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A Near-Total Decline in Caribou on Prince of Wales, Somerset, and Russell Islands, Canadian Arctic

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ABSTRACT. The number of caribou (*Rangifer tarandus*) on Prince of Wales, Somerset, and Russell islands in the south-central Canadian Arctic declined by 98% in 15 years, from an estimated 6048 (16% calves) in 1980 to an estimated 100 (0% calves) in 1995. Those estimates were obtained by systematic aerial surveys that used the same design and methods and comparable survey coverage. We do not have the data needed to determine the rate of decrease between 1980 and 1995 or its possible causes. There is no evidence for large-scale winter mortality in any one year or few consecutive years. A probable explanation for the decline is consequential reductions in long-term survival rates, both of breeding females and of calves in their first year of life, associated with continued caribou harvesting and markedly increased wolf (*Canis lupus*) predation on the dwindling number of caribou through the 1980s and early 1990s. The delay in detecting the decline and the lack of understanding of its causes will handicap the development of an ecologically sound recovery plan. As previous caribou declines have been followed by recovery, some comfort may be drawn from the likelihood of unaided recovery. However, the number of caribou has declined to the point where recovery will be tenuous and lengthy, at best. Unaided recovery could easily fail to occur, so we should not be complacent, especially as extirpation of these few remaining caribou would remove a distinct genetic group and reduce the biodiversity of caribou on Canada's Arctic Islands.

Key words: biodiversity, Canada, conservation, decline, endangered, population size, *Rangifer tarandus*, recovery actions

RÉSUMÉ. Le nombre de caribous (*Rangifer tarandus*) se trouvant sur les îles Prince of Wales, Somerset et Russell, dans le centre-sud de l'Arctique canadien, a chuté de 98 % en 15 ans, passant d'un nombre estimé à 6 048 (dont 16 % étaient des veaux) en 1980 à un nombre estimé à 100 (dont aucun veau) en 1995. Ces estimations ont été obtenues au moyen de relevés aériens systématiques recourant aux mêmes définitions, aux mêmes méthodes et à des aires de relevés comparables. On ne possède pas les données nécessaires pour déterminer le taux de diminution entre 1980 et 1995 ou les causes possibles de cette diminution. Par ailleurs, rien n'indique qu'un taux de mortalité hivernal élevé a été enregistré pendant une année quelconque ou pendant quelques années de suite. Il se peut que le déclin du nombre de caribous enregistré dans les années 1980 et au début des années 1990 soit attribuable aux réductions correspondantes des taux de survie à long terme chez les femelles de reproduction et les veaux pendant leur première année de vie, le tout jumelé au prélèvement continuel des caribous ainsi qu'à la prédation grandement accrue des caribous par les loups (*Canis lupus*). Le retard à détecter ce déclin et le manque de compréhension de ses causes pourront nuire à l'élaboration d'un plan de récupération solide du point de vue écologique. Puisque les déclins précédents de caribous ont été suivis de récupération, on peut se consoler en se disant qu'il est possible que la récupération se fasse spontanément. Cependant, le nombre de caribous a chuté au point où la récupération sera longue et difficile, même dans le meilleur des cas. Il se peut qu'il n'y ait pas de récupération spontanée et par conséquent, on ne devrait pas se contenter de cette situation, surtout puisque l'extirpation des quelques caribous qui restent pourrait éliminer un groupe génétique distinct et réduire la biodiversité du caribou dans l'archipel Arctique canadien.

Mots clés : biodiversité, Canada, conservation, déclin, en voie de disparition, taille de la population, *Rangifer tarandus*, mesures de récupération

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INTRODUCTION

In theory, once a decline that could threaten a wildlife population's "persistence" has been detected, the cause should be identified in time to take action to reverse the decline and allow the population to recover. In practice, however, wildlife conservation is rarely that straightforward. The most difficult situation occurs when a decline is detected only after

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it has reduced the population to the point where recovery efforts are difficult or unlikely, and the cause of that decline is uncertain. In the Arctic, the high cost of aircraft charter and support means that wildlife monitoring is usually sporadic and infrequent. Consequently, a decline in wildlife abundance is not always easy to detect, and when it is detected, it is usually well after the fact.

Recovery efforts are more likely to be successful when we understand the factors involved and how they might have interacted to cause the decline. Delays in detecting a decline reduce the probability that we can determine the initial cause or causes or even the ultimate cause of the decline with a high level of confidence. Further difficulties can arise when there are differences of opinion about the degree of the decline and the possible causes. Differences of opinion between the Inuit and people of other cultures are not uncommon in the Arctic, given that their knowledge has been acquired over different geographic scales and time periods.

In this paper, we report the almost total loss of a major population of caribou (*Rangifer tarandus*) found on three islands in the south-central Canadian Arctic Archipelago: Prince of Wales, Somerset, and Russell islands. Excluding the Baffin Island region, where there are barren-ground caribou, *R. t. groenlandicus*, caribou on the Canadian Arctic islands occur in five regional groupings, delineated geographically by their known seasonal and annual distributions and by their known and perceived genetic and taxonomic relationships. Each of the five groupings is termed a "geographic population," as defined in Miller and Gunn (2003b).

In 1991, the national Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listed caribou on the Queen Elizabeth Islands and Banks Island as "Endangered" and the other caribou on the archipelago (excluding the Baffin Island region) as "Threatened" (COSEWIC, 1991). In doing so, COSEWIC (1991) followed the existing taxonomy in referring to what are actually geographic populations of caribou under the umbrella classification of Peary caribou (*R. t. pearyi*). That taxonomic classification, based on a relatively small and geographically limited sample, has not been revised with a larger and more representative sample since Banfield's (1961) revision of the genus *Rangifer*. Subsequent morphometric data (Thomas and Everson, 1982) and microsatellite DNA data (Zittlau, 2004) suggest a relatively high degree of diversity among those caribou. Thus, the loss of even one distinct segment of a geographic population would reduce the biodiversity of caribou on the Arctic Islands, and the loss of an entire geographic population would reduce it even more.

Causes of the various caribou declines throughout the Canadian Arctic Archipelago differ regionally. On the western Queen Elizabeth Islands, sporadic severe winters with reduced forage availability caused annual winter and spring die-offs in the early 1970s and in the mid 1990s (Miller et al., 1977; Miller, 1998; Gunn and Dragon, 2002; Miller and Gunn, 2003a, b). On Banks Island and northwestern Victoria Island, although diagnosis is hindered by incomplete information, several factors likely interacted to cause the declines. Hunting and wolf (*Canis lupus*) predation contributed to the declines in the 1980s and the 1990s (Nagy et al., 1996). However, forage unavailability caused by unfavorable snow and ice conditions was implicated in some years in the 1970s and 1980s (Gunn et al., 2000b).

