A Report on the Newfoundland Caribou

A summary and interpretation of the state of knowledge of the island of Newfoundland's caribou population and key considerations for sustainable management.

October 2015

Newfoundland Labrador
Environment and Conservation

Message from the Minister

As Minister responsible for wildlife, I would like to thank you for taking time to review the Report on the Island of Newfoundland's Caribou.

Since 2008, the Provincial Government has invested $15.3 million on a comprehensive research and management initiative to improve our understanding of Newfoundland's caribou population dynamics. This work was undertaken in response to a swiftly declining caribou population, but built on a long history of caribou study in Newfoundland and Labrador.

The Newfoundland caribou population decreased from about 94,000 animals in the late 1990s to approximately 32,000 by 2013. At the outset of the caribou initiative, the magnitude of population decline, uncertainty around the causes of decline, unprecedented rates of calf mortality, and uncertainty around the role of coyote were cause for substantial concern. The Provincial Government developed an integrated program of caribou, predator, and habitat research, increased monitoring, and enhanced public education. The scientific research was advised by a team of academics, with expertise from various North American universities including Memorial University of Newfoundland. A Caribou Resource Committee was also established, as a mechanism for stakeholders to provide input into the caribou research.

This report provides an interpretation of the cumulative results of the caribou research program and key considerations for sustainable caribou management on the island of Newfoundland. The information in this report increases our capacity for effective and efficient caribou management. By engaging in this large scale program, the Provincial Government has demonstrated a commitment to caribou conservation and sustainability and is positioned to be a leader in proactive ecosystem-level management.

I look forward to continued engagement with the hunting community and other stakeholders as we move forward to incorporate this comprehensive body of research into our caribou management decision making process. Together, we can ensure that the ecological, cultural and economic value of caribou will continue in the province for many years to come.

The Honourable Dan Crummell
Minister

Newfoundland Labrador

Environment and Conservation

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EXECUTIVE SUMMARY

In 2008, the Department of Environment and Conservation introduced a five-year, $15-million research and management initiative to address the swiftly declining caribou population on the island of Newfoundland (Newfoundland). When this caribou program was implemented, the population had declined by about 60 per cent in a single decade. Demographically, poor calf recruitment, resulting from extremely low calf survival throughout Newfoundland, produced a decline in caribou numbers. Predation rates were increased compared with the pre-decline era, an increase which coincided with the arrival of coyote to Newfoundland. Other evidence, such as a reduction in caribou stature and changes in migration timing, hinted at the possibility of nutritional stress due to a decline in range quality or quantity.

Caribou Science in Newfoundland

Building on existing science and management practices, the five-year initiative was designed to examine the Newfoundland caribou population at an ecosystem level in order to establish the primary and contributing factors responsible for the caribou decline and to effectively and efficiently manage a sustainable caribou population into the future.

The program was delivered through an interconnected suite of scientific research, management activities and education initiatives. The Department of Environment and Conservation implemented a program addressing caribou demographics, caribou ecology and habitat use, major terrestrial predators (black bear, coyote and lynx), social values associated with the caribou system, and a program of enhanced education and outreach. The scientific research was advised by an academic team with specific relevant expertise and Safari Club International Foundation contributed resources to the scientific program. A Caribou Resource Committee was also created to facilitate stakeholder engagement.

Activities undertaken included the continuation of caribou census surveys and herd composition surveys, the Caribou Data Synthesis work and adult caribou collaring. Special collections to

support analysis of caribou food habits, body condition and brain worm prevalence were conducted. Calf mortality studies were continued and expanded. New research in caribou habitat, predator ecology, experimental reduction of predation intensity, and social values associated with the caribou system were implemented. Workshops to improve participation and success of predator harvest were delivered. Although many activities were conducted island-wide, it was not cost-effective, logistically feasible or statistically necessary to conduct all projects in all Newfoundland herds. Thus, representative herds were selected for scientific research on the predator-prey system.

As a result of the caribou program, the department produced tools (e.g. predictive population models, island-wide habitat map, and relational data bases) for improved management. Innovative techniques and state-of-the science methods were used to elevate the reliability and efficiency of data collection and analysis.

The caribou research resulted in substantially increased knowledge of the caribou population and the interactions between caribou, predators, and their shared habitat, and provided an evidence-based understanding of the factors which drive Newfoundland caribou population dynamics.

Why the Newfoundland Caribou Population Declined

Quite simply, the recent decline of the Newfoundland caribou population occurred because caribou were at unsustainably high numbers in the 1990s. Evidence suggests the recent decline is a natural occurrence; the Newfoundland caribou population demonstrates a repeated pattern of rapid increase and rapid decline over time.

The Newfoundland caribou decline was density-dependent in nature; at the population level, caribou displayed several characteristics with consistent patterns over time related to population size. As the population became larger, the caribou began to be restricted by food and/or space, and population growth rate slowed. Individual caribou became less predictable in where they could be found year-to-year and some herds changed the location they used during sensitive periods such as calving season. Broad shifts in habitat use occurred and the caribou diet became

less selective and included more poor-quality foods. Caribou became smaller in size and, in some areas, birth rates declined.

At about the peak population size of approximately 94,000 caribou, multiple predators were able to exploit small and vulnerable calves, reducing calf survival to less than 20 per cent for many years (less than five per cent during the early 2000s). As a result of this high mortality, few young animals entered the population and the population aged. Newfoundland's caribou abundance dropped to less than half of the peak population size within the first 10 years of decline.

Predators have always been an important source of mortality for caribou calves, but were more influential during the decline than during population growth. Experiments to reduce predation intensity indicate that manipulative predator management can improve calf survival but may only be useful under very specific and urgent situations.

Hunting did not cause the Newfoundland caribou population decline, but during the early decline phase caribou continued to be harvested in large numbers. This added to the speed of decline and reduced the male portion of the caribou population.

Development and activity can have adverse effects for caribou, but there is no evidence that human land-use caused the Newfoundland caribou decline. In contrast to the circumstances in other jurisdictions where caribou are limited in space because of human development, vast expanses of caribou habitat remain intact in Newfoundland.

As the population size declined and competition for food and space alleviated, caribou began to show signs of improved vigor. Body size increased and calf survival improved; caribou displayed greater fidelity to seasonal ranges and the rate of population decline slowed. Though these are positive signs, calf survival and recruitment have not yet recovered to a point where the population is stable. Signs of poor range quality continue.

A decline of similar speed and magnitude occurred in the Newfoundland caribou population in the early 1900s. Sometime in the late 1800s there were as many as 100,000 caribou on the island; by the 1920s there may have been as few as 10-20,000. This repeated pattern, viewed in the context of the other ecological and biological changes, strongly suggests there is a limit to the number of caribou which can be sustainably supported by the island of Newfoundland.

What to Expect for Newfoundland Caribou

In the next few years, the caribou population as a whole is expected to continue to decline, though some herds may show stable or increasing trends. We are cautiously optimistic that the Newfoundland caribou population may be approaching stability of numbers. A low but stable population could persist for decades. If range quality or quantity remains low, the ability to reach stability or increase could be compromised; stabilization or growth after a drastic decline can be short-lived and followed by further decrease. However, both past experience and population models suggest there is no risk of population extinction.

Without any changes to overall caribou population management or major ecological shifts, we should expect the population to continue to show large-scale patterns of increase and decrease followed by long periods of low caribou density.

Informing Caribou Management for Long-Term Sustainability

Long-term caribou management for the Newfoundland caribou population has two primary goals:

- **Sustainability**: The caribou population should be managed in such a way as to protect ecological benefits, economic benefits, and cultural benefits for future generations.

- **Public Trust**: As a wildlife resource, caribou should be managed to reflect the Government of Newfoundland and Labrador's role as a steward of the resource in the public interest.

Key Considerations for Sustainable Caribou Management

- **A rich body of evidence is available to inform management decisions.** As a result of investments in caribou research and management over several decades, the Newfoundland caribou population is among the best-studied wildlife populations in the world. The province possesses a great depth and breadth of knowledge related to the caribou population. Foundational questions about island caribou ecology and population dynamics have been addressed, providing a firm base for sustainable population management. However, the volume of data collected during the 2008-2013 work, in addition to data collected since the 1950s, precluded the ability to complete full and comprehensive analyses. New insights will continue to emerge as evaluations are completed; through the process of adaptive management, these will contribute to management decisions as they become available. Despite the current state of knowledge, continued monitoring and research initiatives will continue to be needed to address remaining knowledge gaps, provide data for management decisions, evaluate new and innovative techniques, and investigate emerging phenomenon. The scale of these research needs is, however, much smaller than that of the recent research program.

- **Population structure has multiple scales.** Spatial and genetic data from the Newfoundland caribou population confirms that the caribou population structure on Newfoundland has multiple scales (island, region, herd) and thus management activities can be conducted at scales appropriate to specific goals and objectives.

- **Many population characteristics change in advance of population numbers.** Evidence that trends in certain population characteristics, such as growth rate and body size, changed in advance of the recent decline indicates the possibility of an "early warning system" for future population change.

- **Trends in indicators are more informative than isolated numeric values and provide an opportunity for efficiency.** The direction of population trends, the magnitude and/or timing in of changes in trends and the synchrony (or lack of synchrony) add richness to the information provided by point-estimates of characteristics. Synchronous population trends across herds provide an opportunity for efficiency in monitoring efforts.

- **Predictive models can be a tool for management planning.** Population modelling can be used to predict future trends, test the likely outcome of management changes, and reduce the required frequency of expensive census and survey work.

- **If the caribou population recovers to peak numbers, it will likely crash again.** It is imperative to recognize that if the population recovers to high density, it will likely decline rapidly again. The extreme peaks and valleys of caribou numbers may be preventable if it is more desirable socially and economically, and acceptable ecologically. The feasibility of such an approach in Newfoundland is uncertain.

- R**ange quality and availability is the primary limit of Newfoundland caribou and summer forage resources are particularly important.** Caribou require large contiguous landscapes to meet basic resource requirements.

- **The majority of land traditionally occupied by Newfoundland's caribou remains relatively intact, thus an opportunity still exists to plan human-land use and activity in a way that is complimentary to caribou conservation and management.** In other jurisdictions where land development has infringed heavily on caribou ranges, caribou populations are under intense adverse pressure related to space. Existing research, GIS tools and substantive data sets can aid in environmental assessment and land-use planning.

- **Reductions in hunting opportunities increase the risk of losing an engaged hunting public.** Hunting is an important tool for caribou management as it can be used to manipulate population composition or to reduce local populations if required. Reductions in hunting opportunities increase the risk that hunters become disengaged; losses in hunter numbers may have implications for management in the future.

- **Snow machines and ATVs may pose an unprecedented challenge for caribou.** Increases in activity, particularly in remote areas, may have profound effects on daily energetic balances for caribou, particularly if vehicle operators are not aware of the disruption they are causing.

- **Manipulation of predator populations could benefit caribou under specific circumstances.** The influence of predation on the Newfoundland caribou population may be considered a secondary or symptomatic limit related to range quality, but is nonetheless real. Since neither black bear nor coyote are dependent exclusively on caribou as a food source, these predator populations can remain high even if caribou numbers continue to decline. Reduction of predators through direct management is prohibitively expensive on a large scale, but could be used to benefit caribou under specific and urgent circumstances.

- **The ecology of Newfoundland will change.** Even in the absence of human development or interference, ecological systems change. The island of Newfoundland is not exempt from this and monitoring ecological change and evaluating implications is important.

- **Caribou management is a multi-disciplinary activity**. Conservation and sustainable use of Newfoundland's caribou population over the long term will require collaboration of scientists, managers, enforcement officials, land developers and resource extraction industries. The ecology of Newfoundland will inevitably change over time, and multi-stakeholder cooperation will be important as new and unanticipated challenges arise.

Taking Action

The insights and knowledge gains achieved as a result of dedicated research on the Newfoundland caribou population improves the capacity of government to manage caribou in a sustainable manner. The release of this report is consistent with a commitment to knowledge-based decision-making, openness and transparency.

The key considerations discussed in the report provide a base for decisions which will allow us to act wisely, act efficiently and act collaboratively to provide better service to Newfoundland and Labrador residents and conduct proactive management for the long-term sustainability of caribou. Continuing to build collaborative relationships with stakeholders and meaningful engagement of the public in decision-making is a priority. This document provides guidance as the Department continues to consult and collaborate with stakeholders during the development of management goals and objectives for the caribou population.

CONTENTS

CARIBOU SCIENCE ON THE ISLAND OF NEWFOUNDLAND

Newfoundland and Labrador began scientific monitoring of the island of Newfoundland (Newfoundland) caribou population in the 1950s. Through time, many research projects were also conducted, often to address specific questions about caribou biology or to investigate particular management issues. The very first scientific work on the Newfoundland caribou population was, in part, conducted to address concern around population decline. From as few as 10,000 animals in the 1950s and 60s the Newfoundland caribou population grew to as many as 95,000 in the 1990s. Toward the end of the 1990s, the population began to decline swiftly. Within a single decade, the caribou population decline by about 60 per cent.

In 2008, the Department of Environment and Conservation started a five-year, $15-million research and management initiative to address Newfoundland's rapidly declining caribou population. This program was designed to take an ecosystem-level approach to the issue of declining caribou numbers and the long-term sustainability of the population.

Thanks to the prior efforts in collecting data on the caribou population, there was good knowledge of the size and rate of the decline and of the biological and ecological trends associated with the decline (Mahoney and Weir 2009). Caribou recruitment (the portion of the population comprised of young-of–the-year in fall and winter) was extremely low and this low recruitment was widespread. Although birth rates had dropped in some herds, this was inconsistent across Newfoundland and could not explain the widespread phenomena of absent calves. Calf survival to six months of age was extremely low (less than five per cent in some years of the early 2000s).

Calf mortality resulted primarily from predation by black bear and coyote, although lynx and bald eagle were important in some areas (Norman et al. 2006). As a percentage of calf deaths, the amount of predation increased dramatically since pre-decline times. Coyote were a relatively new predator in the system but it was unknown how much coyote predation was additional, and how much would have been caused by existing predators if coyote were not present.

There were signs of possible nutritional stress suggestive of reduced range quality or quantity. Although caribou appeared to be in good condition in the early 2000s, they were, on average, smaller than in previous years (Mahoney and Weir 2009). Caribou were spending less time on the summer range (Mahoney and Schaefer 2002) and despite the high rates of calf mortality, maternal caribou demonstrated low levels of anti-predator behaviour (Soulliere 2008).

It was apparent that a comprehensive program was needed to weave information together, fill in knowledge gaps, and uncover the nature of linkages between observed trends. The ability to effectively manage a population or, indeed, a system of connected populations, requires strong science-based knowledge about how the system operates. Building on existing science and management practices, a suite of interconnected projects were designed to examine the Newfoundland caribou population at an ecosystem level and determine the cause of decline.

GOALS OF THE 2008-13 CARIBOU INITIATIVE

- Establish the primary and contributing factors responsible for the caribou decline.
- Identify central requirements for effective and efficient long-term management of the Newfoundland caribou population for current and future generations.

PROGRAM OBJECTIVES

- Implement a strategic caribou and predator research program.
- Measure and evaluate the role of predators in the caribou dynamics.
- Test the effectiveness and cost-efficiency of predator manipulation.
- Evaluate caribou habitat quantity and quality.

- Assess public perceptions of caribou and their predators.
- Establish mechanisms for stakeholder participation.
- Provide a comprehensive analysis of historic and current research findings.

