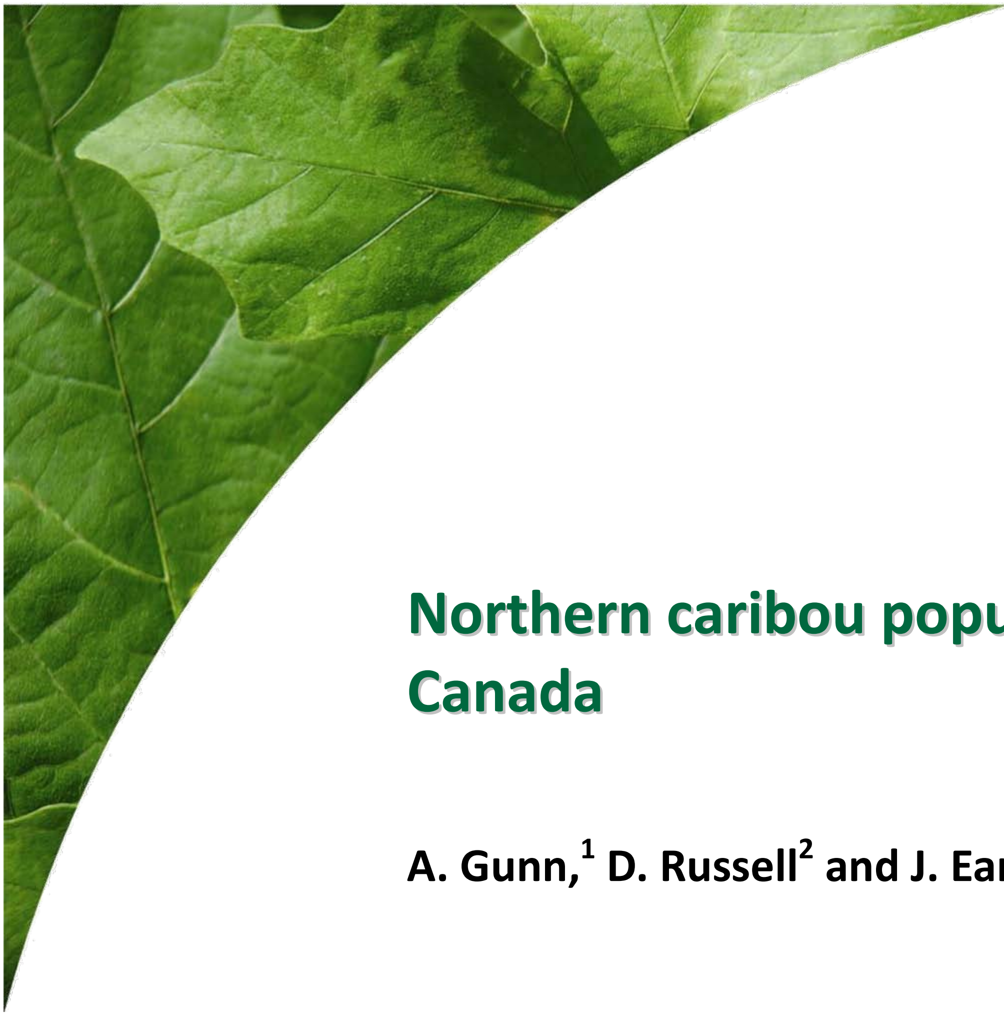


Northern caribou population trends in Canada

A. Gunn,[1] D. Russell[2] and J. Eamer[3]

Canadian Biodiversity: Ecosystem Status and Trends 2010
Technical Thematic Report No. 10
Published by the Canadian Councils of Resource Ministers

[1] 368 Roland Road, Salt Spring Island, BC V8K 1V1
[2] Shadow Lake Environmental Consulting, Box 10038, Whitehorse, YT Y1A 7A1
[3] Environment Canada, Vancouver, BC

Library and Archives Canada Cataloguing in Publication

Northern caribou population trends in Canada.

Issued also in French under title:
Tendances des populations de caribou des zones septentrionales du Canada.
Electronic monograph in PDF format.
ISBN 978-1-100-19923-8
Cat. no.: En14-43/10-2011E-PDF

This report should be cited as:
Gunn, A., Russell, D. and Eamer, J. 2011. Northern caribou population trends in Canada. Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 10. Canadian Councils of Resource Ministers. Ottawa, ON. iv + 71 p.
http://www.biodivcanada.ca/default.asp?lang=En&n=137E1147-1

PREFACE

The Canadian Councils of Resource Ministers developed a Biodiversity Outcomes Framework[1] in 2006 to focus conservation and restoration actions under the *Canadian Biodiversity Strategy*.[2] *Canadian Biodiversity: Ecosystem Status and Trends 2010*[3] was a first report under this framework. It assesses progress towards the framework's goal of "Healthy and Diverse Ecosystems" and the two desired conservation outcomes: i) productive, resilient, diverse ecosystems with the capacity to recover and adapt; and ii) damaged ecosystems restored.

The 22 recurring key findings that are presented in *Canadian Biodiversity: Ecosystem Status and Trends 2010* emerged from synthesis and analysis of technical reports prepared as part of this project. Over 500 experts participated in the writing and review of these foundation documents. This report, *Northern caribou population trends in Canada*, is one of several reports prepared on the status and trends of national cross-cutting themes. It has been prepared and reviewed by experts in the field of study and reflects the views of its authors.

Acknowledgements

This report builds on research and monitoring conducted and synthesized by participants in the CircumArctic Rangifer Monitoring and Assessment (CARMA) Network (CARMA, 2010b). We would like to thank those participants who so willingly shared their information and their time. CARMA is a network of researchers, managers, and community people who share information on the status of the world's wild *Rangifer* (reindeer and caribou) populations and how they are affected by stressors such as climate change and industrial development.

We also thank the reviewers of this report, who were from agencies, boards, and councils with management authority for northern caribou. This report went through two reviews; comments and additional information received from 17 reviewers were invaluable. Any errors or omissions remaining are the responsibility of the authors. This report was produced with the support of the ESTR Secretariat, Environment Canada, with graphics and design by the authors and by Kelly Badger and Jodi Frisk (Environment Canada).

---

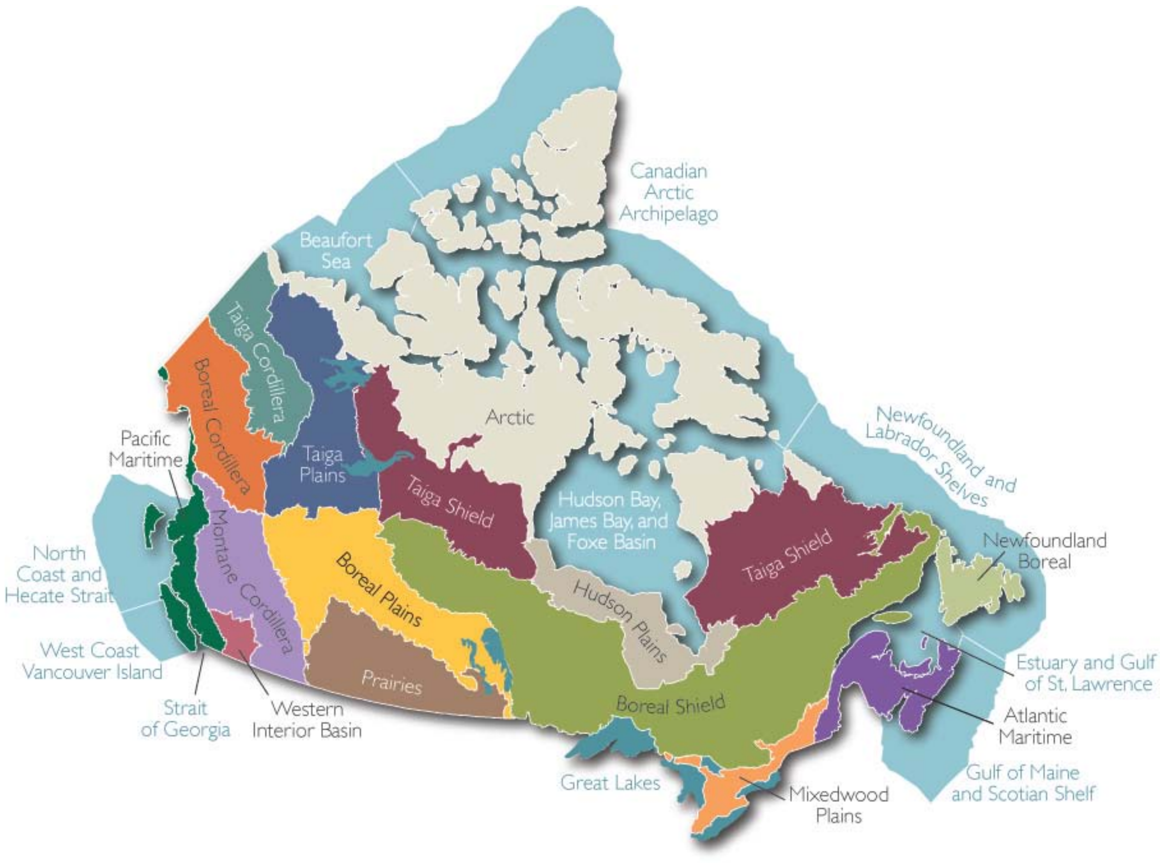
[1] Environment Canada. 2006. Biodiversity outcomes framework for Canada. Canadian Councils of Resource Ministers. Ottawa, ON. 8 p. http://www.biodivcanada.ca/default.asp?lang=En&n=F14D37B9-1

[2] Federal-Provincial-Territorial Biodiversity Working Group. 1995. Canadian biodiversity strategy: Canada's response to the Convention on Biological Diversity. Environment Canada, Biodiversity Convention Office. Ottawa, ON. 86 p. http://www.biodivcanada.ca/default.asp?lang=En&n=560ED58E-1

[3] Federal, Provincial and Territorial Governments of Canada. 2010. Canadian biodiversity: ecosystem status and trends 2010. Canadian Councils of Resource Ministers. Ottawa, ON. vi + 142 p. http://www.biodivcanada.ca/default.asp?lang=En&n=83A35E06-1

Ecological Classification System – Ecozones+

A slightly modified version of the Terrestrial Ecozones of Canada, described in the *National Ecological Framework for Canada*,[4] provided the ecosystem-based units for all reports related to this project. Modifications from the original framework include: adjustments to terrestrial boundaries to reflect improvements from ground-truthing exercises; the combination of three Arctic ecozones into one; the use of two ecoprovinces – Western Interior Basin and Newfoundland Boreal; the addition of nine marine ecosystem-based units; and, the addition of the Great Lakes as a unit. This modified classification system is referred to as "ecozones+" throughout these reports to avoid confusion with the more familiar "ecozones" of the original framework.[5] In this report the three Arctic ecozones of the original framework (Southern Arctic, Northern Arctic, and Arctic Cordillera) are referenced in descriptions of herd ranges for greater clarity.



---

[4] Ecological Stratification Working Group. 1995. A national ecological framework for Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research and Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch. Ottawa/Hull, ON. 125 p. Report and national map at 1:7 500 000 scale.

[5] Rankin, R., Austin, M. and Rice, J. 2011. Ecological classification system for the ecosystem status and trends report. Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 1. Canadian Councils of Resource Ministers. Ottawa, ON. http://www.biodivcanada.ca/default.asp?lang=En&n=137E1147-1

Table of Contents

PREFACE I
Acknowledgements i
Ecological Classification System – Ecozones+ ii

LIST OF FIGURES IV

LIST OF TABLES IV

INTRODUCTION 1
Report objective 3
Information sources 3

WHAT IS HAPPENING? 4

WHY IS IT HAPPENING? 8

WHY IS IT IMPORTANT? 10

THREATS 12
Predation, parasites, disease 12
Harvest 14
Development 17
Pollutants 20
Forest fires 21
Climate change 22

TRENDS IN PROTECTED CARIBOU HABITATS 26

HERD-SPECIFIC ASSESSMENTS 28
Ahiak Herd 28
Baffin Island herds 30
Bathurst Herd 30
Beverly Herd 32
Bluenose-East Herd 34
Bluenose-West Herd 35
Cape Bathurst Herd 36
Dolphin and Union Herd 37
George River Herd 38
Leaf River Herd 39
Lorillard and Wager Bay herds 40
Peary caribou 40
Pen Islands and Cape Churchill herds 45
Porcupine Herd 46
Qamanirjuaq Herd 47
Southampton Island Herd 48
Tuktoyaktuk Peninsula Herd 49

REFERENCES 50

List of Figures

Figure 1. Current distribution and status designations of Rangifer in North America. 2
Figure 2. Northern caribou subspecies and groupings. 2
Figure 3. Ranges and recent trends of northern caribou populations in Canada. 5
Figure 4. The exponential rate of increase and decline of major tundra-dwelling caribou herds in Canada. 7
Figure 5. The relative size of tundra-dwelling wild Rangifer herds (Canada). 9
Figure 6. Human population levels in northern Canadian ecozones+, 1971 and 2006. 15
Figure 7. Bathurst Caribou Herd population estimates. 31
Figure 8. Beverly Caribou Herd population estimates. 32
Figure 9. Bluenose-East Caribou Herd population estimates. 34
Figure 10. Bluenose-West Caribou Herd population estimates. 35
Figure 11. Cape Bathurst Caribou Herd population estimates. 36
Figure 12. Dolphin and Union Caribou Herd population estimates. 37
Figure 13. George River Caribou Herd population estimates. 38
Figure 14. Leaf River Caribou Herd population estimates. 39
Figure 15. Peary caribou population estimates. 43
Figure 16. Porcupine Caribou Herd population estimates. 46
Figure 17. Qamanirjuaq Caribou Herd population estimates. 47
Figure 18. Southampton Island Caribou Herd population estimates. 48

List of Tables

Table 1. Climate change impacts on migratory tundra caribou populations. 25

INTRODUCTION

Historically, caribou were found in all Canadian provinces and territories – they are currently present in seven provinces and the three territories (Figure 1). Northern caribou, as reported on in this assessment (Figure 2), include migratory tundra caribou of three sub-species and the non-migratory Peary caribou (*Rangifer tarandus pearyi*) that are found on the islands of the Canadian Arctic Archipelago (Banfield, 1961; Rothfels and Russell, 2005). The three sub-species included in migratory tundra caribou are: 1) barren-ground caribou (*Rangifer tarandus groenlandicus*), ranging east of the Mackenzie River; 2) Grant's caribou (*R. t. granti*), ranging west of the Mackenzie River; and, 3) certain herds of woodland caribou (*R. t. caribou):* the two large herds in Ungava and two small herds that calve along the south coast of Hudson Bay (Campbell, 1995; Abraham and Thompson, 1998). We follow Bergerud et al. (2008) in referring to the Ungava caribou as migratory tundra caribou based on their ecological strategies for calving. Migratory tundra caribou occur in eight provinces and territories, although they currently occupy an area that is smaller than their historical distribution. Migratory tundra caribou are undergoing an assessment, starting in late 2011, by COSEWIC, the Committee for the Status of Endangered Wildlife in Canada. COSEWIC has assessed Peary caribou as Endangered and the Dolphin and Union Herd is listed as Special Concern (Government of Canada, 2011). In 2011, Peary caribou were listed under Schedule 1 of the federal *Species At Risk Act* (Government of Canada, 2011).

Figure 1. Current distribution and status designations of Rangifer *in North America.*
Migratory tundra populations (this includes barren-ground, Grant's, and some herds of boreal woodland caribou) as well as Peary and Dolphin and Union populations marked on this map are covered in this paper. See Environment Canada (2011) for an update of the current distribution of boreal caribou. Source: adapted from Hummel and Ray (2008). Map reprinted with permission from Dundurn Press Ltd. © 2008.

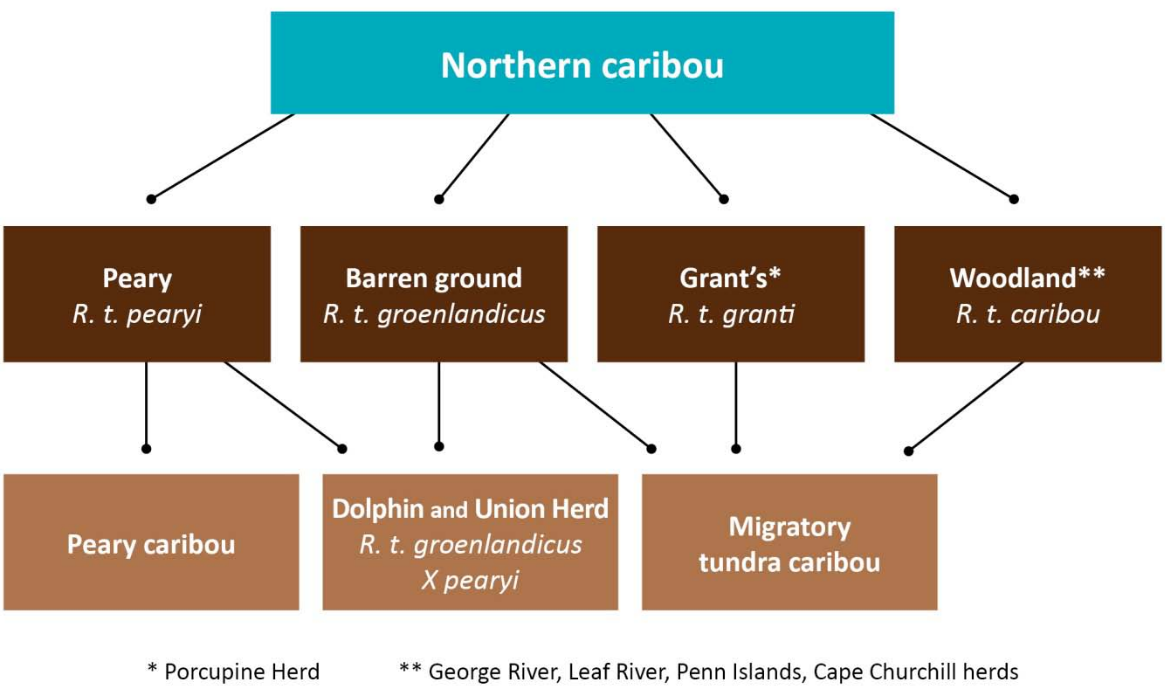


Figure 2. Northern caribou subspecies and groupings.
All caribou belong to the species Rangifer tarandus. *See text for sources.*

Northern caribou are found, at least in some seasons, in all the northern ecozones^{+}: Arctic, Taiga Shield, Taiga Plains, Taiga Cordillera, and Hudson Plains, as well as in the western part of the mid-latitude Boreal Shield Ecozone^{+}. Only Peary caribou and Hudson Plains forest-tundra caribou have annual ranges within or primarily within a single ecozone^{+}; the barren-ground herds and the migratory tundra woodland caribou herds of Quebec and Labrador calve and summer in one ecozone^{+} and winter in one or two other ecozones^{+}. The major and best known migratory tundra herds (Porcupine, Cape Bathurst, Bluenose-West, Bluenose-East, Bathurst, Qamanirjuaq, Beverly, Leaf River, and George River) calve within the Southern Arctic. Campbell et al. (2010) mapped the cumulative distribution of the Qamanirjuaq Herd based on locations of satellite-collared cows from 1993 to 2008. The herd's southern distribution coincides with the northern boundaries of the Boreal Shield and the Hudson Plains ecozones^{+}.

The Ahiak Herd is included in this discussion as a major herd, based on the likely number of caribou and the size of the annual range (Gunn et al., 2000b). The herd was not the focus of much management effort until 2006. The resulting gaps in information have led to uncertainty about the Ahiak Herd's relationship to other herds, especially to the Beverly Herd (Gunn et al., In Press; Nagy et al., 2011). In this report, while we acknowledge these differing interpretations, we refer to the Ahiak as a discrete herd until all the evidence additional to the broad-scale analysis of satellite-collar locations undertaken by Nagy et al. (2011) has been comprehensively reviewed.

Also within the Southern Arctic are the herds on the large islands of Hudson Bay (Southampton, Coats, and Mansell islands). The Northern Arctic includes the northeast Nunavut mainland, where the Wager Bay, Lorillard, Melville Peninsula, and several smaller herds calve. Peary caribou and the Dolphin and Union Herd on Victoria Island also calve in the Northern Arctic.

Report objective

The objective of this report is to summarize information on trends in numbers, distribution, and habitat of northern caribou. As noted in the Preface, this report forms a part of the background material for the 2010 assessment of status and trends of Canada's ecosystems, undertaken by the Canadian Councils of Resource Ministers (Federal, Provincial and Territorial Governments of Canada, 2010). The target audience for this report is resource managers and organizations and individuals with an interest in status and trends of northern caribou.

Information sources

A key finding of the 2010 assessment of Canada's ecosystems was that the assessment had been hindered by the shortage of consistent, long-term, standardized, and accessible ecological monitoring results for Canada (Federal, Provincial and Territorial Governments of Canada, 2010). While there are better data for caribou than for many other species and ecosystem aspects, the experience of the authors in preparing this report supports this general key finding.

The level of monitoring and research on northern caribou varies considerably among herds and their ranges. Survey methods have changed over time and vary from region to region and the level of detail in reporting estimates varies widely. These factors make assessment of broader trends difficult.

Accessibility of survey results is also uneven. The most useful records were reports containing data sets and methodology, either published as agency reports and made available on the internet or published through scientific journals. Much of the data on caribou herds, however, remain in draft or unpublished reports that are difficult to acquire and not archived. Some survey results are only available in file records, media releases, unreferenced websites, or through personal communications. Older herd population estimates have often been repeated in newer publications, often without information on variance or methodology. As the older reports are often difficult to acquire, this is leading to a loss of information from earlier surveys. Some older estimates have been revised based on improved understanding of herd distributions or to make older estimates more comparable with recent survey results. This is a potential source of confusion as it can lead to conflicting population estimates being reported in documents and websites.

In producing this report, data on herd status and trends were compiled through literature searches and consultation with regional caribou experts. Data presented in this report are compiled and annotated, along with references and graphical presentations, and are available in a spreadsheet.

WHAT IS HAPPENING?

Caribou numbers typically rise and fall over a timescale of decades, but the information to measure population trends, especially trends before the 1970s, is more qualitative than quantitative. Aboriginal elders recall periods of abundance and scarcity. Other indicators of past caribou abundance and distribution include traditional place names (Legat et al., 2002). Highs and lows in historic abundance since the 1800s have been reconstructed from the frequency of hoof scars on spruce roots, at least for the Bathurst and George River herds (Payette et al., 2004; Zalatan et al., 2006). Current ranges and trends are presented in Figure 3, based on information summarized in this report.

Figure 3. Ranges and recent trends of northern caribou populations in Canada.
The time spans used to assess the recent trends vary, depending on survey data available. This map has been updated from the version published in Canadian Biodiversity: Ecosystem Status and Trends 2010 *(Federal, Provincial and Territorial Governments of Canada, 2010).*

On the mainland, caribou numbers were low from the 1950s until the 1970s, when the major herds began to increase (Kelsall, 1968 and this report). The increases continued into the 1980s for the major mainland herds, as well as for the Dolphin and Union Herd on Victoria Island. All eight major mainland caribou herds from the Western Arctic east to Hudson Bay have declined since their peak abundance in the mid-1980s to mid-1990s (the exact timing depends on the herd). The herds currently considered to be still in decline are the Bathurst, Beverly, Leaf River, and George River. After a calving ground photographic census in 2008, which was the first census since 1994, the trend for the Qamanirjuaq Herd was determined to be a statistically insignificant decline. The Porcupine Herd increased in numbers in the 2010 census from the previous census in 2001; the Cape Bathurst and Bluenose-West herds have stabilized at low numbers between 2006 and 2009, following a period of sharp declines; the 2010 census of the Bluenose-East Herd showed that the herd has increased since 2006. Since the mid-1980s, the George River Herd declined, based on the census results for 2010. The neighbouring Leaf River Herd, which increased from the mid-1980s at least until the most recent census (2001), is now considered to be declining based on information on demographic rates. The status of the Ahiak and several herds on the northeast mainland (Wager Bay, Lorillard, Melville Peninsula, and other smaller herds on Boothia Peninsula and Simpson Peninsula), Baffin Island, and the smaller islands in Hudson Bay are currently unknown. The exception is the Southampton Island Herd whose abundance is tracked during aerial surveys at relatively regular intervals. By 2007, the herd had declined to half the peak size estimated in 1997. The Dolphin and Union Herd likely declined between 1997 and 2008 after increasing during the 1970s and into the mid-1990s. In the Hudson Plains Ecozone+, the small Cape Churchill Herd appears stable while the Pen Islands Herd may be in decline. On Baffin Island, a recent compilation of reports and local knowledge indicates that caribou numbers are at a low in the cycle of abundance. See herd-specific assessments, on page 28, for further details and references for the trends summarized here.

The trends in abundance are based on one indicator – the number of caribou in the herd, estimated either through calving-ground or post-calving counts (Gunn and Russell, 2008). In a few herds, such as the Bathurst and George River herds, the trends in total numbers are supported by measured trends in demographic indicators such as adult or calf survival. In other herds, especially the Beverly Herd, monitoring of herd size was infrequent and supporting data on demographic rates were not collected.

The rates of increase and decrease of individual herds vary greatly, as can be seen when the rates of change for herds are plotted for periods when they were increasing (after 1970) and periods when they were decreasing (generally after the 1990s) (Figure 4). The herds with the greatest rates of increase were the Southampton and Bathurst, while the Bluenose-West and Porcupine herds showed the lowest rates of increase among herds for which there are sufficient data. During the decline phase, the Cape Bathurst Herd had the greatest rate of decline, although, with only a few breeding females on the Beverly traditional calving grounds in recent surveys, the rate of decline of the Beverly Herd may have been greater. Data are insufficient for the Beverly Herd to calculate this rate.