At the time of the 1991 COSEWIC assessment, the caribou on Prince of Wales, Somerset, and Russell islands were considered one of the two largest populations on the basis of a 1980 aerial survey that had estimated 6048 caribou there (Gunn and Decker, 1984). The only potential threat identified in the COSEWIC assessment was possible high levels of hunting. Then in the late 1980s and early 1990s, Inuit hunters from Resolute Bay, Cornwallis Island (Fig. 1: the airport is Resolute, and the settlement is called Resolute Bay or Qausuittuq), reported increasing difficulty in finding caribou on these three islands. In response to the hunters' concerns, Gunn and Dragon (1998) surveyed caribou and muskoxen (*Ovibos moschatus*) on Prince of Wales, Somerset, and Russell islands during summer 1995 and saw only seven caribou. Then, during an extensive unsystematic helicopter survey of Prince of Wales, Somerset, and Russell islands in late April–early May 1996, Miller (1997) saw only two caribou.

The Prince of Wales, Somerset, and Russell islands–Boothia Peninsula complex was first covered by aerial surveys during the 1970s baseline inventory for the Polar Gas Project (Fischer and Duncan, 1976; Thompson and Fischer, 1980). In this paper, we use the data from the systematic aerial surveys of caribou on Prince of Wales, Somerset, and Russell islands to summarize changes in caribou numbers from 1974 to 1995. The present paper has three purposes: (1) to review evidence from the aerial surveys for changes in caribou abundance on those three islands at the end of the 20th century; (2) to consider the evidence supporting several plausible causes for the observed near-total loss of caribou on those three islands; and (3) to explore implications of changes in abundance in the context of actions to aid caribou recovery.

MATERIALS AND METHODS

Prince of Wales Island (33 339 km^2) and Somerset Island (24 786 km^2) are two of the larger Arctic Islands, and together with Russell Island (940 km^2) and other smaller satellite islands, they have a collective landmass of about 60 000 km^2. The islands are within the Northern Arctic Ecozone, characterized by plains and hills and herb-lichen Arctic tundra. Russell et al. (1978) mapped the plant communities used by both caribou and muskoxen on eastern Prince of Wales and western Somerset islands. The caribou seasonal ranges tended to be within the drier communities with sparse plant cover dominated by dwarf

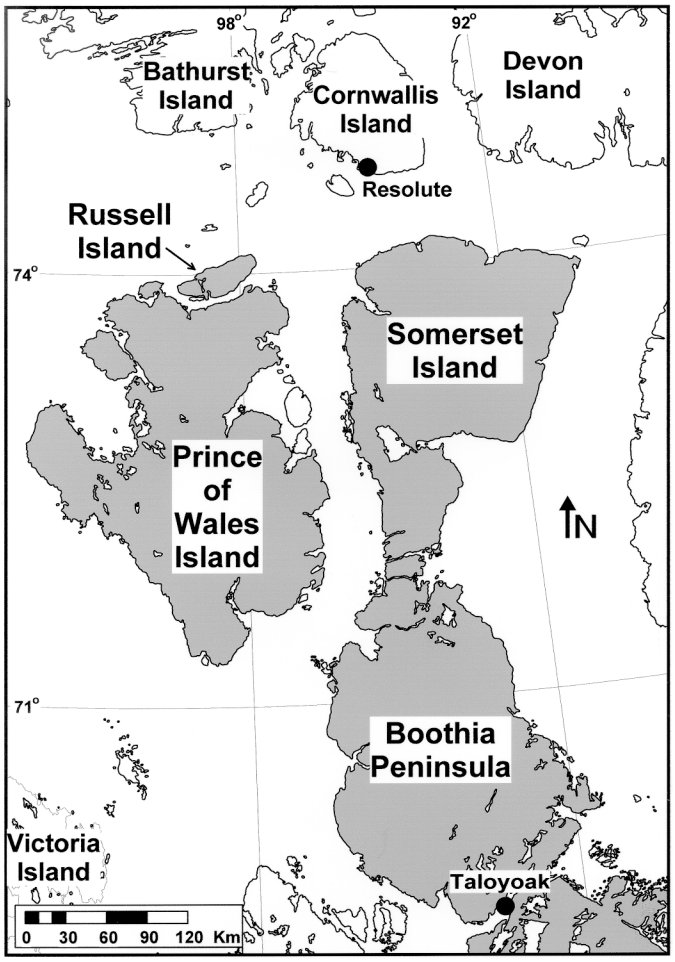

FIG. 1. Study area, Prince of Wales, Somerset, and Russell islands in the south-central Arctic archipelago and the mainland Boothia Peninsula, Nunavut, Canada.

cushion shrubs (*Saxifraga oppositifolia*, *Dryas integrifolia*, *Cassiope tetragona*, and the sedge *Carex ruprestris*). Foliose and fructose lichens contribute only a small percentage to the plant cover. Muskox seasonal ranges were on moist to wet sites with over 50% plant cover dominated by sedges, grasses, rushes, and arctic willow (*Salix arctica*).

The nearest weather station is at Resolute Airport on Cornwallis Island (Fig. 1). Maxwell (1981) included Prince of Wales, Russell, and western Somerset islands within the Northwestern Climatic Region and eastern Somerset Island within the South-Central Climatic Region. The difference is likely important in terms of caribou ecology, as the South-Central Climatic Region has stronger cyclonic activity with intrusions of more moist maritime air (Maxwell, 1981). Even though western Somerset Island is in the Northwestern Climatic Region, it is influenced by the moist maritime air that dominates the South-Central Climatic Region, which results in markedly greater total snowfall on Somerset Island than on Prince of Wales Island (Maxwell, 1980; Miller et al., 1982). The plant-growing season is brief and highly variable in duration. For Truelove Lowlands, Devon Island, in 1970–72, Svoboda (1977) reports a range of 45 to 80 days for the time from snowmelt to mean temperature below freezing. At Resolute during the same years, the number of days with mean daily temperatures above 0°C ranged from 46 to 72 (data from Environment Canada Climate Archives).

Our evaluations of caribou are based on information from aerial surveys, information from Inuit hunters, and pertinent literature in journals and agency reports, including satellite telemetry findings (Manning and Macpherson, 1961; Fischer and Duncan, 1976; G. Eckalook, pers. comm. 1978; Miller and Gunn, 1978, 1980; Thompson and Fischer, 1980; Miller et al., 1982; Thomas and Everson, 1982; Gunn and Decker, 1984; D. Tucktoo, pers. comm. 1986; Miller, 1990, 1997; Gunn and Dragon, 1998; Gunn et al., 2000a, b).

