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Status of endangered and threatened caribou on Canada's arctic islands

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Abstract: Caribou (*Rangifer tarandus*) on the Canadian Arctic Islands occur as several populations which are nationally classified as either endangered or threatened. On the western High Arctic (Queen Elizabeth) Islands, Peary caribou (*R. t. pearyi*) declined to an estimated 1100 caribou in 1997. This is the lowest recorded abundance since the first aerial survey in 1961 when a high of ca. 24 363 caribou was estimated on those islands. Peary caribou abundance on the eastern Queen Elizabeth Islands is almost unknown. On the southern Arctic Islands, three caribou populations declined by 95-98% between 1973 and 1994 but our information is unclear about the numerical trends for the two other populations. Diagnosis of factors driving the declines is complicated by incomplete information but also because the agents driving the declines vary among the Arctic's different climatic regions. The available evidence indicates that severe winters caused Peary caribou die-offs on the western Queen Elizabeth Islands. On Banks Island, harvesting together with unfavourable snow/ice conditions in some years accelerated the decline. On northwestern Victoria Island, harvesting apparently explains the decline. The role of wolf predation is unknown on Banks and notthwest Victoria islands, although wolf sightings increased during the caribou declines. Reasons for the virtual disappearance of arctic-island caribou on Prince of Wales and Somerset islands are uncertain. Recovery actions have started with Inuit and Inuvialuit reducing their harvesting but it is too soon to evaluate the effect of those changes. Recovery of Peary caribou on the western Queen Elizabeth Islands is uncertain if the current trends toward warmer temperatures and higher snowfall persist.

Key words: declines, population status, *Rangifer tarandus, R. t. pearyi,* recovery.

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Introduction

In 1991, the Committee on the Status of Endangered Wildlife in Canada classified caribou *Rangifer tarandus* on both eastern and western Queen Elizabeth Islands (Fig. 1) and on Banks Island as "Endangered" and those on Victoria, Prince of Wales, and Somerset islands and the Boothia Peninsula as "threatened" (Miller, 1990b). The rationale for the endangered status was the steep population declines during the 1970s and no discernible overall recovery in the early 1980s. The designation of threatened was assigned to populations whose harvest appeared high relative to incomplete information on population size.

By 1998, the two Endangered populations of *R. t. pearyi* on the western Queen Elizabeth Islands have further declined and the endangered caribou on Banks Island also appear to have declined further in the late 1990s. The threatened population on Prince of Wales and Somerset islands has almost disappeared, and the threatened northwestern Victoria Island population had further declined but has, perhaps, now started to increase. The status is unknown for the endangered caribou on the eastern Queen Elizabeth Islands and the threatened caribou on southern and east-central Victoria Island and the Boothia Peninsula.

Our paper describes the status of the different populations and summarises information on factors that drove the declines and options for recovery. We

