The Future of Peary Caribou (*Rangifer tarandus pearyi*) in a Changing Climate

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Introduction

In the last half century, trends in mean temperature (increasing), snowfall (increasing), and snow cover (decreasing) that are consistent with global warming predictions have been observed in the Arctic (Brown and Alt 2001; Gitay et al. 2002; Whitfield et al. 2002). Additionally, climate variability in the Arctic has increased: there has been a significant increase in the number of thaw days in autumn and winter (Groisman et al. 2003) and an increase in the frequency of heavy precipitation events (Gitay et al. 2002). These changes confirm reports by Inuit of climate warming and associated ecological changes (Nunavut Tusaavut Inc. 1997; Ashford and Castleden 2001).

Over roughly the same period, 1961–2001, Peary caribou (*Rangifer tarandus pearyi*) populations have declined by 84% (Harding 2003). Several of the declines have resulted from winter die-offs when > 90% of the caribou, as well as muskoxen, died of starvation during severe winter conditions of deep, hard-packed, or frozen snow that prevented access to forage. This has led to speculation that climate change has caused the observed four-decade overall decline in the subspecies (Miller 1991; Ferguson 1996; Gunn 1998; Miller and Gunn 2003b). The declines, however, have been spatially and temporally inconsistent among the various Peary caribou populations: some populations have increased while others have decreased. Additionally, at least two of the die-offs preceded the period of observed global warming. Moreover, postulating a caribou decline because of global warming seems counter-intuitive: the extensive high latitude warming and associated cryosphere changes (e.g., longer snow- and ice-free seasons) that have been documented in the northern hemisphere in recent decades, consistent with predictions of greenhouse gas-forced global warming (Zhang et al. 2000; Brown and Alt 2001; Whitfield et al. 2002), should improve survival, not lessen it. Therefore, a review of the hypothesized connection between Peary caribou populations and climate change is warranted.

Population Declines and Die-offs

During 1974–1975, I found only about 10% of the caribou numbers on Bathurst Island that Tener (1963) found in 1961 (F.F. Slaney & Co. Ltd. 1975). The number of carcasses present proved that many caribou and muskoxen had died. The cause of death was obvious: a thick glaze of ice had formed in the fall of 1973 and again in 1974, which prevented access to forage (Parker et al. 1975). Over the next 20 years, the Bathurst Island population increased at a rate of about 13% per year to achieve near historic population levels, but then starved *en masse* again during three consecutive winters, 1994–1997, which resulted in a 97% decline in the population (Miller 1998) (Fig. 1). Later reviews ruled out other possible causes for the decline such as hunting, interspecific competition, density-dependent mechanisms (e.g., forage depletion), and predation (Gunn and Dragon 2002; Harding 2003; Miller and Gunn 2003a; Miller and Gunn 2003b).

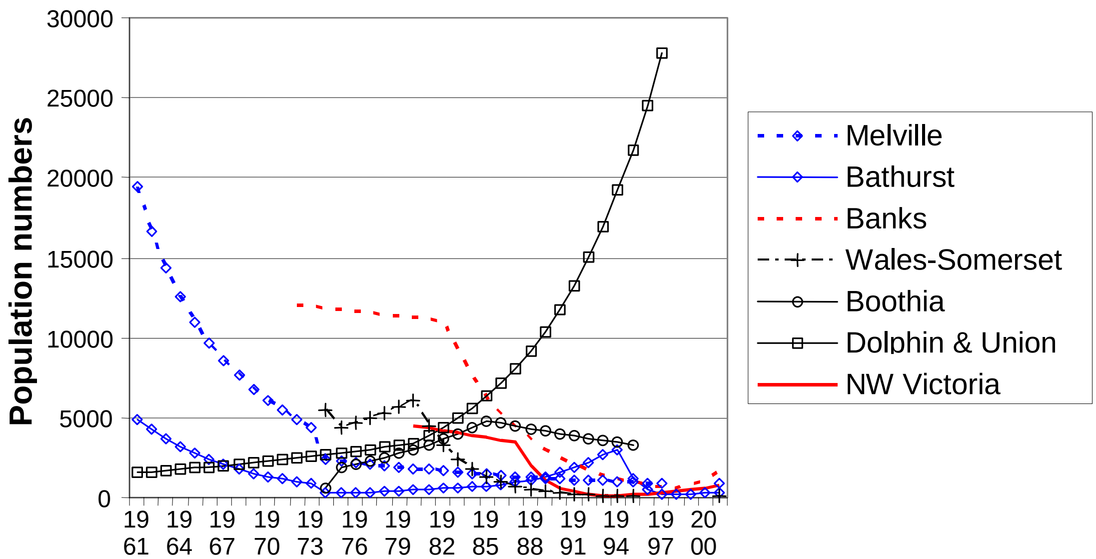

Figure 1. Peary caribou population trends. Sub-units of the same population have the same colors and symbols.