Aerial survey results and observations of caribou crossing trails on the sea ice indicated that many of the caribou that calved and summered on Prince of Wales and Russell islands migrated annually to winter ranges on Somerset Island and Boothia Peninsula (Miller and Gunn, 1978, 1980; Thompson and Fischer, 1980; Miller et al., 1982, 2005b). Those caribou that calved and summered on Prince of Wales Island, Somerset Island, or Russell Island and wintered on Boothia Peninsula returned to their island calving areas and summer ranges each year; therefore, the caribou on those three islands in summertime represented the entire geographic population under consideration.

In 1980 and 1995, estimates for all caribou on Prince of Wales, Somerset, and Russell islands were obtained by systematic fixed-width transect aerial survey. The width of the transect strip was 1.6 km. The 0.8 km strip visible on each side of the aircraft flight path began just beyond the "blind spot" strip immediately beneath the survey plane, which would be ca. 150 m wide at 150 m above ground level (agl). The survey transects were systematically flown to sample the entire land area on each island. In 1995, on the basis of the 1980 results, Prince of Wales Island was divided into four survey strata, rather than just two strata as in 1980. The four survey strata on Somerset Island and the one survey stratum on Russell Island were kept as in 1980. In 1980, survey coverage was 31% (St-I) and 18% (St-II) on Prince of Wales Island; 34% (St-II), 33% (St-IV), 19% (St-III), and 9% (St-I) on Somerset Island; and 34% on Russell Island (Gunn and Decker, 1984). In 1995, survey coverage was 20% on St I–IV on Prince of Wales Island; 35% (St-II), 32% (St-IV), 25% (St-III) and 8% (St-I) on Somerset Island; and 20% on Russell Island (Gunn and Dragon, 1998). Weather conditions were favourable for seeing caribou in both years.

We used the same high-winged, single-engine, fixed-wing Helio-Courier on tundra tires in both 1980 and 1995. The aircraft was flown at a conventional altitude and speed for caribou surveys: i.e., ca. 150 m agl at 160 km per hour. Both the pilot and one of the observers from the 1980 survey also participated in the 1995 survey. The other observer in 1995 was an Inuit hunter from Resolute Bay who was highly familiar with the distribution of caribou within the survey area.

The aerial surveys in the summers of 1974 and 1975 were systematic transect surveys with a 1.6 km transect width, flown at 90 or 150 m agl with airspeeds of 150–220 km per hour. Coverage varied between 9% and 25% (Thompson and Fischer, 1980).

An unsystematic helicopter survey in late winter (April-May) 1996, flown at 30–50 m agl with airspeed of 140–160 km per hour, covered the coastal areas of Somerset and Prince of Wales, as well as northern Prince of Wales and Russell islands, where observations in previous years and information from Inuit indicated caribou or their sign would most likely be found (Miller, 1997). A total of 35 hours were flown over land and 5.3 hours over sea ice under the ideal viewing condition of sunshine on a daily fresh snow background, which increases the visibility of caribou and their trails and feeding craters.

Inuit hunters from Resolute Bay and Taloyoak hunt caribou on Prince of Wales, Somerset, and Russell islands. We did not systematically interview the hunters; however, one of us (A. Buchan) grew up in Taloyoak and knows the area and the hunters. Meetings about the caribou decline included a 1998 IUCN–The World Conservation Union Population and Habitat Workshop (Gunn et al., 1998) where a cross section of people with vested interests in caribou conservation on the Canadian Arctic Islands met to discuss declines and possible recovery actions.

RESULTS AND DISCUSSION

In the summers of 1974, 1975, and 1980, caribou were distributed unevenly among Prince of Wales, Somerset, and Russell islands, both in absolute numbers and in proportion to the land area of each island (Fig. 2A, B). The estimates obtained by systematic aerial survey for all caribou on Prince of Wales, Somerset, and Russell islands were 5682 in 1974, 4830 in 1975, and 6048 in 1980 (Table 1: Fischer and Duncan, 1976; Gunn and Decker, 1984). No variance estimates were made for the 1974 and 1975 estimates of caribou numbers either on each island or on all three islands combined, and this prevents us from statistically comparing any change among 1974, 1975, and 1980. Although the 1974 and 1975 aerial surveys were systematic transect surveys, they are not fully comparable to the 1980 survey in design or effort. Despite these limitations, Gunn and Miller (1983:154) concluded that in 1980 the collective number of caribou on Prince of Wales, Somerset, and Russell islands "was relatively stable in the recent past." By 1995, the caribou numbers had changed drastically.

In 1995, Gunn and Dragon (1998) saw only two bull caribou on transect, both on Prince of Wales Island—too low a count from which to calculate a reliable estimate. However, we use a value of "100" in Table 1 to illustrate the magnitude of the change from 1980 to 1995, and because we realize some few caribou were missed. The 95% CL for the 1980 estimate of 1+-yr-old caribou (1 yr old or older) is ca. 28%

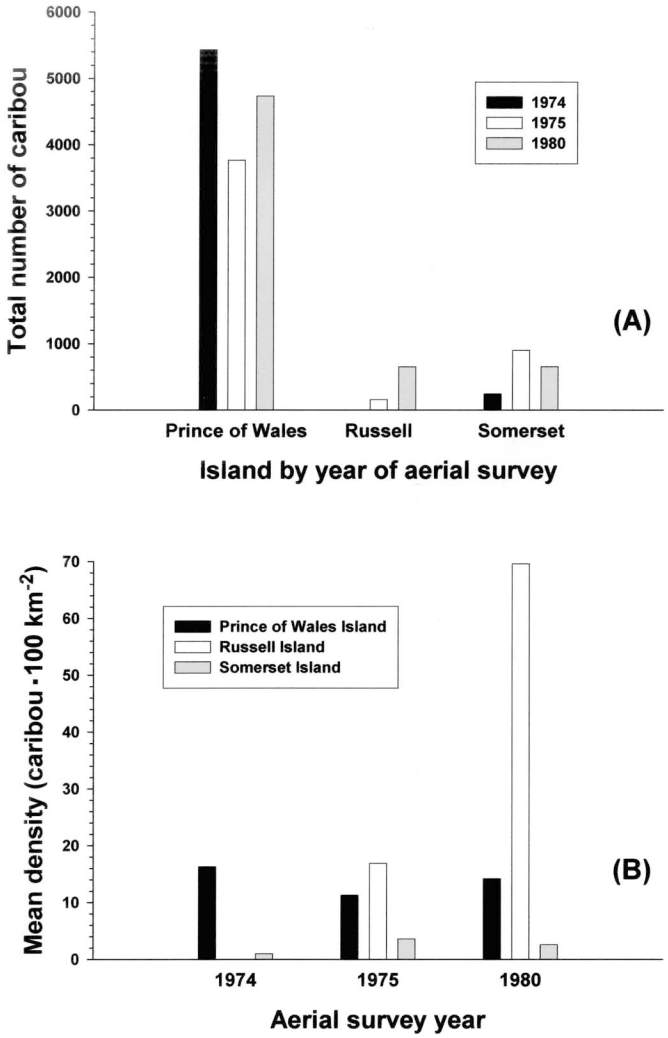

FIG. 2. Caribou estimated by aerial survey on Prince of Wales, Somerset, and Russell islands, Nunavut, Canada: (A) total number (1+-yr-old caribou plus calves); and (B) mean density (caribou • 100 km^{-2}).