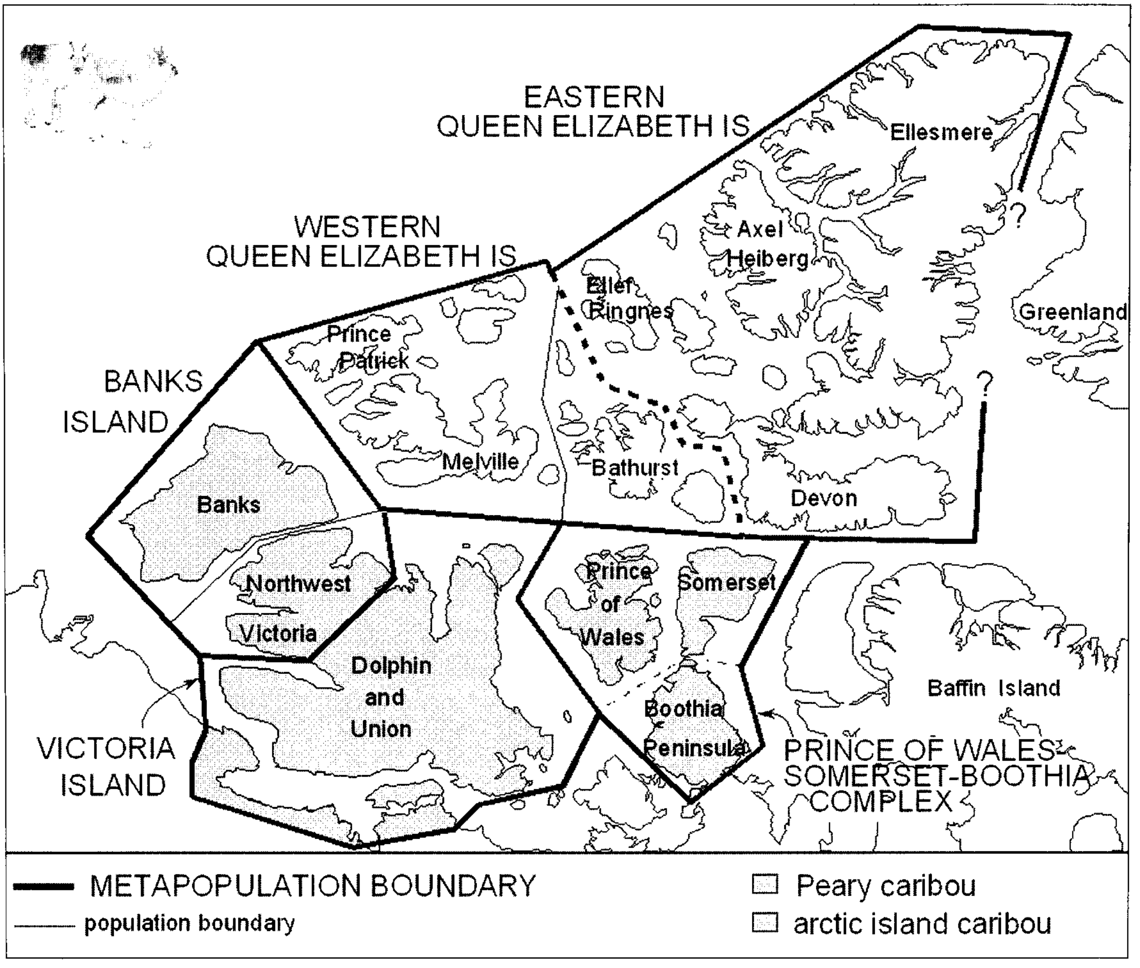

Fig. 1. Currently recognized [or established] population boundaries for Peary caribou and arctic-island caribou and their assumed metapopulation units, Canadian Arctic Archipelago, excluding the Baffin Island region and rhe islands in Foxe Basin and Hudson Bay.

first describe the regional diversity in caribou and the distribution and abundance of the different populations on the Arctic Islands (in this paper, Arctic Islands do not include the Baffin Island region or the islands in Foxe Basin and Hudson Bay). We discuss factors causing the declines and reason that severe winters, characterized by deep snow and freezing rain have been associated with die-offs and low productivity especially on the western Queen Elizabeth Islands. The role of hunting is based on comparing known harvests to caribou numbers but information on other factors proposed as causing declines is sparse: wolf (*Canis lupus*) predation, possible competition with muskoxen (*Ovibos moschatus*), interactions between caribou themselves, weather, the forage supply, and other human activities. We discuss management and recovery while acknowledging that this is no simple task given limitations in the state of knowledge about the ecology of caribou on the Arctic Islands and socio-economic constraints on options for recovery. We conclude with the brief assessment of the outlook for caribou on the Arctic Islands and the need to take a precautionary approach to their management.

Taxonomy and populations

Caribou on the Canadian Arctic Islands are diverse in appearance and size (Manning, 1960; Banfield, 1961; Manning & Macpherson, 1961; Thomas & Everson, 1982; Gunn & Fournier, 1996), suggesting adaptation to the Arctic's regionally different climatic and vegetation zones. The High Arctic (Queen Elizabeth Islands) and Banks, Victoria, Prince of Wales and Somerset Islands encompass five climatic regions (Maxwell, 1981) with different plant growing seasons, diversity and biomass (Edlund & Alt, 1989).

Caribou on the Arctic Islands share physical characteristics but vary in the expression across north-south and east-west clines. Those characteristics held in common include: relatively broad and short skulls, broad hooves (relative to body size), grey antler velvet, light-coloured coats, whitish underparts and absence of a pronounced flank stripe (Banfield, 1961). Those features are most conspicuous among caribou on the Queen Elizabeth Islands although caribou on Banks and northwest Victoria islands exhibit those features more than caribou on south and east Victoria Island and to the east on Prince of Wales and Somerset islands and the Boothia Peninsula.

Currently, we recognise that diversity by defining 'Peary caribou' as those on the Queen Elizabeth Islands (Miller, 1990b: north of ca. 74°N latitude - the Queen Elizabeth Islands). We follow Miller's (1990b) definition of caribou on the southern Arctic Islands (Banks, Victoria, Prince of Wales and Somerset islands, plus some of those caribou on the Boothia Peninsula) as "arctic-island caribou".