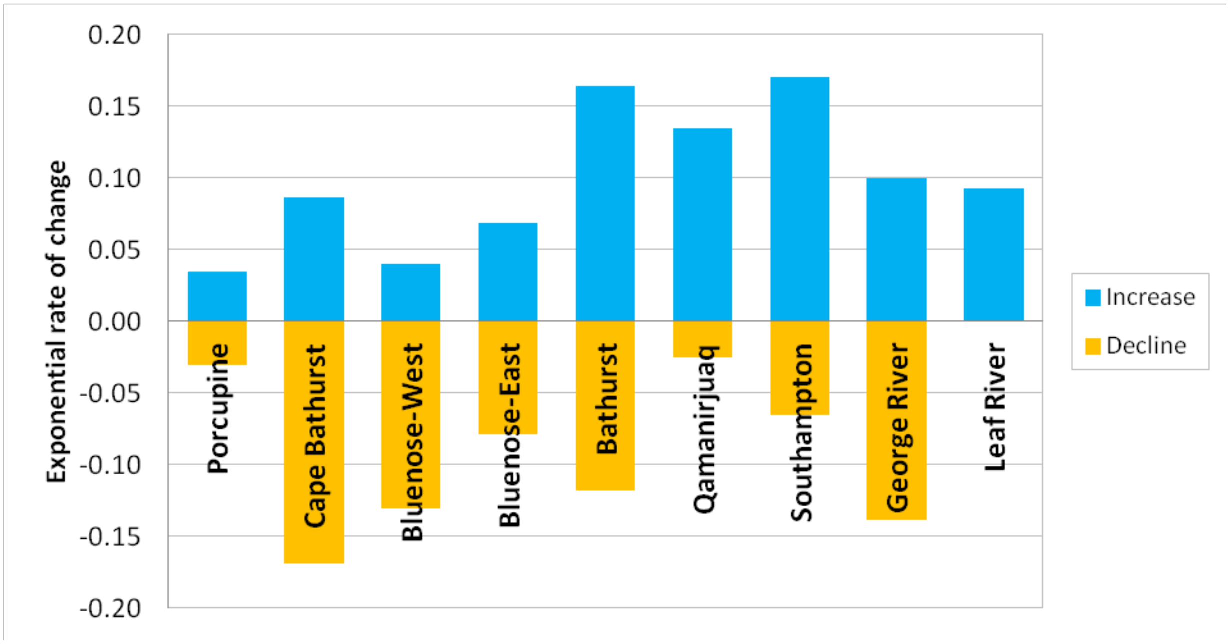


Figure 4. The exponential rate of increase and decline of major tundra-dwelling caribou herds in Canada. The chart shows the annual rate of change during increase and decline phases, based on conversion of the population estimates to natural logarithms. The years used vary among herds depending on when herds were increasing and decreasing and when population estimates were made. For the Porcupine Herd, where a change in trend direction was detected in the 2010 survey, the rate of increase is the average of 0.033 (1972-1989) and 0.035 (2001-2010).
Source: rates based on population estimates that are shown and referenced in the herd-specific assessment section starting on page 28. Methodology based on Caughley (1977) as presented in Gunn and Russell (2008).

Trends in a herd distributions will change through time; shifts in distribution, however, are not well documented and are uncertain. Information from aerial surveys and satellite-collared individuals generally has not been analyzed to describe trends in distribution. Migratory tundra caribou characteristically shift their winter distribution among years and winter ranges often overlap between neighbouring herds (Schmelzer and Otto, 2003; Bergerud et al., 2008). Additionally, as herd abundance rises and falls, distribution – especially winter distribution – can shift (Bergerud et al., 2008). Maps of historical distribution (Banfield, 1961) and winter distribution since the 1970s, at least for the Beverly, Qamanirjuaq, and Bathurst herds (Gunn et al., 2001; BQCMB, 2004), hint at a contraction in the southern boundary of the winter distribution in northern Manitoba, Saskatchewan, and Alberta. During the 1996 to 2010 decline of the Bathurst Herd, the winter distribution of the satellite-collared cows showed a trend towards wintering further north of the 60th parallel (Gunn et al., 2011b).

Trends for Peary caribou are generally more difficult to define, given the infrequency of surveys (COSEWIC, 2004). The overall trend of Peary caribou between 1961 and 2010 is a decline. For Peary caribou on the larger southern islands of the Northern Arctic, declines recorded in the 1990s have not been reversed. On Prince of Wales and Somerset islands, there is no evidence for recovery following the collapse of the population between 1980 and 1995 – almost no caribou were found during 2004 surveys. Peary caribou on Banks and northwest Victoria Island are monitored relatively frequently. Abundance declined sharply in the 1980s and into the 1990s; low numbers have persisted. Further north, on the Queen Elizabeth Islands, there has been an overall decline since 1961, especially on the western Queen Elizabeth Islands (Miller et al., 2005). Those islands include the more frequently surveyed Bathurst Island, where caribou declined from 1961 to 1974. From the late 1970s into the early 1990s, Peary caribou on Bathurst Island recovered to the 1961 levels and then three consecutive severe winters triggered a collapse in numbers, followed by some recovery. See the section on Peary caribou, starting on page 40, for further details and references for the trends summarized here.

WHY IS IT HAPPENING?

The current declining trends for some mainland caribou herds, as well as the recent declining trends with current indications of stabilization or recovery for other herds, are likely a reflection of natural cycles in caribou abundance accentuated by the cumulative effects of increasing human presence on the caribou ranges. More conjectural is to what degree climate warming and attendant broad-scale habitat changes are factors in the natural cycles.

The causes of declines are complex, with the roles of the various contributing factors changing as the declines continue. Caribou are similar to other northern herbivorous mammals (voles, lemmings, and hares) in that their abundance is cyclic (Morneau and Payette, 2000; Gunn, 2003; Zalatan et al., 2006) and, overall, the cycles are likely driven by climate interacting with forage availability, predation, and pathogens. Weather tends to have a decadal pattern, influenced by major patterns, such as the Arctic oscillation, switching between negative and positive phases (Bonsal and Shabbar, 2011). Winter temperatures and snowfall patterns, the most affected weather factors, interact with forage growth and availability. Winter conditions and forage availability influence caribou condition, which determines birth rates and calf survival (Couturier et al., 2009a; Couturier et al., 2009b). Trends in annual calf survival and fecundity also play a role in changing herd abundance.

Weather also interacts with parasites, such as warble flies, whose activity depends on summer weather. Weather affects the transmission of internal parasites, which in turn influences forage intake as caribou alter their feeding sites to try to reduce their exposure to the parasites (Van der Wal et al., 2000). Predation and harvest by humans have a pivotal role in declines as even small annual reductions in adult female survival strongly influence population trends (Gaillard et al., 1998).

Combining population estimate data on Canadian herd numbers since 1970 and scaling herd size relative to maximum estimates for each herd indicates that, on average, northern caribou numbers in Canada have increased from lows around 1975 to a peak around 1995, followed by a decline with some indication of a recent levelling off or reversal of the decline (Figure 5). The timing and magnitude of the changes vary.

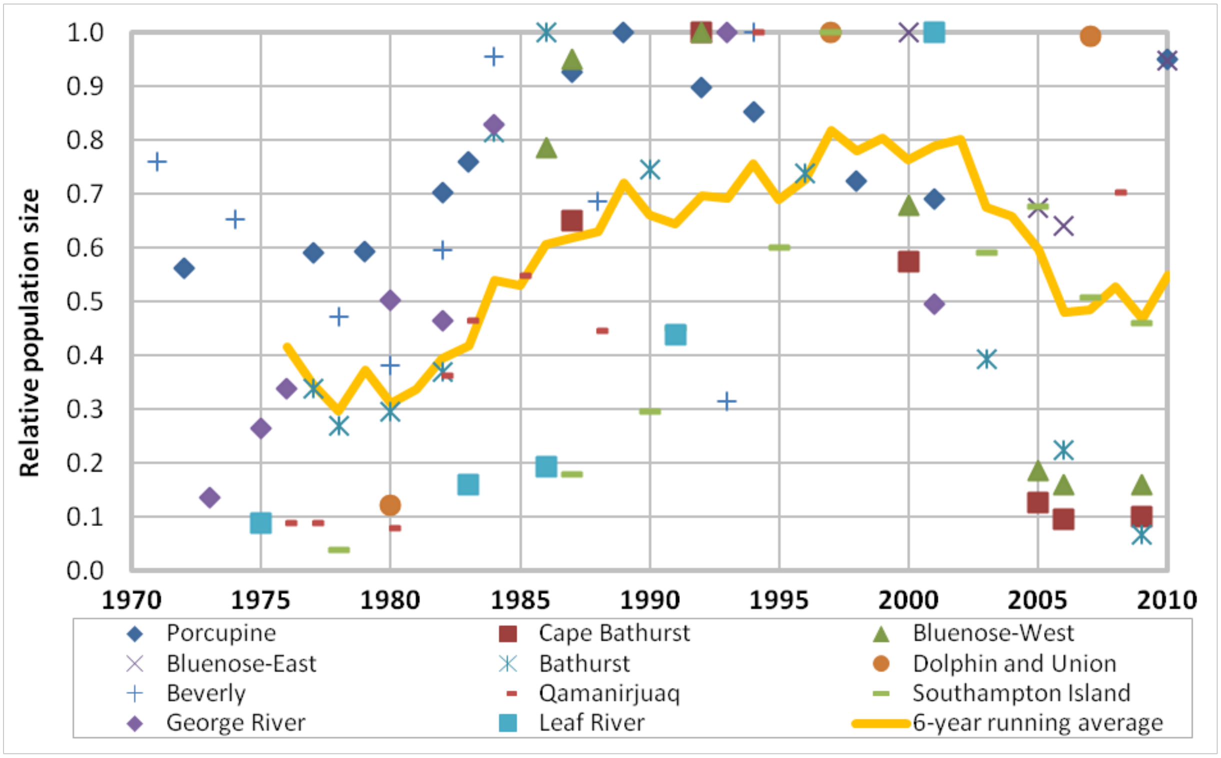


Figure 5. The relative size of tundra-dwelling wild Rangifer *herds (Canada).*
The line represents the six-year running average. Other symbols represent individual herds. Relative population size is calculated as the population estimate for the year as a proportion of the maximum recorded estimate. Note that the maximum recorded estimate is not necessarily the peak population over this timeframe, as surveys usually did not cover the entire period and were not conducted every year.
Source: based on data that are shown and referenced in Figure 7 to Figure 14 and Figure 16 to Figure 18

On the High Arctic islands, weather is an overwhelming influence as periodic severe winters trigger large-scale mortality and reduction in productivity (Miller and Gunn, 2003; Harding, 2004). Although the signals of climate warming are strong in the High Arctic (Zhang et al., 2011), relating those trends in weather to changes in Peary caribou abundance is uncertain, partly because of high annual variability in climate and infrequent monitoring for most Peary caribou. The other reason is that harvest and predation also affect Peary caribou abundance.

Muskox trends in abundance tend to differ from Peary caribou, although this is area specific. Muskox increases relative to Peary caribou decreases have raised the question of competition. The role of intra- or inter-specific competition for forage is conjectural as diet and habitat selection differ considerably between caribou and muskoxen (Gunn and Dragon, 2002). On Banks Island, however, there was overlap in the use of some plants, such as willow, by Peary caribou and muskoxen (Larter and Nagy, 2004), which suggests that a competitive relationship could occur. Less emphasis has been placed on determining whether the increasing muskox abundance supported increased wolf numbers which, in turn, could increase predation rates on Peary caribou (Gunn and Dragon, 2002). Even less attention has been given to studying the relationship between caribou and muskoxen and their parasites. Hughes et al. (2009), however, discussed levels of intestinal nematode worms and warble flies in muskoxen and caribou for the Dolphin and Union Caribou Herd.

The cumulative effects of increasing human presence on caribou ranges (number of people as well as non-renewable resource exploration and extraction and infrastructure development) are largely unknown. However, tools are being developed to examine how responses of the individual caribou can be scaled up to measure population-level effects (Gunn et al., 2011b). Some recently constructed mine projects monitored effects on caribou. Changes in caribou distribution and time spent foraging were reported (Gartner Lee Limited, 2002). In response to large open-pit mines on the tundra summer range of the Bathurst Herd, caribou distribution was reduced in a 10 to 15 km zone of influence around the mines (Boulanger et al., 2004). Changes in the atmospheric transport of contaminants on individual caribou body burdens are monitored for some herds (Gamberg, 2009) and the results evaluated in relation to potential impacts on human health. These evaluations conclude that nutritional benefits of consuming caribou far outweigh any risks from the low levels of contaminants (Van Oostdam et al., 2005; Donaldson et al., 2010).

WHY IS IT IMPORTANT?

Northern people and caribou are so inter-related that, without caribou, the Arctic would indeed be the barrens. Aboriginal people recognize the central role of caribou in tundra and taiga ecology and the inter-connection of caribou with the culture of many Aboriginal Peoples has parallels with the role of salmon on Canada's Pacific Coast.

Caribou are a numerically abundant, large-bodied herbivore in a relatively simple food web. Common species shape ecosystems by their sheer strength of numbers (Gaston and Fuller, 2008) which means that trends in their numbers are important in the structure and functioning of tundra and taiga ecosystems. At its simplest, the caribou role in the ecosystem is the net effect of forage removal, production of greenhouse gas, and return of nutrients through faecal pellets.

Based on energetics modelling (Russell et al., 2005), annually, a caribou:

- removes: 900 kg of forage (2.5 kg per day),
- produces: 20 kg of methane (55 gm per day), and
- returns to ecosystems: nutrients in the form of 270 kg of faecal pellets (30g x 25 times a day).

At the herd scale, annually, 170,000 to 350,000 caribou:

- remove: 153 to 315 million kg of forage,
- produce: 3.4 to 7 million kg of methane, and
- return to ecosystems: nutrients in the form of 46 to 94 million kg of faecal pellets spread over the herd's annual range (150 to 300 kg/km^2).

As caribou travel and rest on frozen waterways, the nutrient return from faecal pellets is to aquatic as well as to terrestrial ecosystems.

The role of caribou in the ecosystem, however, is more intricate and complicated than the mere removal of forage, emission of gasses, and return of nutrients. The boreal and arctic food webs have relatively few links, which does not mean that they are simple systems – the links represent complex inter-relationships among the organisms. Northern ecosystems are nutrient-limited because so much carbon is inaccessible, with only a shallow active layer of the soil thawing each year. Caribou, through their forage intake and output (faecal pellets), have complex and cascading effects that are strongly patterned over time and space (Kielland et al., 2006). As well, caribou support a diverse group of other species, including external parasites such as blood-feeding mosquitoes. Mosquitoes, in turn, through the filter-feeding of their larvae, are a key element in nutrient cycling in aquatic systems. Further up the food webs, caribou support large-bodied and medium-sized predators and scavengers. Earlier debates about top-down (predator) or bottom-up (forage) regulation of caribou populations are now replaced by an appreciation of how nutrition and predation interact (Brown et al., 2007).

Relationships between plants and caribou include the plants' responses to caribou's highly selective foraging. Caribou are selective for individual plant species and forage for buds and young leaves to maximize nutritional value (White and Trudell, 1980; Russell et al., 1993). The gregarious and migratory behaviour of migratory tundra caribou forces their role in ecosystem structure and functioning to be strongly scale dependent (Griffith et al., 2002). As caribou convert plant tissue into body mass and faecal pellets, their local foraging movements and seasonal migrations lead to a redistribution of nutrients within and across ecozones+. In the taiga ecozones+, the effects of caribou herbivory lag by a season as caribou are foraging during winter when most plant growth and nutrient cycling is quiescent due to sub-zero temperatures. Over the timescale of decades, caribou winter ranges expand and contract and the herds cycle from high to low abundance. Abundance can vary three-fold, with cascading effects on plants and nutrient cycling as the plant communities shift from one state to another. Succession of plant communities as a response to intensity of foraging includes, for example, lichen-dominated communities shifting to moss, and moss communities shifting to grass (Van der Wal, 2006).

Nitrogen is a limiting factor for plant growth. Caribou summer grazing can increase the rate of soil nitrogen cycling, 1) through influencing the amount of plant litter, which changes the soil microclimate for decomposition and mineralization processes; and 2) by adding soluble nitrogen from faecal pellets and urine (Olofsson et al., 2004). The changes vary with season and time and with the intensity of grazing (Kielland et al., 2006).

Caribou are often a frequent item in the diet of predators and scavengers, although predator dependence will vary with accessibility, as wolves, grizzly bears, and wolverine will feed on alternate prey and on other food in the absence of caribou. In the Southern Arctic in the mid-1990s, the Bathurst Herd of 350,000 caribou was estimated to support some 1,000 wolves (Cluff, 2004, pers. comm.) and about 450 grizzly bears (based on an estimated minimum density of 3.5 bears per thousand square kilometres: Gau and Veitch, No Date).

Wolves will use caribou at the rate of just under one caribou every 10 days (Hayes and Russell, 2000). On the Bathurst Herd's spring to fall ranges, grizzly bears were effective predators and caribou made up 10 to 93% of their diet, depending on the season (Gau et al., 2002). An adult male needs about 8 kg of caribou meat daily to fulfil its daily energy requirement during normal activity (Walker et al., 2006). Although this evidence points to carnivores being effective predators on caribou, the overall effect of predation in regulating caribou population dynamics is complex and incompletely understood. Krebs et al. (2003) suggest that the Northern Arctic ecosystem is driven less by predation and more by variance in weather.

Caribou have provided the basis of the cultures of people in the Arctic for thousands of years (Gordon, 2005) and still play a central role in their lives. A measure of the importance is the annual harvest, which, in Nunavut (1996 to 2001) averaged 24,522 caribou (Priest and Usher, 2004). In the Northwest Territories, Dene, Inuvialuit, and Métis from almost all communities currently hunt the migratory herds. The minimum annual harvest in the Northwest Territories is about 11,000 caribou (Department of Environment and Natural Resources, 2006).

A study commissioned by the Beverly and Qamanirjuaq Caribou Management Board determined the total net annual economic value of the Beverly and Qamanirjuaq caribou harvest (meat, hides, and antlers) to be $19.9 million, based on an estimated harvest by all communities for the 2005/06 hunting season of approximately 14,000 caribou (InterGroup Consultants Ltd., 2008). This study calculated regional net values per caribou varying from about $1,050 to $1,720 by taking into account differences in production costs (including travel costs) and replacement costs (for high grade beef). The authors also concluded that, above and beyond this direct value, the herds are integral to the maintenance and transfer of knowledge, skills, and culture for people throughout the herds' ranges.

THREATS

Predation, parasites, disease

Although predation, diseases, and parasites are part of the ecology of migratory tundra caribou, they are listed here as threats because their role in trends in caribou abundance interacts with human activities. The interactions work in a number of ways at the individual and herd scales and include variables such as whether predation is additive or compensatory to harvesting. The major predators of migratory tundra caribou are wolves and grizzly bears, but wolverines, lynx, and eagles all take caribou as well. Wolves and grizzly bears are effective predators of caribou of all sex and age classes and caribou have evolved behavioural strategies such as spacing themselves across their landscapes to reduce the risk of predation (Bergerud et al., 2008).

Numbers of predators are infrequently monitored on the ranges of the various caribou herds. Some information is available for the ranges of the Bathurst and Beverly herds. During the 1990s, wolf den occupancy on the Bathurst summer range (Cluff, 2004, pers. comm.) and along the Thelon River in Thelon Game Sanctuary (Hall, 2005, pers. comm.) decreased. The latter is the Beverly Herd's calving and summer range. Wolves are heavily hunted on parts of the Beverly Herd's winter range (Cluff, 2004, pers. comm.) and the trend (based on export permits for pelts) was an increase in wolves harvested in the 1980s compared to the 1970s, which may suggest an increase in abundance of wolves over that period. More recent information has not been compiled. Although annual variability makes measuring trends uncertain, wolf abundance on the Bathurst range may have declined since the late 1990s (Adamczewski et al., 2009). The number of grizzly bears increased during the 1980s and 1990s on the summer and fall ranges of the Beverly and Bathurst herds (Mulders, 2009, pers. comm.).

Information on the status and trends of diseases and parasites in migratory tundra caribou is fragmentary among herds and over time. The lack of information is partly because parasites and diseases have not been considered as important as, for example, predators in caribou population dynamics – which may itself reflect the lack of information. On Southampton Island caribou abundance and condition are monitored and a recent high incidence of brucellosis in both sexes has been implicated in the herd's decline (Campbell, 2008, pers. comm.).

Through the CircumArctic Rangifer Monitoring and Assessment Network (CARMA) International Polar Year projects, the herd-specific statuses for several parasites have been, and continue to be, evaluated. The bacterium causing Johne's disease, known for causing chronic wasting and diarrhea in cattle, has been found in caribou from Greenland and was found at low levels in Bathurst and Bluenose-West caribou in 2008 (Orsel et al., 2008). No evidence of chronic wasting disease was found in Porcupine or Bathurst herds (CARMA, 2010b).

For a long time, appreciation lagged for the role of parasites and pathogens in caribou ecology. However, that is changing: for example, gastro-intestinal worms occur in almost all caribou (deBruyn et al., 2009) and, while the infections may not cause obvious symptoms, they are likely costly to the caribou (Gunn and Irvine, 2003). For Svalbard wild reindeer, infection by parasitic worms influenced fecundity and played a role in regulating caribou abundance (Albon et al., 2002). Trends in parasites are unknown but warming temperatures and the northward extension of some hosts raises concerns. An additional concern is that, on the caribou's southern ranges, the possibility of parasite-host switching occurs where caribou and other deer species overlap in time and space (deBruyn et al., 2009). Hosts exposed to novel parasites maybe more susceptible (Ball et al., 2001).

Several parasites link caribou with their predators because the parasite needs two hosts to complete its life-cycle. The implications of this parasite linkage between predator and prey are unknown for caribou, but are established for other species. For example, the hydatid tape-worm infection in moose may increase the vulnerability of moose to wolf predation. Wolves are the secondary host for this parasite (Joly and Messier, 2004). In caribou, *Besnoitia tarandi* is a single-celled parasite with a two-host life cycle; carnivores and biting flies have been respectively suggested as potential definitive hosts and vectors of besnoitiosis. Typically the parasite can cause areas of roughened skin, but its overall effect on caribou health is unknown (Ducrocq et al., 2009). The status of *Besnoitia*, assessed from caribou harvested in the fall from 2007 to 2009, was variable, with the Leaf River Herd having a higher percentage of infected caribou (77% of males and 57% of females) than in the George River, Bathurst, and Bluenose West herds (all in the range of 30 to 45%), and with the Porcupine Herd having an infection rate of only 8% (Ducrocq et al., 2009).

One parasite whose status is better known is the warble fly, which is widespread on the summer ranges of all herds, although considerably less common on the High Arctic islands.

Caribou reduce their foraging time as they try to avoid the flies and, additionally, there are immune costs once nose-bot and warble flies have parasitized the caribou. Heavy infestations reduce calf growth, adult condition, and pregnancy rates (Weladji et al., 2003; Bergerud et al., 2008). Summer weather influences the activity of the adult flies (Russell et al., 1993) and, at least on the Bathurst Herd's summer range, summers have warmed. The trend between 1957 and 2009 is for an increase in the index of suitable weather and a longer season for warble fly harassment (Gunn and Poole, 2009; Witter, 2010).

Harvest

Harvest of caribou is part of people's relationship with caribou and harvesting is a rich source of information about caribou – their health, distribution, and ecology. However, in a changing world, and especially if the trends in abundance are in decline, even slowly, harvest can play a role in accelerating the decline (Adamczewski et al., 2009; Boulanger et al., 2011). The Cape Bathurst, Bluenose-West, and Bathurst herds were declining in the early 2000s; this decline was likely accelerated by a hunter harvest that remained substantial relative to the declining herd size. When harvests were curtailed, the declines halted (see herd sections starting on page 28).

Changes that have occurred on caribou ranges since the 1970s include an overall increase in number of people and shifting socio-economic patterns (such as wage-earning) which may influence harvest levels. The human populations of the Arctic and the three taiga ecozones+ have all increased, the combined population almost doubling, from 59,390 people in 1971 to 107,213 people in 2006 (Figure 6). The increase in number of people is reflected in the increasing size of larger communities (centralization) (Environment Canada, 2009)and increased seasonal and all-year road developments, especially in the Northwest Territories and northern Saskatchewan, on the southern edges of the winter ranges in the taiga and boreal ecozones+ (BQCMB, 2011; Trottier, 2011, pers. comm.). Caribou are adapted to respond to environmental variability, such as severe winters or increasing predation levels, by changing their patterns of movement across a large-scale landscape (Gunn et al., 2011a).

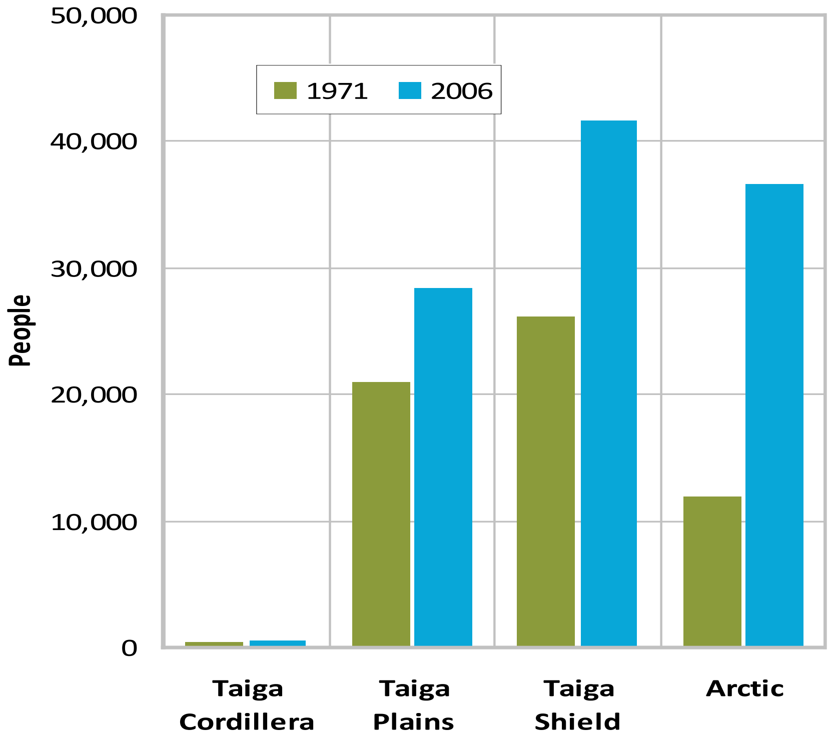


Figure 6. Human population levels in northern Canadian ecozones+, 1971 and 2006. Source: census data from Statistics Canada compiled by ecozone+ (Environment Canada, 2009)

The increasing number of people, a shift to wage-earning, and changing technologies for hunting (snowmobiles, ATVs, aircraft, winter roads, and rapid communications) have likely altered hunting effort and made finding and harvesting caribou more efficient. The relationship between hunting effort and harvest levels, however, is largely unknown and this limits understanding of the effects of hunting. Most of the understanding about the importance of measuring hunting effort is from a range of exploited species other than caribou (Ludwig, 2001). Schooling fish have parallels with gregarious caribou in relation to harvest vulnerability. For pelagic fisheries, constant yield harvests can lead to population collapses if harvesting effort is not directly related to local abundance (Mullon et al., 2005).