Except for the Bathurst Islands die-offs, all of the documented declines have been gradual rather than precipitous. Caribou in the Melville–Prince Patrick Islands group declined from 1961 to 1998, similar to the Bathurst population but without any detected increases or sharp declines (Gunn and Dragon 2002) (Fig. 1). Carcass counts in 1997 showed, however, that a die-off of a lesser magnitude than that in the Bathurst Island group occurred the previous winter (Miller and Gunn 2003a).

The Banks Island-northwestern Victoria Island population declined overall by about 85% from 1972 to 2001 (Gunn et al. 2000; J. Nagy, unpublished data). The rate of decline varied from slight to nil from 1972 to 1983, to a fairly constant decline of 17% per year from 1983 to 1998 (Fig. 1). Although die-offs were reported on Banks Island in 1987–1988, 1988–1989, and 1990–

1991 (Nagy et al. 1996), they did not result in catastrophic population declines. Instead, they may be better characterized as starvation years when productivity was low or nil and some caribou starved, contributing to longer-term declines. Conversely, a range-wide icing occurred following a rain-on-snow event in fall 1993, and no starvation occurred. Larter and Nagy (2000) measured snow depth and hardness together with observations of calf overwinter growth and survival on Banks Island during 1993–1998 and found no statistically significant relationship, although calf production tended to be higher following winters with shallower snow. Hunting may have been a factor early in the decline phase, and predation from wolves, high numbers of which were maintained by the steadily increasing muskox population, may have been a factor later in the decline phase (Larter and Nagy 2000).

The Prince of Wales-Somerset Islands population declined and was scarce through the 1930s and 1940s but increased by 1974, was stable until at least 1980, and then all but disappeared by 1995 (Fig. 1). There were no reports of starving caribou or of freezing rain or other particularly adverse winter conditions, and no cause for the decline was determined (Gunn and Decker 1984; Gunn and Dragon 1998). It is not know if this population decline was gradual or precipitous since no surveys were conducted in the intervening period.

The Dolphin and Union herd numbered around 1000 in 1949 (Banfield 1950) and 3500 in 1980 (Jakimchuk and Carruthers 1980). Following a freezing rain event in the fall of 1988, two collared females died of malnutrition in February 1989, and 28 caribou carcasses or skeletons were found the following summer (Gunn and Nishi 1998). The trend in this population, however, has been steadily increasing, and no large-scale declines have been apparent (Fig. 1) (Gunn et al. 1997; Gunn and Fournier 2000).

The Peary caribou populations on the Boothia Peninsula and the eastern Queen Elizabeth Islands have been surveyed too infrequently to detect any declines that may have occurred, but there have been no reports of die-offs (Harding 2003).

Population Increases

Multi-year increases have been documented in the Bathurst Island complex (13% per year, 1974–1994), the Boothia Peninsula population (10% per year, 1975–1985), the Banks Island–northwestern Victoria Island population (about 24% per year, 1998–2001 after adjusting for problems with the data; see Harding 2003), and the Dolphin and Union population (12.5% per year, 1980–1997) (Fig. 1). According to Aboriginal traditional knowledge reviewed by Harding (2003), increases also occurred before scientific surveys of the Banks Island-northwestern Victoria Island, Prince of Wales-Somerset, and Boothia Peninsula populations were conducted. According to Inuit from Resolute Bay and Grise Fjord, the eastern Queen Elizabeth Islands population has also increased (Harding 2003).