Mitochondrial DNA sequencing (J. Eger, pers. comm.) indicates that arctic-island caribou are not intergrades between barren-ground caribou (*R. t. groenlandicus*) and Peary caribou, but are more likely the ancestral stock for Peary caribou. Given this interpretation, Peary caribou would have evolved from barren-ground caribou as they spread north with Wisconsin glacial retreat. The extreme arctic environment imposes intense selection, resulting in the rapid appearance of local adaptations. Previously, Manning (1960) and Banfield (1961) concluded that Peary caribou had evolved in high arctic refugia and that arctic-island caribou were the results of invading barren-ground caribou interbreeding with Peary caribou on the southern Arctic Islands.

We tentatively define seven populations (herds) based mostly on calving distribution (Fig. 1) although the definitions are based on varying levels of information. The land areas used or ice/water bodies crossed by the populations provide the basis for their names. Seasonal abundance, calving distribution and track surveys were used to define populations on Banks, western Queen Elizabeth Islands and Prince of Wales and Somerset islands. Discrete distributions of satellite- and radio-collared caribou both during calving and rutting defined two populations on Victoria Island and two populations on Boothia Peninsula (one of which is a barren-ground caribou population). Population size and structure in the eastern Queen Elizabeth Islands is unknown.

Distribution and abundance

Peary caribou and arctic-island caribou occur on most Canadian Arctic Islands (except Baffin Island and its satellite islands, and islands in Foxe Basin and Hudson Bay). The seasonal and annual use of smaller islands may depend on densities of caribou population(s) on adjacent larger islands, seasonal migration patterns, and/or existing environmental conditions.

Historic accounts, Inuit knowledge, and aerial surveys since the 1960s, reveal fluctuations in caribou abundance, although the timing and intensity of those fluctuations vary between and among regions. Aerial surveys, which began as recently as the 1960s, were irregular in time and area covered, with variable levels of coverage. This hampers our ability to critically evaluate population estimates and identify trends in size (when available we report those population estimates as the mean ± one standard error and those estimates include calves except when indicated otherwise).

Western Queen Elizabeth Islands

The western Queen Elizabeth Islands include the major islands of Melville, Bathurst and Prince Patrick and their satellite islands (98 000 km^2). The all-time high was 24 363 caribou estimated in 1961 (Tener, 1963). The 1100 Peary caribou estimated there in 1997 (Gunn & Dragon, in prep.) is the lowest abundance recorded since 1974 when 2666 caribou were estimated (Miller, 1990b). Bathurst and its satellite islands have been surveyed most frequently and caribou numbers have gone through two declines and one recovery. In 1961, Tener (1963) estimated there were 3608 caribou within the Bathurst Island complex but the islands were not surveyed again until 1973 and in 1974 when Miller *et al.* (1977) estimated 797 ± 174 and 266 ± 150, respectively. Twenty years later in 1994 Miller (1997b) estimated 3037 caribou on Bathurst and its satellite islands but then the population collapsed and in 1997, Gunn & Dragon (in prep.) estimated 76 ± 25 caribou.

Eastern Queen Elizabeth Islands

The eastern Queen Elizabeth Islands (317 000 km^2) includes the major islands of Ellesmere, Devon, Axel Heiberg (which are 60% glaciers and high mountains) and the relatively low-lying islands of Ellef Ringnes, Amund Ringnes, Cornwall, Graham, King Christian and North Kent. The only essentially complete survey of these islands was in 1961, when Tener (1963) estimated 1482 caribou, but coverage was extremely low (<5%). Subsequently, three surveys have partially covered a few of these islands but survey areas, methods and timing varied considerably. Nonetheless, all of those surveys revealed low caribou densities (Riewe, 1973; Case & Ellsworth, 1991; Gauthier, 1996). In the 1970s, hunters from Grise Fiord reported a decline on southern Ellesmere Island (Riewe, 1973) but, during the mid 1990s, hunters report caribou returning to areas where they had formally been absent (S. Akeeagok, pers. comm.). In the 1990s, caribou surveys flown over northern Ellesmere Island have also revealed extremely low densities. Based on June and August aerial surveys in the mid 1990s, there may be only 50-100 Peary caribou (0.1-0.3 caribou per 100 km^{-2}) within the 37 775 km^2 Ellesmere Island National Park Reserve (R. Wissink, pers. comm.).

Banks Island

On Banks Island, elders reported few caribou in the 1950s, but increasing numbers during the 1960s (Nagy *et al*, in prep.). Results of eight island-wide surveys between 1972 and 1994 indicated a decline from 12 098 in 1972 (Urquhart, 1973) to 897 ± 151 in 1991 (Nagy *et al.,* 1996) and 558 ± 76 caribou in 1998 (J. Nagy, pers. comm.).

We believe that the clear statistical separation (P <0.05) between the estimated number of 1+ yr-old caribou on Banks Island in 1991 and 1992 vs. 1998 indicates a real decline in the size of the Banks Island caribou population between 1991 and 1998 (based on data obtained from Nagy *et al.,* 1996; J. Nagy, pers. comm.).