HOW THE NEWFOUNDLAND CARIBOU INITIATIVE WAS ACCOMPLISHED

To address the objectives, the Department of Environment and Conservation developed a program focused on caribou demographics, caribou habitat, major terrestrial predators (black bear, coyote, and lynx), and social values associated with the caribou system. The program components were delivered through scientific research, management activities and education initiatives. Scientific research work conducted directly by the department was augmented by the involvement of graduate students associated with Memorial University and other institutions in Canada and the United States (U.S.). Safari Club International Foundation dedicated in excess of $250,000 worth of equipment and services to support field and laboratory activities related to predator-prey research, along with providing research advice and networking with other projects and programs with similar goals.

An academic team acted as a science-advisory committee for the research program and was comprised of scientists from Memorial University, Trent University, University of Massachusetts (Amherst), the U.S. Fish and Wildlife Service, and Safari Club International Foundation. The members of the team held expertise in predator-prey dynamics, animal ecology and behaviour, population modeling, wildlife management, and biological and ecological statistics. The academic team provided input on overall study design, graduate student projects, logistic implementation, and interpretation of results.

The Caribou Resource Committee was established as a mechanism for stakeholder input on aspects of the caribou study. Members of the committee assisted and supported the department

by providing comment on program activities, forwarding inquiries and views from stakeholder groups, and disseminating relevant information from the department to stakeholder groups. Members of the committee included representation from the Department of Tourism, Culture and Recreation, the Department of Natural Resources, Executive Council – Rural Secretariat, Newfoundland and Labrador Outfitters Association, Newfoundland and Labrador Trapper's Association, Newfoundland and Labrador Wildlife Federation, the general hunting public, and the academic community.

STUDY AREAS

The research program was designed to address issues at the population-level (that is, at an island-wide scale). Although many activities were conducted island-wide, it was not cost-effective, logistically feasible or statistically necessary to conduct all projects in all Newfoundland herds. Thus, representative herds were selected for scientific research on the predator-prey system.

By convention, migratory and semi-migratory caribou herds are described by affiliation to calving areas and management traditionally occurs at the scale of the herd. In Newfoundland, harvest management areas are approximately defined by herds and their associated ranges, though hunting occurs when caribou are in fall and winter seasonal ranges.

Examination of both the genetic structure of the Newfoundland caribou population (Wilkerson 2010) and annual movement patterns of caribou (Schaefer and Mahoney 2013) suggests four subpopulations of caribou in Newfoundland (Northern Peninsula, southwest coast, Middle Ridge, and Avalon) (Figure 1A). Telemetry data, however, also confirm multiple and predictable aggregations during calving season confirming that identification of caribou herds based on calving distribution is not arbitrary (Figure 1B).

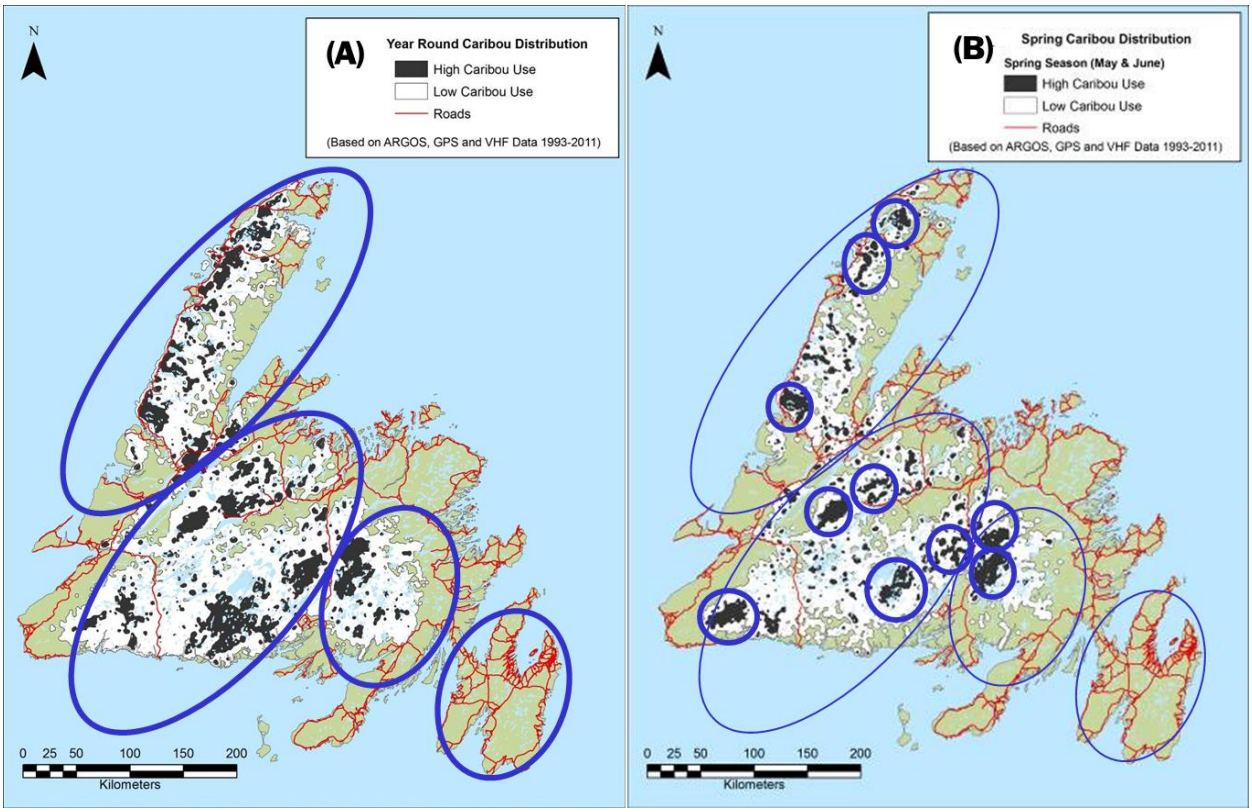

Figure 1. Newfoundland caribou distribution has multiple scales. (A) Regional subpopulations can be identified based on genetic struture (Wilkerson 2010) and spatial behaviour (Schaefer and Mahoney 2013). (b) Aggregative behaviour of females in spring (calving and post-calving seasons) indicates that traditional identification of herds by affiliation to calving areas is a seasonally-relevant scale.

The selection of study areas took into consideration caribou management units (recognized herds and management areas), the number of caribou within a management unit, geographic diversity, the probability of caribou moving from one study site to another during the study tenure, and the amount of historic data available for the area. The study areas chosen contained the ranges of the Northern Peninsula/St. Anthony herds, the La Poile herd and the Middle Ridge herd.

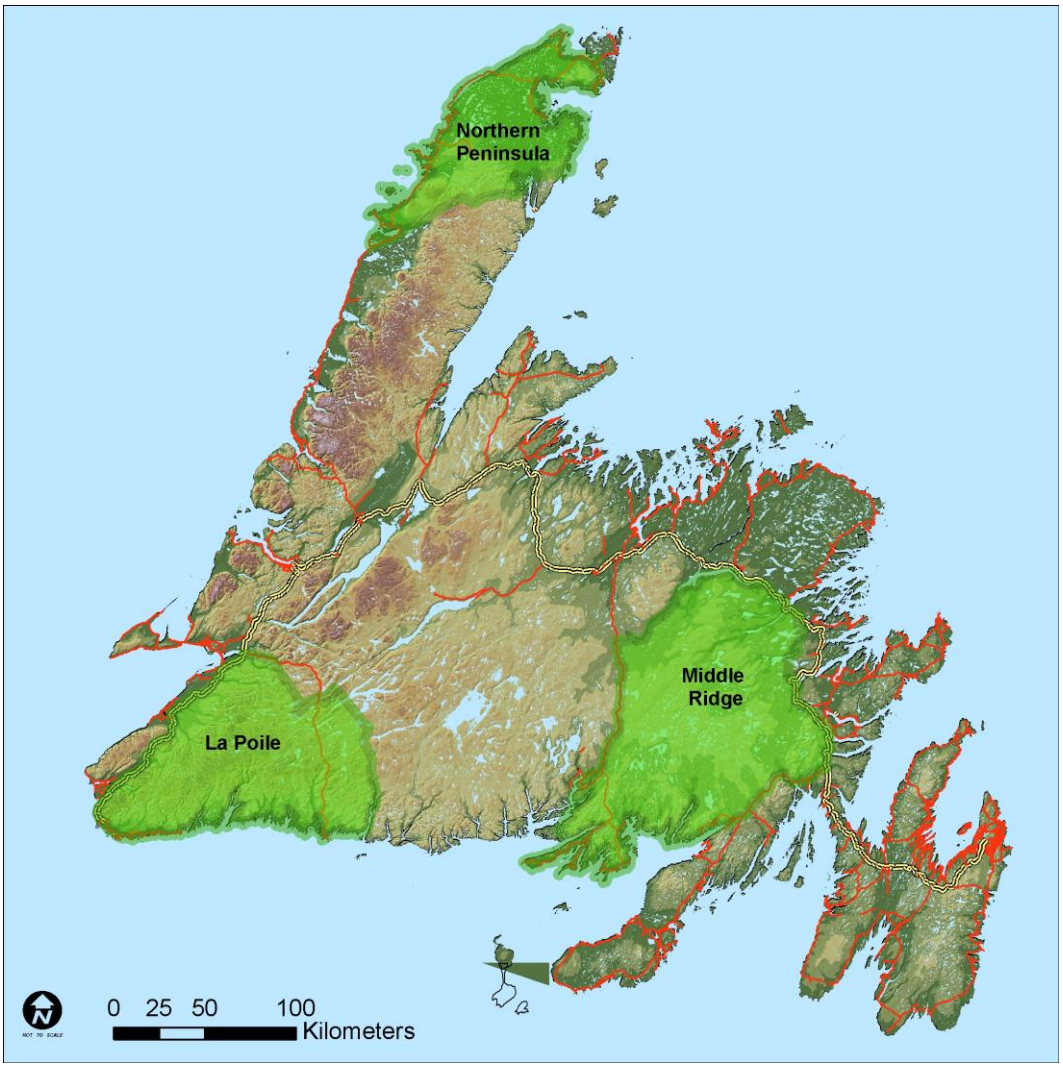

Figure 2. Study areas selected for integrated caribou-predator-habitat research

Together, these study areas contain more than half of the Newfoundland's caribou. The distribution of these sites provided a range of geographic conditions and minimized the likelihood that any individual caribou migrated between sites during the five-year study. Middle Ridge and La Poile were selected based on the existence of substantial and relevant historic data; the Northern Peninsula site, by contrast, was selected in part because little historic data existed and thus was identified as a region with knowledge gaps needing to be filled. The study areas represent three of the four identified regional subpopulations.

Despite the distinctness and geographic isolation of the Avalon Peninsula caribou, population trends over the last few decades are known to be highly influenced by a relatively recent parasitic brain worm infestation, and may present a special case. Although study to determine if the Avalon caribou population is subject to different underlying limitations would be valuable, the overall research design would have been overcomplicated by the potential underlying differences.

PROGRAM COMPONENTS

The 2008-13 caribou initiative was comprised of multiple interconnected projects intended, as a set, to provide a fulsome view of the Newfoundland caribou population in the context of the ecosystem and historic trends. Projects addressed caribou history, status and ecology, predator ecology, range quality and quantity, ecosystem-level interactions, and the effectiveness of a limited set of management options, including enhanced education efforts.

CARIBOU ECOLOGY AND MANAGEMENT

Caribou Data Synthesis. The analytic and interpretive phase of the Caribou Data Synthesis work continued through the five-year program and incorporated new data as these were collected. Initiated in 1996, the synthesis was an effort to collect and evaluate all the data available for Newfoundland caribou since the beginning of scientific work in Newfoundland. Tens of thousands of data files were compiled under this program. The synthesis provided an important long-term view of the Newfoundland caribou population history and context for understanding and identifying the causes and consequences of the current decline. Without the existence of this comprehensive data base, many results of caribou study would have been extremely difficult to interpret.

Demographic trends and population health monitoring. To maintain long-term data sets and continue to collect data traditionally used to inform harvest management, normal monitoring of

the caribou population continued. Population censuses continued to be conducted to estimate the number of caribou in each herd and in the whole population. Helicopter surveys of herd composition were conducted three times a year in major herds to maintain current demographic data (birth rates, recruitment, adult sex ratio and age structure). Hunter submissions continued to be collected providing information on population age-structure and adult body size. A special collection of fat measurements from hunted animals was used to monitor body condition and caribou fecal pellets were collected to assess the prevalence of brain worm.

Calf mortality studies. Ongoing calf mortality studies continued in Middle Ridge and La Poile, and were expanded to the Northern Peninsula. By capturing and radio-collaring large numbers of 0 to 4 day-old calves, monitoring them and investigating the causes of death, these studies assessed the causes, rates and timing to caribou calf mortality. The inclusion of the Northern Peninsula made it possible to test whether the nature of the decline was the same across regions. Calf mortality studies were also critical in assessing the results of experimental predator manipulation, described below.

Adult collaring studies. To obtain current information on adult caribou survival rates, caribou distribution, movement patterns and space-use, and habitat affiliations, the adult collaring program continued and was expanded. Satellite and GPS radio-collars were deployed on hundreds of adult female caribou on the Northern Peninsula, southwest coast and interior, and Middle Ridge area.

PREDATOR ECOLOGY AND MANAGEMENT

Predator ecology studies. To fill knowledge gaps and improve our understanding of the Newfoundland ecological community, studies of basic predator ecology were conducted. Bait stations circled with barbed wire were used to collect DNA from black bear hair and dogs trained to find predator sign were used to collect DNA for coyote, lynx and black bear. Data on individuals identified from DNA was used for estimating predator abundance and density in the study areas, and to support a multi-regional Black Bear Index to monitor trends in bear

abundance on the island. The dog-assisted sampling also provided fecal specimens which were used to evaluate food habits and increase our understanding of the importance of caribou to predators. Black bear, coyote, and lynx were captured and fitted with satellite or GPS radio-collars in all study areas, providing the data necessary to examine movement, space use patterns, distribution, and habitat affiliations. Several graduate student projects focused on aspects of predator ecology.

Experimental predator reduction. Experiments were conducted to test whether reducing predation intensity can result in improved calf survival and to determine the feasibility and effectiveness of direct predator management as a tool for caribou management. After baseline data on caribou calf survival, local predator abundance, and predator movement patterns were established, two techniques of predator management were tested. At one study area calving site, a two-year diversionary feeding experiment was followed by a two-year coyote removal experiment. The remaining calving sites in all study areas acted as untreated controls to compare results from the experimental site.

Harvester workshops. To increase participation in predator harvest and develop a population of competent and effective harvesters capable of contributing to wildlife management goals through legal and humane hunting and trapping, the department developed and delivered workshops across Newfoundland. These workshops covered basic knowledge about predator species and introduced skills and techniques for hunting black bear and coyote, and for trapping coyote. The workshops were well attended and received positive feedback from participants.

Habitat and Land-Use

Caribou habitat. An island-wide land classification illustrating habitat types relevant to the caribou system, and applicable to other wildlife species, was created from satellite imagery. Hundreds of individual sites were visited to describe habitat in order to support the classification and train the software to read the satellite images for habitat types. In combination with the

radio-collar data from adult and calf caribou, is a powerful tool for evaluating how caribou use the landscape.

Caribou food habits and nutrition. To identify the seasonal and annual diet of caribou, fresh caribou pellets were collected from study areas over a two-year period. These pellets were then analyzed by a lab specializing in identifying plants from microscopic fragments. The nutritional implications of Newfoundland caribou food habits were evaluated in the context of habitat quality and known historic food habits.