(n = 1420 animals, 95% CI = 3677–6517 caribou). Therefore, we conclude that there were about 98% fewer caribou on Prince of Wales, Somerset, and Russell islands in 1995 than in 1980. In 1980, we saw a few caribou carcasses, including an assumed wolf kill, but in 1995, we saw no carcasses (skeletal remains or hair patches, which can be easily seen for two to three years) to suggest any recent mortality, let alone a die-off. Our experience is that after two or three years, scavengers have disarticulated most caribou skeletons and scattered the weathered remains, making them relatively inconspicuous.

Speculation about the Caribou Decline from 1980 to 1995

Some hunters from Resolute Bay have expressed disbelief in the survey results for Prince of Wales, Somerset, and Russell islands (A. Idlout, I. Kalluk, pers. comm. 1996). Disbelief among hunters over aerial survey techniques and results is not an uncommon response to aerial surveys, especially if the surveys report declines, and such

TABLE 1. A comparison of statistics for caribou on Prince of Wales, Somerset, and Russell islands, Nunavut, Canada, obtained by systematic aerial survey.

Survey Year	Total number of caribou seen on survey	Number of caribou seen on transect	Estimated number of 1+-yr-old caribou	% change in number of 1+-yr-olds from 1974	Estimated % of newborn calves	Estimated number of calves	% change in number of calves from 1974
1974[1]	847	507	4540	–	20	1142	–
1975[1]	1036	513	3741	-18	23	1089	-5
1980[2]	1859	1523	5097	+12	16	951	-7
1995[3]	7	2	100[4]	-98	0	0	-100

[1] Data were extracted from Fischer and Duncan (1976). Values for estimates of 1+-yr-old caribou were taken from Table 11 (and the 159 total caribou in Table 9 for Russell Island in 1975 was reduced by 16% to equal 134 1+-yr-old caribou). Numbers of calves were obtained by subtracting Table 11 values from estimates of total caribou in Tables 9, 10, and 12. We then divided those values by the total caribou estimates to yield percentages of calves.

[2] Data were taken from Gunn and Decker (1984): 1523 caribou on transect equals 1288 1+-yr-old caribou plus 235 calves; therefore, the percentage and number of calves in 1980 (15.7% and 951 calves) are estimated values, while the extrapolated values are 15.4% and 930 calves.

[3] Data were taken from Gunn and Dragon (1998).

[4] No estimate was made in 1995. The value of 100 caribou is given here only to illustrate the magnitude of the decline and our realization that a small number (≤ 100) of caribou present was not detected.

disbelief is not restricted to the Arctic. For example, Freddy et al. (2004) describe a dispute between wildlife managers and sportsmen over survey results for mule deer (*Odocoileus hemionus*) in Colorado. In the Arctic, the reasons are complex, reflecting Inuit knowledge of and beliefs about fluctuations in caribou numbers and range use over decades, as well as mistrust of and disbelief in government and science. Breakdown of trust between people who depend on wildlife and science-trained managers is not uncommon, and the solutions are tied to short- and long-term changes in communication and attitudes on both sides of a dispute (Weeks and Packard, 1997).

In the case of our 1995 survey, to the best of our knowledge (based on two hours of discussion between F.L. Miller and two hunters from Resolute Bay in 1996) the specific criticism comes from a chance event: that is, the survey crew missed seeing five live caribou that were near some hunters who were cutting up caribou on Somerset Island when the survey plane flew over them. As soon as the survey crew saw the hunters, they turned the aircraft away to minimize any disruption of the hunting activities. Unfortunately, although the hunters and the dead caribou were seen, the five live caribou were not, as they apparently were hidden in the "blind spot" underneath the survey aircraft. This "blind spot" under the aircraft is not included in the survey-transect width and thus does not influence the estimate, which is based only on the number of animals seen on transect within the strip width.

The important point is the magnitude of the difference in the results from the 1980 and the 1995 aerial surveys. A total of 1859 caribou were seen during the 1980 survey (1523 on transect and 336 off transect), compared to seven caribou in 1995 (two on transect and five off transect). Although observers on aerial surveys inevitably miss some animals, the 1980 and 1995 survey techniques were sufficiently similar that the observers (an Inuit hunter, an experienced survey biologist, and an experienced survey pilot) could not have missed so many caribou or even any meaningful fraction of them in the 1995 survey.

Our estimates of caribou numbers were derived from sightings during aerial surveys of standardized design that employed procedures used previously (Fischer and Duncan, 1976; Thompson and Fischer, 1980; Gunn and Decker, 1984). The aerial coverage was systematic across the three islands and covered the known annual ranges. We know of no factual basis for believing the 1995 aerial survey did not yield an accurate approximation of the low number of caribou left on Prince of Wales, Somerset, and Russell islands in summer 1995. Also, there is no evidence that the 1995 aerial survey was meaningfully less accurate or less precise than any other such survey of caribou on the Canadian Arctic Archipelago.

The scarcity of caribou on Prince of Wales, Somerset, and Russell islands was supported by hunters' reports (A. Idlout, pers comm. 1996). In 1995, Inuit at the Creswell Bay outpost camp who spoke with the senior author reported seeing fewer caribou each summer and none in 1995. The virtual absence of caribou or their sign observed on the 1996 survey during the snow-covered period (only two caribou were seen, and both were bulls on Somerset Island; Miller, 1997), when taken together with the results for summer 1995, is strong evidence for the near-absence of caribou on Prince of Wales, Somerset, and Russell islands year-round in 1995–96. The caribou did persist for a few years, as A. Idlout (pers. comm. to F. Miller, 2000) reported seeing at least 12 caribou and tracks of several other groups on northern Somerset Island in 1999. However, in April-May 2004, Inuit hunters from Resolute Bay, using snow machines combined with a helicopter survey, could not find a single caribou or any sign of caribou on

Prince of Wales Island or on Somerset Island (M. Taylor, Government of Nunavut, pers. comm. 2004).