Understanding the effects of harvest is complicated as there are few measures of hunting effort and data on harvest levels are sporadic over time. Levels of, or trends in, wounding loss are unknown, although increased effort in management planning includes education and help from Aboriginal elders about respectful hunting practices (for example PCMB, 2009; Tlicho Government and Department of Environment and Natural Resources, Government of the Northwest Territories, 2011). Harvest levels at the community level vary; this is related to annual variability of the distribution of caribou on their seasonal ranges. In Canada's territories, most hunters are aboriginal and, under Canada's constitution and under land claims settlement acts, their hunting rights are protected. Generally, aboriginal hunters can harvest unlimited numbers of caribou unless there is a conservation issue. A second category of hunters is resident hunters. The trend is for fewer resident hunters in the Northwest Territories

(Government of the Northwest Territories and NWT Biodiversity Team, 2010) as a result of restrictions following the decline of herds. The third category of hunters is under the heading "commercial", which can include both harvesting for commercial meat sales and guided, outfitted hunts by non-residents. The level of commercial harvesting has varied among herds. Commercial use has been progressively reduced as the herds have declined and currently there is no commercial harvesting of any Northwest Territories barren-ground caribou herd (Department of Environment and Natural Resources, 2006) and commercial harvesting has been sharply reduced in Nunavut (Coral Harbour, 2011; Dumond, 2011, pers. comm.).

In the late 1980s, the Government of the Northwest Territories recognized the importance of collecting harvest information and initiated the collection of caribou harvest data from hunters. This was a time when herds were at or approaching peak herd sizes. The Dogrib Harvest Study collected information on the Bathurst Herd during the period 1986 to 1993 and reported that annual harvests ranged from about 7,000 to 23,000 caribou (Boulanger and Gunn, 2007). When the harvest study ended it was not replaced – although information collected in the 2005/06 season from check stations and community hunts indicated a decline in aboriginal harvest to about 4,500 caribou (Boulanger and Gunn, 2007). In 2007, for the Bathurst Herd, the number of tags per resident hunter was reduced from five to two and the harvest was restricted to bulls; in 2010 the harvest was reduced to zero (Miltenberger, 2010).

There is information for other herds on subsistence harvest levels, collected through harvest studies established under land claims legislation (Usher and Wenzel, 1987). For example, the annual caribou harvest in Nunavut from 1996 to 2001 averaged 24,522 animals (Priest and Usher, 2004). Information on the western Northwest Territories herds (Cape Bathurst, Bluenose-West, and Bluenose-East) is available through the Gwich'in Harvest Study (GRRB, 2009) and Inuvialuit Harvest Study (Inuvialuit Renewable Resources Committee, 2003) for community caribou harvests from 1988 to 1997. Information for 1998 to 2005 is available through the Sahtu Harvest Study (SRRB, 2004; Bayha and Snortland, 2006). As an example of harvest trends drawn from these studies, harvest from the Bluenose-West Herd in the Sahtu decreased from 1,022 in 1999 to 270 caribou in 2005 (SRRB, 2007).

The Beverly and Qamanirjuaq Caribou Management Board also provides estimates of caribou harvests in the board's annual reports. The combined harvest of the two herds was estimated at 14,080 in 2005/06, 13,770 in 2006/07, and 13,225 caribou in 2007/08 (BQCMB, 2006; BQCMB, 2007a; BQCMB, 2008a). With a lack of harvest data, the decline of the Beverly Herd, and uncertainty around herd movements and harvest locations, there was not enough information to provide reliable estimates for 2008/09 or 2009/10 (BQCMB, 2009; BQCMB, 2010a). Recent information on distribution of satellite-collared caribou suggests that the communities may also be harvesting caribou from the Ahiak Herd whose winter distribution overlaps with the Beverly Herd's typical winter range. If this is the case, previous harvest estimates for the Beverly Herd are not reliable (BQCMB, 2009).

Monitoring harvest levels is also complicated by different political reporting systems. For example, for the Porcupine Caribou Herd, harvest monitoring is the responsibility of two countries, one state, two territories, and seven aboriginal governments or councils. As a consequence, harvest reporting is sporadic and if detailed surveys are initiated they are seldom continued. Over the last 20 years, a reasonable estimate of total harvest has only been reported for a three-year period (1992 to 1994) (PCMB, 2009). Because the Porcupine Herd had been declining since 1989 and had potentially declined further since the population estimate in 2001, the Porcupine Caribou Management Board, a co-management body that generates management recommendations for the herd in Canada, developed a harvest management plan with options for responding to periods of herd decline, stability, and growth (First Nation of the NaCho Nyäk Dun et al., 2010).

On Southampton Island, caribou have been commercially harvested since the 1990s to supply a local meat processing plant. Commercial harvest averaged 2,432 caribou from 1992 to 2003, with an increasing trend over that period, while domestic harvest was estimated in 2006 at about 1,500 caribou annually (Campbell, 2006). The commercial harvest was suspended after the 2009 harvest because the herd had declined (Coral Harbour, 2011; Dumond, 2011, pers. comm.).

Development

Along with increasing numbers of people on the caribou ranges, there are trends towards more exploration and resource development activity. Most notable are activities associated with mineral and hydrocarbon exploration and development. Caribou behavioural responses to human activities, especially those associated with industrial exploration and development, are quite well known (Wolfe et al., 2000; Stankowich, 2008). As the rate of human activities increases, however, our lack of understanding about the cumulative effects on caribou at the individual and the herd level becomes a more worrisome gap (Cameron et al., 2005). Limited progress has been made in measuring and managing these cumulative effects (Festa-Bianchet et al., 2011; Gunn et al., 2011a).

Mining and oil and gas exploration and development

Mining typically follows boom and bust cycles. Exploration activities for diamonds and uranium were widespread on the Bathurst Herd ranges in the 1990s and over the period 2003 to 2008 on the Beverly Herd's calving and summer ranges. Although the amount of activity can be partially tracked through land-use permits, not all activity is regulated through permits and cumulative effects are difficult to access (Gunn et al., 2011a).

Site-specific contamination occurs at abandoned mines, a concern to local people who fear that the contaminants (for example from tailings) will affect wildlife, including caribou (for example Macdonald et al., 2005). Abandoned mines in the Northwest Territories and northern Saskatchewan still require clean-up (BQCMB, 2008b) despite the trend toward increased efforts since the 1990s to clean up these abandoned sites.

Exploration for and mining of uranium has been the greatest concern in the past among communities that harvest Beverly caribou. Uranium exploration and development has occurred for decades on the Beverly winter range in northern Saskatchewan. Mineral exploration has been increasing over the past 10 years on the ranges of both the Beverly and Qamanirjuaq herds in the Northwest Territories and Nunavut (BQCMB, 2010b). As of May 2010, there were many active prospecting permits, mineral claims, and mineral leases on the Beverly and Qamanirjuaq traditional calving ground (BQCMB, 2010b). The level of camps and aircraft activity associated with those claims and leases is highly variable. Since 1996, four diamond mines have been built and are operational on the Bathurst Herd's summer range. Three of the diamond mines are large open-pit mines and their activities have reduced the occurrence of caribou in their vicinity over a greater distance than expected (Johnson et al., 2005). In mid-2011, three large open-pit mines were at the formal environmental assessment stage for the Bathurst, Beverly, and north Baffin caribou ranges (NIRB, 2011).

In the Western Arctic, increases in oil and gas exploration activities over the last 10 to 15 years are a concern for people on the winter range of the Bluenose-East and Bluenose-West herds. Further west, the range of the Porcupine Caribou Herd extends from northeast Alaska to west of the Mackenzie Delta. The US portion of the herd's core calving range is in the Arctic National Wildlife Refuge. Opening the Arctic National Wildlife Refuge to oil and gas development (a proposal that has been under consideration in the United States for several years) has the potential to constitute a major threat to the Porcupine Caribou Herd. The "1002" area on the Alaskan coastal plain contains both high potential for hydrocarbon deposits and sensitive habitat for the herd during the calving and post-calving periods (Griffith et al., 2002).

Roads and transmission lines

The trend is toward increased access to some caribou seasonal ranges, with additional proposed roads in the planning stages. Roads can create partial barriers to caribou movement and provide easy access, creating the potential for increased harvest levels, including from hunters from communities outside of the region (Wolfe et al., 2000). Restrictions on use of roads for harvesting are difficult to establish and enforce. The three examples below illustrate some issues and concerns regarding linear development on caribou ranges.

1. Beverly Herd

Potential impacts on Beverly caribou from construction and operation of the Athabasca seasonal road through winter range in northern Saskatchewan, as well as a proposal for upgrading to an all-weather road, have raised concerns with the Beverly and Qamanirjuaq Caribou Management Board and with the Athabasca Interim Advisory Panel that is charged with developing a land use plan for a 50 km wide corridor along the road (Athabasca Interim Advisory Panel, 2006; BQCMB, 2009). Expected impacts of the road on caribou include increased hunting pressure from unregulated hunters from southern Canada, as well as cumulative impacts from development of additional roads and trails.

2. Qamanirjuaq Herd

Feasibility studies were first proposed in 1999 for transmission lines and roads from northern Manitoba to communities on the west coast of Hudson Bay, as well as for hydro generation facilities just north of the Manitoba border. These proposed facilities are all located on the Qamanirjuaq Herd range. An all-weather road along the Hudson Bay coast could increase access and possibly affect caribou movements during spring migration, and along the herd's fall migration corridor in southern Nunavut and northern Manitoba (BQCMB, 2007b).

3. Porcupine Herd

The Dempster Highway connects Dawson City, Yukon to Inuvik, Northwest Territories, traversing the winter range of the Porcupine Herd. The Dempster is a challenge to managers because of the access it provides to hunters (PCMB, 2010). Historically, harvest success was linked to the distribution of the herd. Since the construction of the highway, hunters have had access to the herd in the Richardson Mountains, Eagle Plains, and Ogilvie Valley. As well as direct mortality from harvesting, there has been an ongoing concern that portions of the herd's winter range south and east of the highway may be lost if there is a disruption of the migration across the highway due to hunting. In the past, this potential threat was addressed by applying various no-hunting corridor widths along the highway and by completely closing the highway to hunting for one week during the peak of fall migration in the region (Environment Yukon, 2010b). Because implementation of the no-hunting corridors varied from formal regulations to voluntary restrictions, depending on the user group, the success of the corridors was mixed. Enforcement of the no-hunting corridor was halted in 2007 due to legal challenges (PCMB, 2008).

Hydroelectric development

The largest land conversion in the Quebec portion of the Taiga Shield Ecozone+ has been the flooding of land for hydroelectric development. Since the 1970s, about 2,000 km^2 of lake area and about 11,000 km^2 of land have been converted to reservoir for the La Grande development (Therrien et al., 2004). About 6,000 km^2 of forest was lost due to conversion to reservoirs, roads, and other types of infrastructure (ESTR data analysis by F. Ahern based on Leckie et al., 2006), a trend that may continue with expansions and additional hydro projects planned (Hydro-Québec, 2011). In Newfoundland, caribou avoided a hydro-project during construction and operation (Mahoney and Schaefer, 2002).

Shipping

The pattern of increasing access associated with development of caribou ranges is not restricted to terrestrial ecozones+. Shipping is increasing in Arctic passages, with the biggest increases in Hudson Strait and the Mackenzie Delta (Judson, 2010). There are implications of ice-breaking ships for caribou sea-ice crossings, especially in the fall, when changes to the timing and patterns of sea-ice formation could interrupt migration or increase the risks to caribou crossing the ice between Victoria Island and the mainland (Poole et al., 2010). Increased shipping also brings more people to the Arctic. Cruise ship stops and associated tours on land bring a new type of tourism – large groups wishing to observe wildlife in over a short time period. This has the potential for increased impacts on wildlife, a factor now being considered in park management planning (for example Wildlife Management Advisory Council (North Slope), 2006). Passages of cruise ships increased more than threefold between 1993 and 2007 (Judson, 2010).

Pollutants

Atmospheric currents bring pollutants from distant sources and deposits them on snow and vegetation. Some of these pollutants are considered contaminants, as they can accumulate as they move up the food chain – including through the lichen-caribou-human food chain (Gamberg et al., 2005). In general, most contaminants are more of a concern for aquatic ecosystems (especially for marine mammals) than for terrestrial ecosystems (Gamberg et al., 2005). Other pollutants do not accumulate in the plants and animals but have other ecosystem impacts that may indirectly affect caribou. For example, arctic haze, a persistent, diffuse layer in the lower (2 to 5 km) layers of the atmosphere, is a complex mixture of small particles and acidifying pollutants from natural sources such as forest fires and volcanoes, as well from industrial pollution. It forms in winter and the particles are deposited in snow which, as it melts, carries the particles and pollutants into aquatic ecosystems. Dark particles on the snow surface contribute to earlier snow melt, a feedback mechanism known to accelerate global climate change (Rinke and Dethloff, 2008). Currently, the direct effects of arctic haze on terrestrial ecosystems appear to be restricted to the locality of industrial plants, mainly in Russia (AMAP, 2006).

The Canadian Northern Contaminants Program (NCP) has been active in monitoring persistent organic pollutants (POPs), heavy metals, and radionuclides for the last three decades. The following account is derived from the NCP summary report (Northern Contaminants Program, 2003), except where noted. Some 15 different caribou herds across Nunavut, the Northwest Territories, and the Yukon were monitored during the 1990s through two large monitoring programs; additional monitoring has been undertaken since then for some herds (Gamberg, 2009). Assessments of risk to human health from contaminants show that caribou is a safe and nutritious food choice across northern Canada (Donaldson et al., 2010).

Persistent organic pollutants such as DDT, PCBs, dioxins, and furans were found at only very low levels in caribou (often too low to be detected at all) and are not of concern for either caribou or human health (see also Gamberg et al., 2005).

Some heavy metals, however, are found at elevated levels in caribou, though not to the same extent as in some marine mammals. There are wide variations in the levels of metals from herd to herd, probably due to the variation of levels in the underlying geology. Cadmium levels tend to be higher in the kidneys and livers of the Beverly caribou in the Northwest Territories and Nunavut, compared to the levels in other herds. Natural sources of cadmium in the underlying rocks in the area are likely responsible. This cadmium accumulates in lichen, which is then eaten by the caribou. Mercury levels show no clear pattern (Gamberg et al., 2005), with the highest levels found in the Beverly Herd and in Meta Incognita Peninsula caribou (part of the South Baffin population). In the central and northeastern parts of northern Canada, levels of mercury in caribou follow the same geographic pattern as levels found in sediments. Scientists consider that much of this mercury has been transported from human-made sources in other parts of the world. An exception is mercury in caribou from the Yukon, where local geology may be a more important contributing factor.

Radioactivity levels became elevated in caribou during the 1960s from atmospheric nuclear weapons testing, with the highest concentrations of radiocesium found in the large caribou herds of central northern Canada. Levels declined steadily, with a temporary, and relatively small, increase from fallout following the Chernobyl reactor accident. Concentrations now are about ten times lower than in the 1960s and continue to decline (Macdonald et al., 2007).

New and emerging contaminants (contaminants that have recently been found to accumulate in ecosystems) are generally of more concern for aquatic environments – but, nonetheless, they are also a recommended focus for further monitoring and research in terrestrial ecosystems (Gamberg et al., 2005). An example of this class of contaminants is perfluorinated compounds (PFCs, used to make consumer goods like water-repellent coatings and fire-fighting foams), which are known to be widespread globally (Donaldson et al., 2010) and increasing in the Arctic (Ostertag et al., 2009). Caribou liver and meat accumulate PFCs and contribute to the intake of these contaminants by those northern residents who eat caribou frequently. Health risks associated with the current levels measured in people are considered to be very low (Ostertag et al., 2009; Donaldson et al., 2010).

Forest fires

Forest fires are a long-standing part of caribou ecology but trends toward increasing size and severity of fires could change the relationship. The influence of forest fires on northern caribou ecology will vary among herds as the herds vary in the percentage of their annual range that extends below the tree-line. The tree-line dips south in the continental centre of Canada and then turns north toward the Atlantic coast. The George River Herd's annual range is 90% below the tree-line as the area of tundra is narrow. The other herds have between 57 and 79% of their annual range below the tree-line, while the Dolphin and Union and the northeastern mainland herds remain north of the tree-line year-round. Through the cycles of high and low abundance, the winter range shifts, expands, and contracts.

The northern caribou herds use the boreal forests mostly within the Taiga Plains and the Taiga Shield. Partly because of their dry continental climate, fuel types, and relative lack of suppression, fires in these ecozones+ tend to be relatively severe and large (Krezek-Hanes et al., 2011). The annual pattern of forest fires is episodic, with, for example, years of high fire activity (1979, 1989, 1994, 1998 in the Taiga Shield Ecozone+ during the period 1960 to 2007) interspersed with years of lower fire activity (Krezek-Hanes et al., 2011). This episodic pattern is related to variations in weather during the fire season, influenced both by decadal climate shifts caused by the Pacific decadal oscillation and by the trend toward warmer temperatures (Krezek-Hanes et al., 2011).

Average annual area burned by large fires has increased since the 1960s in Canada's taiga ecozones+ (Krezek-Hanes et al., 2011). Results from the Canadian Climate Centre General Circulation Model scenarios suggest a further increase in fire occurrence across Canada of 25% by 2030 and 75% by the end of the century, with the average area burned expected to approximately double from the beginning to the end of the 21st century (Wotton et al., 2010). The magnitude of the changes in fire regimes is projected to be greater at northern latitudes

(Flannigan et al., 2005). Trends toward an increase in forest fire intensity and frequency will affect caribou winter range (Russell et al., 1993; Thomas, 1998) as caribou shift their distribution in response to the pattern of recently burnt areas, as well as in response to snow conditions (Thomas and Kiliaan, 1998; Joly et al., 2003; Barrier, 2011). An increase in forest fires may have additional, long-term effects on lichens. On the tundra-boreal forest ranges of the Western Arctic Caribou Herd in Alaska, lichens have decreased from the combined effects of forest fires, grazing, and possibly the warmer temperatures (Joly et al., 2009; Joly et al., 2010). As lichens decreased, shrubs and grasses increased – a trend also seen elsewhere in the Arctic (Cornelissen et al., 2001).

Two trends characterize the forested winter ranges of the migratory tundra caribou. First, the cumulative effect of forest fires is reducing the areas of mature to old forest, which is where the mats of lichens have reached maximum growth. Between 1990 and 2000, for example, forest fires on the winter range of the Bathurst Herd (including the area south of Great Slave Lake) reduced the area of forest by 30% (Chen et al., In Prep.[a]). Caribou moved through recently burnt areas but did not stay, as lichens, their main winter forage, are rare until about 40 to 60 years after a forest fire. Caribou avoided areas with a high density of burns and selected the older patches of forest with a ground cover of lichens and herbaceous forage, although caribou did use the habitats adjacent to the burn boundary and some caribou occupied habitats in early-succession stages more than expected (Barrier, 2011). On the Beverly winter range, lichen recovery was relatively slow and caribou did not make the highest use of forests until 150 to 250 years after fires (Thomas and Kiliaan, 1998). Caribou harvesters from communities on the Beverly winter range in southern Northwest Territories and northern Saskatchewan believe that loss of habitat due to forest fires on the winter range has resulted in decreased use of large areas by caribou and changes to migration routes (BQCMB, 2005; BQCMB, 2011).

The second trend is an overall contraction of the southern boundary of the forested winter ranges as herd abundance declines (and correspondingly, expansion when herds increase in numerical strength). This is best known through the work of Bergerud et al. (2008) for the George River Herd. However, it is also a recent trend for herds such as the Bathurst Herd (Gunn et al., 2011b).

Climate change

Climate in the North has changed by different magnitudes and at different times of the year depending on location. For example, in northwestern North America, spring has been warming at a high rate over the last few decades. In the central and eastern barrens, spring conditions remained stable or cooled slightly for periods of several years within the same time frame. The overall trend since 1950 across the Canadian Arctic, however, is to annual average temperature increases, with strongest warming in the winter, spring, and summer months (Zhang et al., 2011). The same regional and seasonal diversity in temperature trends, with an underlying warming trend, has been documented in Russia. Climate models demonstrate that the climate will continue to change – and most conspicuously in the North (ACIA, 2005).

Broad-scale trends in patterns and amount of vegetation are related to these trends in climate. For example, the Southern Arctic showed a net increase in the Normalized Difference Vegetation Index (NDVI), an index of photosynthetic activity, of about 24% from 1985 to 2006 (Ahern et al., 2011). Studies relate increases in NDVI in the Arctic to increased growth of shrubs in many areas, accompanied by decreases in tundra vegetation (for example Hudson and Henry, 2009; Olthof and Pouliot, 2010). The global area of arctic tundra was estimated to have decreased about 20% between 1980 and 2000, based on trends in climate and on NDVI studies (Wang and Overland, 2004). However, predicting the changes is complicated as even within a single plant species there are considerable variations in responses to climate. For example, bud, flower, and leaf growth of arctic heather (*Cassiope tetragona*) responses to temperature and precipitation varied among sites and Arctic islands, based on decade-long chronologies (Rayback et al., 2011).

At the scale of individual herd ranges, for example the Bathurst Herd's calving grounds, shrub encroachment may have reduced the area of lichens. Lichen cover, as measured through remote sensing, decreased between 1990 and 2000 from 44 to 22% of the total calving ground area (Chen et al., In Prep.[b]). Other trends in vegetation that have been measured on the Bathurst Herd's summer range include a significant increasing trend in green biomass, based on NDVI satellite imagery (Chen et al., In Prep.[b]).

Annual variability in arctic climate is high – which means detecting trends can be difficult (Chen et al., In Prep.[a]). Additionally, it is difficult to attribute a single event such as an icing storm as being within the "normal" range or as an indication of a warming climate. Examples of this type of event occurred in the fall of 2003, when coastal areas from Alaska to Kugluktuk, Nunavut experienced icing conditions that forced caribou to move in search of accessible forage. Ice on the land formed a barrier between the caribou and their food (Nagy, 2007).

Another factor that adds to the complexity of predicting impacts of climate change is that all herds have evolved and adapted to a unique suite of environmental factors within their ranges – some herds cope with winter ranges characterized by deep, persistent snow, others enjoy mild winter conditions; some herds occupy excellent summer ranges with an abundance of fresh green vegetation; others have to replenish fat and protein reserves depleted over winter with vegetation that is limited by a brief, intense summer growing season. Changes that result in more severe winter range conditions, for example, would have different effects on different herds – even neighbouring herds. For example, under a warmer climate, the annual range for the Leaf River Herd may expand while that of the George River Herd may contract (Sharma et al., 2009).

Further, at the population level, some herds have exhibited a high rate of increase, over 15% annually, while others have increased at rates of less than 5% annually, primarily reflecting higher adult female mortality rates (Figure 4). Environmental changes that result in an increase in adult female mortality would have a greater impact on herds that demonstrate a low rate of increase.

Within the range of the Porcupine Herd, for example, the trends of climate change are marked. Spring strongly warmed over the last three decades. During late spring, after calving, this has resulted in early snowmelt and more food available for nursing mothers. As a consequence early calf survival had improved (Griffith et al., 2002). In early spring, however, when the herd is on migration, warmer weather has resulted in more freeze-thaw cycles as temperatures get above freezing during the day and below freezing at night. Specifically, the number of days during spring migration where the temperature rose above zero doubled during the population decrease phase (1989 to 2001) compared to the previous population increase phase of this herd (1975 to 1988) (Griffith et al., 2002). The greater difficulty in traveling and feeding through ice crusts would result in higher energetic costs and moving onto wind-blown ridges during migration would result in potential increased mortality from wolves, as wolves are at an advantage in shallow snow (Griffith et al., 2002).

Gaps in monitoring impede understanding of the effects of trends in a warming climate and this is accentuated by a lack of baseline information. For example, caribou avidly feed on mushrooms in late summer and mushrooms constitute a late-summer source of protein just after the insect harassment season and prior to the breeding season. But almost nothing is known about the timing and prevalence of the mushrooms. In northern Europe, the timing of the fruiting bodies of fungi (mushrooms) has changed. In Norway, with warmer temperatures and changes in summer rainfall extending the growing season, the average date of mushrooms fruiting in the fall was 13 days later in 2006 than in 1980 (Kauserud et al., 2008).

Table 1 provides a very general treatment of climate impacts on caribou, their ranges, and the communities that depend on them. The table is an updated version of a table contributed by the author (Russell) to Chapter 10 of the Arctic Climate Impact Assessment (ACIA, 2005).

Table 1. Climate change impacts on migratory tundra caribou populations.

Climate change condition	Impact on habitat	Impact on movement	Impact on body condition	Impact on productivity	Management implications
Earlier snowmelt on coastal plain	· Higher plant growth rate	· Core calving grounds move further north · Less use of current calving grounds	· Cows replenish protein reserves faster · Higher calf growth rate	· Higher probability of pregnancy · Higher June calf survival	· Need for flexibility in calving ground protection (adaptive management)
Warmer, drier summer	· Earlier peak biomass · Plants harden earlier · Reduction in mosquito breeding sites · Increased parasitic (oestrid) fly harassment · Increased frequency of fires on winter range · Fewer "mushroom" years	· Movement off of calving grounds earlier · More use of insect relief habitat in July · Avoidance of recently burned winter habitat	· Increased harassment will lower fall body condition	· Reduced probability of pregnancy	· Protection of insect relief areas important
Warmer, wetter fall	· More frequent icing conditions	· Caribou abandon ranges with severe surface icing	· Higher winter mortality · Earlier weaning		
Warmer, wetter winters	· Deeper denser snow · Icing conditions, especially in tundra and arctic islands	· Increased dependence on low snow regions · Stay on winter range longer	· Greater over winter weight loss · Higher incidence of extended lactation	· Lower over winter mortality on calves	· Need to consider protection of low snow regions (adaptive management)
Warmer springs	· More freeze/thaw cycles during spring migration · Faster spring melt	· Movement slowed and/or movement unto drier windswept ridges	· Accelerated weight loss in spring	· Higher wolf predation on cows and calves due to use of windswept ridges	· Concern over timing and location of spring migration in relation to traditional harvesting areas

<u>Overall effect</u>: In very general terms: the calving range improves but with movement and reliance on more northern portions of the calving range; animals leave calving range earlier; cows and calves suffer reduced summer and fall body reserves due to increase in oestrid fly harassment; mosquito harassment may be reduced if summers drier; more frequent icing in fall, winter, and spring ranges, which depend on the location of these ranges; may have moderate to severe implications to body condition and survival.
Source: update of Chapter 10 of the Arctic Climate Impact Assessment (ACIA, 2005) by the author (Russell)

TRENDS IN PROTECTED CARIBOU HABITATS

One of the most frequently raised concerns about caribou is the need to protect calving caribou from human activities when they aggregate on their traditional calving grounds (for example BQCMB, 2004).Currently, no Canadian herd has a fully protected calving ground, although some are partly protected. The Bluenose-West Herd's calving ground is largely within Tuktut Nogait National Park, established in 1996 to protect this calving ground (Government of Canada et al., 1996). In northwest Yukon, the Canadian portion of the Porcupine Herd calving ground is within Ivvavik National Park, which was established in 1984 (Parks Canada, 2007).