Disturbance and human land-use. To describe the importance of human activity and infrastructure, evaluations of caribou behaviour and demographics in relation to human-disturbed landscape were undertaken. Building on previous studies in Newfoundland of caribou reactions to resource extraction industries, graduate students at various universities investigated the effects of habitat fragmentation, forest re-growth after harvest, and power transmission corridors on caribou land-use behaviour.

Social and Cultural Values

Social values. To improve the understanding of the social and cultural needs of residents with respect to the caribou-predator system, a scientifically designed survey was conducted. Values and attitudes of urban and rural dwelling residents as these relate to caribou, black bear and coyote were assessed as part of a graduate student research project.

Major Achievements

Implementation of the comprehensive research and management program was a massive undertaking in itself. Although some components of the work extended or expanded ongoing activities, many components required the design, development of new activities and the associated trial and error of the logistic implementation of unfamiliar or untested methods and

techniques. Despite the many challenges of coordinating and delivering such a broad program over a vast and remote geography, the department successfully met and exceeded the goals. Highlights of the achievements include:

- Established an evidence-based understanding of the recent decline and factors which drive Newfoundland caribou population trends over time;
- Documented population characteristics that provide signals of changing caribou population vigor in advance of changing caribou population size, and thus identified indicators appropriate for monitoring;
- Determined factors which may influence the capacity for Newfoundland to support caribou;
- Introduced useful management tools such as predictive population models and an island-wide habitat base map;
- Used novel and innovative techniques and state-of-the-science methods to improve reliability and efficiency of data collection and analysis; and,
- Attracted the attention of international conservation and science organizations and established Newfoundland as a model for knowledge-based approaches to resource management concerns.

Multiple technical bulletins, internal reports, peer-reviewed professional publications, honours and graduate student theses, and popular science articles were produced. These documents (see Appendix) provide details of the methods and results of the component projects of the larger study.

WHY THE NEWFOUNDLAND CARIBOU POPULATION DECLINED

Quite simply, the recent decline of the Newfoundland caribou population occurred because caribou were at unsustainably high numbers in the 1990s.

The Newfoundland caribou decline was density-dependent in nature; at the population level, caribou displayed a group of characteristics with consistent patterns over time related to population size.

- As the population became larger, the caribou began to be restricted by food and/or space and population growth rate slowed.
- Individual caribou became less predictable in where they could be found year-to-year (Schaefer and Mahoney 2013) and, in at least some cases, herds changed the location they used during sensitive seasons (such as calving season during spring) (Dekelaita 2013).
- Broad shifts in habitat use occurred and the caribou diet became less selective and included more poor-quality foods (Schaefer et al., *unpublished*).
- Caribou became smaller in size and, in some areas, birth rates declined (Weir et al. 2014).

Around the peak population size of approximately 94,000 caribou, multiple predators were able to exploit small and vulnerable calves, reducing calf survival to less than 20 per cent for many years (less than five per cent during the early 2000s) (Lewis and Mahoney 2014). As a result of consistently poor calf survival, young animals were not recruited into the population and the population aged (Mahoney and Weir 2009). During the early decline phase, caribou continued to

be harvested in large numbers, adding to the speed of decline and reducing the portion of male caribou in the population (Luther and Weir, *unpublished*). Complete closure of hunting may have slowed the rate of decrease but could not have prevented population decline.

Caribou numbers dropped to less than half peak population size within the first 10 years after the population peak.

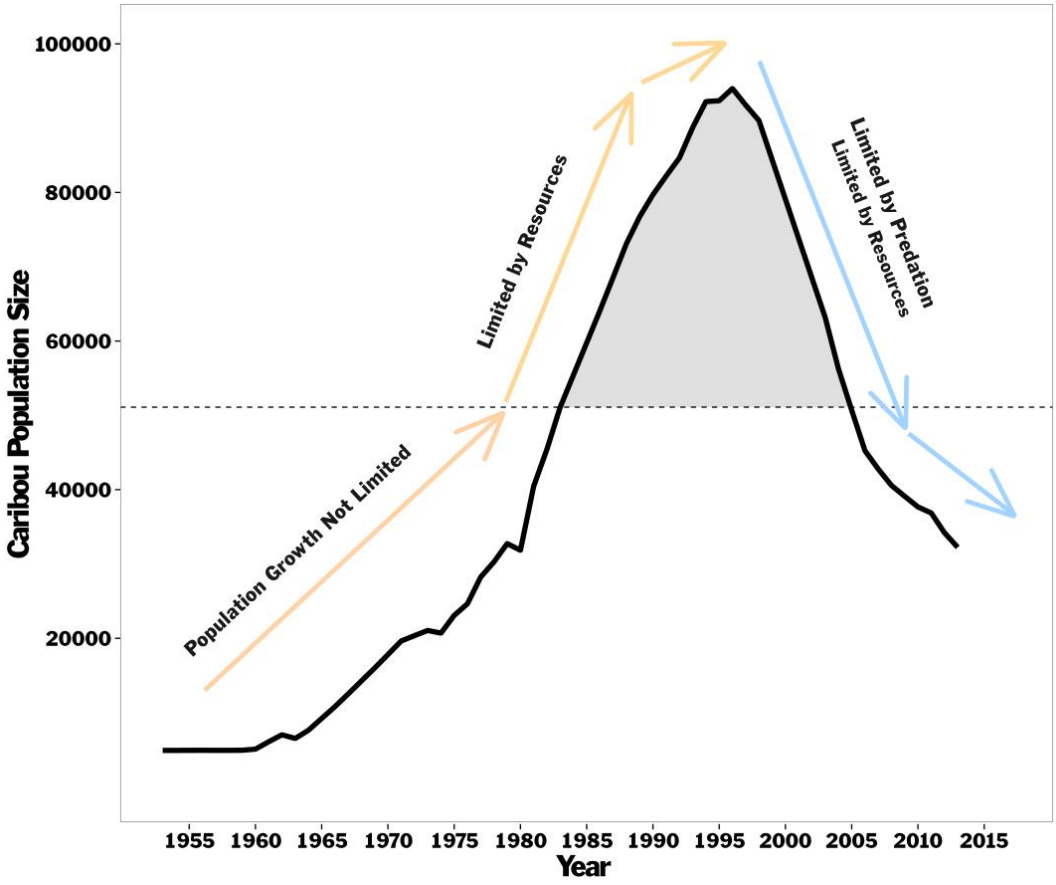

Figure 3. Major factors limiting the Newfoundland caribou population over time. As the population increased from very low numbers in the 1950s, growth was not substantially limited. Although the population continued to grow swiftly, there were indications by the 1980s that the population was inhibited by resource availability. During the decline phase starting in the late 1990s, resource limitation continued to influence the population, but high rates of predation on juvenile caribou drove the rapid decline. In recent years, the speed of decline has slowed and signals of the alleviation of both predation and resource limitation are beginning to appear.

As the population size reduced, caribou began to show signs of improved vigor.

- Body size increased and calf survival improved (Weir et al. 2014).
- Caribou showed greater fidelity to seasonal ranges (Schaefer and Mahoney 2013).
- The rate of population decline slowed (Figure 3.) and some herds have begun to show stable or increasing numbers.

Though these are signs for cautious optimism, calf survival and recruitment have not yet recovered to a point where the population is stable (Morrison et al. 2012). Either as a result of overgrazing or a change in space-use, signs of sub-optimal range quality continue to be observed (Schaefer et al., *unpublished*).

A decline of similar speed and magnitude occurred in the Newfoundland caribou population in the early 1900s (Soulliere and Mahoney 2011). Sometime in the late 1800s there were as many as 100,000 caribou on the island; by the 1920s there may have been as few as 10-20,000. This repeated pattern, viewed in the context of the other ecological and biological changes, strongly suggests there is a limit to the number of caribou which can be sustainably supported by Newfoundland.

DENSITY AND DENSITY-DEPENDENCE

Wildlife populations are confined to suitable habitat, and suitable habitat tends to be finite: animals can only spread out so much. At some point during population growth, they become crowded. How crowded or uncrowded a population is on the landscape can be measured by density (number of individuals in a unit of space).

If densities become high enough, a population can affect its own vigor. Resources, like food, become degraded or scarce and competition for the remaining resources can become severe. Disease and parasites spread more quickly in dense populations. Dense populations can attract and support bigger predator populations. As a result, population growth slows which may lead to

population loss. Following a density-dependent decline, when the population becomes small enough to be supported by remaining resources, the rate of decline changes and the population may stabilize or grow.

When population characteristics such as population growth rate, average size, or survival rate show a pattern related to population density (reliably increases or decreases when density increases, then shows the reverse when density decreases), we consider it to be density-dependent.

Directly measuring resource competition, disease and parasite prevalence, and the interactive effects of prey populations on predator populations is difficult. Instead, it is common practice to measure characteristics affected by these to detect density-dependence. When patterns in multiple indirect measures show coordination with each other and with population density, we have a reasonable certainty that density-dependent processes are occurring.

When taken as a whole, the data available for the Newfoundland caribou population indicates a population highly affected by density.

THE EVIDENCE FOR A DENSITY-DEPENDENT DECLINE

CARIBOU POPULATION SIZE AND DENSITY

Newfoundland's caribou are distributed in clusters across most of the island (Figure 1), but tend to avoid heavily populated areas. Although local density (the number of animals per square kilometre) varies across Newfoundland and changes with seasonal migrations and shifts in social behaviour, the total population is confined to the space of the island. Changes in population size, therefore, approximate changes in density at the population level.

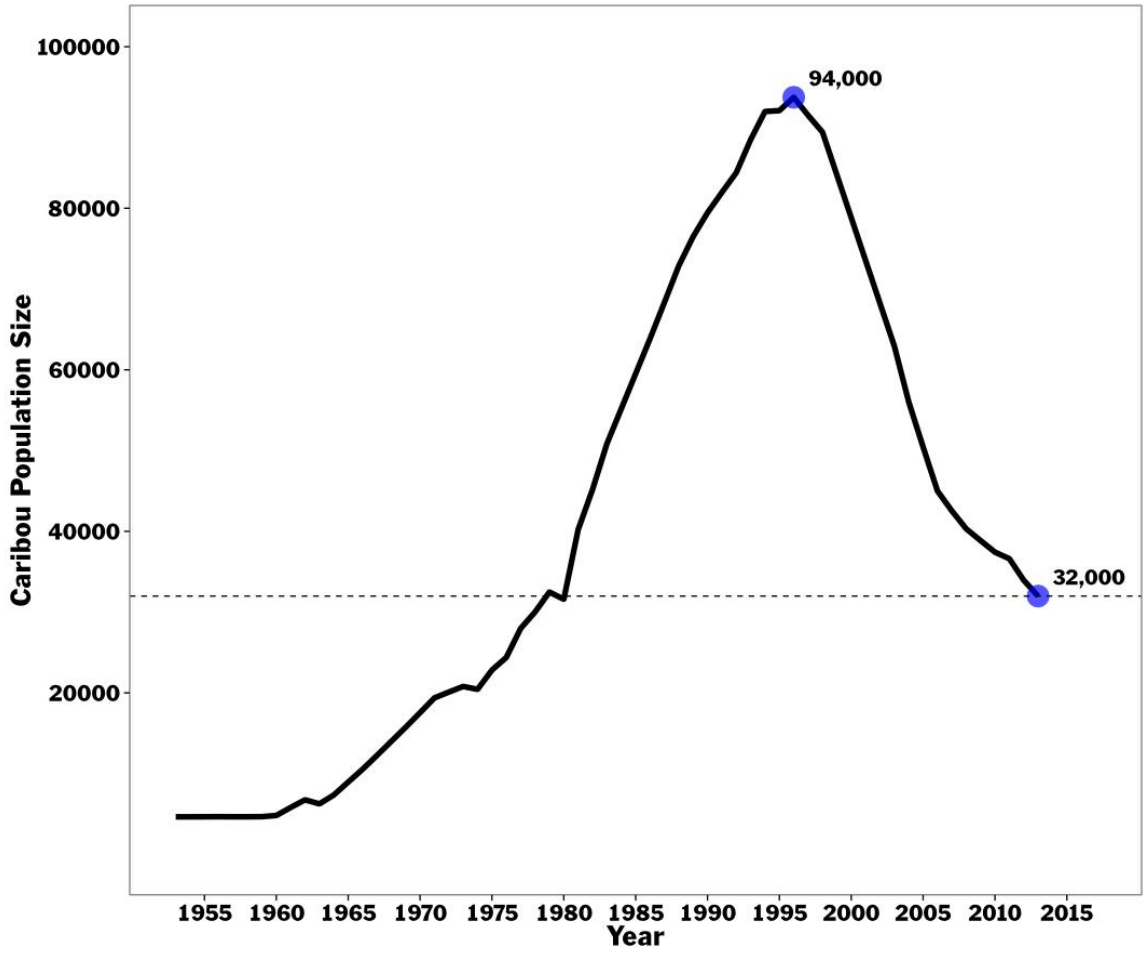

Figure 4. Estimated Newfoundland caribou population size 1952-2013. The rapid increase in abundance followed by rapid decrease is a classic pattern observed density-dependent declines. The current population size is about two-thirds of the peak population size but it is greater than it was from the 1950s through the 1970s.

Pattern of Growth and Decline

Caribou existed at relatively low density through the 1950s and 1960s. In the mid-1970s, the population began to grow very rapidly, increasing about four-fold in 20 years. Following a peak in numbers around 1996, the population decreased rapidly. This general shape (steep increase followed by steep decrease) is typical of populations which experience density-dependent declines.

Counting caribou is not a precise science; even estimates derived from robust census techniques have wide margins of error. The census trends, however, are verified by independent measures and thus interpreted as a reliable record of population abundance. The timing and magnitude of population changes measured through census were reconstructed independently using data from the jawbones collected annually from hunters (Peckham 2008). Information submitted by hunters on license returns (daily number of caribou seen) provided an additional independent measure of trends in caribou abundance and confirmed the pattern observed in census and jawbone models (Mahoney et al. 2014): that caribou numbers increased rapidly until the mid-late 1990s then quickly decreased.

THE REPEATED PATTERN

Reliable historic sources were used to reconstruct population trends over several decades before scientific surveys were available (Mahoney et al., *unpublished*), providing important insights into long-term patterns in caribou numbers (Figure 5). During the late 1800s or early 1900s, caribou densities were very high, but declined rapidly, reaching very low densities by the 1920s. Over the next 40 years, the population remained low but fairly stable despite hunting closures and the disappearance of the Newfoundland wolf, a major caribou predator. The similarity in the speed, magnitude and associated trends (Soulliere and Mahoney 2011) of the two recorded caribou population declines is strongly suggestive of a repetitive pattern. This too, is typical of density-dependence. Newfoundland appears incapable of supporting such high caribou densities for any sustained time.

Caribou herds in Alaska, Greenland and other parts of eastern Canada show similar trends of repeated patterns of rapid increase and swift decline (Gunn 2003). There is substantial evidence that caribou populations generally are subject to cycles in abundance, a trait typical of (though not exclusive to) populations driven by density-dependent factors.

