.62	8.9	12	1.62
2005	8.5	24	1.40	7.5	24	1.32	8.1	14	1.26	7.7	26	1.22
2006	9.6	24	1.24	8.8	22	0.99	9.5	16	1.28	9.7	15	1.03

Calf Survival

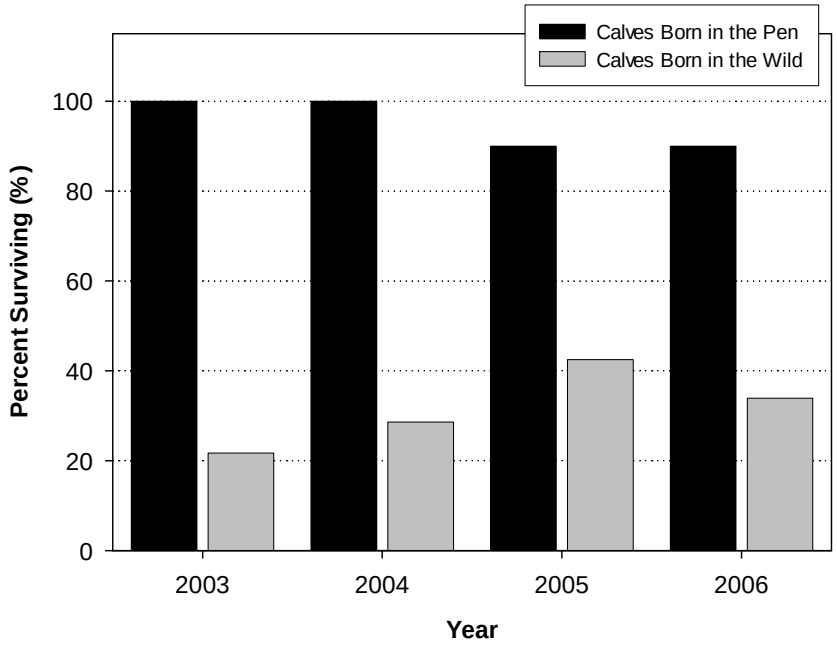
Survival of calves in the pen was very high overall (93%). In 2003 and 2004, all the calves survived to release, but in 2005 and 2006, 5 calves died or were abandoned in each year. In 2005, 2 calves died within < 1 day birth, 1 was abandoned and died about a week after birth, 1 was abandoned at a couple of days of age and was taken to the Yukon Game Farm where it thrived, and 1 calf was euthanized at about 3 weeks of age due to a compound leg fracture; this individual was also exhibiting suspected neurological problems. In 2006, 2 calves were stillborn, another was either stillborn or killed by a small predator (e.g. red fox), 1 was killed by a black bear, and 1 calf was abandoned when its mother died from birth complications; this calf was taken to the Yukon Wildlife Preserve, but it exhibited serious neurological problems and was ultimately euthanized.

The free-ranging, radio-collared cows we monitored in the CCH produced 156 calves during the 4 years of the captive-rearing program. Captive-rearing had a profound effect on short-term survival of calves. For the neonatal period (birth to mid-June release), the survival of pen calves (93%) was significantly greater than wild-born calves (33%; $X21 = 114.84$; $P < 0.001$; Figure 4). The causes of mortality for calves born in the wild were unknown, but it is presumed that they died predominantly from wolf and grizzly bear predation, based on studies of similar caribou herds (Adams et al. 1995*a*, Adams et al. 1995*b*; Valkenburg et al. 2004; Jenkins and Barten 2005). Survival from the time of release (approximately 15 June) until mid-October was also greater for calves born in the pen (70% compared to those born in the wild (52%; $X21 = 5.31$; $P = 0.021$; Figure 5), even though both groups of caribou were free-ranging and presumably equally exposed to predators. Considering the entire monitoring period, spanning from birth until about 5 months of age, a much higher percentage of calves born in the pen survived until 15 October (65%) than calves born in the wild (17%; $X21 = 71.45$; $P < 0.001$; Figure 6).