Some calving grounds have specific restrictions on land-use activities aimed at providing some measure of protection to calving caribou. The federal Caribou Protection Measures for the Beverly and Qamanirjuaq calving grounds have been in effect since 1978; comparable land-use regulation has not been applied to other calving grounds in the territories (Gunn et al., 2007). Quebec has regulations restricting land-use activities on calving grounds, legally identified as a land used by more than five adult females per km^2 from the 15^{th} of May to the 1^{st} of July, based on telemetric locations between 1999 and 2003 (Brodeur, 2011, pers. comm.). However, for the George River Herd, by 2010, calving had shifted to outside the area covered by these regulations (Taillon, 2011, pers. comm.).

Although the trend for most herds is geographic fidelity to calving grounds, the timescale for fidelity varies. Variation among herds is likely, given the differences in trends in abundance among herds (Gunn et al., In Press). The calving grounds of the Beverly and Qamanirjuaq herds, for example, show geographic fidelity – calving ground locations did not show consistent shifts from the 1960s to the 1990s, although the degree of overlap of the two herds on calving grounds varied between consecutive years (Gunn et al., 2007). Subsequently, the fidelity for the traditional calving ground of the Beverly Herd changed, with some cows switching (Gunn et al., In Press; Nagy et al., 2011). Since 1966, when the calving distribution started to be mapped during aerial surveys, the Bathurst Herd has had two periods, totalling 30 years, during which the predictability of the calving ground's location was high. The two periods were separated by an 11-year period (1986 to 1996) during which calving locations shifted from the east to the west of Bathurst Inlet, where calving was also recorded in the 1950s (Gunn et al., 2008).

Beverly caribou, during pre-calving, calving, and post-calving, spend a large part of their annual cycle feeding and traveling on lands protected within the Thelon Wildlife Sanctuary (BQCMB, 2004). The Ahiak Herd's calving grounds, post-calving ranges, and much of the summer range are within the Queen Maud Gulf Migratory Bird Sanctuary and are therefore protected from resource exploration or development (Gunn et al., 2000b). The Sanctuary was designated for the large numbers of nesting lesser snow geese and Ross's geese (Bird Studies Canada and Nature Canada, No Date). The implications of the increasing numbers of snow geese on caribou foraging or disease transmission are unknown.

On the annual ranges of the Porcupine Herd, sensitive areas in Ivvavik National Park and Vuntut National Park are protected from resource development but not from human activity, such as tourism and aircraft over-flights. (Parks Canada, 2007; Parks Canada, 2010b). The calving grounds in the Arctic National Wildlife Refuge and some parts of the fall and winter range in the Richardson Mountains have no permanent protection. The area of the Northern Richardson Mountains within the Gwich'in Settlement Area is protected under the Gwich'in Land Use Plan (Gwich'in Land Use Planning Board, 2003). Another area of the Northern Richardson Mountains is in the Inuvialuit Settlement Region – the sensitivity of this region is addressed in the Aklavik Community Conservation Plan (Community of Aklavik et al., 2008). Other areas within the range of the Porcupine Herd have land use or management plans in place, including the Fishing Branch Protected Area, Tombstone Territorial Park, and Herschel Island Territorial Park (Environment Yukon, 2010a).

Protection of caribou seasonal ranges is increasing in the Northwest Territories through the efforts of the Northwest Territories Protected Areas Strategy (Northwest Territories Protected Areas Strategy Advisory Committee, 1999). Three areas around Great Bear Lake will protect summer, fall, and winter ranges for Bluenose-East Herd and the establishment of Thaidene Nene National Park Reserve will provide protection for part of the winter ranges for the Bathurst, Ahiak, and Beverly herds (Gunn et al., 2011b).

Protection of Peary caribou habitat is increasing, as two national parks in areas important for Peary caribou have been established since the early 1990s, and a third park is under negotiation. On northern Banks Island, Aulavik National Park was established in 1992, protecting land that is mostly summer range for Peary caribou (Parks Canada, 2010a). On the northeastern range of Peary caribou, Quttinirpaaq National Park on Ellesmere Island, the second largest national park in Canada, was established in 2001 (Parks Canada, 2006). The third park initiative potentially providing protection for Peary caribou is on northern Bathurst Island – land for the proposed Tuktusiuqvialuk National Park was set aside for the park in 2010.

There is no clear trend toward increasing protection for migratory caribou calving grounds across Canada (Festa-Bianchet et al., 2011). Although the trend is toward greater protection of annual ranges for some herds through a variety of regimes, movement towards herd-specific land-use planning to ensure the linking of the protected areas is essential for the integrity of caribou seasonal ranges. Globally, concerns are rising for the protection of migratory species (Berger, 2004).

HERD-SPECIFIC ASSESSMENTS

Population estimate data were compiled for this report and for the online database of the CircumArctic Rangifer Monitoring and Assessment Network (CARMA, 2010a). Where possible, publicly available documents containing methodology have been cited. As population estimates are occasionally recalculated based on new data and for consistency with more recent surveys, conflicting estimates appear in the literature for some herds and some years – in these cases, we have selected the most recent estimate that is published in a publicly available document.

The emphasis in these accounts is on trends in herd size and on vital rates such as calf survival, when the information is available, rather than an exhaustive account of population demography. We have also included some information on environmental trends for the herd ranges.

Ahiak Herd

***Ecozones*+** Calving ground: Southern Arctic (also summer into fall); Southern Arctic and Taiga Shield fall and winter ranges

Status and trends

Caribou calving along the Queen Maud Gulf coast were first known from Inuit knowledge and from historical information on caribou distribution. Inuit elders from Gjoa Haven and Hudson Bay traders described how caribou used to calve on the islands along the Queen Maud Gulf coast (Gavin, 1945). The herd was first named after the Queen Maud Gulf (Heard et al., 1986) and then, in the early 1990s, the herd's name was changed to the Inuktitut word Ahiak.

Studies and surveys of the Ahiak Herd have been infrequent, which has hindered describing and interpreting trends. Information is from tracking of satellite-collared cows (1996 to 1997 and 2001 to 2010), pre-calving surveys in 1983 and 1995, and surveys of calving distribution in 1986 and 1996 (Gunn et al., 2000b; Gunn and D'Hont, 2002). In 1986, a stratified visual survey of the coastal calving ground estimated 11,265 ± 1615 (SE) caribou. In 1996, caribou were found calving further west than in 1986 as an elongated coastal calving ground and a lower coverage survey estimated 83,134 ± 5298 (SE) caribou (Gunn et al., 2000b). In 2006, the estimate for this calving ground was 123,226 ± 14,500 (SE) (Johnson, unpublished data). Between 2006 and 2010, annual surveys were flown to map calving distribution and estimate densities of caribou across the Queen Maud Gulf coast between Bathurst Inlet and Chantrey Inlet. There was a 60% decline in the number of caribou on the calving ground between 2006 and 2009, followed by an increase in caribou observed in 2010 compared to 2009 (Kelly, 2011, pers. comm.).

The first interpretation of the historical information and 1986 to 2006 aerial surveys was that the Ahiak Herd calved along the coast and was a discrete, tundra-wintering herd, although in some years the herd's wintering range extended into the boreal forest (Gunn et al., 2000b; Gunn and D'Hont, 2002). Between 2007 and 2009, six satellite-collared cows that had initially calved on the Beverly Herd's calving grounds had switched (Gunn et al., In Press; Nagy et al., 2011) to what had been defined as the traditional coastal calving ground of the Ahiak Herd (Gunn et al., In Press; Gunn et al., 2000b). Based on collar location analysis, Nagy et al. (2011) proposed an alternate interpretation and suggested that the Ahiak and Beverly herds were not discrete herds but have likely been linked as early as the mid-1990s with the gradual shift of Beverly cows to the Ahiak calving ground located in the western half of the Queen Maud Gulf. Nagy et al. (2011) also suggested that another tundra-wintering herd has an overlapping calving distribution with the western Queen Maud Gulf and that the calving ground extends across the eastern portion of the Queen Maud Gulf and across Chantrey Inlet.

Despite the uncertainty in the timing of the Beverly Herd’s change in calving distribution, it is clear that there has been change since 2007, with satellite-collared cows from the Beverly Herd calving on the Ahiak Herd’s calving ground. The timing and mechanism for the shift in calving is a key consideration in interpreting whether the initial increase in caribou calving in the Queen Maud Gulf was the previously identified tundra-wintering Ahiak Herd and/or the on-going northern shift of the Beverly Herd.

Due to two possible interpretations of the movement data of caribou calving in the Queen Maud Gulf area, we have not graphed the estimates of caribou on the calving grounds and acknowledge that the current status of the Ahiak Herd is uncertain. The Ahiak Herd may have gone through a sharp increase from 1986 to 2006 and a subsequent decline from 2006 to 2009, with signs of increase between 2009 and 2010. On the other hand, we may not have a recent estimate of the Ahiak Herd during calving in the Queen Maud Gulf, as Nagy et al. (2011) suggest the apparent increase between 1996 and 2006 may have been the slow colonization of the area for calving by the Beverly Herd.

Spring composition surveys to estimate calf:cow ratios have been undertaken since 2008. Satellite collaring from 1996 to 98 and again from 2001 to 2005 revealed that caribou calving on the Queen Maud Gulf coast wintered mostly on the tundra, although in some years (1997 and 2001) the winter distribution extended south of the treeline (Gunn et al., 2000b; Gunn and D'Hont, 2002). The herd is seasonally hunted by people from Gjoa Haven, Umingmaktok, and Cambridge Bay (Nunavut); Lutsel K’e (NWT); and, in some winters, the communities of northern Saskatchewan.

Baffin Island herds

Ecozones+ Calving ground: Northern Arctic (also summer into fall and winter); some herds also use Arctic Cordillera

Status and trends

Inuit have reported on historic trends in distribution and changes in migration patterns based on observations of abundance of the caribou (Ferguson et al., 1998; Knight Piésold Consulting, 2010). Inuit on Baffin Island report that caribou numbers are cyclic, with 60 to 80 years between peaks in abundance. Historically, on southern Baffin, caribou numbers were low in the 1940s, followed by increases during the 1950s, peaking in the 1980s and early 1990s, depending on the geographic area (Ferguson et al., 1998). Subsequent trends are unreported, although a recent compilation of reports and local knowledge indicates that caribou numbers, at least on north Baffin Island, are at a low point in the cycle of abundance (Knight Piésold Consulting, 2010). No population surveys have been conducted in north Baffin and only one preliminary, non-systematic calf survey was completed in 1997 (Jenkins, 2007). This survey identified calving in the vicinity of the proposed Mary River iron ore open-pit mine.

Bathurst Herd

Ecozones+ Calving ground: Southern Arctic (also summer into fall); Taiga Shield fall and winter ranges

Status and trends

The Bathurst Herd size and distribution has been monitored frequently and trends for herd abundance are relatively well-described. The herd increased during the early 1980s and peaked in 1986 (Figure 7). Then, between 1986 and 2006, the herd declined at a rate of 5% per year, based on censuses in 1996, 2003, and 2006. A population survey in 2009 found only 16,000 breeding females on the calving grounds, translating into a population estimate of 31,600 animals – over a 70% decline from the 2006 estimates. Supporting evidence for the decline comes from a trend of reduced calf survival and relatively low adult survival of cows. Calf survival from 2001 to 2006 was about half the rate of survival measured from 1985 to 1995. Then, in 2007 and 2008, calf survival (based on calf:cow ratios) increased, which may have partially reflected low cow survival (Boulanger et al., 2011). Calf survival and calving distribution are currently monitored annually.

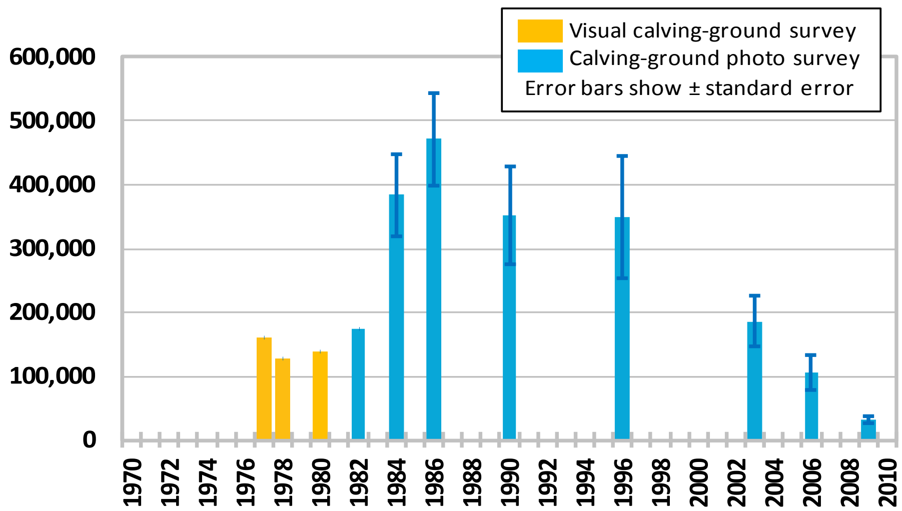


Figure 7. Bathurst Caribou Herd population estimates.
Standard errors were not calculated for the visual surveys and no standard error figure was available for 1982. Estimates are of caribou one year and older. Surveys were all undertaken in June.
Source: based on data compiled for this report – 1977-1984: Case et al. (1996); standard error for 1984: Environment and Natural Resources (No Date[Bathurst]); 1986: Heard and Williams (1991a); 1990: Heard and Williams (1991b); 1996: Gunn et al. (1997); 2003: Gunn et al. (2005); 2006: Adamczewski et al. (2009); 2009: Adamczewski (2011b, pers. comm.)

In 2010, the Wek'èezhìi Renewable Resources Board recommended sharply curtailing aboriginal harvesting and halting resident and commercial harvesting after extensive public hearings on a joint management proposal from the Tlicho Government and the Government of the Northwest Territories (WRRB, 2010).

Historically, based on Tlicho elders' recollections of the supply of caribou in fall hunting camps, there were high numbers of Bathurst caribou in the 1940s, low numbers in the 1950s, and increasing numbers during the 1970s and 1980s (Dogrib Treaty 11 Council, 2001). A similar pattern was determined by examining the frequency of hoof scars on spruce roots (Zalatan et al., 2006). The scar frequency distribution shows low caribou abundance during the 1920s, followed by a high peak during the mid-1940s, then a low period between 1950 and 1970. There was an increasing trend in caribou abundance after the 1970s, with a peak in the 1990s, followed by a significant drop in caribou abundance at the turn of the century.

Since 1996, the location of the calving ground has been relatively predictable and the annual use of post-calving and summer ranges, based on the movements of satellite-collared cows, has not shifted (Gunn et al., 2008). The fall and winter ranges are the largest seasonal ranges and the least predictable on an annual basis (Gunn et al., In Press). Since 1998, the southern boundary of the winter range has contracted (Gunn et al., 2011b). Based on movement data, as calculated from satellite collars on cows, there was a positive relationship between distance from winter range to calving grounds and both mean daily movement rates during May and date of entry into the peak calving area (Gunn and Poole, 2009). Environmental trends for the Bathurst range are consistent with trends recorded at the circumpolar and ecozone+ scales (Gunn and Poole, 2009).

Beverly Herd

***Ecozones*⁺** Calving ground: Southern Arctic (also summer into fall); Taiga Shield fall and winter ranges

Status and trends

Studies and surveys of the Beverly Herd were frequent until the early 1990s. During the 1980s, the overall trend in herd size was an increase (Figure 8). Calf survival was high in earlier studies, but was not measured after 1993. The 1994 photographic survey (Williams, 1995) estimated 151,000 ± 48,700 (SE) caribou one year old and older on the calving grounds. A 2002 visual calving ground survey reported lower densities than in 1994 (Johnson and Mulders, 2009), suggesting that herd size likely peaked in the early to mid-1990s. Subsequently, the recent trends are uncertain as there are gaps in monitoring of caribou abundance between 1994 and 2002 and then between 2002 and 2006. Four calving ground delineation surveys from 2006 to 2009 found few cows and even fewer calves, despite extensive aerial coverage across and surrounding the traditional calving ground (Adamczewski et al., 2009). Previously, calving distribution was characterized by fidelity to a traditional calving ground, based on surveys from 1957 to 1974, 1978 to 1994, 2002, and 2006 to 2009 (Gunn and Sutherland, 1997; Gunn et al., 2007; Johnson and Mulders, 2009; Adamczewski et al., 2009).

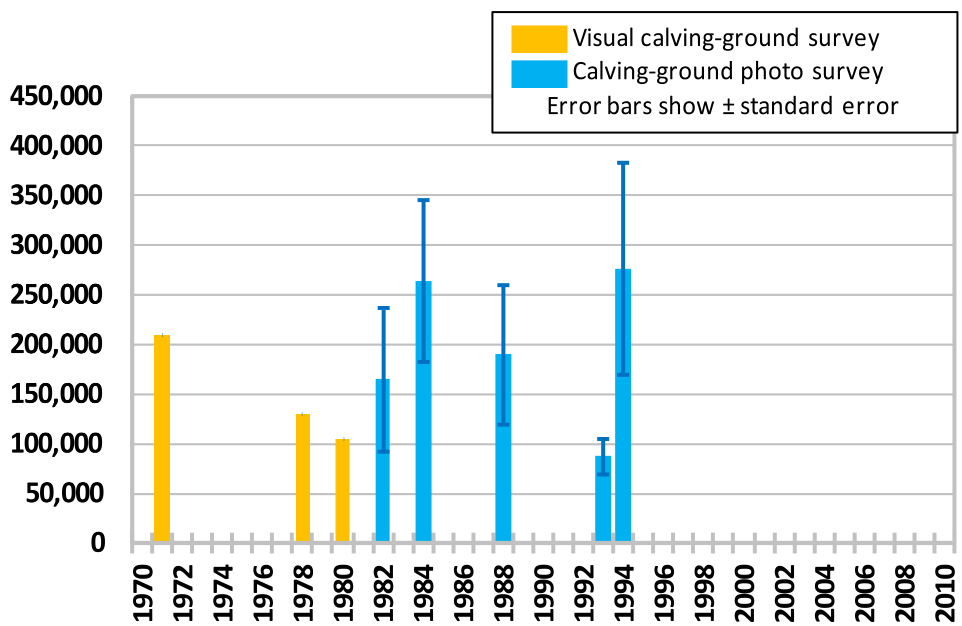


Figure 8. Beverly Caribou Herd population estimates.
Standard errors were not calculated for earlier visual surveys. Population estimates are of caribou one year and older.
Source: based on data compiled for this report – 1971 and 1978: Heard and Decker (1980); 1980: Gunn and Decker (1982); 1982-1988: Heard and Jackson (1990); 1993-1994: Williams (1995)

Satellite collaring of Beverly caribou did not start until 2006, which has hindered the description and interpretation of herd trends. Nagy et al.'s (2010; 2011) interpretation, based on an analysis of telemetry across the Northwest Territories and Nunavut, suggests that a large part of the Beverly Herd shifted its calving ground approximately 200 to 300 km in the 1990s to the western half of the Queen Maud Gulf coast. Nagy et al (2010; 2011) interpreted patterns in satellite telemetry data to infer that the Beverly Herd is currently using two calving grounds, with the majority of the Beverly cows now calving on the western Queen Maud Gulf coast. While caribou calving along the Queen Maud Gulf coast declined significantly between 2006 and 2009 (Adamczewski et al., 2009), the decline of the Beverly Herd may not have been as drastic as previously thought because some Beverly cows have switched their calving area. In any case, the increased human land use on the Beverly traditional calving ground and its possible effects on either the possible calving ground shift or the extreme decline of the herd are of concern (Campbell and Dumond, 2011, pers. comm.).

An alternate interpretation is that the Beverly Herd declined, as did the neighbouring herds (Bathurst and Qamanirjuaq herds – see this report) from 1994 to 2009. Gunn et al. (In Press) interpreted the satellite telemetry for 2006 to 2009 and aerial survey data as a decline in fidelity to the traditional calving ground starting in 2007 as a consequence of the extreme low densities recorded in 2006. From 2007 to 2009, six collared cows switched between the traditional Beverly calving ground and the Queen Maud Gulf coast, the latter previously described as the calving ground of the Ahiak Herd (Gunn et al., 2000b). A shift in use of calving grounds by Beverly caribou is consistent with a substantial reduction in abundance of breeding cows and calves on the traditional ground, which could trigger a behavioural response of remaining cows to move on to a larger herd's calving ground to maintain the advantages of gregarious calving.

The use of the traditional Beverly calving ground is likely to have persisted for thousands of years, based on pre-calving migration across the Thelon River to the calving grounds near Beverly Lake (Gordon, 2005). The Beverly Herd's summer ranges included the Thelon Game Sanctuary and the tundra south of the sanctuary. In fall, the generalized migration pattern was south of the Thelon Game Sanctuary, across the tree-line, and toward northern Saskatchewan (BQCMB, No Date). The fall movements and rut generally were east of Great Slave Lake. Later in winter, the Beverly Herd tended to move west toward and around the East Arm of Great Slave Lake (Thomas et al., 1998). Thomas et al. (1998) related the overall direction and rate of movements to snow conditions in the boreal forest. They noted that in most years caribou moved from East to West across the winter range as snow depths tended to be deeper on the eastern ranges.

Since the 1980s, trends in seasonal distribution have only been reported during the calving season (Gunn et al., In Press; Gunn and Sutherland, 1997; Gunn et al., 2007; Nagy et al., 2011). The satellite-collar information also suggested that the Ahiak Herd's summer ranges overlapped with some known summer ranges of the Beverly Herd, at least since 2006. The Beverly Herd is seasonally hunted by people from Baker (Nunavut); Lutsel K'e (NWT); and, Black Lake, Stony Rapids, and Uranium City, northern Saskatchewan.

Bluenose-East Herd

Ecozones[+] Calving ground: Southern Arctic; winters in the Southern Arctic and the Taiga Plains

Status and trends

The Bluenose-East Herd was not officially recognized as a distinct herd until 1999 (Nagy, 2009b). A photographic post-calving survey was undertaken in 2000, providing an estimate of 104,000 ± 22,100 (95% CI) (Figure 9). This was followed by a decline to an estimated 70,100 ± 8,100 in 2005 and 66,800 ± 5,200 in 2006. This translates into a 10% exponential rate of decline from 2000 to 2006. However, by 2010, the post-calving herd estimate was 98,600 caribou ± 7,100. There are gaps in the information as demographic rates were not monitored and information on distribution based on collared caribou has not been analyzed.

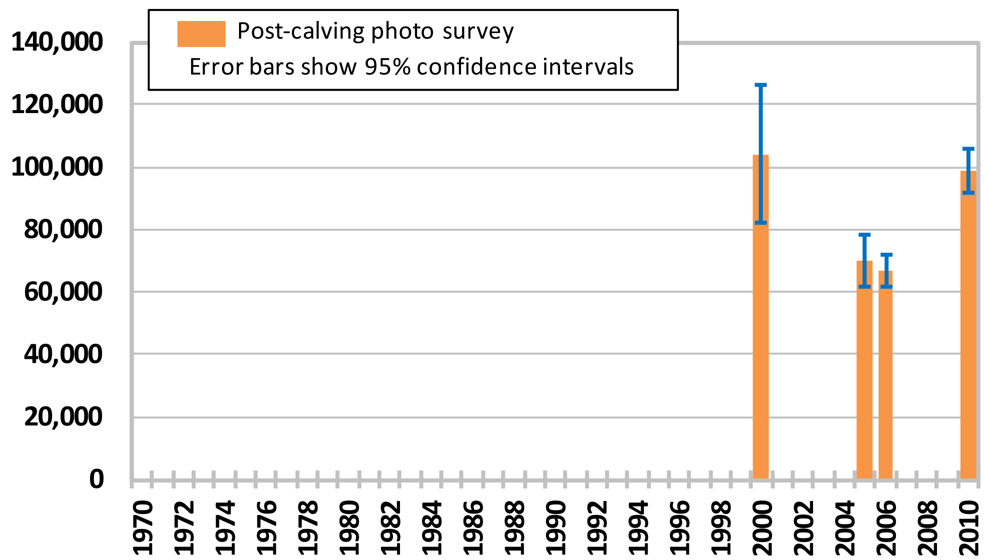


Figure 9. Bluenose-East Caribou Herd population estimates.
Estimates are for caribou one year and older. Surveys were conducted in July.
Source: based on data compiled for this report – 2000: Patterson et al. (2004); 2005: Nagy and Tracz (2006); 2006: Nagy et al. (2008); 2010: Adamczewski (2011c, pers. comm.)

Trends in vital rates are uncertain as monitoring has been infrequent until recently. Spring calf:cow ratios ranged between 25 and 52 calves:100 cows and showed no trend between 2001 and 2009 (Popko unpublished data in Adamczewski et al., 2009).

Bluenose-West Herd

Ecozones[+] Calving ground: Southern Arctic; winters in the Southern Arctic and the Taiga Plains

Status and trends

Although the Bluenose-West Herd was not officially recognized as a distinct herd until 1999 (Nagy, 2009b), population estimates were derived for 1986, 1987, and 1992 based on locations of radio-collars during post-calving surveys of the Bluenose Herd. The herd peaked at 112,400 ± 25,600 (95% CI) in 1992 and then declined to 76,400 ± 14,300 in 2000, and 20,800 ± 2,040 in 2005 (Figure 10). The 2005 estimate was confirmed by an estimate of 18,050 ± 530 caribou in 2006. Since then, the trend appears to have levelled out, with a preliminary estimate for a July 2009 survey of 17,900 ± 1,300 caribou (Davison, 2009, pers. comm.).