Weather and Peary Caribou

In the western Queen Elizabeth Islands, neither total annual snowfall nor total monthly snowfall during September–May were exclusively associated with caribou die-off years (Fig. 2), but maximum snow depth at month end was (Fig. 3). There was no correlation between snow depth and snowfall (r^2 = 0.0036). Based on what happened in the western Queen Elizabeth Islands in the winters of 1973 and 1994, which had similar snow depths, the very high snow depth recorded in 1967 suggests a caribou die-off occurred in that year, and likely contributed to, or caused, a decline that occurred sometime between 1961 and 1973. The snow depths associated with the two documented die-offs and the putative one in 1967 were about two standard deviations above the mean.

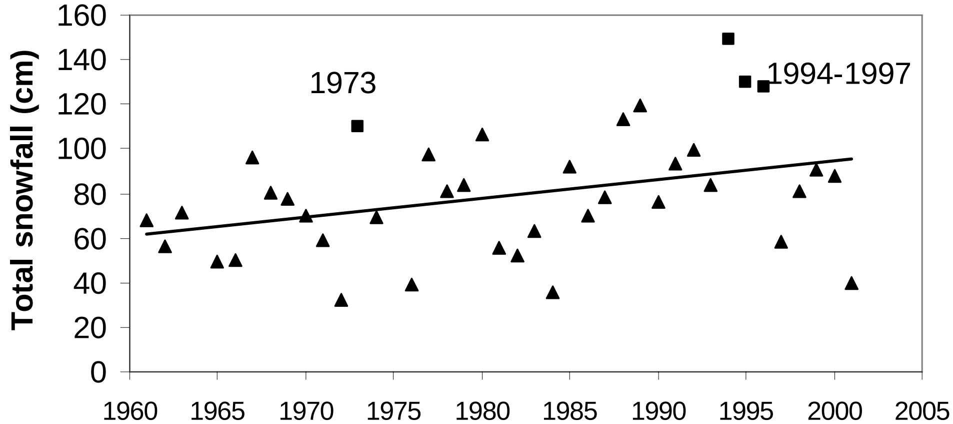

Figure 2. September–May total (sum of mean monthly) snowfall at Resolute Bay, western Queen Elizabeth Islands, Nunavut, 1962–2001. Square symbols represent snowfall amounts during caribou die-off years.

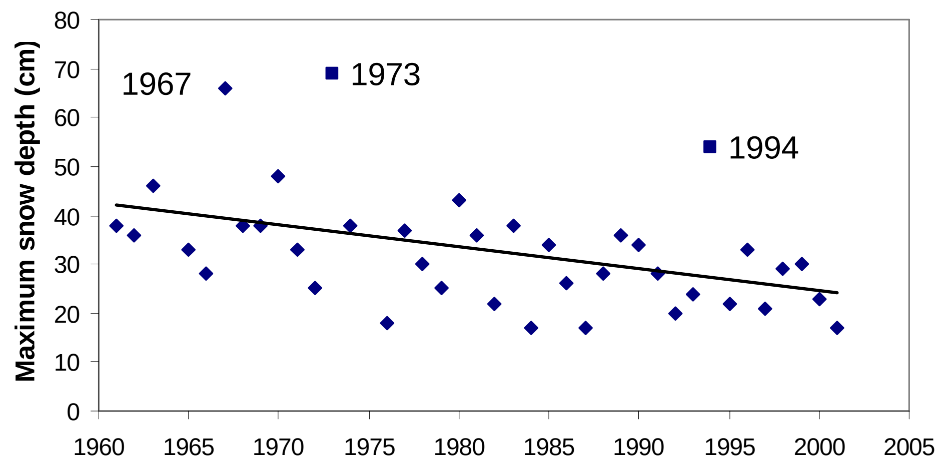

Figure 3. September–May maximum snow depth at month end at Resolute Bay, western Queen Elizabeth Islands, Nunavut, 1962–2001. Square symbols represent caribou die-off years.

At Cambridge Bay on Victoria Island, there was no indication of ameliorating winter conditions during the time that the Dolphin and Union population increased after 1970. On the contrary, the maximum winter snow depth tended to increase during this period (Fig. 4). Although the apparent relationship between total annual snowfall and maximum snow depth was stronger than on Bathurst Island, it was not statistically significant ($r^2 = 0.3577$).