The 1994 estimate is neither significantly (P >0.05) lower than the 1991 and 1992 estimate, nor significantly higher (P>0.05) than the 1998 estimate (1991 and 1992, Nagy *et al.,* 1996; 1994, 709 ± 128 1+ yr-old caribou and 1998, 436 ± 71 1+ yr-old caribou, J. Nagy, pers. comm.). When the 1998 survey is compared to the pooled estimate for 1991-94, however, there is a significant separation (P<0.05) between the early 1990s and 1998 (equations derived for combining independent estimates from a single population: cf. Gasaway *et al.,* 1986). The nonsignificant gradient caused by the 1994 estimate tends to mask the decline in number of caribou on Banks Island. Alternatively, we regressed the four population estimates from 1991 to 1998 on year, weighting each estimate by the inverse of its variance to reflect the relative accuracy of the estimates. This analysis indicated a significant non-zero slope (P=0.026) of -77.9 animals per year. Thus, both methods indicate that the apparent continuing decline in the number of caribou on Banks Island between 1991 and 1998 is real.

Northwest Victoria Island

On northwest Victoria Island, elders reported few caribou in the 1950s, but increasing numbers during the 1960s and 1970s (Nagy *et al.,* in prep.). Surveys between 1980 and 1993 indicated a decline from 4500 in 1980 to 2600 in 1987, and 100 in 1993 (Gunn, in press). During a survey in June 1994, only four caribou were observed on northwest Victoria Island (Nishi & Buckland, unpubl. data). The most recent July 1998 survey estimate of 633 ± 81 (J. Nagy, pers comm.), may indicate that caribou on northwest Victoria Island have started to recover. However, this conclusion is uncertain because the estimate likely includes caribou from the Dolphin and Union herd as the two herds have adjacent summer ranges (Gunn & Fournier, in press). Therefore, it is tenuous to attribute the observed rate of increase entirely to births exceeding deaths. This is especially true as, even when we start with 100 caribou in 1993 or 1994 and assume no 1+ yr-old mortality, the required rate of annual increase (r) would far exceed the accepted maximum of 0.3 for the species (1993 to 1998, r = 0.446; and 1994 to 1998, r = 0.586). Only subsequent survey results and studies of marked caribou will shed light on this matter.

Dolphin and Union herd

Caribou abundance on southern and east-central Victotia Island (Dolphin and Union Herd) has fluctuated from high numbers in the early 1900s, to almost disappearing in the 1920s (Manning, 1960), and then increasing numbers during the 1970s and 1980s (Gunn, 1990). The first estimate was 7900 ± 1100 caribou in August 1980 (Jakimchuk & Carruthers, 1980), and a second estimate of 14 500 ± 1000 caribou was made in June 1994 (Nishi &

Buckland, unpubl. data) but neither survey covered the entire summer range. In October 1997, however, 27 800 ± 2400 caribou were estimated on their rutting area along the southern coast of Victoria Island (Nishi & Gunn, unpubl. data). Expansion of the winter range and resumption of a traditional migration (Gunn *et al*. 1997), together with recent survey data suggest that caribou have increased since 1980. However, the extent of hunting and accidental drownings during fall migration while the straits are freezing over are unknown but give rise to community concerns and reported annual rates of harvest are high in relation to the estimated population size.

Prince of Wales and Somerset Islands

The inter-island population of Prince of Wales and Somerset islands was considered to be relatively stable between 1974 and 1980 when 1+yr-old caribou were estimated to number 4540 in 1974, 3766 in 1975 and 5022 in 1980 (Fischer & Duncan, 1976; Gunn & Miller, 1983). By the late 1980s and early 1990s, hunters had reported seeing fewer caribou and more wolves on those two islands. A subsequent aerial survey in summer 1995 (Gunn & Dragon, 1998) confirmed that the caribou on those two islands had essentially disappeared. A follow-up survey in April-May 1996 confirmed the virtual absence of caribou in late winter (Miller, 1997a).

Boothia Peninsula

Inuit reported that caribou on Boothia Peninsula increased after the 1950s. Aerial surveys in 1985 and 1995 indicated that caribou numbers varied nonsignificantly from an estimated 4831 ± 543 in 1985 to 6658 ± 1728 1+yr-old caribou in 1995 (Gunn & Ashevak, 1990; Gunn & Dragon, 1998). However, interpretation of the estimates is confounded by the northward movement of barren-ground caribou onto the Boothia Peninsula (A. Gunn, unpubl. data). There are two calving areas on the northern Boothia Peninsula, one in the northwest used by arctic-island caribou and one in the northeast used by barren-ground caribou (A. Gunn, unpubl. data). The presence of both kinds of caribou on the Boothia Peninsula seriously complicates any evaluation of the status of arctic-island caribou on Boothia Peninsula.