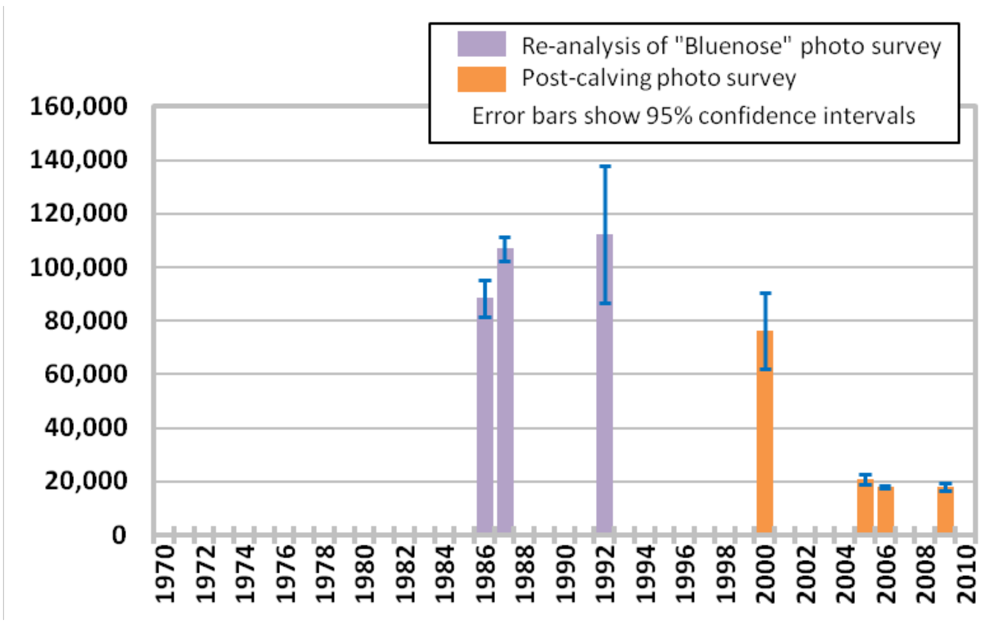


Figure 10. Bluenose-West Caribou Herd population estimates.
Population estimates are for caribou one year and older. Data obtained during photocensus surveys of the "Bluenose" Herd prior to 2000 were re-analyzed to estimate Bluenose-West population trends. These estimates should not be considered as reliable as the later estimates (Adamczewski, 2011a, pers. comm.).
Source: based on data compiled for this report – 1986-2006: Nagy (2009a); also for 2005 and 2006: Nagy and Johnson (2006); 2009: Davison (2009, pers. comm.). See also Government of the Northwest Territories web page for this herd (Department of Environment and Natural Resources, No Date[Bluenose-West]).

Based on recommendations of the Wildlife Management Advisory Council (NWT), the Gwich'in Renewable Resources Board, and the Sahtu Renewable Resources Board, co-management boards in the herd's range, all non-aboriginal hunting of the Bluenose-West Herd ceased in 2006. The co-management boards made further recommendations to restrict aboriginal harvesting of the Bluenose-West Herd by establishing a total allowable harvest and the requirement for a tag to harvest, measures that were implemented in 2007.

Cape Bathurst Herd

***Ecozones*[+]** Calving ground: Southern Arctic; winters in the Southern Arctic and the Taiga Plains

Status and trends

Although the Cape Bathurst Herd was not officially recognized as a distinct herd until 1999 (Nagy, 2009b), population estimates were derived for 1987 and 1992 based on locations of radio-collars during post-calving surveys of the Bluenose Herd (Nagy, 2009a). The herd peaked at 19,300 ± 5,400 (95% CI) in 1992, then declined to about 11,100 ± 1,800 in 2000, 2,430 ± 260 in July 2005, and 1,820 ± 150 in 2006 (Figure 11). This translates into a 17% exponential rate of decline. The preliminary estimate for a July 2009 survey of this herd is 1,930 ± 350, suggesting that the decline had halted.

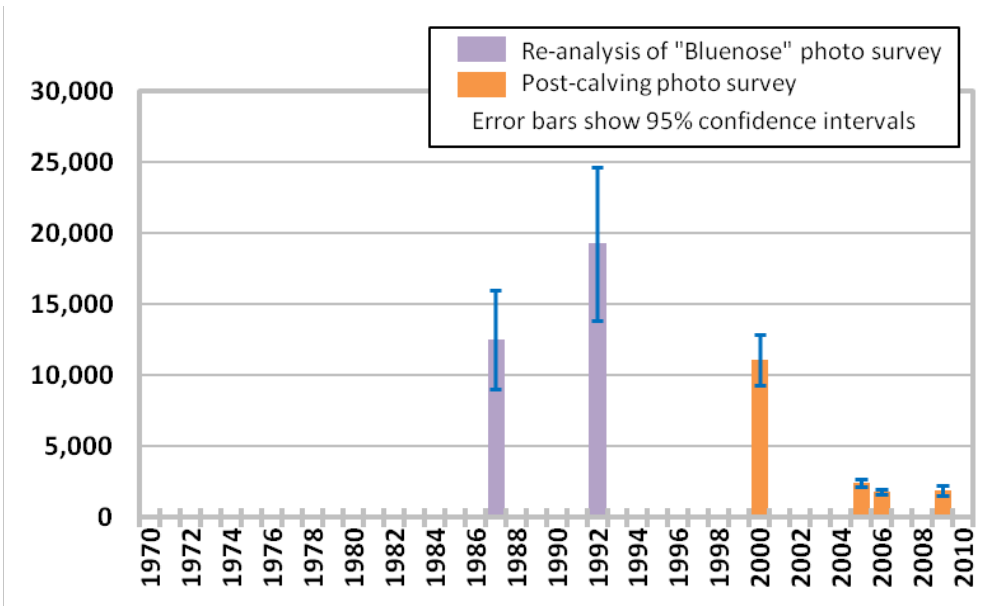


Figure 11. Cape Bathurst Caribou Herd population estimates.
Population estimates are for caribou one year and older. Data obtained during photocensus surveys of the "Bluenose" Herd prior to 2000 were re-analyzed to estimate Cape Bathurst population trends. These estimates should not be considered as reliable as the later estimates (Adamczewski, 2011a, pers. comm.).
Source: based on data compiled for this report – 1987-2006: Nagy (2009a); 2005-2006: Nagy and Johnson (2006); 2009: Davison (2009, pers. comm.). See also Government of the Northwest Territories web page for this herd (Department of Environment and Natural Resources, No Date[Cape Bathurst]).

The Wildlife Management Advisory Council (NWT) recommended an end to all harvesting, with non-aboriginal limitations implemented in 2006 and aboriginal limitations implemented in 2007. Preliminary estimates in 2009 indicate that the herd may have stabilized. As well as harvest restrictions, improved recruitment rates in 2008 and 2009 may have contributed to halting the decline (Davison, 2010, pers. comm.).

Dolphin and Union Herd

***Ecozones*⁺** Calving ground: Northern Arctic (also summer into fall); and winter range is in the Southern Arctic

Status and trends

Historical information and Inuit hunter reports indicate that there may have been as many as about 100,000 caribou on Victoria Island in the early 1800s (Manning, 1960). By the early 1920s, numbers declined and migration across Dolphin and Union Strait halted. The causes were possibly a combination of icing storms and the introduction of rifles. The recovery was slow and caribou were rare until the 1970s. By the 1990s, numbers were increasing and 28,000 caribou were estimated in 1997 (Figure 12). Subsequently, the herd has been at best stable but possibly declining slightly between 1997 and 2007, based on preliminary analyses (Poole et al., 2010; Dumond, 2011, pers. comm.).

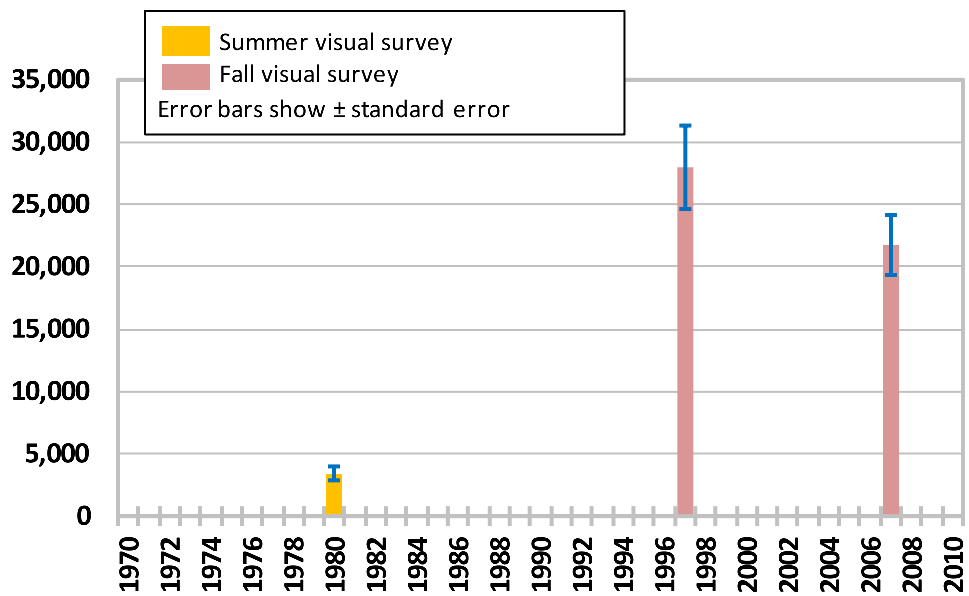


Figure 12. Dolphin and Union Caribou Herd population estimates.
The 2007 estimate is considered preliminary.
Source: based on data compiled for this report – 1980: Jakimchuk and Carruthers (1980) as cited in COSEWIC (2004); 1997: Nishi and Gunn (2004); 2007: Dumond (2011, pers. comm.)

Calving is dispersed over about half of northern and central Victoria Island and, based on sightings, the summer, fall, and winter ranges have increased in size since the early 1980s. A trend to an increasing size of winter range was manifested as fall migrations across the newly formed sea ice to the mainland coastal areas, which is a resumption of the migrations that were observed up until the 1920s. The caribou return across the sea ice to Victoria Island in April to May. The date of freeze-up is increasingly delayed – 8 to 10 days later than in 1982, a trend which may lead to changes in the fall migration across the sea ice (Poole et al., 2010).

George River Herd

Ecozones[+] Calving ground: Arctic Cordillera; summer and winter in the Taiga Shield

Status and trends

Trends in the size and distribution of the George River Herd have been relatively well-described based on monitoring and studies (Couturier et al., 2004; Bergerud et al., 2008; Couturier et al., 2009a; Couturier et al., 2009b). The herd increased from about 5,000 animals in the 1950s to a peak of about 776,000 ± 104,000 (90% CI) in 1993 (Figure 13). At that point summer habitat was degraded, which may have initiated the decline to about 385,000 ± 108,000 individuals in 2001, followed by a further decline to 74,100 ± 12,600, based on the 2010 post-calving photocensus. The trend in abundance revealed by the aerial photographic counts is also supported by trends in lichen abundance (Boudreau and Payette, 2004a; Boudreau and Payette, 2004b) and hoof scars in tree roots aged by annual tree growth rings (Boudreau et al., 2003).

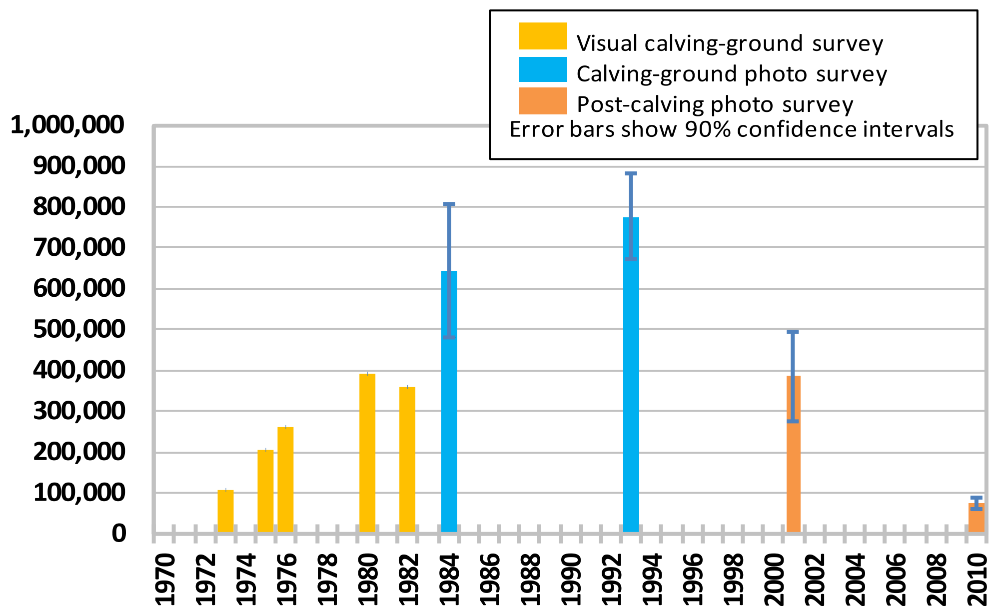


Figure 13. George River Caribou Herd population estimates.
Estimates, based on calving ground (June) and (for 2001 and 2010) post-calving (July) surveys, are all extrapolated to provide total herd population estimates for October, including calves. No confidence intervals were calculated for the visual surveys.
Source: based on data compiled for this report – 1973 and 1975: Messier et al. (1988); 1976-1982: Couturier et al. (1990); 1984 and 2001: Couturier et al. (2004); 1993: Couturier and Courtois (1996); 2010: Ressources naturelles et Faune (2010) and CARMA (2011)

Trends in vital rates, including pregnancy and calf survival, are monitored and summarized (Couturier et al., 2004; Bergerud et al., 2008; Couturier et al., 2009a; Couturier et al., 2009b). The monitoring has been supported with studies of body condition and body mass for calves and yearlings. Couturier et al. (2009b) suggest that monitoring trends in the birth and fall mass of calves will be useful in determining when herds approach their peak abundance.

Leaf River Herd

Ecozones*[+]* Calving ground: Northern Arctic and Southern Arctic; winters in the Taiga Shield

Status and trends

The Leaf River (Rivière-aux-Feuilles) Herd was identified as a herd in 1975. The herd increased from 56,000 caribou in 1975 to 101,000 ± 43,400 (90% CI) in 1983, 121,000 ± 56,400 in 1986, 276,000 ± 75,900 in 1991, and 1,193,000 ± 565,000 in 2001 (Figure 14), although Couturier et al. (2004) suggested using the lower confidence limit (628,000) for the 2001 population estimate. Body condition of adult females and calves, as well as recruitment, were poor in 2007 and 2008, suggesting that the population has likely decreased. The next survey (results not available at time of writing) was planned for the summer of 2011 (Ressources naturelles et Faune, 2010). Recruitment, mortality of collared animals, body condition of mature females and calves, and consistent field observations suggest that the herd has been decreasing since the 2001 census. Management measures consistent with a decreasing population trend are under development (Brodeur, 2011, pers. comm.).

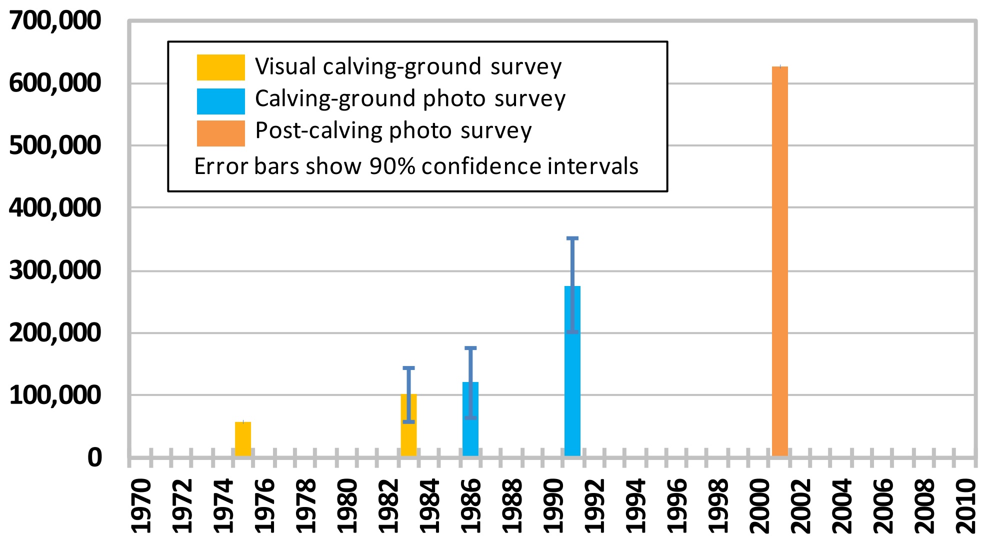


Figure 14. Leaf River Caribou Herd population estimates.
Estimates, based on calving ground (June) and (for 2001) post-calving (July) surveys, are all extrapolated to provide total herd population estimates for October, including calves. No confidence interval estimate for 1975. The 2001 estimate shown is the lower limit of the confidence interval (recommended for management purposes).
Source: data from Couturier et al. (2004)

Monitoring was conducted on movement rates (1986 to 2003) and environmental indicators (1973 to 2003) (Couturier et al., 2009b). The monitoring reveals complex interactions between caribou condition, weather, and population dynamics.

The location of the calving grounds has shifted substantially northward in recent years (Taillon, 2011, pers. comm.).

Lorillard and Wager Bay herds

Ecozones[+] Calving ground: Northern Arctic (also summer into fall); Southern Arctic fall and winter ranges

Status and trends

The Lorillard and Wager Bay are the two largest herds of possibly eight tundra wintering herds on the northeast mainland. There is relatively little information on the herds in the northeastern mainland (Gunn and Fournier, 2000; Gunn et al., 2000a; Oli, 2003), although an increase in the number of satellite collared caribou is improving understanding of seasonal movements (Campbell, 2005; Campbell, 2007; Nagy et al., 2011).

In the late 1970s, surveys found a combined total of about 4,000 caribou on the Lorillard and Wager Bay calving grounds (Donaldson, 1981 in Heard et al., 1986). Caribou numbers likely increased until the mid-1990s. Inuit hunters reported that there were fewer caribou and that the caribou were in poor health in the mid-1990s (Buckland et al., 2000). Pre-calving surveys in 1995, compared to 1983 surveys, found a decline in caribou north of Wager Bay. Further surveys of the Lorillard calving grounds found no change between 1999 and 2003, while the estimated number of Wager Bay caribou increased between 2000 and 2004 (Campbell, 2005; Campbell, 2007). Trends in abundance and distribution of the smaller herds on the northeastern mainland are uncertain.

Peary caribou

Ecozone[+] Northern Arctic

Status and trends

In 1961 there were about 26,000 Peary caribou on the Queen Elizabeth Islands and possibly about 22,000 Peary caribou on the larger southern islands and on the Boothia Peninsula (COSEWIC, 2004). Since then the overall trend has been a decline. The rate of decline has varied over time and among the different island populations, with both reversals of some declines and absence of recovery for other populations. Survey intervals are irregular and only two of the six geographic populations (Banks Island and Bathurst Island complex) have been surveyed at regular intervals. In 2001, the total number of Peary caribou was extrapolated to about 8,000 (COSEWIC, 2004). The most recent estimates are: about 4,000 Peary caribou in Nunavut, based on surveys from 2001 through 2008 (Jenkins et al., 2011), and about 2,000 in the Northwest Territories (Carrière, 2009, pers. comm.).

Populations

Melville and Prince Patrick islands

Surveys have been infrequent but have documented a steep decline between 1961 and 1972 to 1973. The rate of decline was less rapid between 1974 and the next surveys in 1987 and 1997. The survey intervals of 16 and 10 years mean that recoveries and subsequent losses would not have been detected. See Figure 15a and Figure 15b.

Prince of Wales-Somerset islands group

Peary caribou seasonally cross the sea ice between the islands in this group. Between 1974 and 1980, caribou numbers were stable in the range of 4,000 to 6,000, which was one of the largest Peary caribou populations in the 1970s and 1980s. There was then a 15-year hiatus in surveys until 1995, when only a few caribou were found. In 2004, no caribou were seen during an aerial survey of the islands. See Figure 15c.

Bathurst Island (and its satellite islands)

Between 1961 and 1974, Peary caribou numbers declined by an order of magnitude. Between 1974 and 1994, numbers recovered to the 1961 level. An abrupt decline followed and, by 1997, fewer than 100 caribou remained. A survey in 2001 revealed the trend was for a recovering population. See Figure 15d.

Banks Island

Peary caribou on Banks Island formed one of the larger populations as they peaked at about 12,000 in the early 1970s and remained relatively stable until 1982. Numbers declined to about 1,000 caribou by 1992 and an initial small recovery by 2001 was likely lost during an icing storm early in the winter of 2003 (Nagy and Gunn, 2006). A 2010 survey led to an estimate of 1,097 ± 343 (95% CI) non-calf caribou, which confirmed the persistence of low numbers on Banks Island. See Figure 15e.

Northwest Victoria Island

Trends in Peary caribou on northwest Victoria Island are less clear than on Banks Island as surveys have been less frequent. Numbers were high, about 2,600 in 1987, and declined during the 1980s until, in 1993, only a few caribou were seen during an aerial survey. The population then slowly recovered, based on estimates of 95 ± 60 (95% CI) in 1998 and 204 ± 103 in 2001. However, in 2005, the estimate was 66 + 61 non-calf caribou, which suggested that some recovery was lost during two winters (2002/03 and 2003/04) with icing events (Nagy and Gunn, 2006). A subsequent survey in 2010 returned an estimate of 150 ± 104 non-calf caribou, which confirmed the persistence of low numbers. See Figure 15f.

Boothia Peninsula

Peary caribou on the Boothia Peninsula increased throughout the 1970s and early 1980s. Caribou in this region were last estimated in 1994 and showed a decline from the 1985 estimate (Gunn and Dragon, 1998). Trends are difficult to distinguish as satellite telemetry has shown that both barren-ground caribou and Peary caribou use the peninsula (Gunn et al., 2000a).

Eastern Queen Elizabeth Islands (Ellef Ringnes, Amund Ringnes, Devon, Ellesmere, Axel Heiberg Islands, Cornwall, King Christian, Graham)

There is relatively little information available to assess trends. The islands were surveyed in 1961, although coverage was so low that the resulting estimate of close to 1,500 caribou was an approximation (Tener, 1963). Since 2001, the Nunavut Department of Environment has undertaken aerial spring surveys on the islands, resulting in the following population estimates of caribou 10 months and older (Jenkins et al., 2011):

- Ellesmere Island (including Graham Island), surveyed partly in 2005 and partly in 2006: combined survey results yield an estimate of 1,021 caribou
- Axel Heiberg Islands, surveyed 2007: 2,291 (95% CI of 1,636 to 3,208) caribou
- Amund Ringnes, Ellef Ringnes, King Christian, Cornwall, and Meighen Islands, surveyed 2007: total of 282 (95% CI of 157 to 505) caribou
- Lougheed Island, surveyed 2007: 372 (95% CI of 205 to 672) caribou
- Devon Island, surveyed 2008: 17 caribou counted in an extensive survey

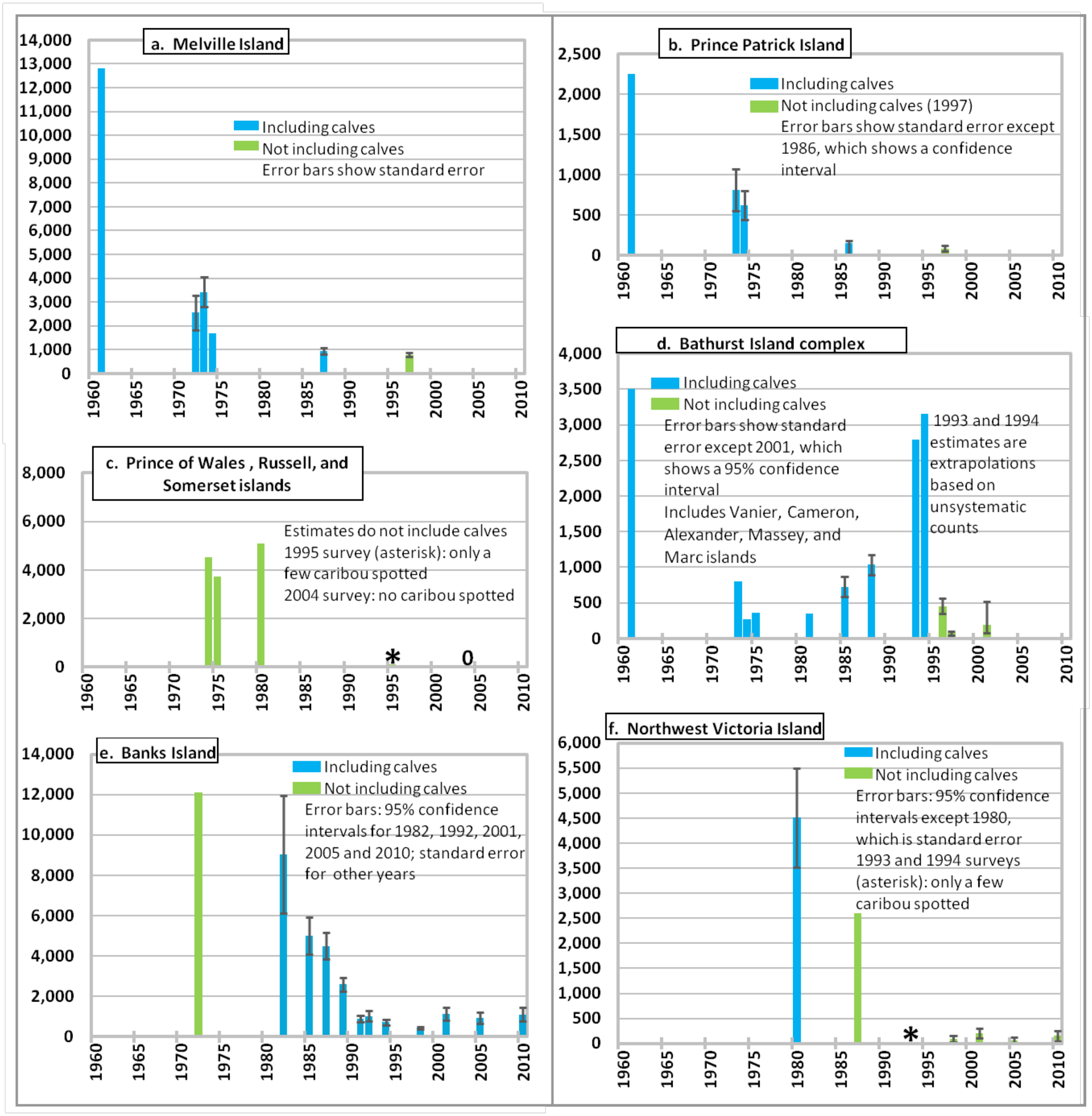


Figure 15. Peary caribou population estimates. (Data sources on the next page.)