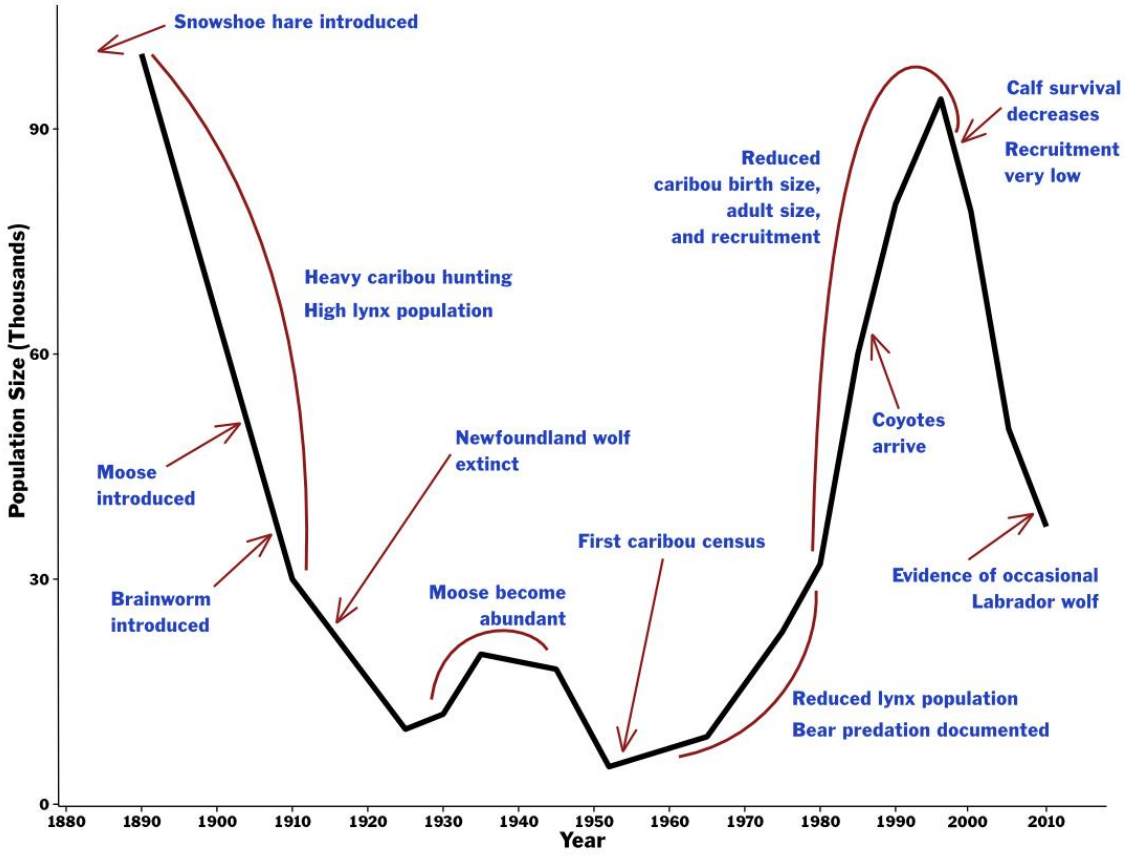

Figure 5. Newfoundland caribou population trends 1890 – present and important ecological events which may influence caribou abundance and distribution. The similarity in the speed and magnitude of the two major declines (1890-1920 and 1997-present) may indicate a repetitive pattern in population abundance.

DEMOGRAPHIC RATES

Population numbers are dependent on various population characteristics, often referred to as demographic or vital rates, which drive the direction of growth (positive or negative). The effects of increases or decreases to demographic rates often precede changes in population numbers, particularly in long-lived species with long generation times. Year-to-year variation in demographic rates is natural for all populations, but examining the direction of multi-year trends in these rates can allow changes in population size to be forecast. The timing and direction of

change to demographic rates can be used as indicators for population vigor and provide information on the nature of what drives population change.

Growth Rates

Like human populations, wildlife populations require a supply of new individuals to grow and persist. By nature of being on an island, the Newfoundland caribou population does not gain new animals from immigration or lose animals through emigration. Changes in population size result from population-specific characteristics and influences.

Although population numbers continued to increase through the mid-1990s, the rate of growth began to slow in a sustained decreasing trend 12 to 15 years ahead of the population peak (Figure 6). The rate of growth declined steadily for many years, with the lowest growth rates (highest rates of decline) occurring in the early 2000s. Growth rates have been increasing over the last several years, coincident with reduced population size, resulting in a slowed rate of population decrease.

The growth rate trends are density-dependent in pattern; the beginning of a consistent declining trend in growth rate in the early 1980s suggests density-related stress on the population may have begun when the population was as small as 55,000 animals.

Recruitment and Adult Survival

The portion of the population made up of young-of-the-year which survived infancy is referred to as recruitment. A combination of demographic features affects recruitment (adult survival, birth rate, calf survival), making it a valuable statistic to monitor. Some portion of the adult caribou population will die every year so in order to maintain a population size, recruitment needs to replace this loss; when this does not happen, the population decreases.

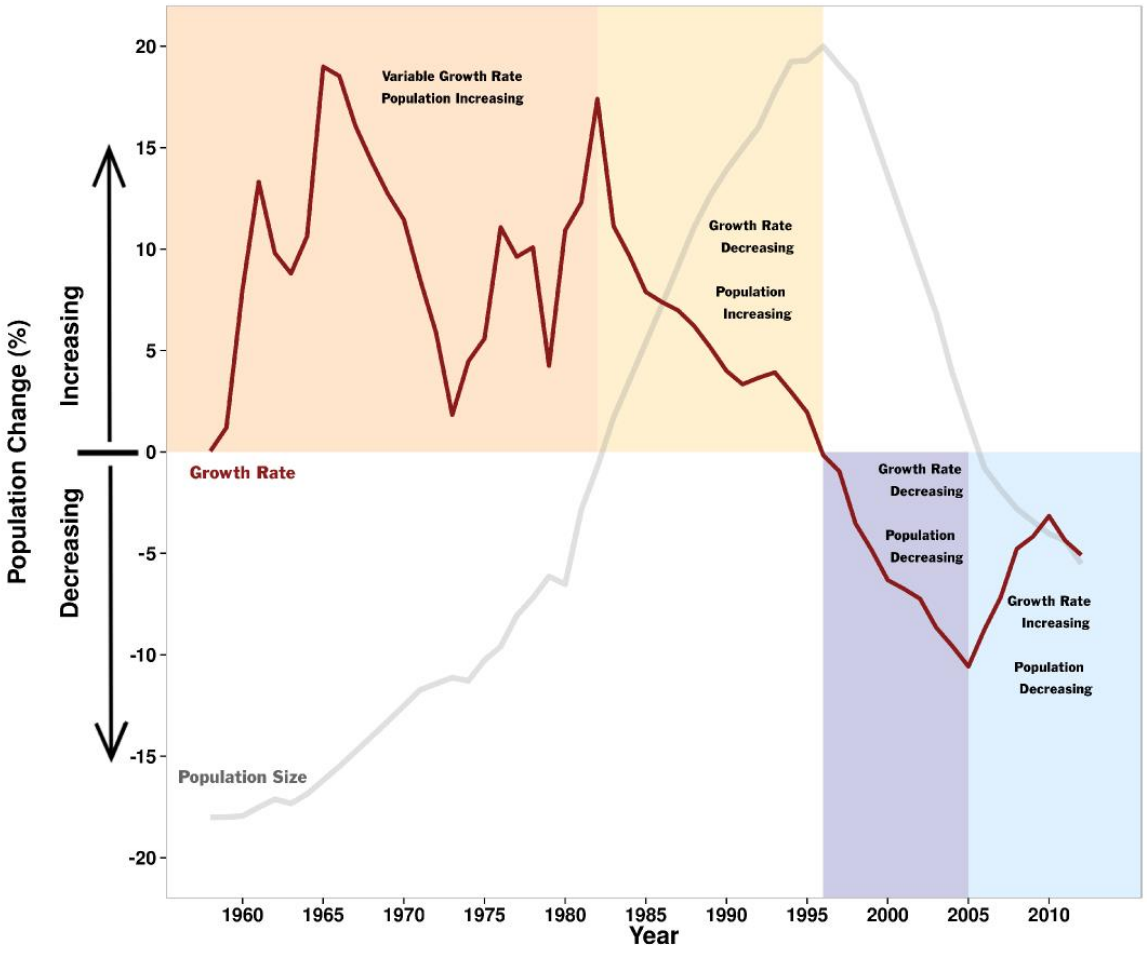

Figure 6. Growth rate (3-year average) of the Newfoundland caribou population 1958-2013. Caribou population growth was variable but positive and showed no consistent trend until the early 1980s when the growth rate began to decline steadily. This declining trend in population growth preceded the population decline by about 15 years.

Wildlife populations are theoretically most sensitive to changes in adult survival (particularly of females), but changes in any of the attributes contributing to recruitment can have population consequences. At a population level, there is no evidence of low adult survival contributing to the decline despite anecdotal reports of high adult mortality around the population peak. In many grazing or browsing game species (such as moose, deer, and caribou), adult survival tends to remain constant and changes in calf survival tend to drive large population changes (Raithel, et al. 2007, Gaillard et al. 2000). In Newfoundland, adult caribou survival was the same prior to the

decline as it was during the decline (Figure 7). On average, 87 per cent of adults alive in any one year will still be alive in the next year (Weir et al. 2014). This is within the range we would expect for wild deer in North America and appears to be reasonably stable over time.

Calf recruitment in the fall (when calves are approximately five months old), was more than twice as high during population growth than during the decline (Figure 7); winter recruitment (calves nearing one year old) showed the same pattern (Weir et al. 2014). The portion of calves in the population was substantially higher during population increase than during decline. Calves, not adults, were missing from the population.

Several consecutive years of poor recruitment resulted in an aging caribou population (Mahoney and Weir 2009). Density-dependent population aging can exacerbate declines by causing apparent decreases in adult survival (due to lower survival rates of older animals which make up a higher portion of the adult population) which reduces the reproductive potential of the population (Festa-Bianchet et al. 2003). There is no scientific evidence such an event occurred in Newfoundland but data gaps do exist around the time of the population peak.

Coinciding with reduced caribou density in recent years, coincident with reduced caribou density, recruitment has stopped declining but is not yet showing an increasing trend. The increase in the portion of males in the population over this time period may mask improvements to recruitment (Milner et al. 2007) since proportional changes in any age and sex class will influence proportions of others. Alternatively, other unknown demographic characteristics may be limiting recruitment or unknown factors may affect the accuracy of classification surveys (e.g. if females maintaining calves through summer are less likely to join rutting aggregations than those which do not). Also concurrent with reduced population size, the aging population trend is reversing (Weir et al. 2014) and the risk of a sudden increase in adult mortality appears to have passed (Morrison et al. 2012).

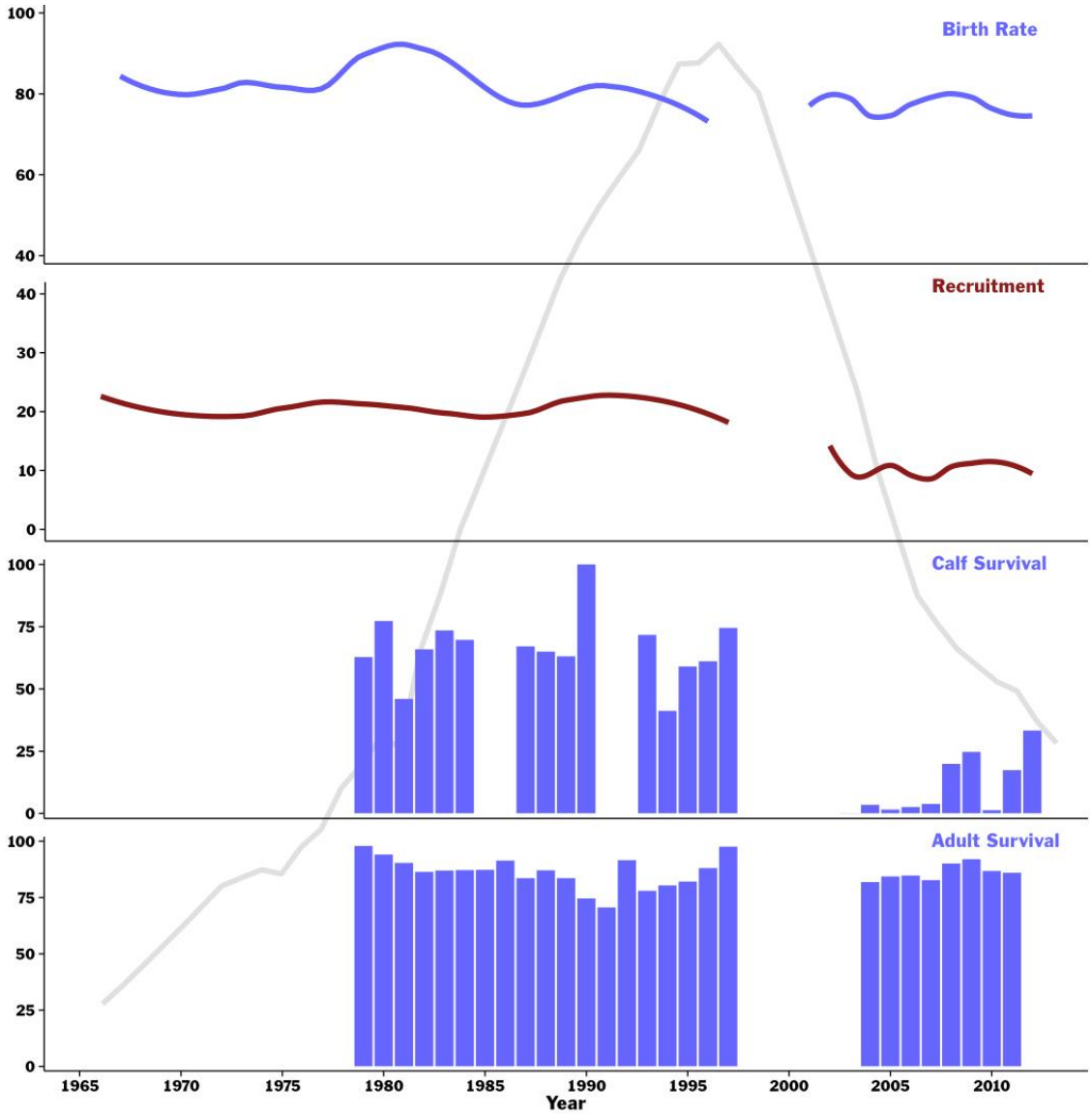

Figure 7. Birth rate, recruitment, calf survival and adult survival in the Newfoundland caribou population 1966-2012 (No data were collected 1998-2002). The demographic mechanism of caribou decline was low recruitment of juveniles to the population. Although birth rates did decline and have begun to recover, this occurred in only some herds. Extremely low calf survival was recorded in all studied herds and was the cause of low recruitment. Although demonstrating an improving trend, calf survival remains below thresholds required for population stability. There is no evidence that adult survival rates influenced population abundance or recruitment.

Birth Rates and Calf Survival

The number of calves in a population in any given year is affected by birth rate (the portion of adult females giving birth) and calf survival.

Despite the population decline, calves continued to be born. Birth rates in the Newfoundland caribou population decreased somewhat as population size approached its highest point and have recovered somewhat during the population decline (Figure 7). This small decrease in birth rates at the island-scale is caused by larger changes in birth rates confined to only a few herds (Weir et al. 2014). The inconsistent changes in birth rates cannot explain the synchronous decrease in recruitment or the island-wide population decline.

Compared to when the population was increasing, calf survival decreased drastically after the population peak (Figure 7). In some years, fewer than five per cent of calves survived to 1 year of age (Lewis and Mahoney 2014). In every herd studied, calf survival was extremely low compared to pre-decline rates, providing the kind of synchrony required to explain the population decline: not enough calves survived to be recruited into the population.
Calf survival showed an increasing trend in recent years, explaining the slowed rate of population decrease. This improvement in calf survival rates with lower population density is consistent with density-dependent mechanisms causing the population decline.