Causes of declines

Information on factors causing declines is sparse because detection of declines must be after-the-fact and documentation of causes or contributing factors is often impossible and always too late. Diagnosis of the causes of declines has focused on the most conspicuous factors affecting caribou survival, *i.e.,* winter die-offs and hunting.

Winter weather

Most information on winter-die-offs is from the western Queen Elizabeth Islands. The climate is sufficiently severe that plants and herbivores are at the extreme edge of their range and weather has relatively intense effects. Caribou throughout that entire region experienced a ca. 50% decline over the 1973/74 winter-spring period and caribou within the Bathurst Island complex declined by *ca.* 68% (Miller *et al.,* 1977). Following the winter of 1996/97, Gunn & Dragon (in prep.) documented another major regional die-off throughout the western Queen Elizabeth Islands.

The most detailed information on the effects of severe winters is from the Bathurst Island complex where a 9-year project documented a series of favourable winters followed by a run of three severe winters (Miller, 1997b; Miller, 1998; Gunn & Dragon, in prep.). The 3037 caribou estimated on Bathurst and its satellite islands declined by *ca.* 30% in 1994/95. Widespread deep snow and icing from freezing rain in early winter and then springtime ground fast ice that restricted forage availability appears to be the sole cause of the decline. The following two severe winters caused further declines at the rates of 78% in 1995/96 and 83% in 1996/97. Overall, the estimated number of caribou within the Bathurst Island complex declined by 97% from summer 1994 to summer 1997. The time required for any recovery will be affected by at least three factors. The first is severe to near total losses of calf production and yearling recruitment in at least, 1995, 1996, and 1997. The second complication is the time lag in the numerical response of the associated wolf population. The third is the favourability of near future weather and the time interval to the next major die-off.

Since weather records began in the late 1940s, the heaviest total snowfalls in the western Queen Elizabeth Islands were in the three consecutive winters, 1994/95-1996/97 when high to extremely high rates of caribou deaths were recorded (Miller, 1997b; Miller, 1998; Gunn & Dragon, in prep.). Deep, hard-packed, windblown snow along with ice in the snow cover and ground fast ice either prevented the caribou from getting to the vegetation and/or forced them to expend too much energy in finding forage and, thus, the caribou died from extreme undernutrition (malnutrition).

The decline in Peary caribou on Bathurst Island is documented from changes in population estimates and counts of caribou carcasses. However, some hunters doubt the survey results because they encountered caribou in areas not typically used by the animals. Instead, they suggest that caribou moved away rather than died. Environmentally-forced movements occur as individual caribou seek forage elsewhere when snow and ice make foraging impossible or extremely difficult on their usual ranges (Miller, 1990a). Desperation movements are also known from hunter's reports for Banks Island caribou in the early 1950s (McEwen, 1955) and for Bathurst Island caribou in 1973-74, 1995 and 1996 (Miller *et al.,* 1977; Miller, 1998). At least for Bathurst Island, the proportion of caribou leaving Bathurst and its satellite islands is relatively small as the estimated number of carcasses explains most of the decline of estimated caribou numbers. Also satellite telemetry within the Bathurst Island complex (1993-97) showed that only one cow among six collared animals (5 cows and 1 bull) moved a relatively long distance beyond her known traditional range in response to apparent unfavourable range-wide forage unavailability - and all six animals died (Miller, 1998; Miller, unpubl. data).

The absence of any information on caribou die-offs in the eastern Queen Elizabeth Islands may be a lack of detection and reporting more than of fact. Also, at the extremely low densities that caribou occur at in the eastern Queen Elizabeth Islands, even proportionally large declines would still involve relatively few individuals in areas rarely travelled. A die-off could easily have gone undetected. Elsewhere, die-offs have been recorded for Banks Island during severe winters in the 1950s (McEwen, 1955; Manning & Macpherson, 1958), 1970s (Morrison, 1978) and 1980s (McLean & Fraser, 1992) and marked calf crop reductions in the early 1990s (J. Nagy, pers comm.). But the influence of those die-offs on population trend was indistinguishable from other factors, and the proportions that died, while significant, were not apparently as severe as recorded on the western Queen Elizabeth Islands.

Hunting

On the southern Arctic Islands, the influence of other factors confounds the effect of weather on population dynamics. Hunting was a factor in the declines for at least two populations on the southern Arctic Islands, especially, if not solely in the final stages of the declines (Nagy *et al.,* 1996; Gunn, in prep.). The harvest remained high while the populations declined on Banks and northwest Victoria islands. Therefore, while weather caused caribou die-offs in some years on Banks Island, the overall decline was accelerated and prolonged by hunting (and possibly predation in the later stages of the decline) on at least Banks and northwestern Victoria islands.