Data sources for Figure 15:

<u>a. Melville Island</u>: 1961: Tener (1963) as cited in Miller et al. (1975); 1972-1974: Miller et al. (1977); 1987: Miller (1988); 1997: Gunn and Dragon (2002)

<u>b. Prince Patrick Island</u>: 1961 : Tener (1963) as cited in Miller et al. (1975); 1973 and 1974 : Miller et al. (1977); 1986 : Miller (1987);1997 : Gunn and Dragon (2002)

<u>c. Prince of Wales, Russell, and Somerset islands:</u> 1980: Gunn and Decker (1984) as cited in Gunn et al. (2006); 1995: Gunn and Dragon (1998); 2004: Jenkins et al. (2011)

<u>d. Bathurst Island complex</u>: 1961 : data from Tener (1963) adjusted by Miller and Barry (2009) to standardize the size of islands used in calculations for comparability with later surveys; 1973 and 1974: Miller et al. (1977) as cited in Miller and Barry (2009);1975: Fischer and Duncan (1976) as cited in Miller and Barry (2009);1981: data from Ferguson (1987) adjusted by Miller and Barry (2009) to account for smaller islands not surveyed;1985 and 1988: Miller (1991); 1993 and 1994: data from Miller (1998) adjusted by Miller and Barry (2009) to account for smaller islands not surveyed; 2001: Jenkins et al. (2011)

<u>e. Banks Island</u>: 1972: Urquhart (1973) cited in Gunn et al. (2000c); 1982: data from Latour (1985) reanalyzed by Nagy et al. (2009f); 1985: McLean et al. (1986); 1987: McLean (1992); 1989: McLean and Fraser (1992); 1991: Fraser et al. (1992); 1992: Nagy et al. (2009b); 1994 and 1998: Larter and Nagy (2001); 2001: Nagy et al. (2006); 2005: Nagy et al. (2009c); 2010: Davison et al. (In Prep.)

<u>f. Northwest Victoria Island</u>: 1980: Jakimchuk and Carruthers (1980) cited in Gunn (2005); 1987: Gunn et al. (2000c); 1993 and 1994: Gunn (2005); 1998: Nagy et al. (2009d); 2001: Nagy et al. (2009e); 2005: Nagy et al. (2009a); 2010: Davison et al. (In Prep.)

Pen Islands and Cape Churchill herds

***Ecozone*⁺** Hudson Plains

Note: the following section is summarized with authors' permission from the Hudson Plains Ecozone⁺ ecosystem status and trends assessment (Abraham et al., 2012).

Status and trends

These two herds in northern Ontario and northeastern Manitoba are considered a migratory forest-tundra ecotype and have received sporadic monitoring and assessment over the last two decades.

The **Pen Islands Herd** is decreasing and its range is shifting to the east. The herd became the focus of attention in the mid-1980s after several years of observations of large numbers along the coast in summer. Periodic photographic counts of the Pen Islands Herd during summer along the Hudson Bay coast of Ontario and Manitoba from 1979 to 1994 estimated an increase from a minimum of 2,300 animals in 1979 to a high of 10,798 animals in 1994 (Abraham and Thompson, 1998). In approximately the last 10 years there have been major changes. The herd traditionally calved and summered on the Hudson Bay coast in the area of the Pen Islands and wintered inland near the boundary of the Boreal Shield and Hudson Plains ecozones⁺. Using photographic survey data (Thompson and Abraham, 1994), non-systematic surveys, and incidental observations from 1965 to 2003, Magoun et al. (Magoun et al., 2005) documented an eastward shift in use of coastal areas since the late 1990s, with caribou becoming more common east of the Severn River. Systematic spring and summer surveys in 2008 and 2009 over the southern Hudson Bay coastal area documented a major shift in summer use of coastal areas, with most caribou being observed even farther east, near Cape Henrietta Maria (Abraham et al., Accepted for publication). The surveys also indicated the probability of a significant decline in numbers. These results may represent: 1) a shift in range use of the Pen Islands Herd; and/or 2) an independent decrease in numbers of caribou in the former Pen Islands range coupled with an increase in caribou numbers in the east.

The **Cape Churchill Herd**, although not well studied, is thought to have increased in numbers at a fairly rapid rate starting in the mid-1960s and then remained stable in numbers over the past decade. Aerial surveys of the herd in 1965 estimated the population at approximately 58 individuals while another survey in 1988 estimated the population as ranging between 1,800 and 2,200 individuals (Campbell, 1995). The minimum population size was estimated in 1997/98 to be 3,013 adult caribou (Elliott, 1998). Parks Canada conducted an aerial survey on May 28-29, 2005 and along flight lines over the known calving area counted 644 animals (Stewart, 2009, pers. comm.). Three counts of an opportunistic aerial photograph survey taken on July 20, 2007 averaged 2,937 adult animals, suggesting no change in minimum population size from 1997/1998 (Abraham et al., 2012).

Porcupine Herd

Ecozones[+] Calving ground: Southern Arctic (calving and early summer) and Taiga Cordillera (also year round); Taiga Plains (spring, fall, and winter ranges)

Status and trends

The herd is intensively monitored, with locations of calving grounds identified every year since the early 1970s, early calf survival monitored every year since 1983, and comparable population estimates since 1976. Early movement of the herd from the Alaskan coastal plain and bad weather during late June and early July prevented population estimates being made from 2003 through 2009. There are currently 169,000 caribou in the herd, based on results from the 2010 census (Campbell, 2011). See Figure 16.

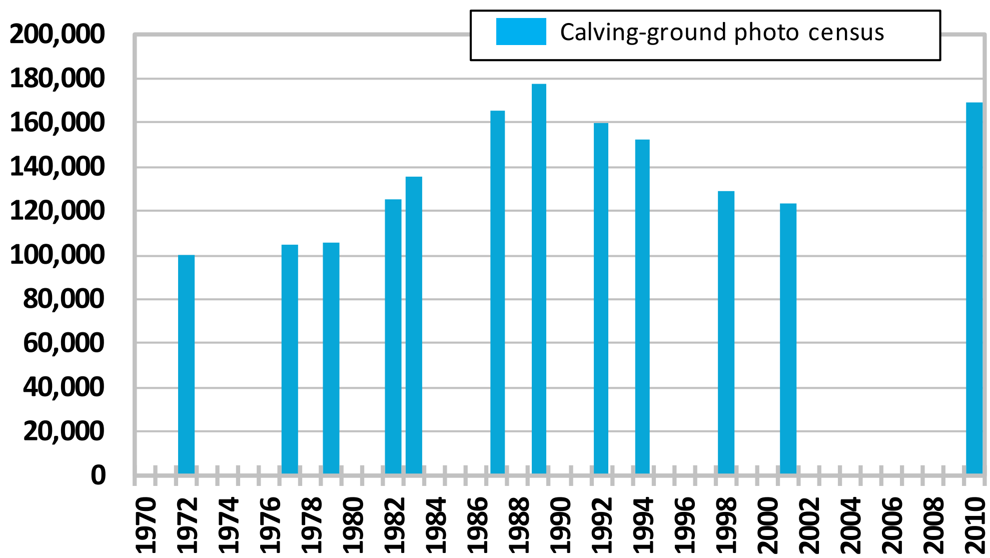


Figure 16. Porcupine Caribou Herd population estimates.
Survey method is aerial photo-direct count extrapolation. Total count – no variance estimates calculated. Includes calves.
Source: based on data compiled for this report – 1972-2001: Caikoski (2009), see also Joly et al. (2011); 2010: Campbell (2011)

The Porcupine Herd reached a peak in 1989 (178,000) and declined at least until the 2001 census at a rate of 3.5% per year, based on censuses in 1992, 1994, 1998, and 2001. Of all herds in North America that increased in the latter quarter of the 20th century, the Porcupine Herd had the lowest rate of increase and is thus the least productive of the large migratory herds (Figure 4).

In general, the Porcupine Caribou Herd travels north from wintering grounds in central Yukon and Alaska, arriving on the foothills of the Brooks Range in Alaska and the British Mountains in the Yukon by late May. Calving takes place in early June either in the foothills of the coastal plain or on the coastal plain, depending on snow conditions (Russell et al., 1993; Griffith et al., 2002). Recent analysis of locations of radio-collared caribou indicates that shifts in calving and post-calving distribution may be related to variations in spring temperatures and snow conditions and their influence on vegetation (Russell, unpublished data). The warm spring weather in the 1990s resulted in more calving on the coastal plain; the relatively cooler springs of the 1980s and the 2000s resulted in more calving in the foothills, associated with higher predation rates on new-born calves. See the climate change section (page 22) for discussion on the impacts of climate change and variation on population dynamics of the Porcupine Caribou Herd.

Qamanirjuaq Herd

Ecozones[+] Calving ground: Southern Arctic (also summer into fall); Taiga Shield fall and winter ranges

Status and trends

Numbers were low in the 1970s and increased during the 1980s until 1994 (496,000 caribou) (Figure 17). In 2008, the Government of Nunavut completed calving ground and fall composition surveys and estimated 349,000 ± 44,900 (SE) caribou, indicating the herd may have peaked then declined by about 30% since 1994. However, the decline is not statistically significant. The trend in spring cow:calf ratios was a decline from 50:100 in 1992, to 42:100 in 1996, to 30:100 in 1999, to 26:100 in 2003, and then to less than 20:100 between 2006 and 2008 (Campbell et al., 2010).

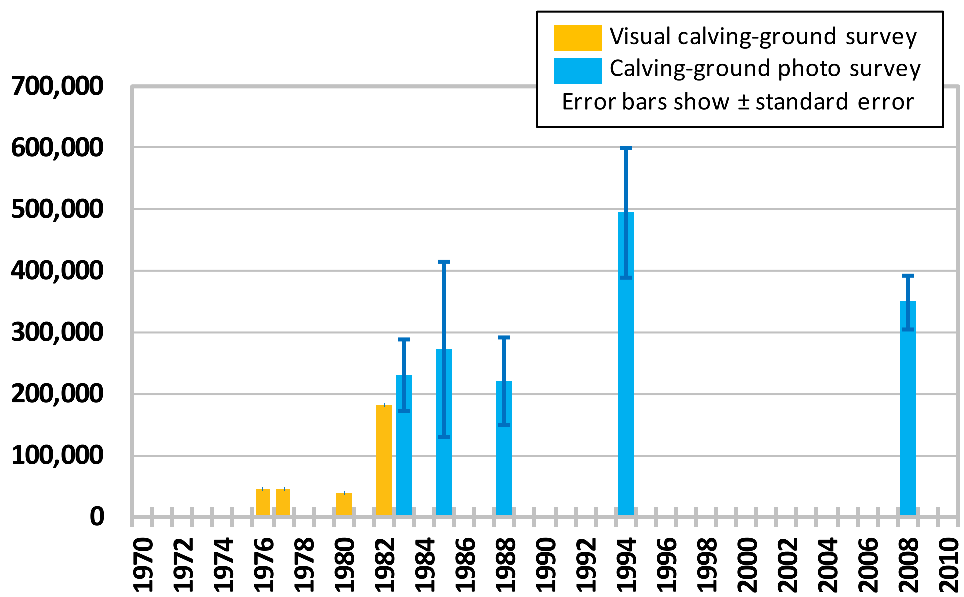


Figure 17. Qamanirjuaq Caribou Herd population estimates.
For years where no standard error is shown, none was calculated for the survey.
Source: based on data from Campbell et al. (2010)

Southampton Island Herd

Ecozones[+] Calving ground: Southern Arctic (also summer into fall and winter); Northern Arctic: winter range

Status and trends

Trends for caribou on Southampton are known through relatively intense monitoring since the caribou were re-introduced in 1967 (Parker, 1975; Heard and Ouellet, 1994; Campbell, 2006; Campbell, 2007). Forty-eight caribou (28 of which were females) were introduced from Coats Island after caribou had been extirpated, in part through over-hunting, by 1952 (Parker, 1975). In the absence of wolves, which had become locally extinct by 1937, the caribou increased rapidly, by approximately 27% per year, and had peaked at about 30,000 by 1997. Between 1997 and 2007 the herd declined by 50% at an annual exponential rate of decline of 6%. The estimates in 2003 and 2005 were not significantly different: 18,000 ± 2,100 in June 2003 and 20,600 ± 3,100 in June 2005 (Figure 18).

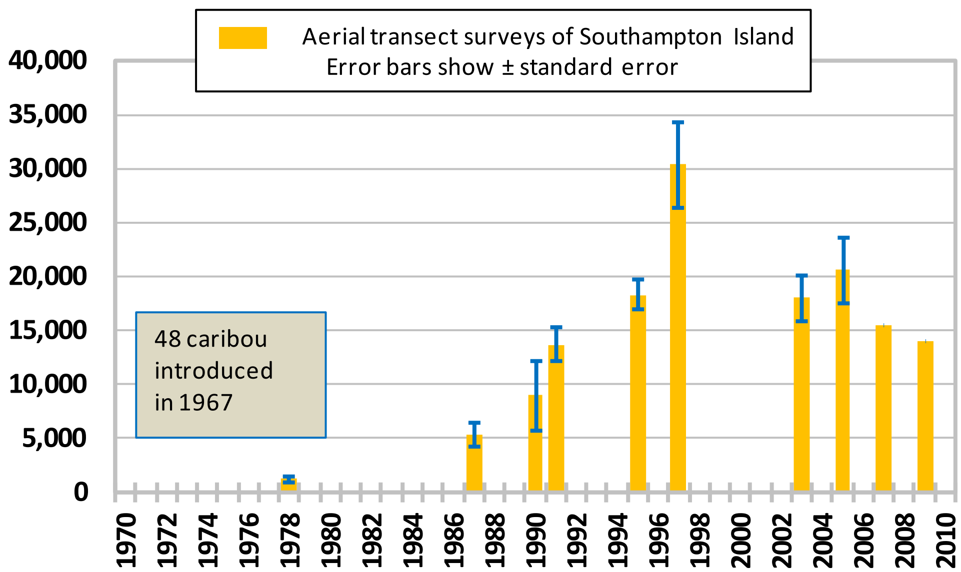


Figure 18. Southampton Island Caribou Herd population estimates.
Source: based on data compiled for this report – 1968-1991: Heard and Ouellet (1994); 1995-2005: Campbell (2006); 2007 and 2009: Wildlife Management Division, Department of Environment, Government of Nunavut (2009)

The increase in herd size was the basis for a commercial harvest in the 1990s and 2000s (see harvest section starting on page 14). During commercial harvesting, the caribou were sampled for health and condition. From 1995 to 1998, caribou condition slowly declined, then recovered to 1995 levels by 2000 (Campbell, 2006). Between 2004 and 2005, body condition declined while over the same period caribou diets shifted from primarily grasses and lichens to mosses (Campbell, 2006). Fall icing in 1998 and 2005 may have limited access to grasses in early and mid-winter, which could have influenced body condition (Campbell, 2006). In 2003, pregnancy rates declined from between 90 and 95% in the period 1997 to 2000 to 60% in 2003, followed by a further decline to 25% in February 2005, accompanied by a decline in body condition in 2005 (Campbell, 2007). Contributing factors to the low pregnancy rates may be the high incidence of *Brucella suis* and the low percentage of prime bulls (only 12% in April 2005) (Campbell, 2006).

Tuktoyaktuk Peninsula Herd

In 2005, hunters reported that there were more caribou on the Tuktoyaktuk Peninsula after the private herd of reindeer had been moved away in about 2001. A systematic aerial count in September 2005 estimated 2,700 caribou (including calves), of which about 20% were domesticated reindeer (Department of Environment and Natural Resources, 2005). In March 2006, 26 caribou, including 19 females, were fitted with satellite-collars. This revealed that movements appeared to be relatively restricted to the upper peninsula (Department of Environment and Natural Resources, 2005). In July 2006, a post-calving photographic survey estimated 2,866 non-calf reindeer/caribou (Nagy and Johnson, 2006). The herd was surveyed again on 25 June 2007 (Davison et al., 2007) and again in 2009, when 2,752 ± 276 (95% CI) caribou were estimated (Department of Environment and Natural Resources, No Date[Tuktoyaktuk Peninsula]).

The trend in late winter productivity, as indexed by calf:cow ratios for 2008 to 2011, suggests consecutive years of higher calf:cow ratios following 2007, when the ratio was 30 calves:100cows (Davison and Branigan, 2011).

Harvesting is unrestricted except for a closure from 1 April to 15 June. This closure allows the neighbouring Cape Bathurst Herd to migrate through the Tuktoyaktuk Peninsula on the way to the Cape Bathurst calving grounds. The harvest total and the sex ratio of the harvest are unknown for the Tuktoyaktuk Peninsula Herd. Hunters have expressed concerns about predators as they report seeing large wolf packs in the caribou range. The proposed all-weather road from Tuktoyaktuk to Inuvik will cross the wintering range of the Tuktoyaktuk Peninsula Herd (Department of Environment and Natural Resources, No Date[Tuktoyaktuk Peninsula]).

References

Abraham, K.F., McKinnon, L.M., Jumean, Z., Tully, S.M., Walton, L.R. and Stewart, H.M. (lead coordinating authors and compilers). 2012. Hudson Plains Ecozone+ status and trends assessment. Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Ecozone+ Report. Canadian Councils of Resource Ministers. Ottawa, ON.

Abraham, K.F., Pond, B.A., Tully, S.M., Trim, V., Daryll, H., Chenier, C. and Racey, G.D. Accepted for publication. Recent changes in summer distribution and numbers of migratory caribou on the southern Hudson Bay coast. Rangifer.

Abraham, K.F. and Thompson, J.E. 1998. Defining the Pen Islands Caribou Herd of southern Hudson Bay. Rangifer 10:33-40.

ACIA. 2005. Arctic climate impact assessment. Cambridge University Press. New York, NY. 1042 p.

Adamczewski, J. 2011a. Personal communication. Information in review of draft northern caribou report. Department of Environment and Natural Resources, Government of the Northwest Territories. Yellowknife, NT.

Adamczewski, J. 2011b. Personal communication. Results of Bathurst Caribou Herd survey, 2009. Department of Environment and Natural Resources, Government of the Northwest Territories. Yellowknife, NT.

Adamczewski, J. 2011c. Personal communication. Results of Bluenose-East Caribou Herd survey, 2010. Department of Environment and Natural Resources, Government of the Northwest Territories. Yellowknife, NT.

Adamczewski, J., Boulanger, B., Croft, B., Cluff, D., Elkin, B., Nishi, J., Kelly, A., D'Hont, A. and Nicolson, C. 2009. Decline in the Bathurst Caribou Herd 2006-2009: a technical evaluation of field data and modeling. Department of Environment and Natural Resources, Government of the Northwest Territories. Yellowknife, NT. Draft (17 December, 2009).

Ahern, F., Frisk, J., Latifovic, R. and Pouliot, D. 2011. Monitoring biodiversity remotely: a selection of trends measured from satellite observations of Canada. Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 17. Canadian Councils of Resource Ministers. Ottawa, ON. http://www.biodivcanada.ca/default.asp?lang=En&n=137E1147-0.

Albon, S.D., Stein, A., Irvine, R.J., Langvatn, R., Ropstad, E. and Halvorsen, O. 2002. The role of parasites in the dynamics of a reindeer population. *In* Proceedings of the Royal Society of London, B-Biological Sciences. Vol. 269, pp. 1625-1632.

AMAP. 2006. AMAP assessment 2006: acidifying pollutants, arctic haze, and acidification in the Arctic. Arctic Monitoring and Assessment Programme. Oslo, Norway. 111 p.

Athabasca Interim Advisory Panel. 2006. Núhenne K'eyághë ëá éghádádá (working on the land together), draft Athabasca land use plan: stage one (draft, March 2006). Athabasca Interim Advisory Panel. SK. 116 p.

Ball, M.C., Lankester, M.W. and Mahoney, S.P. 2001. Factors affecting the distribution and transmission of *Elaphostrongylus rangiferi* (Protostrongylidae) in caribou (*Rangifer tarandus caribou*) of Newfoundland, Canada. Canadian Journal of Zoology 79:1265-1277.

Banfield, A.W.F. 1961. A revision of the reindeer and caribou, genus *Rangifer*. National Museum of Canada Bulletin No. 177. Queen's Printer. Ottawa, ON. 137 p.

Barrier, T.A. 2011. Factors influencing the distribution of Bathurst barren-ground caribou (*Rangifer tarandus groenlandicus*) during winter. Thesis (M.Sc.). University of Northern British Columbia. Prince George, BC. 108 p.

Bayha, J. and Snortland, J. 2006. Sahtu settlement harvest study data report: 2004 & 2005. Sahtu Renewable Resources Board. Tulita, NT. 63 p.

Berger, J. 2004. The last mile: how to sustain long-distance migration in mammals. Conservation Biology 18:320-331.

Bergerud, A.T., Luttich, S.N. and Camps, L. 2008. The return of the caribou to Ungava. McGill-Queen's University Press. Montréal, QC. 586 p.

Bird Studies Canada and Nature Canada. No Date. Queen Maud Gulf [online]. http://www.ibacanada.com/site.jsp?siteID=NU009&lang=EN (accessed 26 January, 2011).

Bonsal, B. and Shabbar, A. 2011. Large-scale climate oscillations influencing Canada, 1900-2008. Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 4. Canadian Councils of Resource Ministers. Ottawa, ON. iii + 15 p. http://www.biodivcanada.ca/default.asp?lang=En&n=137E1147-0.

Boudreau, S. and Payette, S. 2004a. Caribou-induced changes in species dominance of lichen woodlands: an analysis of plant remains. American Journal of Botany 91:422-429.

Boudreau, S. and Payette, S. 2004b. Growth performance of *Cladina stellaris* following caribou disturbance in Subarctic Quebec. Écoscience 11:347-355.

Boudreau, S., Payette, S., Morneau, C. and Couturier, S. 2003. Recent decline of the George River Caribou Herd as revealed by tree-ring analysis. Arctic, Antarctic, and Alpine Research 35:187-195.

Boulanger, J. and Gunn, A. 2007. Exploring possible mechanisms for the decline of the Bathurst Herd of barren-ground caribou using demographic modeling. Manuscript Report No. 175. Department of Environment and Natural Resources, Government of the Northwest Territories. 56 p.

Boulanger, J., Gunn, A., Adamczewski, J. and Croft, B. 2011. A data-driven demographic model to explore the decline of Bathurst Caribou Herd. Journal of Wildlife Management 75:883-896.

Boulanger, J., Poole, K., Fournier, B., Wierzchoswski, J., Gaines, T. and Gunn, A. 2004. Assessment of Bathurst caribou movements and distribution in the Slave Geological Province. Manuscript Report No. 158. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Yellowknife, NT. 108 p.

BQCMB. No Date. Range used during fall migration/rut by Beverly and Qamanirjuaq caribou (generalized). (Map) [online]. Beverly and Qamanirjuaq Caribou Management Board. http://www.arctic-caribou.com/parttwo/pdf/fr.pdf (accessed 17 May, 2011).

BQCMB. 2004. Protecting calving grounds, post-calving areas and other important habitats for Beverly and Qamanirjuaq caribou: a position paper. Beverly and Qamanirjuaq Caribou Management Board annual report, 2007-2008. Beverly and Qamanirjuaq Caribou Management Board. Stonewall, MB. 26 p.

BQCMB. 2005. Caribou news in brief [online]. Beverly and Qamanirjuaq Caribou Management Board. http://www.arctic-caribou.com/news_dec05.html (accessed 11 April, 2011).

BQCMB. 2006. Beverly and Qamanirjuaq Caribou Management Board 24th annual report, 2005-2006. Beverly and Qamanirjuaq Caribou Management Board. Stonewall, MB. 47 p.

BQCMB. 2007a. Beverly and Qamanirjuaq Caribou Management Board 25th annual report, 2006-2007. Beverly and Qamanirjuaq Caribou Management Board. Stonewall, MB. 51 p.

BQCMB. 2007b. Caribou news in brief [online]. Beverly and Qamanirjuaq Caribou Management Board. http://www.arctic-caribou.com/news_july07.html (accessed 11 April, 2011).

BQCMB. 2008a. Beverly and Qamanirjuaq Caribou Management Board 26th annual report, 2007-2008. Beverly and Qamanirjuaq Caribou Management Board. Stonewall, MB. 55 p.

BQCMB. 2008b. Caribou news in brief [online]. Beverly and Qamanirjuaq Caribou Management Board. http://www.arctic-caribou.com/news_summer08.html (accessed 11 April, 2011).

BQCMB. 2009. Beverly and Qamanirjuaq Caribou Management Board 27th annual report, 2008-2009. Beverly and Qamanirjuaq Caribou Management Board. Stonewall, MB. 66 p.

BQCMB. 2010a. Beverly and Qamanirjuaq Caribou Management Board 28th annual report, 2009-2010. Beverly and Qamanirjuaq Caribou Management Board. Stonewall, MB. 43 p.

BQCMB. 2010b. Mining interests on the caribou ranges [online]. Beverly and Qamanirjuaq Caribou Management Board. http://www.arctic-caribou.com/mining.html (accessed 11 April, 2011).

BQCMB. 2011. BQCMB Caribou Workshop February 2010 overview report: challenges facing the Beverly and Qamanirjuaq caribou herds and some possible solutions. Beverly and Qamanirjuaq Caribou Management Board. Stonewall, MB. 26 p.

Brodeur, V. 2011. Personal communication. Information on Leaf River Herd. Ministère des Ressources naturelles et de la Faune, Direction de l'expertise Énergie-Faune-Forêts-Mines-Territoire du Nord-du-Québec. Chibougamau, QC.

Brown, G.S., Landriault, L., Sleep, D.J.H. and Mallory, F.F. 2007. Comment arising from a paper by Wittmer et al.: hypothesis testing for top-down and bottom-up effects in woodland caribou population dynamics. Oecologia 154:485-492.

Buckland, L., Dragon, J., Gunn, A., Nishi, J. and Abernethy, D. 2000. Distribution and abundance of caribou on the northeast mainland, NWT in May 1995. Manuscript Report No. 125. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Yellowknife, NT. 24 p.

Caikoski, J.R. 2009. Porcupine Caribou Herd - units 25A, 25B, 25D, and 26C. *In* Caribou management report of survey-inventory activities 1 July 2006-30 June 2008. Edited by Harper, P. Alaska Department of Fish and Game. Juneau, AK. pp. 240-258.

Cameron, R.D., Smith, W.T., White, R.G. and Griffith, B. 2005. Central Arctic caribou and petroleum development: distributional, nutritional, and reproductive implications. Arctic 58:1-9.