Nutrition

If caribou ranges were subject to overcrowding and/or overgrazing as a result of high population density, we would expect to see evidence of nutritional stress. At an island-wide scale, measures of caribou body size (calf weight, female jawbone size, male antler size) declined with increasing caribou density and showed signs of improvement with decreasing density. Evidence from body and tooth condition, feeding behaviour, and diet are also consistent with low range quality and nutritional limitations associated with the peak in caribou population density. Multivariate

analysis suggests that the caribou population decline can be at least partially explained by a density-dependent decline in summer range quality (Bastille-Rousseau 2015).

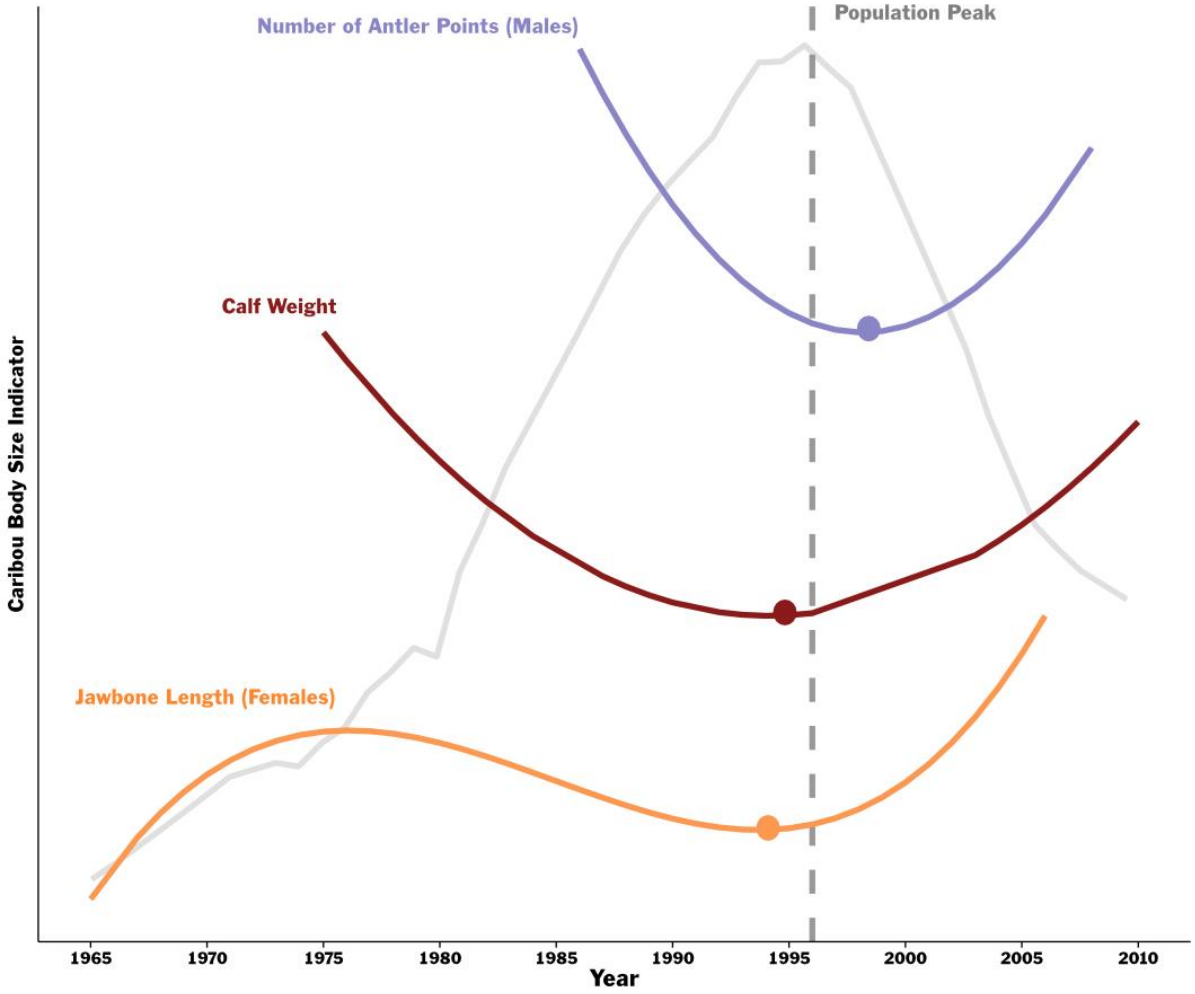

Figure 8. Caribou body size in relation to population density. Number of antler point for male caribou, calf weight at capture (0-4 days old), and residual female jawbone length all display a clear and consistent pattern of decreasing size as population density increases and increasing size as population density decreases.

Body Size

Calf birth weight, female body size, and male antler size all showed a similar pattern: caribou became smaller as the population grew (Weir et al. 2014). Around the population peak, caribou

were at their smallest and as population size fell, caribou body size enlarged (Figure 8). Each of these traits relies on different energetic sources (maternal resources for fetal development, multi-year foraging conditions for calf to adult growth, annual conditions for antler formation) but all show a clear relationship with population density.

Female jawbone length and calf weight were lowest just preceding the population peak, whereas antler continued to decline in number until after the decline began (Figure 8). The delayed nadir in antler points may indicate that the worst annual conditions occurred at and just following the population peak, or may be related to the heavily male-biased harvest which persisted for several years after the population decline began (Luther and Weir, *unpublished*).

Reports of small caribou were also recorded during the decline in the early 1900s (Mahoney et al., *unpublished*), providing further evidence that these declines were similar in nature (Soulliere and Mahoney 2011) and that they are related to high population density. Competition for food can cause nutritional stress, affecting fetal development and caribou growth.

As the Newfoundland caribou population peaked and began to decline, other aspects of density-dependence may have exacerbated size reductions. Small mothers tend to have small calves and if food resources continue to be limited, young will grow slowly and become even smaller adults producing even smaller calves. During the increasing phase of the population, calf survival was influenced by the body size of mothers; during the decreasing phase, calf survival was influenced by both maternal size and calf size (Bastille-Rousseau 2015).

Potentially exacerbating reduced calf size, older mothers tend to have smaller calves than younger mothers (Weladji et al. 2010) and several years of poor calf survival resulted in an aging caribou population (Mahoney and Weir 2009). Concurrent with reduced population density and improvements in body size and calf survival, this aging population trend is reversing (Weir et al. 2014). A younger age structure is returning and any appreciable risk of a sudden increase in adult mortality appears to have passed (Morrison et al. 2012).

Male-biased sex ratios can also contribute to small calf size (Milner et al. 2007). The connection between low male to female sex ratios and calf size is untested in Newfoundland, but the Newfoundland caribou population contained a very low portion of males just after the population peak. Recent changes to the relative proportion of male-only and either-sex licenses led to an increase in the proportion of males in the population (C. Doucet, *pers. comm*.).

Whatever the underlying causes of reduced size of adults and calves, trends have reversed in recent years and caribou size is showing signs of recovery. Likewise, the average age of the population is decreasing (a larger portion of the population is made up of younger animals) and there is an increased adult male presence.

Body Condition

Caribou appeared to remain in good condition based on standard fat measurements (Humber et al. 2009) despite overall changes in body size. These standard interpretations, however, indicate good condition for females who raised calves through the summer, yet most females in the population lost their calves in spring during the early decline phase. Without the burden of a calf, caribou should have been carrying more fat than they were (Cook et al. 2012), suggesting summer nutrition was restrictive.

Food Habits and Diet Quality

Consistent with other patterns related to space use and habitat selection, changes in diet are suggestive that summer, and perhaps spring, forage quality was limited when the population reached its peak. Based on the current diet, range quality appears relatively poor which is consistent with either a range shift to poorer quality habitat or overgrazing of preferred food when the population was high.

The diversity of plants in the summer caribou diet was relatively low in the 1980s, increased substantially by the 1990s and increased further by the 2010s; spring diet diversity similarly increased from the 1990s to the 2010s, but fall and winter diet diversity remained unchanged

(Figure 9). Increased diversity of large herbivore diets is associated with competition for resources and/or degradation of habitat resulting from overgrazing (Kelley et al. 2011) suggesting that caribou had access better food resources in the 1980s than during later time periods (Schaefer et al., *unpublished*). The continued increase in diet diversity, despite reduced population size, indicates that caribou are still experiencing food limitation and likely using poorer quality ranges.

When examining general groups of food sources, caribou showed a decreased reliance on lichen and an increased reliance on herbaceous plants in summer in the 1990s; these trends reverted to some extent in the 2010s (Figure 9). Throughout the year, however, caribou are using more mosses compared with the 1990s and less high quality forage such as grasses and shrubs (Schaefer et al., *unpublished*). Moss has negative nutritional value for ruminants like caribou and thus increased moss in the diet suggests that preferred foods are scarce (Ihl and Barboza 2007).

While lichen is not a particularly high quality food source it is a very important component of caribou diets throughout the circumpolar north. Compared to parts of Labrador, lichen abundance in Newfoundland seems to be low at present, particularly in areas known to be used by caribou (I. Schmelzer, *pers. comm.*). Although it is tempting to suggest that this is the result of overgrazing, we do not know if lichen abundance has changed as a result of the high density caribou population or would be relatively low in Newfoundland even in the absence of caribou. However, lichen is very slow growing and the long period of low but stable population density following the decline in the early 1900s could be explained by the long recovery time required for lichen (Klein 1987).

As caribou age, their teeth become worn down by cropping and chewing food. The speed at which the teeth wear out is typically predictable enough to use for estimating caribou age. Poor-quality food items, however, can speed-up the rate of wear. Increased wear-at-age was associated with a density-dependent decline of reindeer (same species as caribou) as a result of switching to lower quality food items (Skogland 1990). In Newfoundland, tooth wear was fairly stable and predictable from the 1970s through the 1990s, however, caribou born between 2000 and 2005

show relatively quick tooth wear (Luther and Smith 2010), indicating a probable shift to poorer forage quality in the population decline phase.

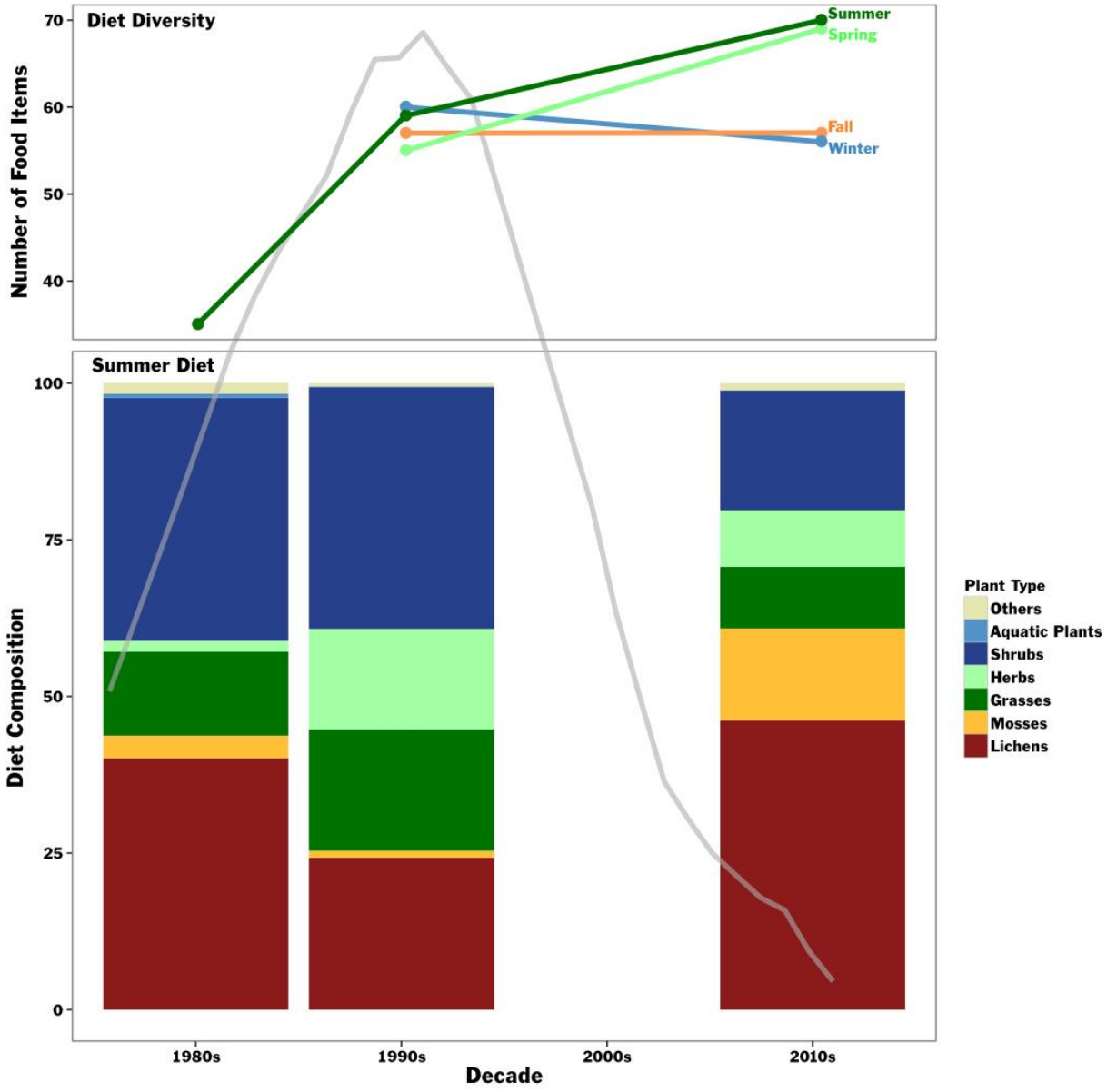

Figure 9. Changes in Newfoundland caribou food habits during population increase and decline. Top: The diversity of food items (by Genus) in the caribou diet increased for spring and summer from the 1980s and 1990s through the 2010s suggesting caribou were unable to rely on preferred food only. Bottom: Summer diet composition by food group shows a decreased use of lichen and increased reliance on grass and other herbaceous plants as the population neared peak numbers. In the 2010s caribou are relying more heavily on very poor quality mosses and less heavily on high quality shrub forage.

PREDATION AND CARIBOU CALF MORTALITY IN NEWFOUNDLAND

When causes of caribou calf mortality were studied in Newfoundland during the recent decline, a striking consistency was found: although the importance of specific predators varied from herd to herd and year to year, predation always accounted for the vast majority of calf deaths (Lewis and Mahoney 2014). Further, predation accounted for a greater percentage of calf deaths following the start of the population decline than it had during the increasing phase of the population (Weir et al. 2014). Reduced calf size and/or nutritional stress likely contributed to increased calf vulnerability to predation.

The importance of specific predators varied over decades, between areas and between years, but black bear and coyote are consistently the most prominent predators in all studied herds in recent years (Figure 10). Lynx and bald eagle were also significant predators in some areas, but mortality due to these predators is relatively low and appears restricted to a short period of time (Trindade et al. 2011) when calves are very small and naïve.

Predation mortality happens throughout the year, but the vast majority of caribou calf kills occur during the first few weeks of life (Lewis and Mahoney 2014). Though some portion of Newfoundland's female caribou disperse and give birth in seclusion, most migrate to calving areas where they form social aggregations (Figure 1B, Fifield et al. 2013) of females and young calves. These calving groups are a dense source of food for predators that is predictable in space and time. Predator density in caribou calving areas during calving season, however, is low (Lewis and Fifield 2013), suggesting it is unlikely that large numbers of predators migrate to calving areas to exploit the resource. Low predator density is consistent with the high movement rates and extraordinarily large home ranges displayed by both black bear and coyote in Newfoundland compared to mainland North America (Fifield et al. 2013).