Contribution to Calf:Cow Ratios

Calf:cow ratios varied over the period 1987 to 2006 (Figure 7). In the 14-year period immediately prior to the onset of recovery efforts for the CCH (1987–2002), calf:cow ratios were exceedingly low (mean = 6.3 calves:100 cows, range = 0–14:100; Figure 7). Coinciding with our recovery efforts, in 2003–2006 calf:cow ratios naturally increased markedly (mean = 18.2 calves:100 cows, range 15–24:100; Figure 7), without the contribution of captive-rearing efforts. Regardless, captive-rearing provided a substantial contribution ranging from 7% – 32% to the observed calf:cow ratios in 2003–2006 (Figure 7).

A.



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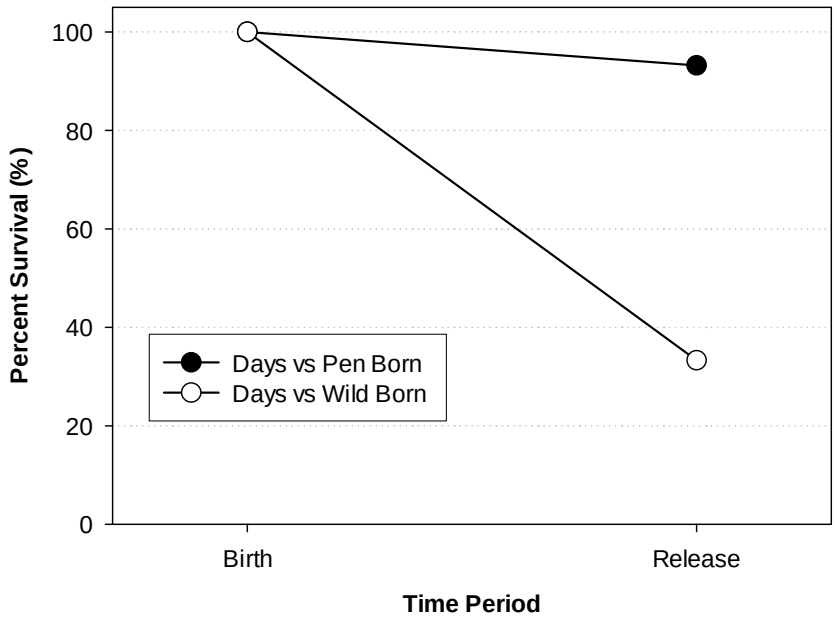

Figure 4. A) Percent of calves born in the pen surviving from birth (~ May 25) to release from the pen (~ June 15), compared to calves born in the wild and monitored during the same time period. B) Pooled survival of calves in 2003–2006 born in the pen (*n* = 146 calves) and in the wild (*n* = 156 calves) that survived from birth to release of penned animals.