Caribou were hunted on Prince of Wales and Somerset islands up to and including the time when hunters reported finding only a few caribou. But the effect of hunting on the near disappearance of caribou is unknown as harvest levels are not available and the last two population estimates were 15 years apart. Prince of Wales Island and western Somerset Island are in the same climatic region as Bathurst Island. However, in summer 1995, we saw no carcasses which suggests that the caribou had disappeared before the 1994-95 severe winter.

There is no reason to believe that hunting has played an important role in the major die-offs of Peary caribou on the western Queen Elizabeth Islands. Although no die-offs are reported for caribou on the eastern Queen Elizabeth Islands, Riewe (1973) suggested that caribou had declined locally in the Grise Fiord area due to over-harvesting.

Wolf predation

Predation by wolves could accelerate caribou declines, especially in the final stages of those declines when caribou populations are small. Predation could also prevent or temporally retard recovery of remnant caribou populations. Essentially no information exists for wolves on the Canadian Arctic Islands especially on ptedation rates and prey selection. We do not know whether wolves select caribou relative to availability and or in preference to smaller or larger prey (arctic hares, *Lepus arcticus,* and muskoxen, *Ovibos moschatus: cf.* Potvin *et al.* (1988) regarding ungulate selection by size among mainland wolves).

Wolf survival on the Arctic Islands is undoubtedly strongly tied to ungulate prey populations - both caribou and muskoxen (Miller, 1995; Miller & Reintjes, 1995) but, regional diversity across the Arctic Islands should introduce caution into extrapolating predation rates and wolf diet between or among regions. On islands where muskoxen are more abundant than caribou (e.g., Ellesmere), or areas where caribou are absent (e.g., North and East Greenland, Marquard-Petersen, 1998), muskoxen are the major prey item in the wolf's diet. Field examination of wolf scats within the Bathurst Island complex where caribou were relatively abundant to muskoxen and where both species recently have experienced major die-offs suggests that caribou and muskoxen were utilized in proportion to their availability, particularly when fed on as carrion (F. L. Miller, pers. observ.; A. Gunn & F. L. Miller, pers. observ.). It is apparent that wolves occur and den on some western Queen Elizabeth Islands where only caribou were abundant enough to support wolves year-round (e.g., Cameron Island: F. L. Miller, pers. observ.). Incidental observations between 1968 and 1978 on Bathurst Island, where both caribou and muskoxen occur showed that wolves routinely kill caribou and a single wolf had no problem killing an adult caribou or muskoxen. D. Gray (unpubl. data) described three successful attacks including a single wolf killing a cow; three unsuccessful attacks and five suspected wolf kills, all in an area where muskoxen far outnumbet caribou.

Densities and distributions of arctic hares are higher and more continuous on the mountainous eastern Queen Elizabeth Islands than on the western Queen Elizabeth Islands (F. L. Miller, pers. observ.). Also, arctic hare populations periodically experience lows and cyclic-like 'crashes,' so they are undependable in all years, even as secondary prey. With declines in both caribou and muskoxen, wolf predation will become more important in the dynamics of those local ungulate populations.

Interspecific and intraspecific competition for forage

Fluctuating abundance of herbivores often raises the questions of whether and how interspecific and intraspecific competition for forage influence population trends. Interspecific competition, usually with muskoxen, has often been implied but not demonstrated as having a role in affecting a caribou decline or preventing their recovery. Although caribou declines on Banks, northwest Victoria, Prince of Wales and Somerset islands coincided with increases in muskox numbers, caribou increases and decreases on the western Queen Elizabeth Islands and southern Victoria Island changed in synchrony with muskox numbers.

Much of the concern about caribou and muskox relationships originated from Banks Island in the early 1970s where the high coverage of herbaceous tundra and rolling terrain is particularly favourable muskox habitat. Muskoxen on Banks Island rapidly increased between 1973 and 1994 and muskoxen outnumbered caribou on average by about 44 to 1 in 1992 and about 80 to 1 in 1994 (extrapolated from Nagy *et al.,* 1996). The most recent aerial survey in July 1998 indicates that muskoxen on Banks Island have declined (J. Nagy, pers. comm.), however, the mean ratio of muskoxen to caribou has actually widened to about 101 to 1.

Although diet and habitat use is mostly dissimilar between caribou and muskoxen (e.g., Kevan, 1974; Parker & Ross, 1976; Wilkinson *et al.,* 1976; Miller *et al.,* 1977; Parker, 1978; Thomas & Edmonds, 1984), recent work by Larter & Nagy (1997) shows that both ungulates consume willow (*Salix* spp.) and legumes. Thus, under high muskox densities or difficult foraging conditions (i.e., deep snow and/or widespread icing), relationships may change and diet or habitat use could overlap.