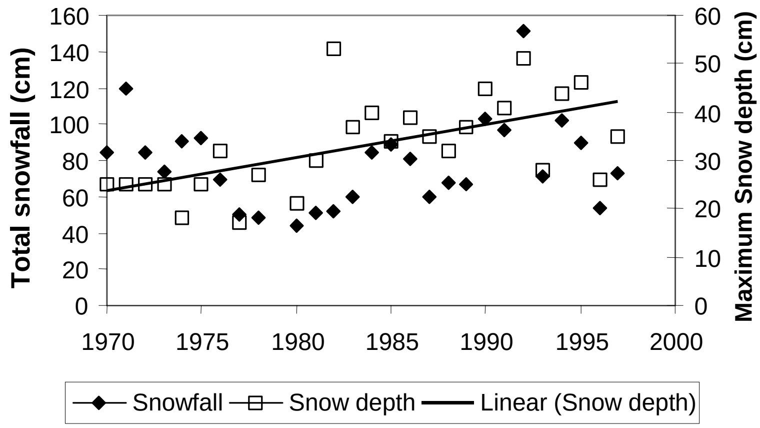

Figure 4. Trends in total winter (September–May) snowfall and maximum winter snow depth at Cambridge Bay, Victoria Island, Nunavut, 1970–2001.

At Sachs Harbour on Banks Island, neither higher winter snowfall nor winter snow depth was exclusively associated with caribou starvation years, although snow depth records were missing for two of the starvation years (Fig. 5). More severe winters, in terms of either total winter snowfall or maximum snow depth, occurred in years without reported caribou starvation episodes and during the period of population increase after 1998. In fact, the opposite seems true: the caribou population appeared to decline when snow depth and snowfall decreased, and appeared to increase when snow depth and snowfall increased.

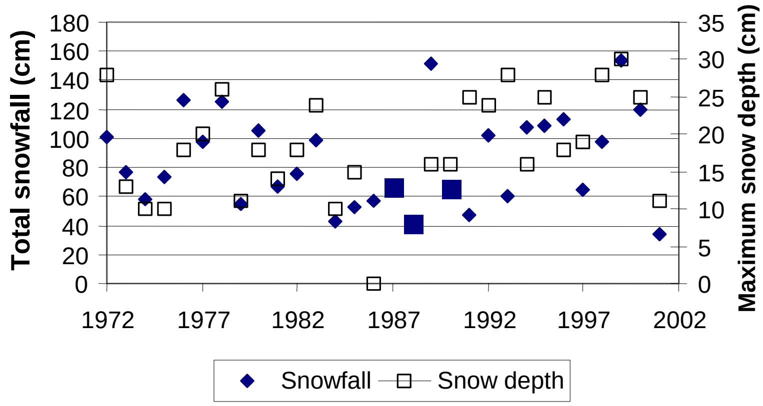

Figure 5. Trends in total winter (September–May) snowfall and maximum winter snow depth at Sachs Harbour, Banks Island, Northwest Territories, 1972–2001. Square symbols in the snowfall series are years in which caribou starvation occurred and icing was reported (snow depth data are not available for 1988 or 1989).

Conclusions

Why have Peary caribou populations declined when the weather seems to be improving (i.e., the weather is warmer overall with earlier spring snow melt and longer snow-free periods)? The resolution of this paradox is in the increasing variability of the changing climate and the nature of events that precipitate die-offs. Conditions that cause hard and/or crusted snow are not continuous variables like temperature or snowfall. Rather, they are threshold events, such as when temperatures rise above 0°C and thaw the snow, then drop below 0°C and refreeze it. Starvation is also a threshold event: exhaustion of fat reserves precipitates a cascade of biological events which may include abortion or reabsorption of fetuses, and ultimately, death. If spring snowmelt and green-up—also threshold events—occur after the loss of fetuses but before death, the result is a decline in productivity; if they occur after many caribou have died, the result is a die-off. One or two weeks can make the difference between a decline in productivity and a die-off. Muskoxen have a higher snow depth threshold than caribou because they can paw through deeper snow; hence, some muskox populations did not decline concurrently with caribou; hence, some muskox populations increased while sympatric caribou populations declined.

It was not higher snowfall *per se* that caused the caribou population declines, but rather, variations in the fine details of winter weather, such as wind and temperature, that allowed the snow to become unusually deep and hard or crusted. If the Arctic Archipelago were to experience increasingly warm, moist weather with longer snow-free periods, Peary caribou populations could respond favourably. Whether or not they do will depend on the frequency of the chance combinations of wind, snowfall, and temperature that cause exceptionally deep and hard or crusted snow.

Acknowledgments

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