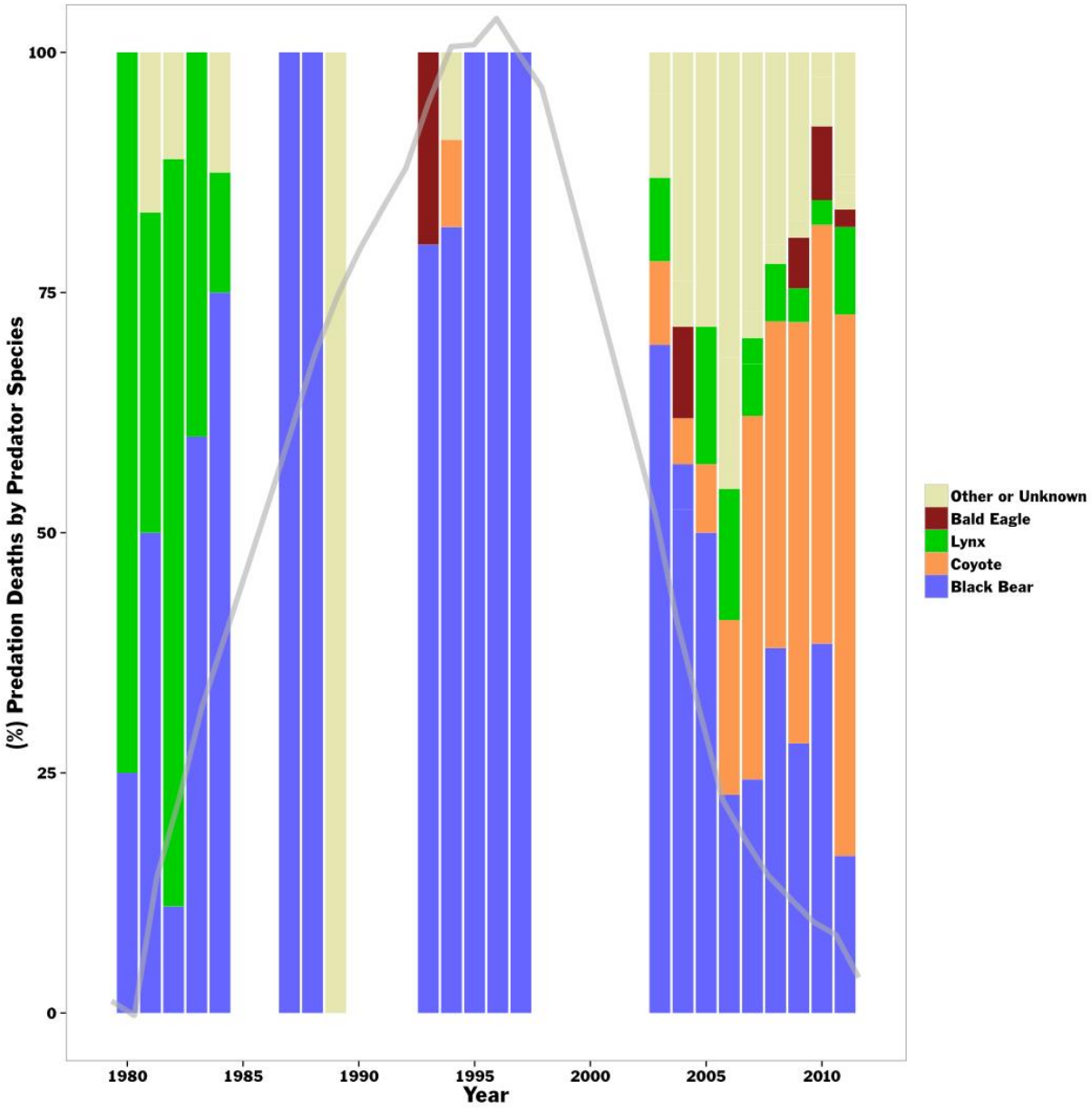

Figure 10. Relative contribution of predator species to predation-caused calf mortality in Newfoundland 1979- 2011. Over time, the importance of lynx as a caribou calf predator has declined and the importance of coyote has increased. Black bear were consistently responsible for large portions of calf predation mortality. Bald eagle can be important in some areas in some years.

HABITAT AND SPACE-USE

OVER-CROWDING AND OVER-GRAZING

At high densities, caribou not only compete for access to good forage, they deplete food items more quickly than at lower densities. This may force them to spread out and use new areas (Wal 2006, Ferguson et al. 2001). These areas may have been avoided before because of poor quality or availability of food, greater predation risk, higher disturbance, or simply a lack of familiarity.

Without pre-existing data on range quantity and quality, it can be tricky to assess whether any changes have occurred. Nonetheless changes observed in range fidelity, timing of seasonal migrations, habitat choices, and caribou distribution show a strong and consistent pattern: when caribou reached very high densities, their relationship to the landscape changed in ways which suggested overcrowding and/or overgrazing.

RANGE FIDELITY AND THE TIMING OF MIGRATION

During calving season and the summer foraging season which follows calving, female caribou in Newfoundland tend to return very closely to the same place year after year (Schaefer and Mahoney 2013). This high degree of fidelity in spring and summer speaks to the particular importance of these seasonal ranges. At this time of year, calves are at their highest vulnerability to predation thus choosing habitat with low predation risk is important. At the same time, choosing habitat with high quality food resources is also important. Female caribou have very high energetic requirements to support milk production, replenish body reserves lost over winter, and to accumulate fat reserves for upcoming breeding, pregnancy, and winter. Habitat suitable for predator avoidance may not be adequate for foraging needs and caribou may have to trade off one requirement to meet the other.

Around the time of the population peak, caribou showed lower fidelity to their summer range than during the growth phase (Figure 11). The biological importance of calf rearing and spring and summer feeding did not likely change during the 1990s, so reduced fidelity signals a lower

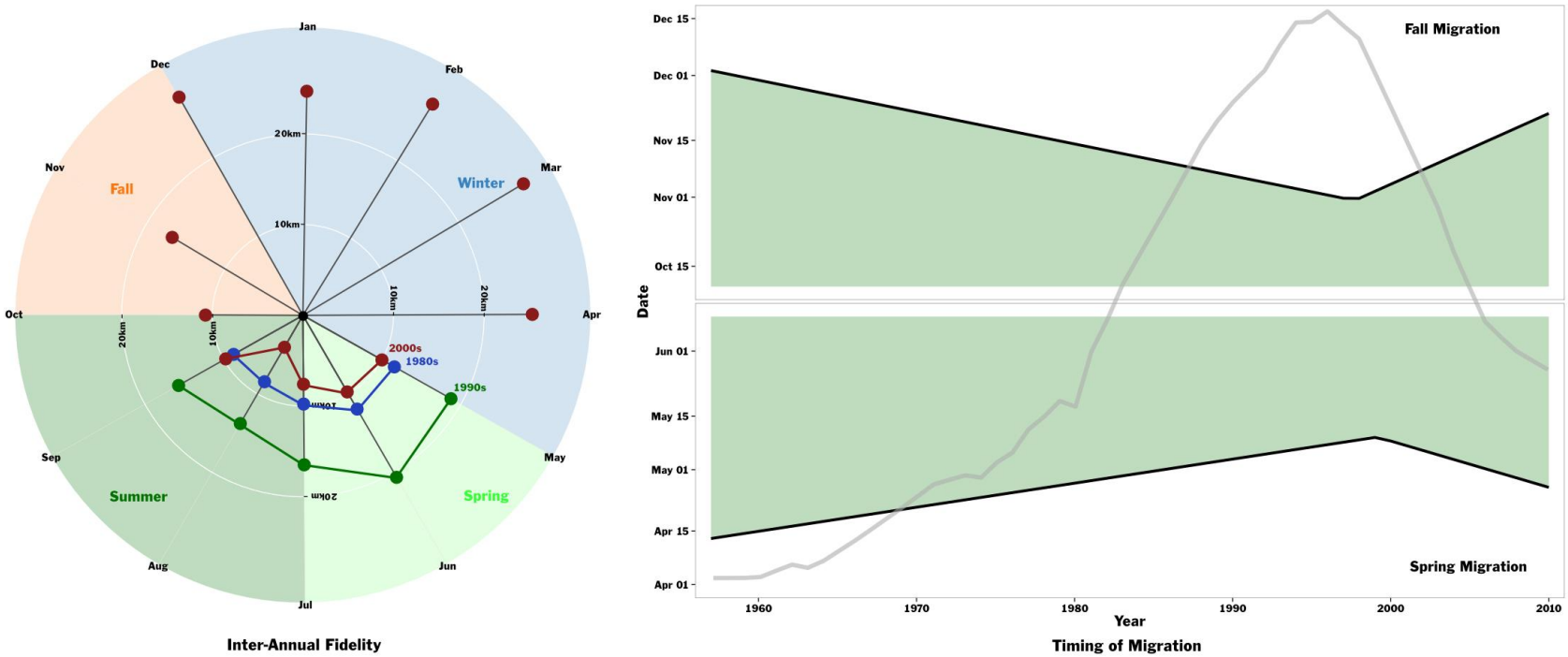

Figure 11. Long-term trends in fidelity and timing of migration. Left: Inter-annual fidelity to seasonal ranges. Fidelity is displayed as the monthly mean distance from the previous year's location (represented by central point). Fidelity is strongest in spring and summer and most relaxed in winter. Spring and summer range fidelity was weaker in the 1990s (near peak population numbers) compared to the 1980s. With reduced population density, caribou are demonstrating a return to strong spring/summer range fidelity. Right: Timing of Spring and summer migration of the Buchans caribou herd. As population density increased, caribou arrived later and left sooner from their summer foraging range. As population density decreased, this trend reversed.

motivation to return to the same place, possibly due to a reduction in range quality. Similar to body size measurements, fidelity trends have reversed in recent years (Schaefer and Mahoney 2013); caribou are demonstrating increased confidence in summer ranges.

The timing of seasonal migration changed with population size in at least some regions (Figure 11). As caribou density increased, caribou spent less time in summer foraging areas (Schaefer and Mahoney 2002). This suggests poor range conditions at exactly the time of year when food quality is expected to be greatest. In recent years, as caribou density has decreased, this trend is reversed and caribou are spending more time in summer areas again (Schaefer and Mahoney 2013).

HABITAT USE

At an island-wide scale, caribou primarily use shrub and sparse-forest but show a preference for open habitat, such as barrens and bogs (Schaefer and Mahoney 2013). From the 1980s when the caribou population growth rate began to slow, through the peak and persisting since the decline, caribou have consistently decreased their use of forest habitat and increased their use of open and shrub-dominated habitat (Figure 12).

Where caribou ranges overlap with forest management areas (commercial operations), caribou show a preference for old cut-overs (regenerated) and mature coniferous forest (Hebert and Weladji 2013). Despite the high predation-risk associated with young cutovers, caribou are known to sometimes use fairly recent clear cuts, likely to access good quality food during regeneration (R. Otto, *pers. comm*., Hebert and Weladji 2013).

Female caribou habitat selection is primarily driven by access to food resources regardless of predation risk (Bastille-Rousseau 2015) suggesting that food has been limiting to population growth, at least during the population decline phase and possibly for some time prior to the decline (Bastille-Rousseau 2015, Fryxell and Sinclair 1988).

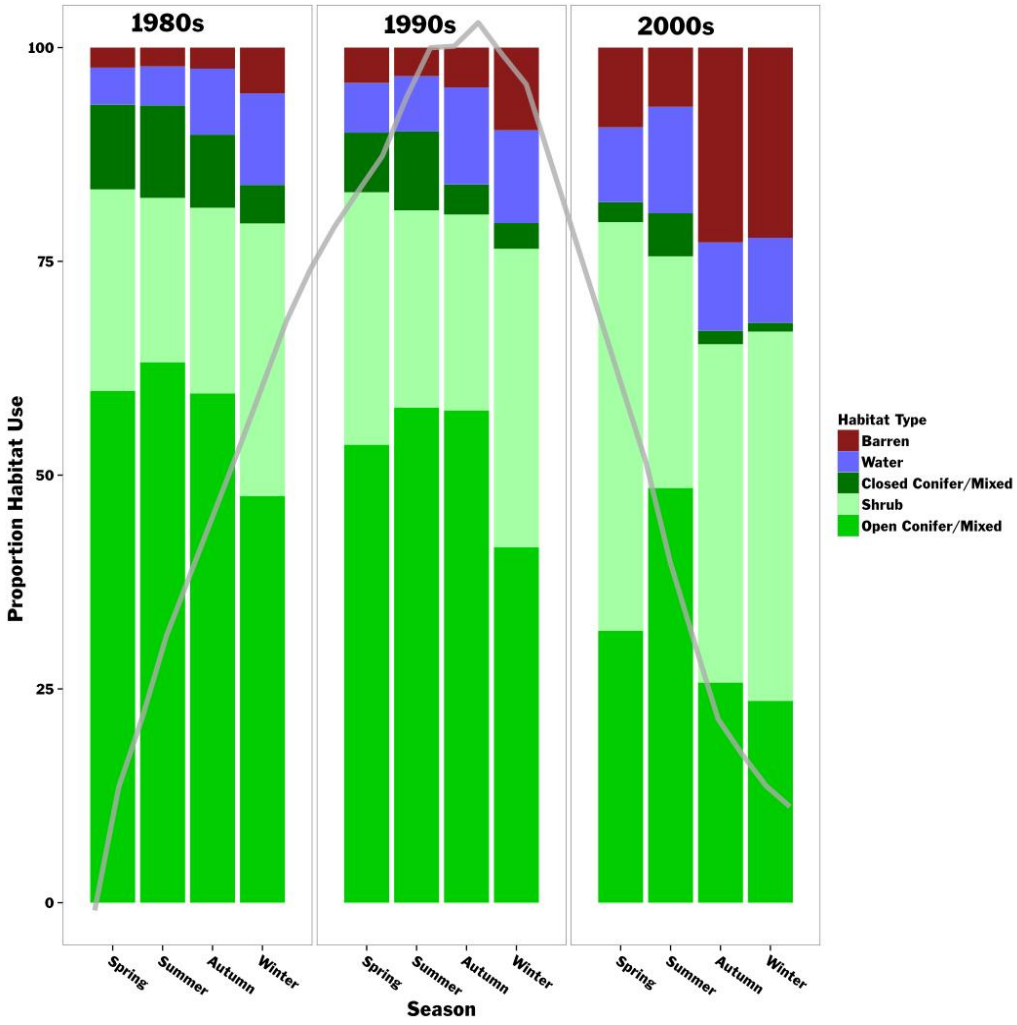

Figure 12. Comparison of seasonal habitat use across decades. Since the 1980s, caribou have generally decreased their use of forested areas and increased their use of relatively open habitats such as barren and shrub land.

During the early decline phase, caribou with calves fed more intensely than those without at the expense of anti-predator behaviour in spring and summer (Soulliere 2008). This behaviour is unexpected because, normally, females with calves are more alert than those without (Boving and Post 1997, Childress and Lung 2003, Toigo 1999, Hunter and Skinner 1998). The trade-off of alertness and calf-monitoring in favour of feeding and the use of risky habitat in order to access nutrients may increase calf vulnerability when food resources are limited.