Reasons for the Caribou Decline between 1980 and 1995

Inuit hunters did not report difficulties in obtaining caribou on Prince of Wales, Somerset, or Russell islands until the late 1980s and early 1990s. We surmise that the decline either had not started until then or was not well advanced before the late 1980s, and it went undetected simply because the hunters had no difficulty finding enough caribou. A likely complication is that the relative importance of contributing factors and the rate of decrease probably changed as the decline advanced.

One approach to diagnosing a decline is to start by identifying environmental changes that may have coincided with the decline (Caughley and Gunn, 1996). Peery et al. (2004) summarize five other approaches to diagnosing a decline, but those approaches require more data, particularly more demographic data, than are available for caribou on Prince of Wales, Somerset, and Russell islands. We recognize that our approach is coarse, as we have few indices of environmental changes and no exact measure of the onset of the decline or its annual rate of decrease. However, we will now describe the evidence for seven candidate factors that may have contributed to the decline.

Winter Weather

First, we considered winter weather because large-scale die-offs involving both caribou and muskoxen have occurred on Arctic Islands when snow and ice conditions were exceptionally severe and prevented or seriously reduced access to forage (Miller et al., 1977; Miller, 1998; Gunn and Dragon, 2002; Miller and Gunn, 2003a, b). Bathurst Island is in the same climatic region as Prince of Wales and western Somerset islands (Maxwell, 1981). Caribou numbers increased noticeably between 1985 and 1994 on Bathurst Island, which suggests overall favourable weather (Miller, 1998). Weather records then reveal that snowfall on Bathurst Island was exceptionally heavy in winter and spring (September to June) from 1994–95 to 1996–97, when a major (98%) three-year caribou die-off was recorded there (Miller and Gunn, 2003a).

Around 1986–87, Aleeasuk Idlout and Isaac Kulluk reported dead caribou on the west coast of Somerset Island (GNWT, 1997). Additionally, Josh Hunter (1989 letter to M. Ferguson, in the files of the Department of Environment and Renewable Resources, GNWT) reported that he had found 21 dead caribou on the west coast of Somerset Island in March and May 1989 and that harvested caribou were skinny. Hunter commented that "ice and wolves are the main problems this year."

The nearest weather station, at Resolute, recorded the fourth highest snowfall over the 55 years of record during the 1989–90 winter (Miller and Gunn, 2003a). However, at least on Bathurst Island, where Peary caribou productivity was being monitored, the snow where caribou were feeding in late winter was deep but powdery. Although survival of adult caribou was not affected, calving in 1990 was late, and early calf survival was relatively low compared to that of other years between 1988 and 1994 (Miller and Gunn, 2003a). Thus it is possible that the 1989–90 winter was severe enough to cause an unknown level of caribou deaths on Somerset and Prince of Wales islands, and calf survival was also likely reduced in 1990. However, in the absence of an investigation at the time, we have no clear picture of what happened, and especially of how widespread and how severe the event was.

Inter-Specific and Intra-Specific Competition

Inuit hunters raised the question whether either intra-specific or inter-specific competition for forage might have contributed to the decline (Gunn et al., 1998). Any assessment of competition for forage is hindered by our incomplete understanding of how Arctic plants respond to grazing and browsing and how the plant growth is affected by weather, especially by the kind, amount, and timing of precipitation. We also lack complete understanding of how herbivores in general respond to reduced forage availability by shifting their diet or foraging behaviour (Caughley, 1981).

Elsewhere on islands, intra-specific competition for forage has been inferred from periodic increases and declines in caribou abundance. However, in those situations where caribou numbers have increased and then declined, contributing factors other than overgrazing were not ruled out, and the evidence for overgrazing was ambiguous (Gunn et al., 2003).

One factor that changed markedly between 1980 and 1995, mainly on Prince of Wales Island but to lesser extents on Somerset and Russell islands, is that muskox numbers increased nearly fivefold (Gunn and Dragon, 1998). At the 1998 IUCN Workshop, some participants identified competition with muskoxen as a factor in the caribou decline (Gunn et al., 1998). Caribou and muskoxen are sufficiently different in their anatomical and physiological adaptations that the probability of important competition over the long term is low (Gunn and Adamczewski, 2003). Over the short term, however, high numbers of one species or weather conditions such as deep snow could increase the density of either species in the same habitat, so that diet overlap would increase.

On Prince of Wales Island, Russell et al. (1978) identified potential overlap between caribou and muskoxen in the use of willow, as both species fed in summer on willow-moss-lichen patterned ground, one of the most common plant communities. On Banks Island, where muskox density is an order of magnitude higher than on Prince of Wales Island, Larter and Nagy (1997) report high overlap in summer use of willows in areas of high muskox density (165 muskoxen • per 100 km^{-2}), but the number of muskoxen continued to increase. Willows compensate for

browsing with greater stem growth and bud production (Tolvanen et al., 2003), but we have not measured either the limits of the compensation or how it is affected by annual variation in weather. Additionally, diet overlap is not the same as a competitive relationship (reduced forage availability and its demographic consequences). We note that the recovery of caribou numbers on Banks Island between 1998 and 2001 occurred while muskox numbers continued to increase to an all-time known high (J. Nagy, pers. comm. 2004). To date, there is no factual evidence to support inferences, suppositions, or speculations that competition with muskoxen caused the drastic decline of caribou on Prince of Wales, Somerset, and Russell islands.

Wolf Predation

We have no measures for rate of wolf predation, but we suspect that it may have increased between 1980 and 1995. This supposition is based on the increasing number of muskoxen between 1980 and 1995 (Gunn and Dragon, 1998) that could have supported a greater number of wolves. Inuit hunters reported seeing wolf-killed caribou in the late 1980s and early 1990s, and some hunters thought that wolf numbers were higher on Prince of Wales, Somerset, and Russell islands (G. Eckalook, pers. comm. 1995) than in the early 1980s, when there were at least 30 wolves on Prince of Wales Island (Miller and Reintjes, 1995; F.L. Miller, pers. observ. 1976–80).

Wolves are large carnivores that require appreciable amounts of meat for their sustenance. Accurately estimating how many caribou are killed by wolves within the study area would require a detailed assessment of several variables, including nutritional requirements and hunting behaviour of the wolves; annual availability of ungulate prey by number and kind; and the value, if any, of seasonally available alternative small prey. We have a single 1985 observation from the Boothia Peninsula, which is within the known winter range of caribou from Prince of Wales and Somerset islands. The observation suggests that predation rates can, on occasion, be relatively high. Taloyoak wildlife officer Joe Ashevak reported to Anne Gunn (pers. comm., 1985) finding 25 dead caribou along a 15 km stretch of the Garry River. The caribou had been heavily fed on by wolves. Nine of those carcasses were found grouped under cliffs, which possibly indicates a specialized hunting strategy, as hunters saw wolves chasing a caribou over a cliff.