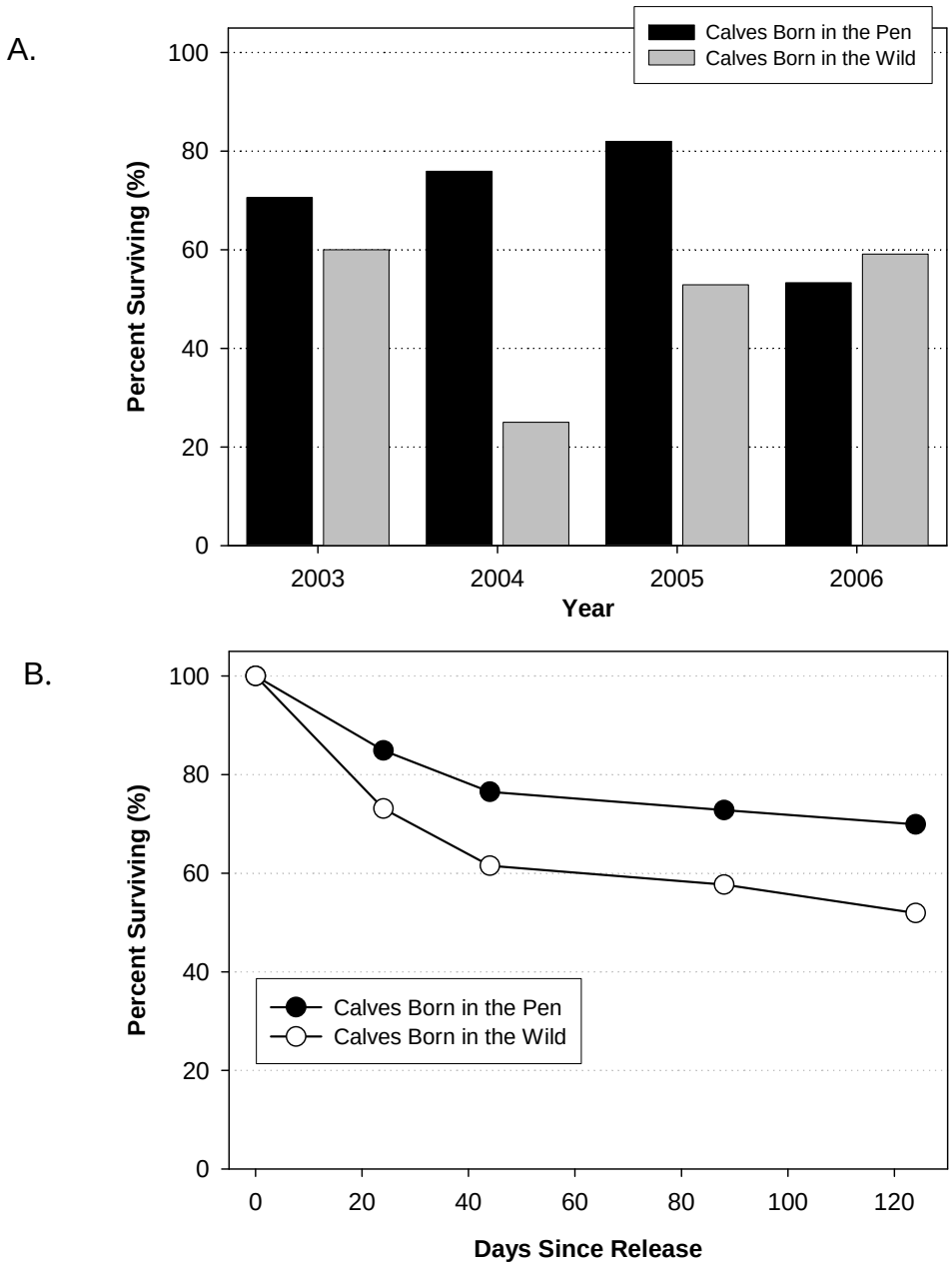

Figure 5. A) Percent of calves born in the pen surviving from release from the pen (~ June 15), until early fall (~ October 15), compared to calves born in the wild and monitored during the same time period. B) Pooled survival of calves across years (2003–2006) released from the pen (*n* = 136 calves) and calves born in the wild (*n* = 52 calves) that survived from release of the penned calves (~ 15 June) until fall (~ 15 October ; 4 months post-release).