Our ability to interpret interspecific relationships is hampered by a basic lack of understanding on relationships between summer weather, plant growth and how the herbivores themselves interact with their forage. However, some information suggests that, at least for muskoxen, the relationship between grazing and plant growth depends on the plant species as well as grazing intensity (Raillard, 1992; Mulder & Harmsen, 1995; Smith, 1996). Almost nothing is known about the functional or numerical relationships between caribou and their forage let alone the effects of caribou on their forage.

Winter survival depends partly on winter foraging but is strongly influenced by the fat and protein reserves accumulated during the previous summer (Adamczewski *et al.,* 1993). We, however, know little about the extent to which caribou can compensate during the summer following nutritional stress during the previous winter although compensatory growth is recorded for other cervids (e.g., Suttie & Webster, 1995). Pregnancy rates depend on cows attaining sufficient body reserves by the end of autumn, which is influenced by the quality and quantity of summer food (Thomas, 1982).

Quantitative information on range conditions before, during and after population declines is fragmentary but it is bolstered by empirical observations. Studies are underway on Bathurst and Banks islands but they occur after-the-fact of significant caribou declines. In summer 1961, when Peary caribou numbers were high on the western Queen Elizabeth Islands, initial calf production and early calf survival was high. In summer 1973, before the 1973/74 winter die-off, calf production and early survival was also moderately good on the western Queen Elizabeth Islands. Most recently, in the Bathurst Island complex, annual survival of 1+ yr-old caribou, initial calf production and early calf survival were all high in the year preceding the 1994/95-1996/97 winter-spring die-offs. Those favourable population dynamics for both Peary caribou and muskoxen immediately prior to the major die-offs of both species adds further support to our position that range deterioration or destruction (quality and/or quantity) did not cause or contribute to those declines.

The conspicuous factors of winter-die-offs and hunting may mask or interact with other factors. A diagnosis of a factor causing a decline is supported, but not confirmed, when amelioration or reversal of that factor is followed by recovery. However, to assume that the factors causing a decline and recovery are necessarily symmetrical is simplistic. Ecological influences on populations are rarely simple and can change over time (Holmes, 1995) and we acknowledge possible incompleteness in out diagnosis of factors causing declines for some geographic areas. We note, for example, that although there is no current evidence for the effect of parasites such as gastro-intestinal nematodes, they are prevalent in the Dolphin and Union herd which is the only population examined for parasites (Gunn *et al.,* 1991) and the nematodes depress appetite in Svalbard reindeer (Arneberg *et al.,* 1996).

Management and recovery

Peary caribou and arctic-island caribou are currently the management responsibility of the Government of the Northwest Territories which will divide in April 1999 into Nunavut and the Northwest Territories. In Nunavut, the government will have ultimate responsibility for wildlife management while the Nunavut Wildlife Management Board has responsibility for co-management, access to wildlife and ensuring that Inuit are effectively involved in wildlife management. On the western Arctic Islands, the Inuvialuit Game Council has responsibility for co-management together with the Northwest Territorial Government, which has ultimate responsibility.

Recovery actions will require the support of local people, especially from those whose lives are directly affected, and that support will not be forthcoming without their involvement in recovery planning. To this end, information on population status and factors affecting caribou have been presented and discussed at community meetings. Also, the Conservation Breeding Specialist Group (SSG/IUCN) facilitated a workshop in March 1998 to bring together co-management boards, community representatives and biologists to exchange views on the declines and recovery of caribou (Gunn *et al.,* 1998). More consultation is planned to draft implementation plans which will be part of the National Recovery Sttategy produced by the Recovery of Nationally Endangered Wildlife, Peary caribou and arctic-island Caribou Recovery Team.

The national recovery strategy's goal is to prevent extinctions and to maintain and enhance populations of Peary caribou and arctic-island caribou. The choice of activities is relatively limited as the effect of weather cannot be ameliorated, and it is not feasible on a range-wide basis to offset forage unavailability by supplementary feeding (e.g, Miller & Reintjes, 1993). The most immediate and manageable recovery prescription is to reduce caribou death. The first action is to reduce hunting and ensure that alternate caribou sources are available as replacement meat.