Indirect evidence for higher wolf numbers may come from reports of increased parasites in caribou (A. Taylor, unpubl. data 2003). We have heard reports from Pelly Bay (Kuuqaruk) and Taloyoak that, as caribou numbers increased through the 1980s, wolf numbers also increased, and more caribou were found with *Taenia* spp. tapeworm cysts (wolves are the primary *Taenia* host).

During the 1998 IUCN Workshop, Inuit from Resolute Bay and Taloyoak rated wolf predation as the major cause of the decline (Gunn et al., 1998). A similar situation occurred on Banks Island, where caribou numbers decreased and muskox and wolf numbers increased (Nagy et al., 1996). However, we acknowledge that such correlations between abundance of predators and two or more prey species do not necessarily imply cause and effect, and a causal relationship would be difficult to prove (Holt and Lawton, 1994).

The effect of wolf predation on trends in caribou numbers depends on levels of caribou recruitment, but for the caribou on Prince of Wales, Somerset, and Russell islands, we have little information on productivity and recruitment. Pregnancy rates were high in the 1970s, which was the only time they were measured (Thomas, 1982), but calf survival to one year of age (yearling recruitment) was low (Miller and Gunn, 1979). Those fragmentary data lead us to speculate that wolf predation could have had an increasing effect on caribou during the 1980s and 1990s and could have accelerated and probably deepened the decline in the number of caribou on Prince of Wales, Somerset, and Russell islands.

Hunting

Inuit from Resolute Bay and Taloyoak hunt caribou on Prince of Wales, Somerset, and Russell islands, as well as on Boothia Peninsula. In the late 1970s and early 1980s, annual harvests by Resolute Bay hunters were reported as 150–250 caribou from Prince of Wales, Somerset, and Russell islands (Gunn and Decker, 1984). At the time, Gunn and Decker (1984) cautioned that, given the available data, the population could not sustain any increase in harvest. The hunters from Resolute Bay had voluntarily stopped hunting on Bathurst Island after the major 1973–74 die-off of caribou there (Freeman, 1975; Miller et al., 1977; Ferguson, 1987; Miller, 1998). In the late 1980s, the annual harvest of caribou on Prince of Wales, Somerset, and Russell islands was 85–170 animals (Donaldson, 1988; A. Idlout, pers. comm. 1999). This reduction cannot be explained by the resumption of caribou hunting within the Bathurst Island complex in 1989: only several caribou were reported killed there in 1989 and 1990, and the annual harvest remained below 25 until 1995. By the late 1990s, Inuit from Resolute were no longer hunting caribou on Prince of Wales Island (A. Idlout, pers. comm. 2000).

An additional uncertainty is the level of harvest of caribou that had migrated each year from Prince of Wales, Somerset, and Russell islands to winter ranges on Boothia Peninsula. Those caribou movements among the three islands and Boothia Peninsula are known to have been in place for nearly a century (e.g., Macpherson, 1959; Manning and Macpherson, 1961; A. Ooyukuluk via M. Ferguson, pers. comm. 2000). Thus, Inuit who hunted on Boothia Peninsula had access to caribou that moved from Prince of Wales, Somerset, and Russell islands, as well as to year-round residents on Boothia Peninsula and south on the mainland in winter and to barren-ground caribou that calve and summer on eastern Boothia Peninsula. The

hunters prefer the taste of and select for "Kingailik *tuktu*" (i.e., Prince of Wales Island caribou). The annual caribou harvest by Taloyoak hunters in the 1980s was about 1100 animals (Gunn et al., 1986).

Parasites and Disease

During necropsies of caribou collected in 1975 and 1977, no evidence was found of disease or heavy parasite burdens: the caribou blood serum tested negative for brucellosis. However, a single clinical case of brucellosis was reported subsequently (M. Ferguson, GNWT files, 1997), and brucellosis has been recorded on Boothia Peninsula (Forbes, 1991). When caribou carcasses were found on the west coast of Somerset Island in the winter of 1989–90 and 1992, hunters suspected disease and parasites. However, no large number of carcasses was ever reported, especially a large number clumped in a relatively small area. Therefore, evidence for disease and parasites contributing to this caribou decline is equivocal.

Emigration

Some hunters have suggested that caribou numbers declined on Prince of Wales, Somerset, and Russell islands because the caribou moved elsewhere (Gunn et al., 1998). Although caribou are adaptable in their evolutionary strategies, including their use of space (e.g., Bergerud, 1996; Ferguson and Messier, 2000), it would require an extremely severe and prolonged environmental stimulus to cause several thousand caribou to completely abandon their calving areas and summer ranges. The most likely driving force would be exceptionally severe and prolonged snow or ice conditions—and there is no evidence from the Resolute Airport weather records for such conditions between 1980 and 1994. Also, we could find no published factual examples of mass emigration, with several thousand caribou abandoning their calving areas and summering ranges and moving beyond their traditional annual home ranges.

One approach to assessing emigration is to see if caribou numbers in adjacent areas have increased. This approach is hampered by piecemeal information, especially on the relative timing of changes in numbers. The overall decline of caribou on Prince of Wales, Somerset, and Russell islands in 1980–95 coincided with increases in caribou numbers in the Dolphin and Union caribou herd on Victoria Island, within the Bathurst Island complex in the south-central Queen Elizabeth Islands, and on Boothia Peninsula. The increase in caribou numbers on Victoria Island began in the 1970s, while caribou numbers were still high on Prince of Wales, Somerset, and Russell islands (Gunn, 1990). More importantly, the Dolphin and Union caribou differ considerably from other caribou on the Canadian Arctic Islands, both in appearance and genetically (Manning, 1960; Banfield, 1961; Gunn and Fournier, 1996; Zittlau, 2004). Inuit hunters and caribou biologists on Victoria Island would most likely recognize caribou from Prince of Wales Island or Somerset Island as not being from Victoria Island.

Caribou numbers on Bathurst and its satellite islands increased ninefold from summer 1974 to summer 1994 (Miller, 1998). However, caribou from Prince of Wales, Somerset, and Russell islands also look different from Peary caribou within the Bathurst Island complex (Thomas and Everson, 1982), and none were seen by Inuit hunters or caribou biologists on Bathurst Island during the 1974–94 increase.