DISTRIBUTION

Major geographic shifts in calving areas are known to correspond with density extremes (population peaks: Bergerud 1996; Hinkes et al. 2005; Taillon et al. 2012; population lows: Gunn et al. 2012). Coinciding with density-related changes in fidelity and migration patterns, the distribution of caribou changed in a very short time period sufficiently that previously defined areas of importance to caribou do not coincide with current distribution (Wildlife Division, 2011).

Changes in Newfoundland caribou calving habitat selection appeared to favour increased forage quality (Dekelaita 2013, Bastille-Rousseau 2015) regardless of predation risk (Bastille-Rousseau 2015). Changes in the location of calving aggregations in some major herds coincided with the population peak and decline (Dekelaita 2013); calving grounds that were predictable for at least 40 years suddenly shifted to new areas around the time of the population peak. This behavioural change may contribute to calf vulnerability.

The relaxation of fidelity and changes in migration timing might indicate a period of redistribution to new areas, likely motivated by over-crowding or degraded food resources in traditional areas. The persistence and extension of changes in habitat preference, in spite of reduced population size, further suggests a change in caribou distribution occurred.

THE ROLE OF PREDATION

The multiple observed changes in caribou population vigor, correlated with population density, provide strong evidence that the cause of the recent caribou decline was, at its root, related to overcrowding and/or overgrazing. However, caribou numbers did not decline due to starvation or disease related to high densities: the primary mechanism of decline was extremely high calf mortality predominantly due to predation (Weir et al. 2014).

When the caribou population reached its peak, there was a dramatic rise in calf mortality and especially in predator-driven mortality. From the late 1970s through the late 1990s, mortality studies consistently revealed a calf survival rate of higher than 55 per cent; in the early 2000s, calf survival was lower than 10 per cent (Figure 7) and although there has been a trend of improved calf survival since about 2007, it remains below the threshold required to enable population stability (Morrison et al. 2012, Randell et al. 2012). Predation continues to be the primary cause of mortality.

Coinciding with this increase in the importance of predation as a source of mortality for caribou, coyote became widely dispersed across Newfoundland and relatively common. It is unknown if there was a change in black bear abundance or distribution corresponding with the caribou decline. Despite their importance as caribou calf predators, and despite the increase in abundance and distribution of coyote, both species occur at low densities in the calving areas (Mumma 2014, Fifield and Lewis 2013).

Analysis of movement behaviour of black bear and coyote relative to caribou distribution suggests that, at the population level, caribou calves are incidental prey for both predators (Bastille-Rousseau 2015): that is, neither species tends to use the landscape as though they are searching for caribou. However, a portion of individual bears use caribou calving areas year after year, using them primarily during calving season (Rayl 2012). This type of calf-seeking behaviour suggests that individual bears may be caribou calf specialists. At least some individual black bear and coyote kill multiple caribou calves (Mumma 2014); whether this suggests specialization by individuals or coincidental overlap between individual home range and caribou calving areas is unknown.

In many species, increased predation on juveniles is commonly associated with density-dependent declines (Gaillard et al. 1998); nutritional stress can

- produce smaller and weaker neonates (infants) and juveniles;
- reduce protection from adults struggling to meet their own nutritional requirements; and,

- increase exploitation by predators not normally capable of effectively killing robust young.

Not surprisingly, caribou research from Newfoundland demonstrates that smaller caribou calves are more vulnerable to predation than larger calves (Lewis and Mahoney 2014). This may be due to disadvantages in running speed, lower strength, or limits to the ability of some predators to handle larger prey. Some caribou predators (bald eagle and lynx, for example), only make use of the caribou calves for a very short period of time (Trindade et al. 2011), possibly because calf size plays a large role in hunting success.

Predators in Newfoundland are omnivorous and opportunistic, capable of relying on multiple food sources. As a result, when caribou become scarce, predator populations can remain high by making use of other prey species and food items; reductions in the caribou population itself will not necessarily result in reduced food availability or for predator populations. This can result in disproportionately high predation on caribou if constant numbers of predators are competing for fewer caribou.

With a decreasing caribou population, increases in the proportion of calves killed by predators can occur without any improvement to predator efficiency or increase in predator abundance. As caribou numbers continue to decline, however, they may become more difficult to find, so the alleviation of predation pressure may occur concurrent with a decrease in forage competition between caribou; in such systems it can be very difficult to tease apart the independent effects of predation and nutrition.

A Note Regarding Coyote

The importance of predation to calf survival increased around the time that the caribou population began to decline. The arrival of coyote to Newfoundland, as a consequence of population range dispersal, coincided with the beginning of the decline in the growth rate of the caribou population. By the time the seemingly robust caribou population began to crash, coyote had become noticeably abundant and widely dispersed throughout Newfoundland (McGrath et

al., *unpublished*). It is understandable then, that there is a strong perception by residents that predation, and especially coyote predation, was directly responsible for the declining caribou numbers.

Though coyote have been observed killing adult caribou, adult caribou mortality did not increase with increasing coyote abundance and cannot account for the decreasing caribou numbers. Like black bear, coyote are an important and efficient predator of caribou calves, particularly in the first few weeks after birth. Coyote do not hibernate in winter but during this season, when coyote are the only effective calf predator on the land, calf mortality is low. Coyote are not exerting a strong influence on calf survival through the entire year.

The improvement observed in the experimental area (see below: Experiments to Reduce Predation of Caribou Calves) after coyote reduction indicates that at least some coyote predation is in addition to calf mortality that would have occurred without the arrival of coyote. However, changes which occurred in caribou population growth rate, body size and space-use began before coyote were widely distributed across Newfoundland. Although risk to calves of coyote predation did increase while the caribou population declined, the risk of bear predation increased over the same time period (Bastille-Rousseau 2015). This strongly suggests that regardless of any additive effect of coyote, caribou were more vulnerable to predators generally at this time.

Coyote exert an influence on caribou population dynamics, but these predators are not directly responsible for the caribou population decline. Further, the recent trend of increasing calf survival is occurring despite evidence of an increasing or stable coyote population (McGrath et al., *unpublished*). Perhaps the real coincidence of these two species was that caribou may have aided the successful establishment of coyote on the island as caribou were both easily available and vulnerable when coyote first arrived.

EXPERIMENTS TO REDUCE PREDATION OF CARIBOU CALVES

Predation mortality accounts for the vast majority of calf deaths and calf survival is directly implicated as a mechanism for caribou population decline. Intuitively, this raises the question of

whether management to reduce predator encounters with calves can result in improved calf survival and improved population growth.

A pilot project aimed at facilitating increases in normal legal predator harvest in calving areas resulted in only marginal increases in bear harvest, despite logistic and financial support to relocate outfitter camps to caribou calving areas for bear hunting (Dyke 2009). Voluntary engagement of trappers was not viable due to poor accessibility to remote calving areas and low pelt value during late spring/early summer and non-resident hunters seem reluctant to participate in such remote hunting (Dyke 2009).

During the five-year caribou initiative, experimental reduction of predation pressure was conducted in a small calving area in one study area. Trends in calf mortality in the experimental area were compared to those in an adjacent calving ground and more distant calving areas acting as experimental controls.

The provision of supplementary food (bakery waste and beaver carcasses) on the calving area effectively attracted black bear to the baits and resulted in reduced rates of bear-specific calf mortality; coyote were not attracted to the baits (Lewis et al. 2014). Calf survival improved somewhat, although not significantly. A subsequent lethal removal of a large portion of local coyotes resulted in a substantial improvement in calf survival (Lewis et al. 2014), though survival rates remained below that required for population stability or increase (Morrison et al. 2012, Randell et al. 2012). A combined experiment of lethal coyote removal and black bear diversion by supplemental feeding did not occur; it is reasonable, however, to speculate that such a combination (or lethal removal of both species) would further improve calf survival.

Local trappers were employed to conduct the coyote removal; voluntary engagement of trappers and hunters, even with logistic support, was again found not feasible given the scale of operation required (Soulliere et al. 2014). Immigration of coyote into the removal area was swift, as expected based on experience in other jurisdictions (Soulliere et al. 2014, Smith and Doucet

2008) and the capacity of Newfoundland's coyote for long-distance movement (Fifield et al. 2013).

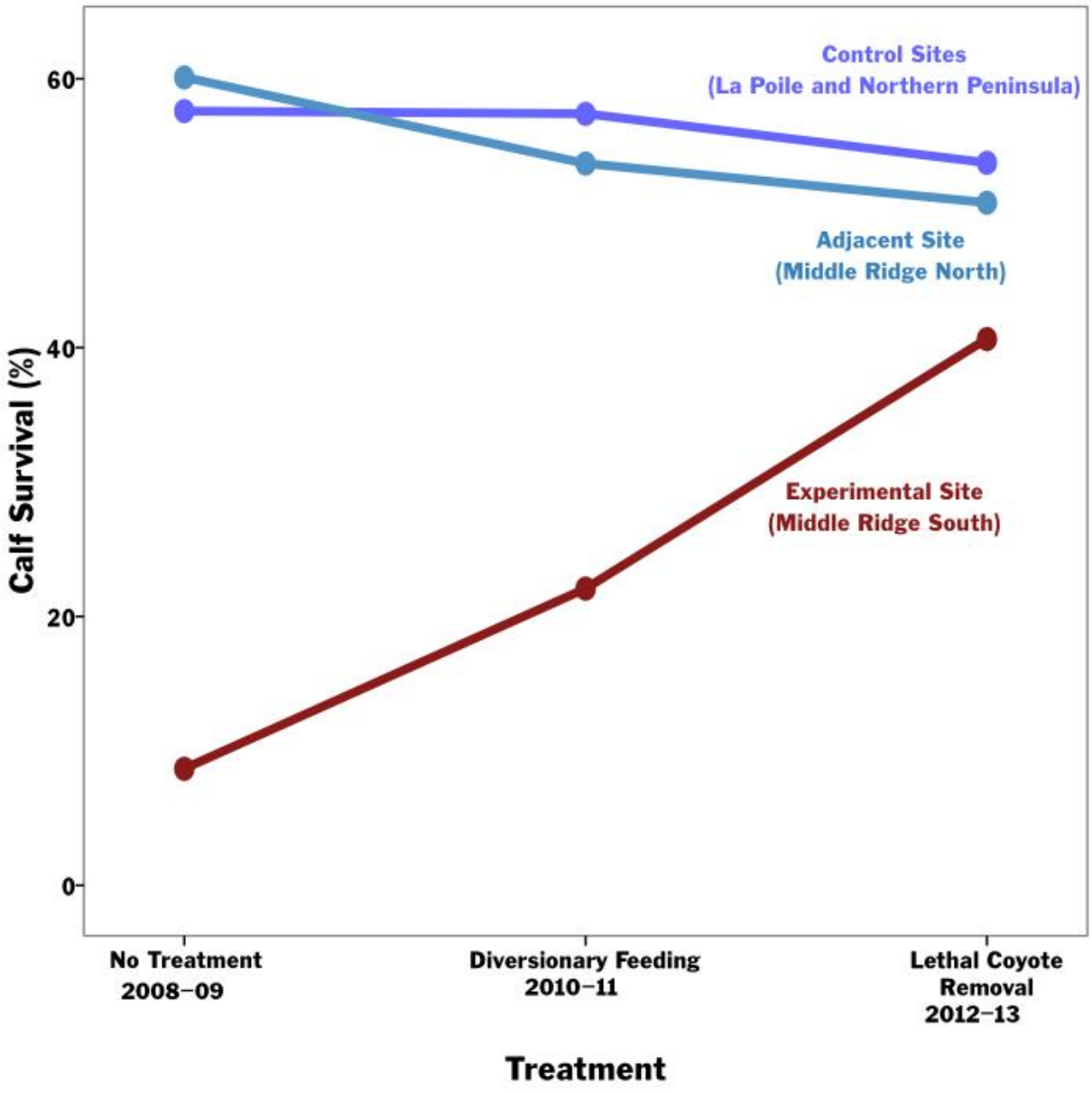

Figure 13. Effects of experimental predator manipulation on calf survival in the southern Middle Ridge calving area. Calf survival remained relatively unchanged in the control areas and the adjacent calving ground. Experimental treatments of diversionary feeding of black bear and lethal removal of coyote resulted in improved survival.

Manipulating predator populations to reduce predation pressure on calves is costly and likely prohibitively expensive on a large scale (such as island-wide) or on a continuous basis; any management application would require an ongoing commitment to intensive removal (Lewis et al. 2014).

THE ROLE OF HUNTING

In examining declines in any wildlife population which is subject to hunting, the influence of hunting itself and the possibility of over-hunting must be considered. In Newfoundland, harvested caribou are taken by resident hunters primarily for meat and a by non-residents primarily as a trophy hunt (Mahoney et al. 2014). The non-resident hunt is only a small portion of the overall harvest, thus adverse effects of trophy hunting cannot account for reductions in morphology and vigor preceding the population decline (Mahoney et al. 2011).

Time lags between population change and harvest management response are common for managed wildlife populations in many jurisdictions. Delays between data collection and analysis, logistic challenges associated with surveying wild animals in remote areas, and statistical variation in survey-to-survey results can result lead to an inability to detect population change immediately. A general reality of wildlife management is that harvest regimes can be inadvertently mismatched with population trends.

In Newfoundland, total license allocations increased during the growth phase of the caribou population, but the proportion of the population harvested in the 1980s and early 1990s remained relatively low (approximately four per cent). Due to data gaps and normal time lags, hunting license allocations remained high as the population began to decline (Figure 14). This resulted in an unintended but elevated harvest rate (5.9 to 7.9 per cent from 1999-2005: in some herds the rate of harvest was more than 12 per cent) (Luther and Weir, *unpublished*).