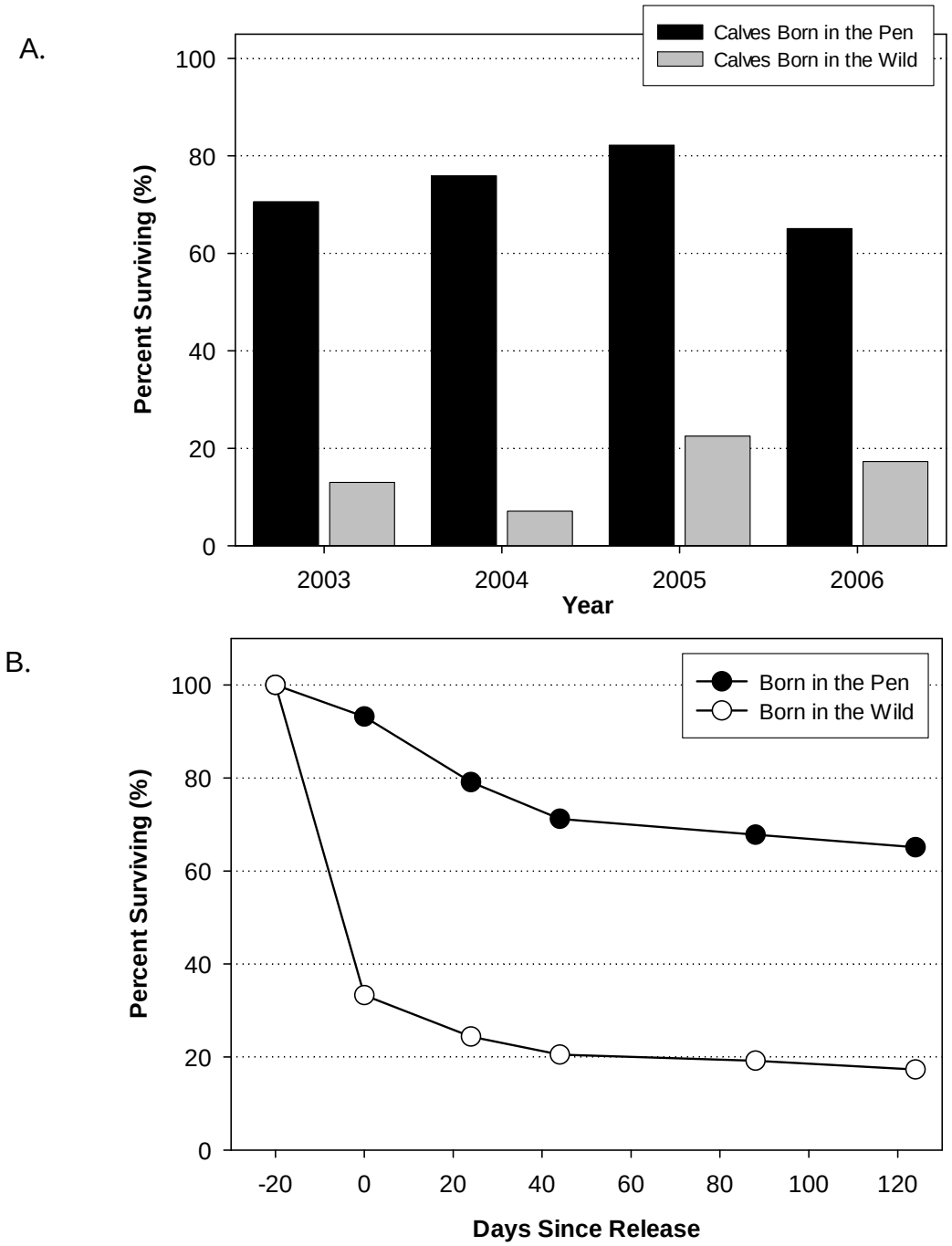

Figure 6. A) Percent of calves born in the pen surviving from birth until early fall (~ October 15), compared to calves born in the wild and monitored during the same time period. Numbers above the bars is the number of radio-collared calves monitored. B) Pooled survival of calves across years (2003–2006) born in the pen (*n* = 146 calves) and radio-collared calves born in the wild (*n* = 156 calves) that survived from birth until fall (~ 15 October ; 4 months post-release).