The role that immigration to Boothia Peninsula from Prince of Wales, Somerset, and Russell islands might have played in the decline remains open for further consideration. Between 1985 and 1995, Boothia Peninsula caribou appeared to increase from 4831 to 6658 (Gunn and Dragon, 1998), or at an average annual rate of only ca. 3%, which is at the lower end of possible annual population growth. The average annual rate of decline for caribou on Prince of Wales, Somerset, and Russell islands during the same time period was -24% per year. We cannot rule out a trickle immigration over time, but we believe the decrease of about 6000 caribou on Prince of Wales, Somerset, and Russell islands compared to the increase of about 2000 on Boothia Peninsula during the same time period cannot be explained by mass immigration, unless it was accompanied immediately or shortly afterwards by a high rate of death among the migrants.

Genetically, the caribou on Bathurst Island (samples collected in 1994–97), those on Prince of Wales and Somerset islands (samples collected in 1974–77), and those on Boothia Peninsula (samples collected in 1976–77, 1995) all have different allele frequencies (Zittlau, 2004). There is evidence that intermittent gene flow must have occurred in the distant past between Bathurst and Prince of Wales Islands, more so than to the Boothia Peninsula (Zittlau, 2004). The scale of influx and the time period involved are unknown, but could be as few as one or two individuals or could have involved more individuals over many generations in the distant past (Zittlau, 2004).

We do not know with certainty what happened to the caribou on Prince of Wales, Somerset, and Russell islands between 1980 and 1995, or how long it took for those changes to occur. We suggest that the decline has parallels with the 90% decline in caribou numbers on Banks Island between 1982 and 1998 (Nagy et al., 1996; J. Nagy, pers. comm. 2003). Nagy et al. (1996) concluded that causes of the decline included a combination of overharvesting and increased wolf predation when wolf numbers responded numerically to increasing muskox abundance. As the caribou declined on Banks Island, hunting most likely accelerated the decline and deepened it, even if hunting had not initiated the decline. Thus, we conclude that a probable explanation for the near-total loss of caribou on Prince of Wales, Somerset, and Russell islands is long-term consequential reductions in survival rates of breeding females

and of calves during the first year of life, in association with continued caribou harvesting throughout the 1980s and early 1990s and markedly increased wolf predation on the dwindling number of caribou during that time.

Conservation Implications

Even though we are uncertain about the mechanisms of the decline, awaiting greater certainty to implement recovery actions could place the few remaining caribou on Prince of Wales, Somerset, and Russell islands at greater risk. The longer a population stays "small," the greater the probability of "bad luck" (cf. Caughley and Gunn, 1996). With only a few caribou left, accidents or increased predation, even if it is only incidental predation, could prevent recovery—or in the extreme, extirpate the population. Other unknowns affecting persistence of the population are whether current numbers are sufficient for behaviours that depend on the presence of other individuals (the "Allee Effect": Stephens et al., 1999). Such behaviours in caribou could include group vigilance as an anti-predator strategy or breeding behaviour. At such a low number, extirpation is a distinct possibility.

The relative importance of its starting size for a recovering population cannot be overemphasized (Fig. 3A, B). At a relatively high annual rate of increase of 10%, a starting population of 100 caribou would need 37 years of favourable weather to reach about 3300 animals, almost twice as long as it would take a population starting at 500 animals. On the Queen Elizabeth Islands, where environmental conditions are more severe, 20 years is the longest series of consecutive favourable years realized in the last half of the 20th century (e.g., Miller, 1998).

After the decline on Banks Island was detected, Inuvialuit hunters and the Wildlife Management Advisory Committee implemented recovery actions that included reduced hunting. At their lowest number in 1998, there were still about 500 caribou estimated on Banks Island (J. Nagy, pers. comm. 2003). By comparison, when a caribou population has reached about 100, as on Prince of Wales, Somerset, and Russell islands in 1995, recovery is not a certainty and, if it happens, it will take decades (Fig. 3A, B). The Banks Island caribou population began its recovery by 2001, after Inuvialuit increased their harvest of wolves in the 1990s and curtailed their caribou hunting (J. Nagy, pers. comm. 2003). However, caution in evaluating the recovery is needed, as the calf-to-cow ratio observed during July 2004 was the second-lowest documented on Banks Island since 1994. Inuvialuit hunters reported that freezing rains occurred on Banks Island during October in 1993 and 2003 (J. Nagy, pers. comm. 2004).

In contrast to the relatively quick response to the detected caribou decline on Banks Island, recovery actions have not yet been implemented for the caribou on Prince of Wales, Somerset, and Russell islands. Timing may partly account for the delay, as many things were happening in the late 1990s that diverted attention. At the political and

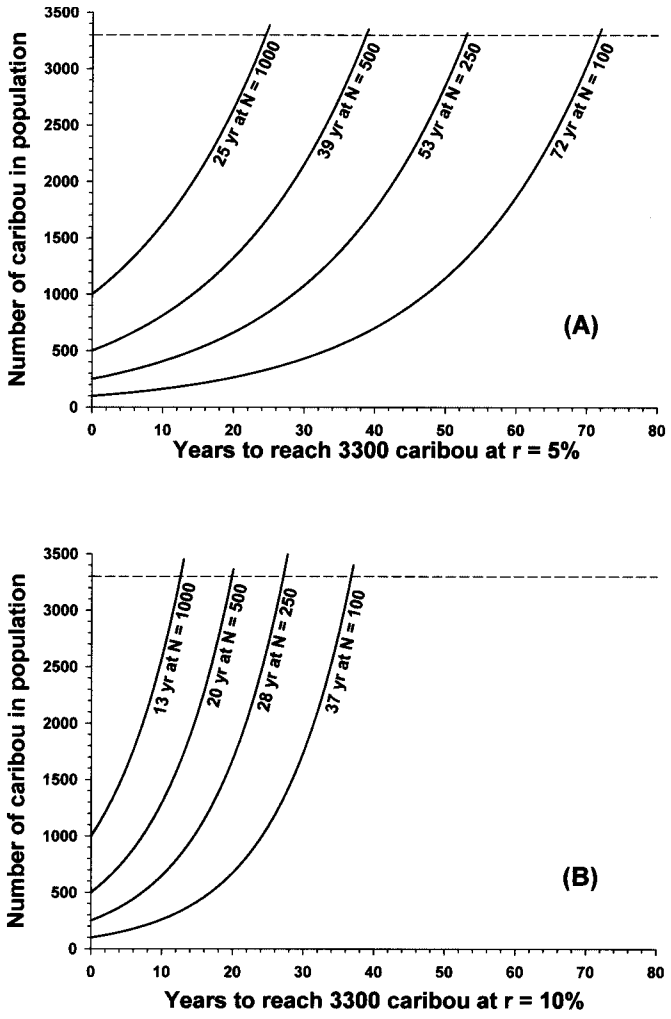

FIG. 3. The importance of starting population size for population recovery. The figure shows how long it would take for a depleted caribou population of 100, 250, 500, and 1000 animals to recover to a population size of 3300 at two average rates of annual increase (r): (A) r = 5% and (B) r = 10%. (The target size of 3300 would sustain an annual harvest of 150–300 animals, depending on the sex and age composition of the kill.)

administrative level, attention was focused on the formation of Nunavut. At the federal level, with its responsibility for "Endangered" or "Threatened" wildlife, the *Species At Risk Act* was passed in 2003 (Government of Canada, 2003). With hindsight, consultation with the communities could have been more intensive.