Campbell, C. 2011. Porcupine Caribou Herd shows growth [online]. Alaska Department of Fish and Game. http://www.adfg.alaska.gov/index.cfm?adfg=pressreleases.pr03022011 (accessed 4 May, 2011). Press Release No. 11-14.

Campbell, M. 2005. The seasonal distribution and herd delimitation of northeastern mainland caribou (*Rangifer tarandus groenlandicus*). Final Status Report No. 2. Department of Environment, Government of Nunavut. Iqaluit, NU. 22 p.

Campbell, M. 2006. Monitoring condition, feeding habits and demographic parameters of island bound barren-ground caribou (*Rangifer tarandus groenlandicus*), Southampton Island, Nunavut. Final Status Report No. 3. Department of Environment, Government of Nunavut. Iqaluit, NU. 18 p.

Campbell, M. 2007. Wildlife research in the Kivalliq Region of Nunavut with implications to the needs of Nunavummiut. Final Wildlife Report No. 18. Department of Environment, Government of Nunavut. Iqaluit, NU. 34 p.

Campbell, M. 2008. Personal communication. Department of Environment, Government of Nunavut.

Campbell, M. and Dumond, M. 2011. Personal communication. Department of Environment, Government of Nunavut.

Campbell, M., Nishi, J. and Boulanger, J. 2010. A calving ground photo survey of the Qamanirjuaq migratory barren-ground caribou (*Rangifer tarandus groenlandicus*) population - June 2008. Technical Report Series 2010 No. 1-10. Government of Nunavut. 129 p.

Campbell, M.W. 1995. The winter ecology of Cape Churchill caribou (*Rangifer tarandus* ssp.). Thesis (M.Sc.). University of Manitoba. Winnipeg, MB. 216 p.

CARMA. 2010a. Caribou herd information [online]. CircumArctic Rangifer Monitoring and Assessment Network. http://carmanetwork.com/display/public/Herds (accessed 23 December, 2010).

CARMA. 2010b. The CircumArctic Rangifer Monitoring and Assessment Network [online]. CircumArctic Rangifer Monitoring and Assessment Network. http://www.carmanetwork.com/display/public/home (accessed 23 December, 2010).

CARMA. 2011. CARMA newsletter issue 4, November 2010 [online]. CircumArctic Rangifer Monitoring and Assessment Network. http://www.carmanetwork.com/download/attachments/1114336/CARMA+Newsletter+-+November+2010+-+Issue+4.pdf?version=1 (accessed 27 May, 2011).

Carrière, S. 2009. Personal communication. Department of Environment and Natural Resources, Government of the Northwest Territories.

Case, R., Buckland, L. and Williams, M. 1996. The status and management of the Bathurst Caribou Herd, Northwest Territories, Canada. File Report No. 116. Department of Renewable Resources, Government of the Northwest Territories. Yellowknife, NT. 34 p.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley and Sons. New York, NY. 234 p.

Chen, W., Russell, D.E., Gunn, A., Croft, B., Chen, W., Fernandes, R., Zhao, H., Li, J., Zhang, Y., Koehler, K., Olthof, I., Fraser, R.H., Leblanc, S.G., Henry, G.R., White, R.G. and Finstad, G.L. In Prep.[a]. Habitat indicators for migratory tundra caribou under a changing climate: winter and pre-calving migration ranges. Draft report available through Wek'eezhii Renewable Resources Board. http://wrrb.ca/public-information/public-registry/habitat-indicators-migratory-tundra-caribou-under-changing-clima-1 (accessed 17 May, 2011).

Chen, W., Russell, D.E., Gunn, A., Croft, B., Li, J., Chen, W., Zhang, Y., Koehler, K., Olthof, I., Fraser, R.H., Leblanc, S.G., Henry, G.R., White, R.G. and Finstad, G.L. In Prep.[b]. Habitat indicators for migratory tundra caribou under a changing climate: calving ground and summer range. Draft report available through Wek'eezhii Renewable Resources Board. http://wrrb.ca/public-information/public-registry/habitat-indicators-migratory-tundra-caribou-under-changing-climat (accessed 17 May, 2011).

Cluff, D. 2004. Personal communication. Department of Environment and Natural Resources, Government of the Northwest Territories.

Community of Aklavik, Wildlife Management Advisory Council (NWT) and Joint Secretariat. 2008. Aklavik Inuvialuit community conservation plan: a plan for the conservation and management of renewable resources and lands within the Inuvialuit Settlement Region in the vicinity of Aklavik, Northwest Territories. Wildlife Management Advisory Council (NWT). Inuvik, NT. 150 p.

Coral Harbour. 2011. Coral Harbour, the legendary Canadian North [online]. Coral Harbour. http://www.coralharbour.ca/coralharbour_wildlife.html (accessed 21 May, 2011).

Cornelissen, J.H.C., Callaghan, T.V., Alatalo, J.M., Michelsen, A., Graglia, E., Hartley, A.E., Hik, D.S., Hobbie, S.E., Press, M.C., Robinson, C.H., Henry, G.H.R., Shaver, G.R., Phoenix, G.K., Gwynn Jones, D., Jonasson, S., Chapin, F.S., Molau, U., Neill, C., Lee, J.A., Melillo, J.M., Sveinbjornsson, B. and Aerts, R. 2001. Global change and Arctic ecosystems: is lichen decline a function of increases in vascular plant biomass? Journal of Ecology 89:984-994. doi:10.1111/j.1365-2745.2001.00625.x.

COSEWIC. 2004. COSEWIC assessment and update status report on the Peary caribou *Rangifer tarandus pearyi* and the barren-ground caribou *Rangifer tarandus groenlandicus* (Dolphin and Union population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ON. 91 p.

Couturier, S., Brunelle, J., Vandal, D. and St-Martin, G. 1990. Changes in the population dynamics of the George River Caribou Herd, 1976-87. Arctic 43:9-20.

Couturier, S., Côté, S.D., Huot, J. and Otto, R. 2009a. Body-condition dynamics in a northern ungulate gaining fat in winter. Canadian Journal of Zoology 87:367-378.

Couturier, S., Côté, S.D., Otto, R., Weladji, R.B. and Huot, J. 2009b. Variation in calf body mass in migratory caribou: the role of habitat, climate, and movements. Journal of Mammalogy 90:442-452.

Couturier, S., Courtois, R., Crépeau, H., Rivest, L.-P. and Luttich, S. 1996. Calving photocensus of the Rivière George Caribou Herd and comparison with an independent census. Rangifer Special Issue 9:283-296.

Couturier, S., Jean, D., Otto, R. and Rivard, S. 2004. Demography of the migratory tundra caribou (*Rangifer tarandus*) of the Nord-du-Québec region and Labrador. Ministère des Ressources naturelles, de la Faune et des Parcs, Direction de l'aménagement de la faune du Nord-du-Québec and Direction de la recherche sur la faune. Québec, QC. 68 p.

Davison, T. 2009. Personal communication. Preliminary results of caribou surveys for 2009. Department of Environment and Natural Resources, Government of the Northwest Territories. Inuvik, NT.

Davison, T. 2010. Personal communication. Department of Environment and Natural Resources, Government of the Northwest Territories. Inuvik, NT.

Davison, T. and Branigan, M. 2011. Field summary of the April 2011 recruitment surveys for the Tuktoyaktuk Peninsula and Cape Bathurst Herd. Department of Environment and Natural Resources, Government of the Northwest Territories. Inuvik, NT. 7 p. Unpublished report.

Davison, T., Pongracz, J. and Williams, J. In Prep. Caribou and muskox survey on Banks Island and northwest Victoria Island, 2010 summary. Department of Environment and Natural Resources, Government of the Northwest Territories. Inuvik, NT.

Davison, T., Popko, R. and Wright, W. 2007. An aerial survey of barren-ground caribou calving grounds, Tuktoyaktuk Peninsula, Cape Bathurst, and Bluenose-West herds, June 2007.

Department of Environment and Natural Resources, Government of the Northwest Territories. Inuvik, NT and Sahtu, NT. 7 p. Unpublished report.

deBruyn, N., Hoberg, E., Chilton, N., Ruckstuhl, K. and Kutz, S. 2009. Using DNA to map the diversity and distribution of cervid GI nematodes in northwest Canada. Fifth annual meeting of the CircumArctic Rangifer Monitoring and Assessment Network. Vancouver, BC. Conference poster.

Department of Environment and Natural Resources. No Date[Bathurst]. Bathurst Caribou Herd [online]. Government of the Northwest Territories. http://www.enr.gov.nt.ca/_live/pages/wpPages/Bathurst_Caribou_Herd.aspx (accessed 3 May, 2011).

Department of Environment and Natural Resources. No Date[Bluenose-West]. Bluenose-West Herd [online]. Government of the Northwest Territories. http://www.enr.gov.nt.ca/_live/pages/wpPages/Bluenose-West_herd.aspx (accessed 3 May, 2011).

Department of Environment and Natural Resources. No Date[Cape Bathurst]. Cape Bathurst Herd [online]. Government of the Northwest Territories. http://www.enr.gov.nt.ca/_live/pages/wpPages/Cape_Bathurst_herd.aspx (accessed 3 May, 2011).

Department of Environment and Natural Resources. No Date[Tuktoyaktuk Peninsula]. Tuktoyaktuk Peninsula Herd [online]. Government of the Northwest Territories. http://www.enr.gov.nt.ca/_live/pages/wpPages/Tuk_Pen_Caribou.aspx (accessed 17 May, 2011).

Department of Environment and Natural Resources. 2005. Caribou on the Tuktoyaktuk Peninsula. Government of the Northwest Territories. 14 p. Unpublished report.

Department of Environment and Natural Resources. 2006. Caribou forever - our heritage, our responsibility: a barren-ground caribou management strategy for the Northwest Territories 2006-2010. Department of Environment and Natural Resources, Government of the Northwest Territories. Yellowknife, NT. 38 p.

Dogrib Treaty 11 Council. 2001. Caribou migration and the state of their habitat - final report. Dogrib Treaty 11 Council and West Kitikmeot Slave Study Society. Yellowknife, NT. 276 p.

Donaldson, S.G., Van Oostdam, J., Tikhonov, C., Feeley, M., Armstrong, B., Ayotte, P., Boucher, O., Bowers, W., Chan, L., Dallaire, F., Dallaire, R., Dewailly, E., Edwards, J., Egeland, G.M., Fontaine, J., Furgal, C., Leech, T., Loring, E., Muckle, G., Nancarrow, T., Pereg, D., Plusquellec, P., Potyrala, M., Receveur, O. and Shearer, R.G. 2010. Environmental contaminants and human health in the Canadian Arctic. Science of the Total Environment 408:5165-5234.

Ducrocq, J., Lair, S. and Kutz, S. 2009. Prevalence and intensity of *Besnoitia tarandi* in caribou herds: preliminary results. Fifth annual meeting of the CircumArctic Rangifer Monitoring and Assessment Network. Vancouver, BC. Conference poster.

Dumond, M. 2011. Personal communication. Information on Nunavut caribou surveys and harvest levels. Department of Environment, Government of Nunavut. Kugluktuk, NU.

Elliott, C. 1998. Cape Churchill caribou: status of herd and harvest 1997/98. Manuscript Report No. 98-05. Manitoba Natural Resources, Operations Division, Northeast Region. Winnipeg, MB. 14 p.

Environment Canada. 2009. Unpublished analysis of population data by ecozone+ from the Statistics Canada Human Activity and the Environment Series, 1971-2006. Community profile data used to adjust for ecozone+ boundary changes.

Environment Canada. 2011. Scientific assessment to inform the identification of critical habitat for woodland caribou (*Rangifer tarandus caribou*), boreal population, in Canada: 2011 update. Environment Canada. Ottawa, ON. xiv + 103 p.

Environment Yukon. 2010a. Territorial parks [online]. Government of Yukon. http://www.environmentyukon.gov.yk.ca/parksconservation/yukonparks.php (accessed 23 December, 2010).

Environment Yukon. 2010b. Yukon hunting regulations summary. Government of Yukon. Whitehorse, YT. 89 p.

Federal, Provincial and Territorial Governments of Canada. 2010. Canadian biodiversity: ecosystem status and trends 2010. Canadian Councils of Resource Ministers. Ottawa, ON. vi + 142 p. http://www.biodivcanada.ca/default.asp?lang=En&n=83A35E06-1.

Ferguson, M.A.D. 1987. Status of Peary caribou and muskox populations on Bathurst Island, N.W.T., August 1981. Arctic 40:131-137.

Ferguson, M.A.D., Williamson, R.G. and Messier, F. 1998. Inuit knowledge of long-term changes in a population of Arctic tundra caribou. Arctic 51:201-219.

Festa-Bianchet, M., Ray, J.C., Boutin, S., Cote, S. and Gunn, A. 2011. Conservation of caribou (*Rangifer tarandus*) in Canada: an uncertain future. Canadian Journal of Zoology 89:419-434.

First Nation of the NaCho Nyäk Dun, Gwich'in Tribal Council, Inuvialuit Game Council, Tr'ondëk Hwëch'in, Vuntut Gwitchin Government, Government of the Northwest Territories, Government of Yukon and Government of Canada. 2010. Harvest management plan for the Porcupine Caribou Herd in Canada. Porcupine Caribou Management Board. 45 p.

Fischer, C.A. and Duncan, E.A. 1976. Ecological studies of caribou and muskoxen in the Arctic Archipelago and northern Keewatin. Renewable Resources Consulting Services Ltd. Edmonton, AB. 194 p.

Flannigan, M.D., Logan, K.A., Amiro, B.D., Skinner, W.R. and Stocks, B.J. 2005. Future area burned in Canada. Climatic Change 72:1-16.

Fraser, P., Gunn, A. and McLean, B. 1992. Abundance and distribution of Peary caribou and muskoxen on Banks Island, NWT, June 1991. Manuscript Report No. 63. Department of Renewable Resources, Government of the Northwest Territories. Yellowknife, NT. 18 p.

Gaillard, J.M., Festa-Bianchet, M. and Yoccoz, N.G. 1998. Population dynamics of large herbivores: variable recruitment with constant adult survival. Trends in Ecology and Evolution 13:58-63.

Gamberg, M. 2009. Arctic caribou and moose contaminant monitoring program. *In* Synopsis of research conducted under the 2008-2009 Northern Contaminants Program. Edited by Smith, S., Stow, J. and Edwards, J. Public Works and Government Services Canada. Ottawa, ON. pp. 179-184.

Gamberg, M., Braune, B., Davey, E., Elkin, B., Hoekstra, P.F., Kennedy, D., Macdonald, C., Muir, D., Nirwal, A., Wayland, M. and Zeeb, B. 2005. Spatial and temporal trends of contaminants in terrestrial biota from the Canadian Arctic. Science of the Total Environment 351:148-164.

Gartner Lee Limited. 2002. The Bathurst Caribou Herd: a compilation of research and monitoring. Report submitted to the North Slave Métis Alliance. 17 p.

Gaston, K.J. and Fuller, R.A. 2008. Commonness, population depletion and conservation biology. Trends in Ecology and Evolution 23:14-19.

Gau, R.J., Case, R., Penner, D.F. and McLoughlin, P.D. 2002. Feeding patterns of barren-ground grizzly bears in the Central Canadian Arctic. Arctic 55:339-344.

Gau, R.J. and Veitch, A. No Date. Population estimate of grizzly bears inhabiting the NWT, 1999: a discussion paper - revised. Department of Environment and Natural Resources, Government of the Northwest Territories. Yellowknife, NT. 47 p. Unpublished report.

Gavin, A. 1945. Notes on mammals observed in the Perry River District, Queen Maud Sea. Journal of Mammalogy 26:226-230.

Gordon, B.C. 2005. 8,000 years of caribou and human seasonal migration in the Canadian barrenlands. Rangifer Special Issue 16:155-162.

Government of Canada. 2011. Species at Risk Public Registry: caribou [online]. Government of Canada. http://www.sararegistry.gc.ca/search/advSearchResults_e.cfm?stype=species&advkeywords=caribou (accessed 23 December, 2010).

Government of Canada, Government of the Northwest Territories, Inuvialuit Game Council, Inuvialuit Regional Corporation, Paulatuk Community Corporation and Paulatuk Hunters and Trappers Committee. 1996. The Tuktut Nogait Agreement [online]. Parks Canada. http://www.pc.gc.ca/pn-np/nt/tuktutnogait/docs/plan1.aspx (accessed 23 December, 2010).

Government of the Northwest Territories and NWT Biodiversity Team. 2010. Northwest Territories state of the environment - 2010 biodiversity special edition. Department of Environment and Natural Resources, Government of the Northwest Territories. Yellowknife, NT. 48 p.

Griffith, B., Douglas, D.C., Walsh, N.E., Young, D.D., McCabe, T.R., Russell, D.E., White, R.G., Cameron, R.D. and Whitten, K.R. 2002. The Porcupine Caribou Herd. *In* Arctic refuge coastal plain terrestrial wildlife research summaries, U. S. Geological Survey, Biological Resources Division, Biological Science Report USGS/BRD/BSR-2002-0001. Edited by Douglas, D.C., Reynolds, P.E. and Rhode, E.B. pp. 8-37.

GRRB. 2009. Gwich'in harvest study. Gwich'in Renewable Resource Board. Inuvik, NT. 164 p.

Gunn, A. 2003. Voles, lemmings and caribou - population cycles revisited? Rangifer Special Issue 14:105-111.

Gunn, A. 2005. The decline of caribou on northwest Victoria Island: a review. File Report No. 133. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Yellowknife, NT. 57 p.

Gunn, A. and D'Hont, A. 2002. Extent of calving for the Bathurst and Ahiak caribou herds, June 2002. Manuscript Report No. 149. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Yellowknife, NT. 35 p.

Gunn, A. and Decker, R. 1982. Survey of the calving grounds of the Beverly Caribou Herd, 1980. File Report No. 20. N.W.T. Wildlife Service. 27 p.

Gunn, A. and Decker, R. 1984. Numbers and distributions of Peary caribou and muskoxen in July 1980 on Prince of Wales, Russell and Somerset islands, N.W.T. File Report No. 38. N.W.T. Wildlife Service. 56 p.

Gunn, A. and Dragon, J. 1998. Status of caribou and muskox populations within the Prince of Wales Island-Somerset Island-Boothia Peninsula complex, NWT, July-August 1995. File Report No. 122. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Yellowknife, NT. 45 p.

Gunn, A. and Dragon, J. 2002. Peary caribou and muskox abundance and distribution on the western Queen Elizabeth Islands, Northwest Territories and Nunavut June-July 1997. File Report No. 130. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Yellowknife, NT. 93 p.

Gunn, A., Dragon, J. and Boulanger, J. 2001. Seasonal movements of satellite-collared caribou from the Bathurst Herd. Final report to the West Kitikmeot Slave Study Society. Yellowknife, NT. 72 p.

Gunn, A., Dragon, J. and Nishi, J. 1997. Bathurst calving ground survey 1996. File Report No. 119. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Yellowknife, NT. 70 p.

Gunn, A. and Fournier, B. 2000. Identification and substantiation of caribou calving grounds on the NWT mainland and islands. File Report No. 123. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Yellowknife, NT. 177 p.

Gunn, A., Fournier, B. and Morrison, R. 2000a. Seasonal movements and distribution of satellite-collared caribou cows on the Boothia and Simpson Peninsula areas, Northwest Territories 1991-93. Manuscript Report No. 126. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Yellowknife, NT. 77 p.

Gunn, A., Fournier, B. and Nishi, J. 2000b. Abundance and distribution of the Queen Maud Gulf Caribou Herd, 1986-98. File Report No. 126. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Yellowknife, NT. 76 p.

Gunn, A. and Irvine, R.J. 2003. Subclinical parasitism and ruminant foraging stategies - a review. Wildlife Society Bulletin 31:117-126.

Gunn, A., Johnson, C.J., Nishi, J.S., Daniel, C.J., Carlson, M., Russell, D.E. and Adamczewski, J.Z. 2011a. Addressing cumulative effects in the Canadian Central Arctic - understanding the impacts of human activities on barren-ground caribou. *In* Cumulative effects on wildlife management: a critical aspect of impact mitigation. Edited by Krausman, P.R. and Harris, L.K. Taylor and Francis. Chapter 8.

Gunn, A., Miller, F. and Nishi, J. 2000c. Status of endangered and threatened caribou on Canada's Arctic islands. Rangifer Special Issue 12:39-50.

Gunn, A., Miller, F.L., Barry, S.J. and Buchan, A. 2006. A near-total decline in caribou on Prince of Wales, Somerset, and Russell islands, Canadian Arctic. Arctic 59:1-13.

Gunn, A., Nishi, J., Boulanger, J. and Williams, J. 2005. An estimate of breeding females in the Bathurst Herd of barren-ground caribou, June 2003. Manuscript Report No. 164. Department of Environment and Natural Resources, Government of the Northwest Territories. 75 p.

Gunn, A. and Poole, K.G. 2009. Environmental trends across the range of the Bathurst Caribou Herd and timing of the arrival of cows on their calving ground 1996-2009. Unpublished report submitted to the Department of Environment and Natural Resources. Yellowknife, NT. 32 p.

Gunn, A., Poole, K.G. and Nishi, J.S. In Press. A conceptual model for migratory tundra caribou to explain and predict why shifts in spatial fidelity of breeding cows to their calving grounds are infrequent. Accepted 2011 for publication in Rangifer.

Gunn, A., Poole, K.G. and Wierzchowski, J. 2008. A geostatistical analysis for the patterns of caribou occupancy on the Bathurst calving grounds 1966-2007. Unpublished report submitted to Indian and Northern Affairs Canada. Yellowknife, NT. 51 p.

Gunn, A., Poole, K.G. and Wierzchowski, J. 2011b. Migratory tundra caribou seasonal and annual distribution relative to Thaidene Nene, a national park reserve proposal in the East

Arm of Great Slave Lake and Artillery Lake area, Northwest Territories. Unpublished report for Parks Canada. Fort Smith, NT. 46 p.

Gunn, A., Poole, K.G., Wierzchowski, J. and Campbell, M. 2007. Assessment of caribou protection measures. Unpublished report submitted to Indian and Northern Affairs Canada. Gatineau, QC. 45 p.

Gunn, A. and Russell, D. (eds.). 2008. Monitoring *Rangifer* herds (population dynamics). CircumArctic Rangifer Monitoring and Assessment Network. 52 p.

Gunn, A. and Sutherland, M. 1997. Surveys of the Beverly caribou calving grounds, 1957-1994. File Report No. 120. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Yellowknife, NT. 119 p.

Gwich'in Land Use Planning Board. 2003. Nành' geenjit gwitr'it t'igwaa'in, working for the land: Gwich'in Land Use Plan. 166 p.

Hall, A. 2005. Personal communication. Outfitter and guide. Fort Smith, NT.

Harding, L.E. 2004. The future of Peary caribou (*Rangifer tarandus pearyi*) in a changing climate. Edited by Hooper, T.D. Victoria, BC.

Hayes, R.D. and Russell, D.E. 2000. Predation rate by wolves on the Porcupine Caribou Herd. Rangifer Special Issue 12:51-58.

Heard, D.C. and Decker, R. 1980. An estimate of the size and structure of the Beverly Caribou Herd, 1978-79. N.W.T. Wildlife Service unpublished report. 39 p. As cited in: Williams, T.M., Raddi, M., Bradley, M., Heard, D.C. and N.W.T. Wildlife Service. 1983. Beverly and Kaminuriak barren-ground caribou herds: an annotated bibliography. Prepared for the Caribou Management Board. p. 55.

Heard, D.C. and Jackson, F.J. 1990. Beverly calving ground survey June 2-14, 1988. File Report No. 86. Department of Renewable Resources, Government of the Northwest Territories. Yellowknife, NT. 27 p.

Heard, D.C. and Ouellet, J.P. 1994. Dynamics of an introduced caribou population. Arctic 47:88-95.

Heard, D.C. and Williams, T.M. 1991a. Appendix C. Bathurst calving ground survey, June 1986. *In* Bathurst calving ground survey 1996. Edited by Gunn, A., Dragon, J. and Nishi, J. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Yellowknife, NT. pp. 30-46.

Heard, D.C. and Williams, T.M. 1991b. Appendix D. Bathurst calving ground survey, June 1990. *In* Bathurst calving ground survey 1996. Edited by Gunn, A., Dragon, J. and Nishi, J. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Yellowknife, NT. pp. 47-62.

Heard, D.C., Williams, T.M. and Jingfors, K. 1986. Precalving distribution and abundance of barren-ground caribou on the northeastern mainland of the Northwest Territories. Arctic 39:24-28.

Hudson, J.M.G. and Henry, G.H.R. 2009. Increased plant biomass in a High Arctic heath community from 1981 to 2008. Ecology 90:2657-2663.

Hughes, J., Albon, S.D., Irvine, R.J. and Woodin, S. 2009. Is there a cost of parasites to caribou? Parasitology 136:253-265.

Hummel, M. and Ray, J.C. 2008. Caribou and the North: a shared future. Dundurn Press. Toronto, ON. 320 p.

Hydro-Québec. 2011. Strategic plan, 2009-2013. Hydro-Québec. 86 p.

InterGroup Consultants Ltd. 2008. Economic valuation and socio-cultural perspectives of the estimated harvest of the Beverly and Qamanirjuaq caribou herds. InterGroup Consultants Ltd. Winnipeg, MB. 28 p. + 3 appendices.

Inuvialuit Renewable Resources Committee. 2003. Inuvialuit harvest study: data and methods report 1988-1997. Inuvik, NT. 209 p.

Jakimchuk, R.D. and Carruthers, D.R. 1980. Caribou and muskoxen on Victoria Island, N.W.T. Jakimchuk Management Associates Ltd. for Polar Gas Project. Sidney, BC. 93 p.

Jenkins, D.A. 2007. Estimating Peary caribou *(Rangifer tarandus pearyi)* and muskox *(Ovibos moschafus)* numbers, composition and distribution on Ellesmere Island, Nunavut. Status Report No. 28. Department of Environment, Government of Nunavut. Iqualuit, NU. 7 p.

Jenkins, D.A., Campbell, M., Hope, G., Goorts, J. and McLoughlin, P. 2011. Recent trends in abundance of Peary caribou (*Rangifer tarandus pearyi*) and muskoxen (*Ovibos moschatus*) in the Canadian Arctic Archipelago, Nunavut. Wildlife Report No. 1. Department of Environment, Government of Nunavut. Pond Inlet, NU. 184 p.

Johnson, C.J., Boyce, M.S., Case, R.L., Cluff, H.D., Gau, R.J., Gunn, A. and Mulders, R. 2005. Cumulative effects of human developments on Arctic wildlife. Wildlife Monographs 1-36.