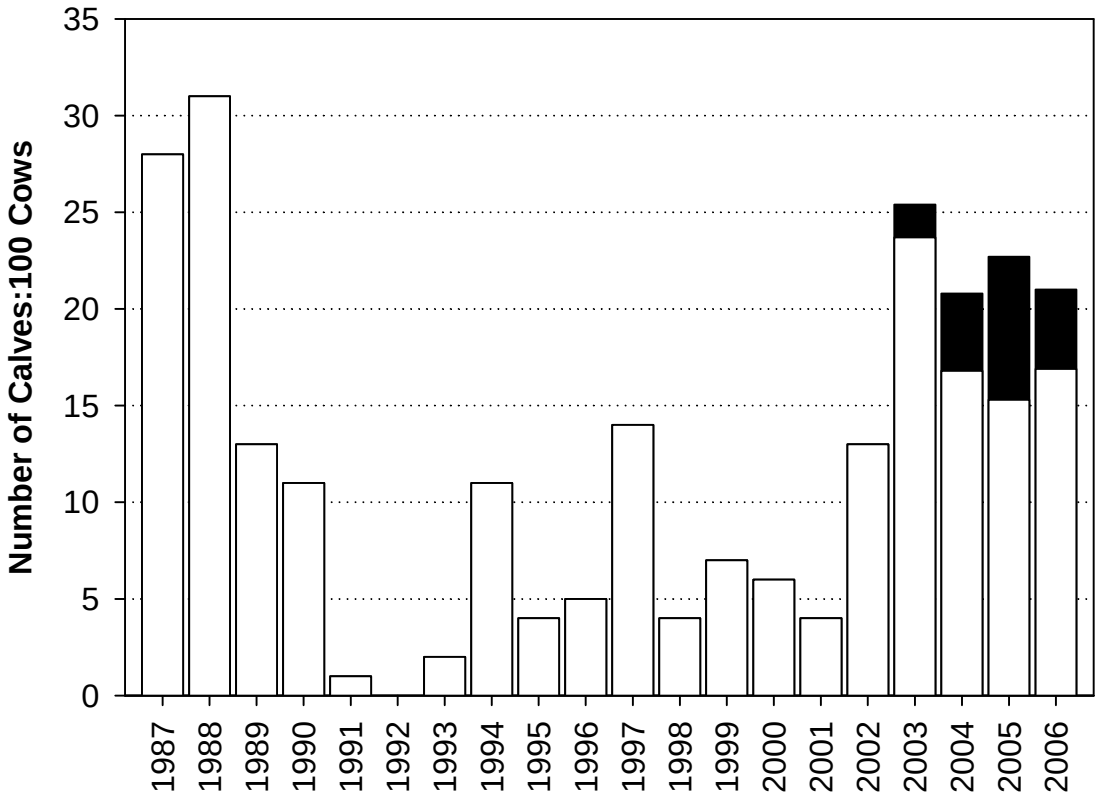

Figure 7. Number of calves per 100 cows observed during fall composition surveys of the Chisana Caribou Herd, 1987–2006. Shaded portions of the bars for 2003–2006 indicate the annual contribution of captive-reared calves to observed calf : cow ratios. Data for 1987 – 2002 from Farnell and Gardner (2002).

DISCUSSION

Individual-level Effects

Our 4 years of captive-rearing trials demonstrated that woodland caribou could be captured and put into temporary pens within their range for short periods of the annual cycle, could give birth and raise calves over the neonatal period, and then be successfully released into the wild. Using what amounted to primarily a psychological barrier, we were able to keep caribou cows within the pen for over 2.5 months each year, and predators out, effectively reducing predation on pregnant cows and newborn calves. *In situ* captive-rearing on native range appeared to offer a feasible alternative to *ex situ* captive-breeding with unnatural fostering and subsequent reintroduction into the wild. Cows and their calves never left their natal range to be bred in captivity, thus there was no associated concerns about genetic loss, artificial selection, transfer of diseases, or loss of natural instincts that are common to more standard *ex situ* captive-breeding and reintroduction programs for endangered populations.

The primary goal of our work was to evaluate the efficacy of *in situ* captive-rearing as a means to increase neonatal calf survival in a small, declining woodland caribou herd. Survival rates of calves born in the pen over the neonatal period were nearly 3 times greater than that for calves born to free-ranging cows, demonstrating that our captive-rearing trials were successful in markedly increasing neonatal survival of captive-reared calves. However, even if calf survival over the neonatal period was increased, if calves did not survive to recruit into the population after release from the pen, then, the contribution of captive-rearing to calf survival would be negligible. Through monitoring of calves born in the pen and those born to free-ranging cows, captive-rearing had a positive effect on survival of calves even after release from the pen. Survival rates after release were approximately 35% higher for calves born in the pen compared to those born outside the pen; thus our data demonstrates that captive-rearing had a positive effect on calf survival that lasted beyond the neonatal period and release to the wild. In this light, captive-rearing contributed to calf survival, and hence recruitment, in the CCH. We surmised that increased survival of calves born in the pen, both during the neonatal period and thereafter once the calves were released from the pen, was attributable to reduced predation as well as increased growth and development of calves resulting from their mothers obtaining nutritious feed during critical periods (e.g. late-winter, gestation and lactation).