However, one reason for the delay in recovery actions may have been that the 1980–95 decline is not the first recorded decline in the collective experience of the hunters. Hunters from Taloyoak report that caribou numbers on Prince of Wales, Somerset, and Russell islands and Boothia Peninsula were low from the 1940s to the early 1970s (Macpherson, 1959; Manning and Macpherson, 1961; D. Tucktoo, pers. comm. 1993). We can also see the signature of earlier declines in caribou genetics as sampled from DNA. A genetic bottleneck was detected in the caribou from Prince of Wales Island sampled in the 1970s (Zittlau, 2004). Although we have no means of comparing those past levels of low caribou abundance with the level found

in 1995, the previous declines may have reduced the population to a few individuals. This is suggested by the differences in microsatellite DNA from caribou tissue collected on Prince of Wales Island in 1958 and in the mid-late 1970s (Zittlau, 2004). In very small populations, genetic drift is relatively rapid and could explain the genetic differentiation of the caribou.

One implication of previous caribou declines is that recovery is possible and intervention—management—is unnecessary. However, we suggest that the past is not necessarily a secure guide to the future, as there is now less certainty about the future given the predictions for climate change. The predicted changes in weather include higher temperatures and greater precipitation, which together increase the likelihood of rain and freezing rain in the spring and autumn (Maxwell, 1997).

Recent trends in weather in the Canadian Arctic include a slight summer warming trend after the 1960s, an increase in autumn precipitation in the 1980s and 1990s, and an increase in winter precipitation especially between 1988 and 1997 (Maxwell, 1997). Caughley and Gunn (1993), Behinke (2000), and Miller and Gunn (2003b) have argued that caribou on Arctic islands are in a "non-equilibrium grazing system" where sporadic, unpredictable changes in abiotic variables (such as snow and ice) usually govern the fate of the caribou over time. Direct influences on mortality (wolf predation or hunting) and influences on productivity through reduced forage availability (inter- or intra-specific competition) could be masked or magnified by the sporadic, unpredictable effects of weather. The predictions for global climate change include an increase in the frequency of severe weather; thus, we can expect that the herbivore-forage relationships will be more variable and more taxing on both plant and animal.

Recovery actions need not be restricted to treating the original causes of the decline, if they are known. For example, even if harvesting is not a factor in a decline, reducing hunting will assist recovery. More intrusive methods may be necessary to accelerate and foster the recovery. At the 1998 IUCN Workshop, participants discussed possible recovery actions (Gunn et al., 1998). Reducing predators and lessening food competition (from muskoxen) were the two options identified, although only wolf control was discussed in detail. Ideally, this could be accomplished by providing incentives to encourage Inuit hunters to take more wolves. "Do nothing" was not identified as a recommendation. Some actions, such as winter feeding, were not supported, and captive breeding and translocation need further discussion with communities. In any case, the possibility of using translocations to "quick-start" recovery is hampered by the limitation that translocations should not modify existing patterns of diversity by introducing dissimilar genotypic groupings and phenotypes (IUCN, 1987). The microsatellite DNA findings showed that caribou on Prince of Wales and Somerset islands are genetically distinctive from other populations of caribou from the western and central Canadian Arctic Islands, and no complete match is known to exist anywhere else (Zittlau, 2004). Additionally, the "source" population must have sufficient individuals so that removal of some does not jeopardize its well-being (Caughley and Gunn, 1996).

A clear lesson for wildlife conservation is that allowing intervals of 15 years between surveys to track changes in abundance is risky. Survey frequency is mostly determined by funding and socio-political priorities. The problem with waiting until hunters report a change in local sightings or harvest in relation to hunter effort is that a decline can already be underway or even advanced, as happened in 1995. A logical approach to survey interval is to relate it to population size, rates of change, and severity of causes of decline. Thus small populations (< 500 individuals) should be surveyed more frequently (Miller et al., 2005a), and reports of a "bad-weather year" and especially of die-offs should be triggers for population surveys, regardless of time since the last survey. However, we suggest that the question of survey frequency is sufficiently involved to be outside the scope of this paper, particularly as we know that a single-year winter or spring die-off can reduce a population by 30% to 80% (Miller et al., 1977; Miller, 1998; Gunn and Dragon, 2002; Miller and Gunn, 2003a, b). Discussions on this topic require input from both the Inuit and wildlife agencies. Perhaps the appropriate forum is at the level of "national recovery planning" that since the passing of Canada's *Species At Risk Act* in 2003 is now mandatory.

Also with hindsight, our experience from the reception of the 1995 survey results indicates that the local people have to be involved as more than aerial observers. They should be actively involved in all parts of the survey, from design through to completion. Subsequently, progress toward this end has occurred with a workshop in Grise Fiord in October 1996, when Inuit hunters and biologists used all sources of knowledge to design a survey for caribou on the eastern Queen Elizabeth Islands (GNWT, 1997). The workshop recommendations were used to design the combined snow machine and helicopter survey of caribou on Prince of Wales and Somerset islands that was carried out in April-May 2004.

The delay in detecting the decline, the inadequate understanding of its causes, and the disagreement surrounding the degree and importance of the decline have handicapped recovery actions and will continue to do so. As previous caribou declines were followed by recovery, some comfort may be drawn from the likelihood of unaided recovery. However, this geographic population of caribou has declined to the point where recovery in number will be lengthy and tenuous at best, and failure to recover is entirely possible. We should not be complacent, especially since these caribou, one of five geographic populations of caribou on the Canadian Arctic Islands, have been identified as genetically distinct. Their extirpation would reduce the biodiversity of caribou on Canada's Arctic Islands. We recommend that specific steps for

recovery be identified through involvement with the affected communities. Ultimately, to be effective, conservation action for this geographic population of caribou rests on support from the people who depend on those caribou—in this case, the Inuit of Resolute Bay and Taloyoak.

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