Recovery actions have started with hunters taking voluntary measures to restrict their hunting. On Bathurst Island, in 1975, Inuit banned caribou hunting after the 1973-74 winter die-off (Freeman, 1975). In 1989, hunting for up to 25 bulls was allowed but halted in 1996 after the die-off in 1995/96. On Ellesmere Island, Inuit from Grise Fiord halted caribou hunting near their community for 10 years from 1975 to 1985 (Ferguson, 1987). More recently on Banks Island, in 1991, the Hunters' and Trappers' Committee of Sachs Harbour established an annual quota of 30 male caribou which was increased in 1992 to 36. In 1993, the Olokhaktomiut Hunters' and Trappers' Committee (Holman) agreed not to hunt caribou from northwest Victoria Island. The Government of the Northwest Territories has assisted communities in acquiring caribou from other areas as replacement meat and has increased muskox quotas to encourage the use of readily assessable muskox populations.

If declines continue, and wolf predation has been demonstrated to be a factor, then the next action to further reduce caribou deaths could be to decrease predation. There is justification for acting without additional information, as a satisfactory level of detection is unlikely and remnant caribou populations likely would perish before evidence is obtained and corrective action is taken (whether there is an adequate number of muskoxen to support the wolves or whether there is not). If wolf removal by translocating or hunting wolves were to be undertaken, wolves would be reduced only on those islands designated as having priority for caribou conservation. The high arctic wolf (*C. l. arctos*) warrants protection at the regional level outside of 'caribou priority areas' to help assure its persistence in the Canadian High Arctic.

Longer-term recovery actions relate to habitat and ensuring that caribou have sufficient forage. If competition with muskoxen is demonstrated to cause caribou declines or impede recoveries, accelerated muskox harvesting is an option. Habitat protection through land use regulations up to protected areas including national parks will also add a degree of security to the persistence of caribou.

Caribou as a cold desert herbivore may have similar population dynamics to a hot desert herbivore, the red kangaroo (*Macropus rufus*) whose long-term aperiodic fluctuations in population size are a mathematical consequence of unpredictable short-term fluctuations in weather (Caughley & Gunn, 1993). Increasing and decreasing trends are intrinsic to the system and do not necessarily reflect special and persistent causes. If this is the case for Peary and arctic-island caribou, then long-term management would need to ensure that hunting does not amplify natural fluctuations. That is, in the absence of human-caused climate change which cause extremes beyond those experienced by natural variation in the weather. In particular, populations that have reached a low level would not be hunted or hunted at a low rate until recovery was well established.

If, however, global warming (whether a natural or human-caused change) is both possible and likely, it will influence the magnitude of and interactions between or among factors influencing caribou numbers (for example, warmer, wetter summers may increase parasite infectivity). Weather trends in the western and central Arctic are toward warmer temperatures and heavier snowfall, which are consistent with predictions for global warming (Houghton *et al.*, 1995; Maxwell, 1997).

Increased severity of winters and frequency of deep, hard-packed, windblown snow and/or heavy icing conditions is an obvious starting point for the likelihood of a cascade of changes as plants, caribou and other herbivores adjust. Those changes will be felt most on the edges of caribou distribution and where the effects of global warming are predicted to be the strongest - the western Arctic (Maxwell, 1997). Global climate change could impose some symmetry on population changes which is why we find the declines of three of the five western and central populations during the 1980s and 1990s a cause for concern. The near disappearance of caribou from Prince of Wales and Somerset islands is a strong reminder against complacency.

We suggest that Peary caribou and arctic-island caribou will be vulnerable to any persistent perturbations in their ecology. The declines of the Banks Island population and the northwest Victoria Island population, even if cessation of hunting initiates some recovery, leaves those two populations relatively small and thus vulnerable to extreme environmental changes and/or predation. The effect of environmental severity is the most marked on the western Queen Elizabeth Islands and those caribou are now at a historic low. The populations on central Victoria Island and on the Boothia Peninsula are still numbered in the thousands and may be stable or possibly increasing. The abundance of Peary caribou in the eastern Queen Elizabeth Islands is unknown and we suspect it to be relatively low given the climate and terrain.

Management of endangered and threatened caribou populations on Canada's Arctic Islands requires implementation of recovery actions despite gaps in our knowledge and uncertainties in diagnoses of declines. Given reduced abundance of caribou in the northwestern and western climatic regions, if population declines continue or even if their status is unknown, we must seriously weigh the risks of inaction. Although predictions for ecological responses to a changing climate are hedged with uncertainties and we caution against making generalities among populations, we suggest that precautionary actions such as translocation of caribou within the Arctic Islands or captive breeding be considered as potential recovery actions

- these actions require considerable public consultation.

Precautionary approaches have been recommended for management of the high-latitude marine mammal ecosystem (Tynan & Demaster, 1997). The argument for the precautionary approach is strengthened for the terrestrial ecosystem by the possibility that environmental changes are underway, and by the time we have determined how wildlife populations will respond, they will already be doing so. The changes will likely exceed anything experienced over the last 400 years and thus, the past will be an insecure guide to the future.

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