Population-level Effects

Despite our success in substantially increasing survival and recruitment of captive-reared calves, captive-rearing only contributed between 7.1 and 32.3% of the calves in the wild in the fall of each year (an average of 26%; Figure 7). This suggests that at the scale of our efforts (17–45 calves per year), captive-rearing had a limited effect on recovery of the CCH. When we began the captive-rearing program, the CCH was thought to number < 360 caribou (Farnell and Gardner 2002). However, in October 2003, with additional radio-

collared cows in the herd from that year's captive-rearing project, and increased effort to assess herd size, the herd was estimated at 720 caribou (90% CI = 606–833; Adams 2003). The higher population estimate was subsequently corroborated by additional censuses (Adams and Roffler 2005, 2007). Given that the caribou herd was twice as large as suspected, the relative contribution of captive-rearing to herd growth was reduced proportionally. However, through simple population modeling, we estimated that the captive-rearing program increased the CCH by about 11%, or 70 animals, during 2003–2006, over the modeled herd size without captive rearing. The combination of improved natural calf recruitment and the contribution of calves from the captive-rearing program likely held the herd near stability during 2003–2006.

MANAGEMENT IMPLICATIONS

We suggest that captive-rearing is likely more acceptable to local communities and the public than other available alternatives to recover small, declining caribou populations. Our study received considerable support from local communities because of a strong interest by First Nations in recovering caribou *in situ*. However, the cost of constructing a pen, and capturing and caring for 50 or more caribou, in a remote location without road access was extremely high. Costs for applying our approach should be substantially lower for those small, threatened herds that are on more accessible ranges.

Captive-rearing of caribou calves through the neonatal period was effective at substantially increasing survival of those calves. Unfortunately, the level of captive-rearing required to increase the CCH was greater than achieved during the 4 years of our study, and without addressing the limiting factors affecting the population growth rate, the population would likely continue to decline once captive-rearing stopped. For the CCH, the initial population size was likely too large to make captive-rearing a feasible option for markedly increasing the size of the herd because the number of cows required to rear in a pen was higher than we could reasonably handle or afford.

For smaller caribou herds, or other small ungulate populations, which are limited by poor calf recruitment due to predation immediately following birth and that are at imminent risk of extirpation, captive-rearing may be an effective management action to stabilize or even increase population size. Based on our trials, we believe it would be feasible to use a captive-rearing approach to keep a small population on the landscape until the limiting factors were improved, or the population grew to a level it could effectively escape a "predator pit" (*sensu* Messier 1994). Of note, captive-rearing should only be viewed as a temporary management action until such time that limiting factors can be adequately addressed. Regardless of captive-rearing efforts, stochastic events may dramatically affect the recovery of small populations.

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Plate 1. Top photo: The capture crew secures a caribou into the orange "deer bag" to safely restrain her for the helicopter ride to the pen, April 2005. Clockwise from left Nathan Ferguson, Duane Broeren, and Jamie McLelland. Bottom photo: Tom Jung (left) and Grant Lortie bring a sedated caribou into camp, March 2003.

Plate 2. Wildlife biologists process the caribou once it arrives at the pen at Boundary Lake, March 2004. Top photo: Gretchen Roffler (left) and Michelle Oakley. Bottom photo: clockwise from back left: Grant Lortie, Don Russell, Layne Adams, and Gretchen Roffler.

Plate 3. Caribou in the pen at Boundary Lake with radio-collars and individual numbered visibility bands.

Plate 4. The captive-rearing pen at Big Boundary Lake in spring 2004.

Plate 5. Top photo: Nathan Ferguson (left) and Lorne Larocque constructing a tree-top observation platform (blind) within the enclosure at Boundary Lake, April 2004. Bottom photo: Sara Nielsen keeps a careful eye on caribou in the pen in May 2005.

Plate 6. Students and Michelle Oakley pick lichens near the Haines Summit for transport to the pen in late-winter.

Plate 7. Grant Lortie patrols the enclosures for signs of predators (top photo) and to check the condition of the fence (bottom photo).

Plate 8. Don Russell (top photo), Martin Kienzler and Kathi Egli (bottom photo) assessing the condition of a newly born caribou calf in the pen and applying a radio collar at Big Boundary Lake.

Appendix A. The Chisana Caribou Recovery Team (2002–2006)

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Jeff Gross, Alaska Department of Fish and Game
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