Johnson, D. 2011. 2006 calving ground survey results, Queen Maud Gulf coast. Department of Environment and Natural Resources, Government of the Northwest Territories. Unpublished data.

Johnson, D. and Mulders, R. 2009. Beverly calving ground survey, June 2002. Manuscript Report No. 188. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Yellowknife, NT. 63 p.

Joly, D.O. and Messier, F. 2004. Factors affecting apparent prevalence of tuberculosis and brucellosis in wood bison. Journal of Animal Ecology 73 :623-631.

Joly, K., Chapin, F.S. and Klein, D.R. 2010. Winter habitat selection by caribou in relation to lichen abundance, wildfires, grazing, and landscape characteristics in northwest Alaska. Ecoscience 17:321-333.

Joly, K., Dale, B.W., Collins, W.B. and Adams, L.G. 2003. Winter habitat use by female caribou in relation to wildland fires in interior Alaska. Canadian Journal of Zoology 81:1192-1201.

Joly, K., Jandt, R.R. and Klein, D.R. 2009. Decrease of lichens in Arctic ecosystems: the role of wildfire, caribou, reindeer, competition and climate in north-western Alaska. Polar Research 28:433-442.

Joly, K., Klein, D.R., Verbyla, D.L., Rupp, T.S. and Chapin, F.S. 2011. Linkages between large-scale climate patterns and the dynamics of Arctic caribou populations. Ecography 34:345-352.

Judson, B. 2010. Trends in Canadian Arctic shipping traffic - myths and rumours. Unpublished report presented at the 20th International Offshore (Ocean) and Polar Engineering Conference and Exhibition.

Kauserud, H., Stige, L.C., Vik, J.O., Okland, R.H., Hoiland, K. and Stenseth, N.C. 2008. Mushroom fruiting and climate change. Proceedings of the National Academy of Sciences of the United States of America 105:3811-3814.

Kelly, A. 2011. Personal communication. Department of Environment and Natural Resources, Government of the Northwest Territories.

Kelsall, J.P. 1968. The migratory barren-ground caribou of Canada. Canadian Wildlife Service Monograph Series No. 3. Department of Indian Affairs and Northern Development. Ottawa, ON. 340 p.

Kielland, K., Bryant, J.P. and Ruess, R.W. 2006. Mammalian herbivory, ecosystem engineering and ecological cascades in Alaskan boreal forests. *In* Alaska's changing boreal forest. Edited by Chapin III, F.S., Osowood, M.W., Van Cleve, K., Viereck, L.A. and Verbyla, D.L. Oxford University Press. New York, NY. pp. 211-226.

Knight Piésold Consulting. 2010. Mary River project: environmental impact statement. Vol. 6 terrestrial environment. Available at Nunavut Impact Review Board: http://www.nirb.ca/Reviews.html.

Krebs, C.J., Danell, K., Angerbjorn, A., Agrell, J., Berteaux, D., Brathen, K.A., Danell, O., Erlinge, S., Fedorov, V., Fredga, K., Hjalten, J., Hogstedt, G., Jonsdottir, I.S., Kenney, A.J., Kjellen, N., Nordin, T., Roininen, H., Svensson, M., Tannerfeldt, M. and Wiklund, C. 2003. Terrestrial trophic dynamics in the Canadian Arctic. Canadian Journal of Zoology 81:827-843.

Krezek-Hanes, C.C., Ahern, F., Cantin, A. and Flannigan, M.D. 2011. Trends in large fires in Canada, 1959-2007. Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 6. Canadian Councils of Resource Ministers. Ottawa, ON. v + 48 p. http://www.biodivcanada.ca/default.asp?lang=En&n=137E1147-0.

Larter, N.C. and Nagy, J.A. 2001. Population demography of High Arctic caribou on Banks and Melville islands. Rangifer Special Issue 14:153-159.

Larter, N.C. and Nagy, J.A. 2004. Seasonal changes in the composition of the diets of Peary caribou and muskoxen on Banks Island. Polar Research 23:131-140.

Latour, P. 1985. Population estimates for Peary caribou and muskoxen on Banks Island in 1982. File Report No. 49. Northwest Territories Wildlife Service. Yellowknife, NT. 21 p.

Leckie, D., Burt, W., Johnson, L., Hardman, D., Hill, D., Paradine, D. and Tammadge, D. 2006. Deforestation mapping activity summaries for Canada's national deforestation estimate 2006. Canadian Forest Service. Victoria, BC. 25 p.

Legat, A., Chocolate, G., Chocolate, M., Williah, P. and Zoe, S.A. 2002. Habitat of Dogrib traditional territory: placenames as indicators of biogeographical knowledge - final report. Dogrib Treaty 11 Council and West Kitikmeot Slave Study Society. Yellowknife, NT. 92 p.

Ludwig, D. 2001. The era of management is over. Ecosystems 4:758-764.

Macdonald, C., Elkin, B. and Gunn, A. 2005. Analysis of the elemental composition of tissues and faecal ash in a moose (*Alces alces*) exposed to tailings at the abandoned Colomac gold mine, NWT. Manuscript Report No. 162. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Yellowknife, NT. 39 p.

Macdonald, C.R., Elkin, B.T. and Tracy, B.L. 2007. Radiocesium in caribou and reindeer in northern Canada, Alaska and Greenland from 1958 to 2000. Journal of Environmental Radioactivity 93:1-25.

Magoun, A.J., Abraham, K.F., Thompson, J.E., Ray, J.C., Gauthier, M.E., Brown, G.S., Woolmer, G., Chenier, C.J. and Dawson, F.N. 2005. Distribution and relative abundance of caribou in the Hudson Plains Ecozone of Ontario. Rangifer 16:105-121.

Mahoney, S.P. and Schaefer, J.A. 2002. Hydroelectric development and the disruption of migration in caribou. Biological Conservation 107:147-153.

Manning, T.H. 1960. The relationship of the Peary caribou and barren-ground caribou. Technical Paper No. 4. Arctic Institute of North America. Montréal, QC. 42 p.

McLean, B., Jingfors, K. and Case, R. 1986. Abundance and distribution of muskoxen and caribou on Banks Island, July 1985. File Report No. 64. Department of Renewable Resources, Government of the Northwest Territories. Inuvik, NT. 45 p.

McLean, B.D. 1992. Abundance and distribution of caribou on Banks Island, NWT July 1987. File Report No. 95. Department of Renewable Resources, Government of the Northwest Territories. Inuvik, NT. 28 p.

McLean, B.D. and Fraser, P. 1992. Abundance and distribution of Peary caribou and muskoxen on Banks Island, NWT June 1989. File Report No. 106. Department of Renewable Resources, Government of the Northwest Territories. Inuvik, NT. 28 p.

Messier, F., Huot, J., Henaff, D.L. and Luttich, S. 1988. Demography of the George River Caribou Herd: evidence of population regulation by forage exploitation and range expansion. Arctic 41:279-287.

Miller, F.L. 1987. Peary caribou and muskoxen on Prince Patrick Island, Eglinton Island, and Emerald Isle, Northwest Territories, July 1986. Technical Report Series No. 29. Canadian Wildlife Service, Prairie and Northern Region. Edmonton, AB. 58 p.

Miller, F.L. 1988. Peary caribou and muskoxen on Melville and Byam Martin islands, Northwest Territories, July 1987. Technical Report Series No. 37. Canadian Wildlife Service, Prairie and Northern Region. Edmonton, AB. 58 p.

Miller, F.L. 1991. Estimating Bathurst Island Peary caribou and muskox populations. Arctic 44:57-62.

Miller, F.L. 1998. Status of Peary caribou and muskox populations within the Bathurst Island complex, south-central Queen Elizabeth Islands, Northwest Territories, July 1996. Technical Report Series No. 317. Canadian Wildlife Service. Edmonton, AB. 147 p.

Miller, F.L. and Barry, S.J. 2009. Long-term control of Peary caribou numbers by unpredictable, exceptionally severe snow or ice conditions in a non-equilibrium grazing system. Arctic 62:175-189.

Miller, F.L., Barry, S.J. and Calvert, W.A. 2005. Conservation of Peary caribou based on a recalculation of the 1961 aerial survey on the Queen Elizabeth Islands, Arctic Canada. Rangifer Special Issue 16:65-75.

Miller, F.L. and Gunn, A. 2003. Catastrophic die-off of Peary caribou on the western Queen Elizabeth Islands, Canadian High Arctic. Arctic 56:381-390.

Miller, F.L., Russell, R.H. and Gunn, A. 1975. The recent decline of Peary caribou on Western Queen Elizabeth Islands of Arctic Canada. Polarforschung 45:17-21.

Miller, F.L., Russell, R.H. and Gunn, A. 1977. Distributions, movements and numbers of Peary caribou and muskoxen on western Queen Elizabeth Islands, Northwest Territories, 1972-74. Technical Report Series No. 40. Canadian Wildlife Service. Edmonton, AB. 55 p.

Miltenberger, J.M. 2010. NWT caribou conservation measures. Statement to the Legislative Assembly, January 27, 2010. 4 p.

Morneau, C. and Payette, S. 2000. Long term fluctuations of a caribou population revealed by tree ring data. Canadian Journal of Zoology 78:1784-1790.

Mulders, R. 2009. Personal communication. Department of Environment and Natural Resources, Government of the Northwest Territories. Yellowknife, NT.

Mullon, C., Freon, P. and Cury, P. 2005. The dynamics of collapse in world fisheries. Fish and Fisheries 6:111-120.

Nagy, J. 2009a. Population estimates for the Cape Bathurst and Bluenose-West barren-ground caribou herds using post-calving photography. Manuscript Report No. 193. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Yellowknife, NT. 190 p. Draft.

Nagy, J. and Gunn, A. 2006. Productivity of Peary caribou on Banks, northwest Victoria and Melville islands. Department of Environment and Natural Resources, Government of the Northwest Territories. Yellowknife, NT. Unpublished report.

Nagy, J.A. 2007. Plummeting numbers: the mysterious decline of the Arctic coastal herds. Northern Perspectives 31:36-37.

Nagy, J.A. 2009b. Evidence that the Cape Bathurst, Bluenose-West, and Bluenose-East calving grounds are not theoretical and justification for division of the "Bluenose" Herd into the Cape Bathurst, Bluenose-West, and Bluenose-East herds. Draft Manuscript Report No. 194. Department of Environment and Natural Resources, Government of the Northwest Territories. Yellowknife, NT. 84 p.

Nagy, J.A., Gunn, A. and Wright, W.H. 2009a. Population estimates for Peary caribou (Minto Inlet Herd), Dolphin and Union caribou, and muskox on northwest Victoria Island, NT, July 2005. Manuscript Report No. 203. Department of Environment and Natural Resources, Government of the Northwest Territories. Inuvik, NT and Yellowknife, NT. 39 p.

Nagy, J.A., Gunn, A. and Wright, W.H. 2009b. Population estimates for Peary caribou and muskox on Banks Island, NT, August 1992. Manuscript Report No. 198. Department of Environment and Natural Resources, Government of the Northwest Territories. Inuvik, NT and Yellowknife, NT. 31 p.

Nagy, J.A., Gunn, A. and Wright, W.H. 2009c. Population estimates for Peary caribou and muskox on Banks Island, NT, July 2005. Manuscript Report No. 200. Department of Environment and Natural Resources, Government of the Northwest Territories. Inuvik, NT and Yellowknife, NT. 37 p.

Nagy, J.A. and Johnson, D. 2006. Estimates of the number of barren-ground caribou in the Cape Bathurst and Bluenose-West herds and reindeer/caribou on the upper Tuktoyaktuk Peninsula derived using post calving photography, July 2006. Manuscript Report No. 171. Department of Environment and Natural Resources, Government of the Northwest Territories. Inuvik, NT and Fort Smith, NT. 56 p.

Nagy, J.A., Johnson, D.H., Campbell, M.W., Kelly, A., Larter, N.C. and Derocher, A.E. 2010. The Beverly Barren-Ground Caribou Herd has not disappeared: it just changed calving grounds. 13th North American Caribou Workshop. Winnipeg, MB. Abstract, presentation.

Nagy, J.A., Johnson, D.L., Larter, N.C., Campbell, M.W., Derocher, A.E., Kelly, A., Dumond, M., Allaire, D. and Croft, B. 2011. Subpopulation structure of caribou (*Rangifer tarandus* L.) in Arctic and Subarctic Canada. Ecological Applications 21:2334-2348.

Nagy, J.A., Larter, N. and Wright, W.H. 2006. Population estimates for Peary caribou and muskox on Banks Island, NT, July 2001. Manuscript Report No. 199. Department of Environment and Natural Resources, Government of the Northwest Territories. Inuvik, NT and Fort Simpson, NT. 37 p.

Nagy, J.A., Larter, N. and Wright, W.H. 2009d. Population estimates for Peary caribou (Minto Inlet Herd), Dolphin and Union caribou, and muskox on northwest Victoria Island, NT, July 1998. Manuscript Report No. 201. Department of Environment and Natural Resources, Government of the Northwest Territories. Inuvik, NT and Fort Simpson, NT. 29 p.

Nagy, J.A., Larter, N. and Wright, W.H. 2009e. Population estimates for Peary caribou (Minto Inlet Herd), Dolphin and Union caribou, and muskox on northwest Victoria Island, NT, July 2001. Manuscript Report No. 202. Department of Environment and Natural Resources, Government of the Northwest Territories. Inuvik, NT and Fort Simpson, NT. 36 p.

Nagy, J.A., Latour, P. and Wright, W.H. 2009f. Population estimates for Peary caribou and muskox on Banks Island, NT, July 1982: a retrospective analysis. Manuscript Report No. 197. Department of Environment and Natural Resources, Government of the Northwest Territories. Inuvik, NT. 42 p.

Nagy, J.A. and Tracz, B. 2006. Estimates of the number of barren-ground caribou in the Bluenose-East Herd derived using post calving photography, July 2006. Draft Manuscript Report. Department of Environment and Natural Resources, Government of the Nortwest Territories. Yellowknife, NT.

Nagy, J.A., Tracz, B. and Gunn, A. 2008. Estimates of the number of barren-ground caribou in the Bluenose-East Herd derived using post calving photography, July 2005. Manuscript Report No. 177. Department of Environment and Natural Resources, Government of the Northwest Territories. Yellowknife, NT. In press.

NIRB. 2011. Public registry [online]. Nunavut Impact Review Board. http://www.nirb.ca/PublicRegistry.html (accessed 8 January, 2011).

Nishi, J.S. and Gunn, A. 2004. An estimate of the herd size for the migratory Dolphin and Union Caribou Herd during the rut (17-22 October 1997). File Report No. 131. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Yellowknife, NT. 52 p.

Northern Contaminants Program. 2003. Highlights of the Canadian Arctic contaminants assessment report II. Indian and Northern Affairs Canada. Ottawa, ON. 118 p.

Northwest Territories Protected Areas Strategy Advisory Committee. 1999. The Northwest Territories Protected Areas Strategy. A balanced approach to establishing protected areas in the Northwest Territories. iv + 102 p.

Oli, M.K. 2003. Response to Korpimaki et al.: vole cycles and predation. Trends in Ecology and Evolution 18:495-496.

Olofsson, J., Stark, S. and Oksanen, L. 2004. Reindeer influence on ecosystem processes in the tundra. Oikos 105:386-396.

Olthof, I. and Pouliot, D. 2010. Treeline vegetation composition and change in Canada's western Subarctic from AVHRR and canopy reflectance modeling. Remote Sensing of Environment 114:805-815.

Orsel, K., Kutz, S., Barkema, H. and De Buck, J. 2008. Presence of *M. avium* spp *paratuberculosis* in free-ranging caribou. Fifth annual meeting of the CircumArctic Rangifer Monitoring and Assessment Network. Vancouver, BC. Poster presentation.

Ostertag, S.K., Tague, B.A., Humphries, M.M., Tittlemier, S.A. and Chan, H.M. 2009. Estimated dietary exposure to fluorinated compounds from traditional foods among Inuit in Nunavut, Canada. Chemosphere 75:1165-1172.

Parker, G. 1975. An investigation of caribou range on Southampton Island, N.W.T. (Northwest Territories). Canadian Wildlife Service Report Series No. 33. Canadian Wildlife Service. Ottawa, ON. 83 p.

Parks Canada. 2006. Quttinirpaaq National Park of Canada: management plan. Parks Canada. 75 p.

Parks Canada. 2007. Ivvavik National Park of Canada: management plan. Parks Canada. 73 p.

Parks Canada. 2010a. State of the park report 2010: Aulavik National Park of Canada. Parks Canada. 50 p.

Parks Canada. 2010b. Vuntut National Park of Canada: management plan. Parks Canada. 54 p.

Patterson, B.R., Olsen, B.T. and Joly, D.O. 2004. Population estimate for the Bluenose-East Caribou Herd using post-calving photography. Arctic 57:47-58.

Payette, S., Boudreau, S., Morneau, C. and Pitre, N. 2004. Long-term interactions between migratory caribou, wildfires and Nunavik hunters inferred from tree rings. Ambio 33:482-486.

PCMB. 2008. Porcupine Caribou Management Board 2007-08 annual report. Porcupine Caribou Management Board. Whitehorse, YT. 28 p.

PCMB. 2009. Harvest management plan for the Porcupine Caribou Herd in Canada. Porcupine Caribou Management Board. 41 p.

PCMB. 2010. The Porcupine Caribou Management Board [online]. Porcupine Caribou Management Board. http://taiga.net/pcmb/ (accessed 19 January, 2011).

Poole, K.G., Gunn, A., Patterson, B.R. and Dumond, M. 2010. Sea ice and migration of the Dolphin and Union Caribou Herd in the Canadian Arctic: an uncertain future. Arctic 62:414-428.

Priest, H. and Usher, P.J. 2004. The Nunavut wildlife harvest study. Nunavut Wildlife Management Board. Iqaluit, NU. 816 p.

Rayback, S.A., Lini, A. and Henry, G.H.R. 2011. Spatial variability of the dominant climate signal in *Cassiope tetragona* from sites in Arctic Canada. Arctic 64:98-114.

Ressources naturelles et Faune. 2010. Results of the George River Caribou Herd census [online]. Government of Quebec. http://www.mrn.gouv.qc.ca/english/press/press-release-detail.jsp?id=8713 (accessed 23 December, 2010). Press release.

Rinke, A. and Dethloff, K. 2008. Simulated circum-arctic climate changes by the end of the 21st century. Global and Planetary Change 62:173-186.

Rothfels, M. and Russell, D. 2005. Mammal fact sheets: caribou. Hinterland Who's Who. Canadian Wildlife Federation and Environment Canada. http://www.hww.ca/en/species/mammals/caribou.html.

Russell, D. 2011. Analysis of Porcupine Caribou Herd telemetry data. Unpublished data.

Russell, D.E., Martell, A.M. and Nixon, W.A. 1993. The range ecology of the Porcupine Caribou Herd in Canada. Rangifer Special Issue 8:1-168.

Russell, D.E., White, R.G. and Daniel, C.J. 2005. Energetics of the Porcupine Caribou Herd: a computer simulation model. Technical Report Series No. 431. Canadian Wildlife Service. Ottawa, ON. 64 p.

Schmelzer, I. and Otto, R. 2003. Winter range drift in the George River Caribou Herd: a response to summer forage limitation? Rangifer Special Issue 14:113-122.

Sharma, S., Couturier, S. and Côté, S.D. 2009. Impacts of climate change on the seasonal distribution of migratory caribou. Global Change Biology 15:2549-2562.

SRRB. 2004. Harvest study [online]. Sahtu Renewable Resources Board. http://www.srrb.nt.ca/harstudy.html (accessed 16 November, 2009).

SRRB. 2007. Report on a public hearing held by the Sahtu Renewable Resources Board and reasons for decision on the setting of a total allowable harvest for the Bluenose-West Caribou Herd. Sahtu Renewable Resources Board. Fort Good Hope, NT.

Stankowich, T. 2008. Ungulate flight responses to human disturbance: a review and meta-analysis. Biological Conservation 141:2159-2173.

Stewart, H. 2009. Personal communication. Parks Canada (Wapusk National Park).

Taillon, J. 2011. Personal communication. Université Laval. Québec, QC.

Tener, J.S. 1963. Queen Elizabeth Islands game survey, 1961. Occasional Paper No. 4. Canadian Wildlife Service. 50 p.

Therrien, J., Verdon, R. and Lalumière, R. 2004. Environmental monitoring at the La Grande Complex. Changes in fish communities. Summary report 1977-2000. GENIVAR Groupe Conseil Inc. and Direction Barrages et Environnement, Hydro-Québec Production. Montréal, QC. 129 p. and appendices.

Thomas, D.C. 1998. Fire-caribou relationships: (V) winter diet of the Beverly Herd in northern Canada, 1980-1987. Technical Report Series No. 313. Canadian Wildlife Service, Prairie and Northern Region. Edmonton, AB. 41 p.

Thomas, D.C. and Kiliaan, H. 1998. Fire-caribou relationships: (IV) recovery of habitat after fire on the winter range of the Beverly Herd. Technical Report Series No. 312. Canadian Wildlife Service, Prairie and Northern Region. Edmonton, AB. 115 p.

Thomas, D.C., Kiliaan, H.P.L. and Trottier, T.W.P. 1998. Fire-caribou relationships: (III) movement patterns of the Beverly Herd in relation to burns and snow. Technical Report Series No. 311. Canadian Wildlife Service, Prairie and Northern Region. Edmonton, AB. 176 p.

Thompson, J.E. and Abraham, K.F. 1994. Range, seasonal distribution and population dynamics of the Pen Islands Caribou Herd of southern Hudson Bay. Ontario Ministry of Natural Resources. 94 p.

Tlicho Government and Department of Environment and Natural Resources, Government of the Northwest Territories. 2011. Revised joint proposal on caribou management actions in Wek'èezhìi: implementation plan. Behchoko, NT and Yellowknife, NT. 61 p. Report submitted to the Wek'èezhìi Renewable Resource Board.

Trottier, T. 2011. Personal communication. Unpublished information on population growth and development in northern Saskatchewan. Government of Saskatchewan and Beverly and Qamanirjuaq Caribou Management Board.

Urquhart, D.R. 1973. Oil exploration and Banks Island wildlife: a guideline for the preservation of caribou, muskox, and arctic fox populations on Banks Island, N.W.T. Northwest Territories Game Management Division. Yellowknife, NT. 105 p.

Usher, P.J. and Wenzel, G.W. 1987. Native harvest surveys and statistics: a critique of their construction and use. Arctic 42:145-160.

Van der Wal, R. 2006. Do herbivores cause habitat degradation or vegetation state transition? Evidence from the tundra. Oikos 114:177-186.

Van der Wal, R., Irvine, J., Stien, A., Shepherd, N. and Albon, S.D. 2000. Faecal avoidance and the risk of infection by nematodes in a natural population of reindeer. Oecologia 124:19-25.

Van Oostdam, J., Donaldson, S.G., Feeley, M., Arnold, D., Ayotte, P., Bondy, G., Chan, L., Dewaily, E., Furgal, C.M., Kuhnlein, H., Loring, E., Muckle, G., Myles, E., Receveur, O., Tracy, B., Gill, U. and Kalhok, S. 2005. Human health implications of environmental contaminants in Arctic Canada: a review. Science of the Total Environment 351:165-246.

Walker, M.D., Wahren, C.H., Hollister, R.D., Henry, G.H.R., Ahlquist, L.E., Alatalo, J.M., Bret-Harte, M.S., Calef, M.P., Callaghan, T.V., Carroll, A.B., Epstein, H.E., Jónsdóttir, I.S., Klein, J.A., Magnússom, B., Molau, U., Oberbauer, S.F., Rewa, S.P., Robinson, C.H., Shaver, G.R., Suding, K.N., Thompson, C.C., Tolvanen, A., Totland, O., Turner, P.L., Tweedie, C.E., Webber, P.J. and Wookey, P.A. 2006. Plant community responses to experimental warming across the tundra biome. *In* Proceedings of the National Academy of Sciences. National Academy of Sciences. Washington, DC. Vol. 103, pp. 1342-1346.

Wang, M.Y. and Overland, J.E. 2004. Detecting arctic climate change using Köppen climate classification. Climatic Change 67:43-62.

Weladji, R.B., Holand, O. and Almoy, T. 2003. Use of climatic data to assess the effect of insect harassment on the autumn weight of reindeer (*Rangifer tarandus*) calves. Journal of Zoology 260:79-85.

White, R. and Trudell, J. 1980. Patterns of herbivory and nutrient intake of reindeer grazing tundra vegetation. *In* Proceedings of the Second International Reindeer/Caribou Symposium, 17-21 September 1979, Roros, Norway. pp. 180-195.

Wildlife Management Advisory Council (North Slope). 2006. Herschel Island Qikiqtaruk Territorial Park management plan. Yukon Government. Whitehorse, YT. 62 p.

Wildlife Management Division. 2009. Wildlife tracks, news from Nunavut's Wildlife Management Team. Department of Environment, Government of Nunavut. 12 p. Fall 2009 issue.

Williams, T.M. 1995. Beverly calving ground surveys, June 5-16 1993 and June 2-13 1994. File Report No. 114. Department of Environment and Natural Resources, Government of the Northwest Territories. Yellowknife, NT. 36 p.

Witter, L.A. 2010. Interrelationships between weather, parasitic insects, and barren-ground caribou (*Rangifer tarandus groenlandicus*) behaviour in Northwest Territories and Nunavut. Thesis (M.Sc.). University of Northern British Columbia. Prince George, BC. 178 p.

Wolfe, S.E., Griffith, B. and Gray, C. 2000. Response of reindeer and caribou to human activities. Polar Research 19:63-73.

Wotton, B.M., Nock, C.A. and Flannigan, M.D. 2010. Forest fire occurrence and climate change in Canada. International Journal of Wildland Fire 19:253-271.

WRRB. 2010. WRRB caribou recommendation report submission [online]. Wek'èezhìi Renewable Resources Board. http://www.wrrb.ca/content/wrrb-caribou-recommendation-report-submission (accessed 26 January, 2011).

Zalatan, R., Gunn, A. and Henry, G.H.R. 2006. Long-term abundance patterns of barren-ground caribou using trampling scars on roots of *Picea mariana* in the Northwest Territories, Canada. Arctic, Antarctic, and Alpine Research 38:624-630.

Zhang, X., Brown, R., Vincent, L., Skinner, W., Feng, Y. and Mekis, E. 2011. Canadian climate trends, 1950-2007. Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 5. Canadian Councils of Resource Ministers. Ottawa, ON. iv + 21 p. http://www.biodivcanada.ca/default.asp?lang=En&n=137E1147-0.