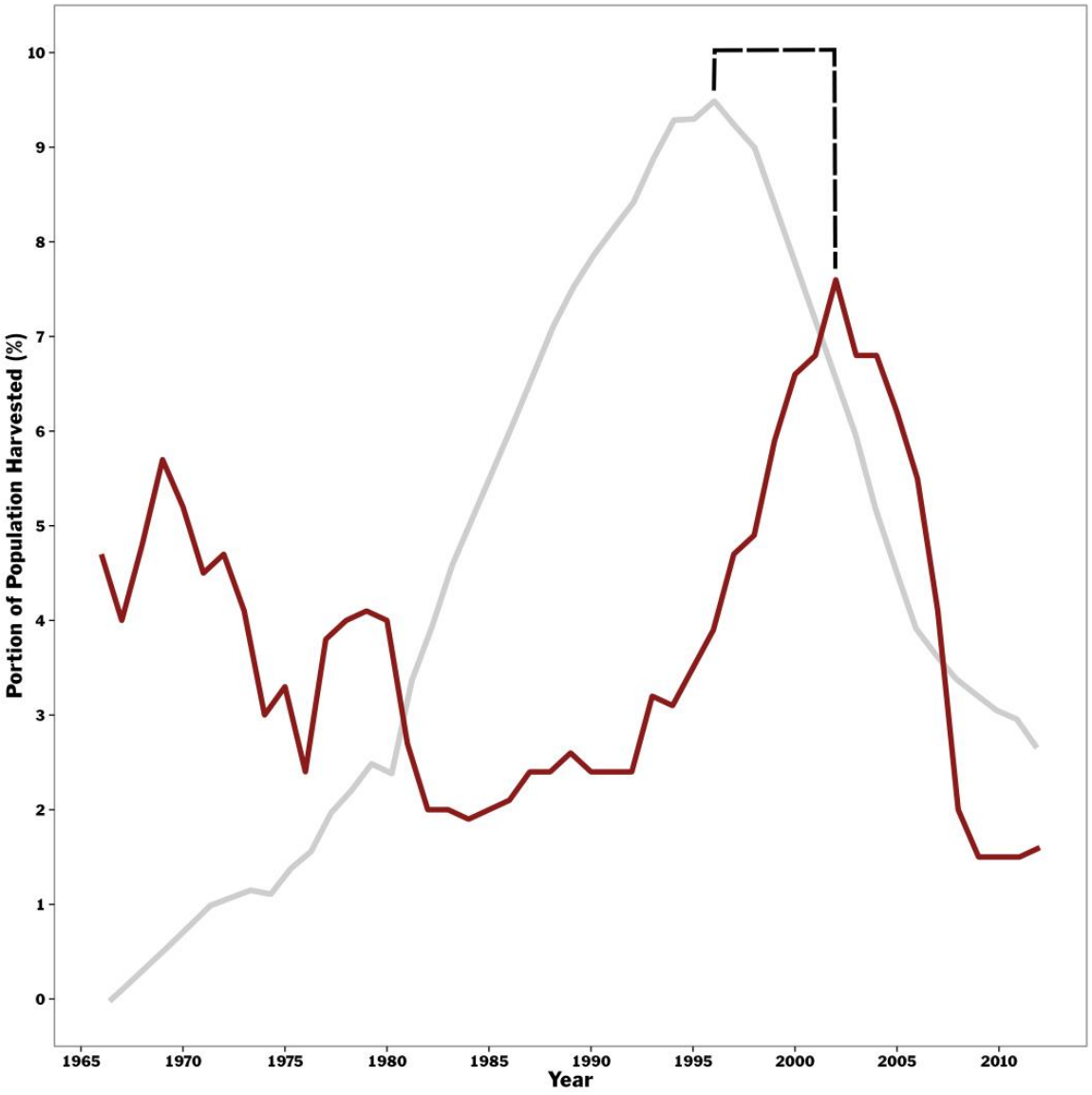

Figure 14. Proportional harvest of the caribou population 1965-2012. Despite increased licence allocations during the population increase, the proportional harvest remained low. As the population began to decline but population data were not yet available, a greater portion of the population was harvested despite stability in licence allocations

The high rate of harvest in the early part of the decline phase exacerbated the rate of decline (Weir et al. 2014), but hunting did not cause the decline. Population models confirm that although the speed at which the caribou population decreased would have been slower if hunting

was closed, the complete closure of hunting could not have stopped the decline (Weir et al. 2014, Randell et al. 2012).

Issues related to illegal hunting and enforcement were not explicitly investigated; however, there are no data to suggest illegal harvest had a substantial influence on population trends during the recent decline.

THE ROLE OF HUMAN ACTIVITY AND LAND USE

Human activity and land-use has long been identified as a source of disturbance to caribou populations, and a major factor limiting population abundance in some regions (Sleep 2007, Thomas and Gray 2002). Studies in Newfoundland (summarized in Mahoney and Weir 2009) demonstrate that resource extraction activities and recreational activity can displace caribou, disrupt feeding and create additional energy demands. How these effects on individual caribou translate to the population level are unknown.

Habitat fragmentation resulting from resource extraction industries has been demonstrated to be highly detrimental to caribou populations (Environment Canada 2008, Sleep 2007). Jurisdictions where this has become a critical problem (such as in Alberta) have a much higher density of industrial infrastructure than exists in Newfoundland. At present, vast expanses of suitable caribou habitat remains intact (Figure 15) (Wells et al. 2011).

Despite the predictable geographic separation of herds during spring, some caribou do not participate in aggregated calving, or do not travel to calving grounds in years when they are not productive. So although aggregations can be identified and delineated in space and time, highly vulnerable calves and energetically stressed females can occur outside these areas; these already stressed females and calves may be particularly sensitive to activity and disturbance during spring and early summer. Some mixing of herds appears to occur during rutting season and

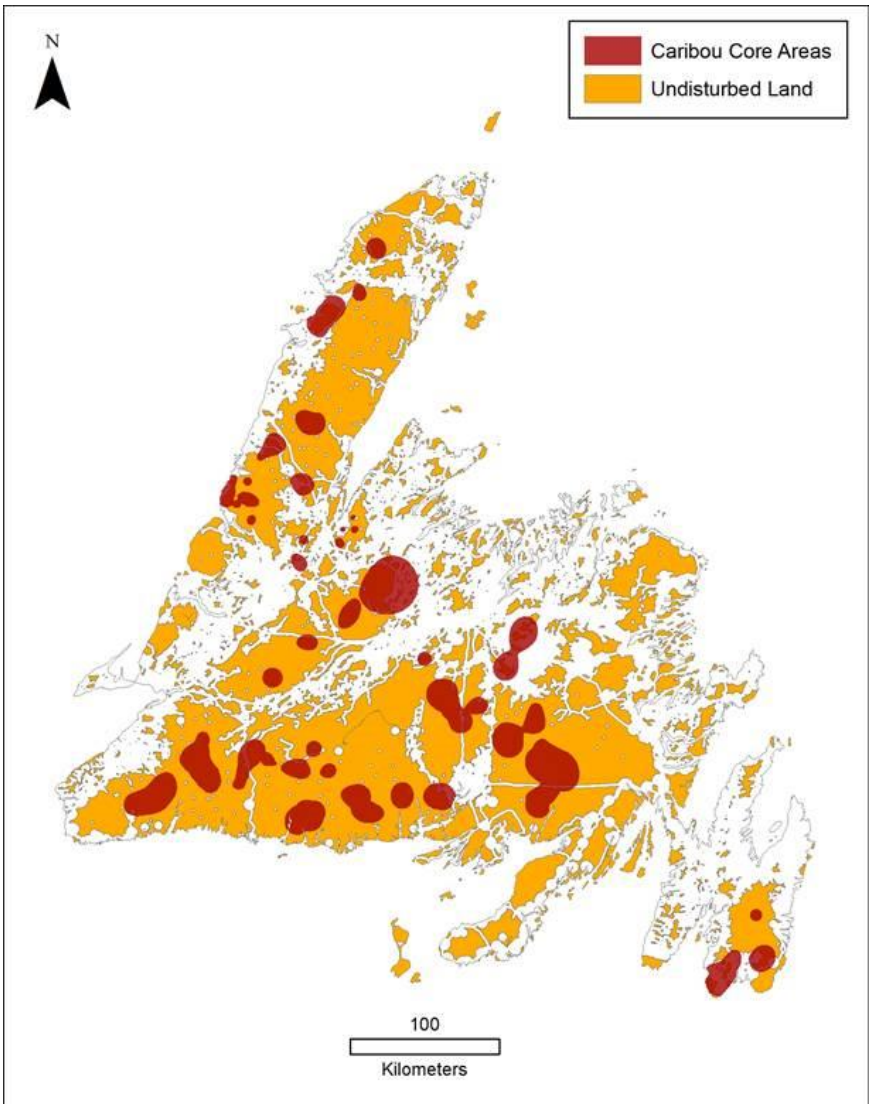

Figure 15. Intact (undisturbed) land relative to core caribou distribution in Newfoundland (adapted from Wells et al. 2011)

substantial mixing occurs during winter. Due to the behaviour of caribou migrating to relatively few wintering areas, caribou may be particularly vulnerable to chronic or cumulative disturbance in wintering areas. Social aggregative behaviour makes caribou particularly vulnerable to localized disturbance and catastrophic events during spring, fall and winter.

WHAT TO EXPECT FOR NEWFOUNDLAND CARIBOU

In the next few years, the caribou population as a whole is expected to continue to decline, though some herds may show stable or increasing trends. Predictive models based on recent population statistics for birth rate, survival, and age distribution show that if nothing changes, the population will continue to decline indefinitely (Randell et al. 2012, Morrison et al. 2012). It is not, however, realistic to expect these population parameters will never change.

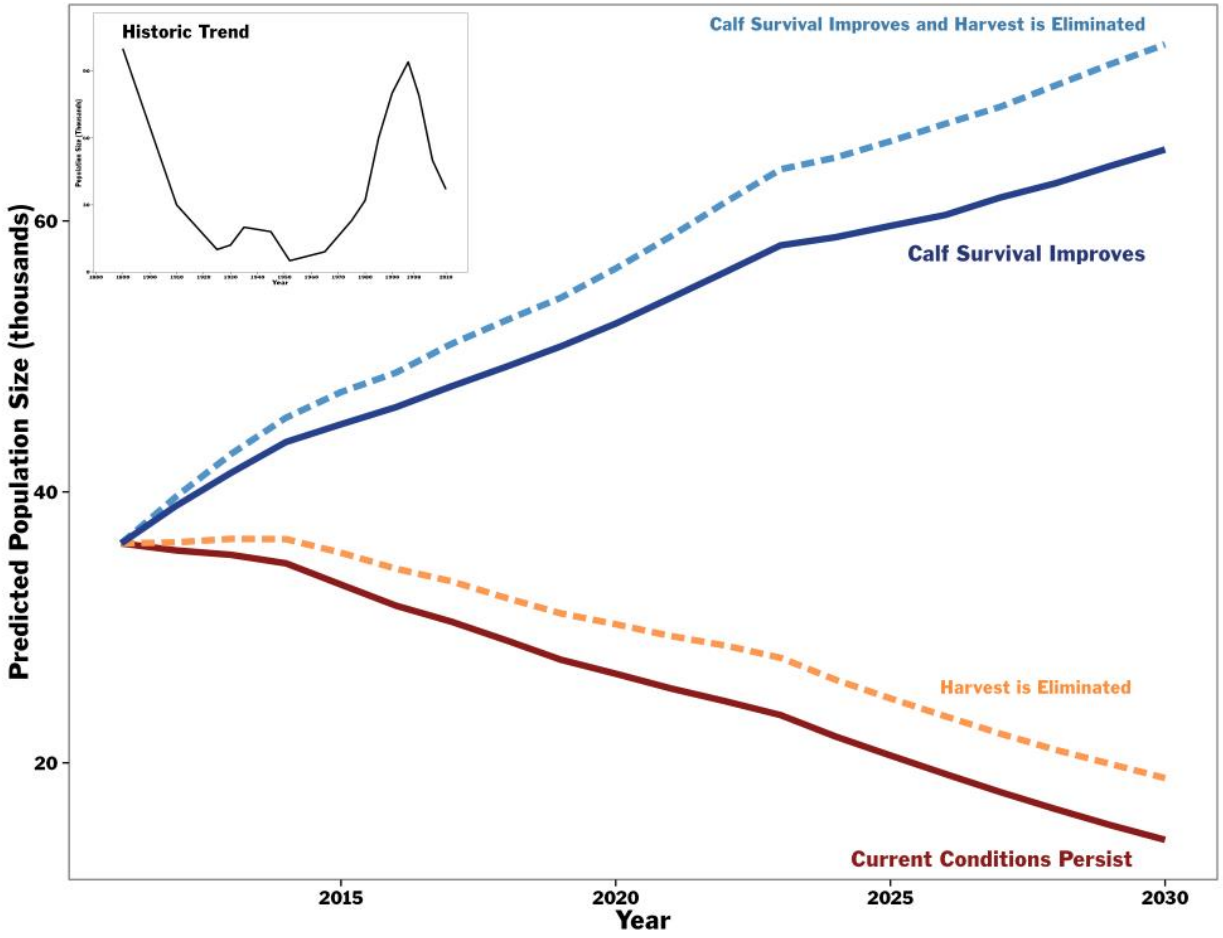

Figure 16. Projections of Newfoundland caribou population abundance using population viability analysis for predictive modeling (adapted from Randell et al. 2012). Based on the scenarios presented, the elimination of legal harvest can influence the number of caribou in the population, but not the trend in population numbers. Under current conditions, the population is expected to continue to decline. If calf survival improves to pre-decline levels, the caribou population could increase dramatically within a couple of decades. Density-dependence is not accounted for in this model but is known to affect the Newfoundland caribou population when abundance is high, thus it would be prudent to anticipate population declines if abundance nears historic peaks.

The swift rate of decline observed in the early 2000s has slowed and many associated trends are also showing signs of improvement. Calf survival rates, though still below the threshold required for population stability, show an increasing trend since 2007. Some herds are showing stable or slightly increasing numbers and increases in caribou body size have been measured. Caribou are staying in summer foraging ranges for longer than they did in the 1990s. Taken together, these are positive signals that the population may be approaching stability of numbers.

However, caution must be exercised regarding expectations. Although many indicators are showing positive change, the evidence of continued reliance on a poor-quality diet suggests that there may be some continued food limitation. If range quality or quantity is low, or good quality habitat is risky to use, the ability of the population to reach stability or increase could be compromised. Unless range or habitat recovery occurs, Newfoundland may not be capable of supporting a larger population. As was seen in the George River caribou herd in Labrador and with Atlantic cod populations, stabilization or growth after a drastic decline can be short-lived and followed by further decrease.

If the historic pattern repeats itself, the caribou population will likely remain low, but fairly stable for a few decades. This is consistent with the long regeneration time for lichen following overgrazing by caribou and reindeer (Klein 1987) and is a pattern typical of north Atlantic caribou herds (Gunn 2003). During this time, small or moderate fluctuations in total population size may occur. Predators will likely continue to exploit the population and continue to exert a strong influence on calf survival. Once habitat conditions improve sufficiently, caribou are expected to become more robust and less vulnerable to predation mortality.

Caribou are expected to persist in the Newfoundland ecosystem over the long term. Both past experience and predictive population models indicate little or no risk of population extinction (Randell et al. 2012). Population growth is anticipated when range quality improves sufficiently;

that growth will likely become rapid, allowing the population to reach very high densities again, provoking another major decline.

Without any changes to overall caribou population management or major ecological shifts, the population is expected to continue to show large-scale patterns of increase and decrease followed by long periods of low caribou density. It is reasonable, however, to also anticipate also change will occur in the caribou system in both predictable and unpredictable ways.

Many changes have occurred since the large caribou decline of the early 1900s (Figure 5): Newfoundland was transected by a railway, later removed and replaced by a continuous highway; changes in technology allowed the forestry industry a period of extraordinary growth and activity; snow machines became available and popular, changing human access to remote areas; brain worm was inadvertently introduced and is now present in all caribou herds; moose were introduced to Newfoundland and have become abundant and widely distributed, Newfoundland wolves became extinct; coyotes arrived through natural range expansion and have become widely dispersed; there is evidence that wolves may arrive periodically from Labrador and though there is no evidence of breeding, this raises the possibility of re-establishment of a wolf population in future years.

The underlying caribou population pattern is familiar, but the ecology of Newfoundland has undergone substantial change. It would be imprudent to have absolute certainty that the future will repeat the past.

Medium- and long-term expectations for the caribou population will be highly related to how caribou and other wildlife are managed in the future. Consistent monitoring of population indicators and updating of predictive models could prove a valuable tool for anticipating caribou population changes.

INFORMING CARIBOU MANAGEMENT FOR LONG-TERM SUSTAINABILITY

GOALS FOR CARIBOU MANAGEMENT

SUSTAINABILITY

Recognizing that caribou provide ecological, economic and cultural benefits to the land and the residents of Newfoundland and Labrador, the primary goal of caribou management for Newfoundland is the maintenance of a sustainable population.

A sustainable caribou population protects

- ecological benefits: caribou are large wide-ranging herbivores critically important for ecological integrity by providing grazing services and nitrogen enrichment to the landscape and providing a food source to a diverse predator community;
- economic benefits: caribou are a food source for a portion of residents, provide opportunity for revenue through non-resident hunting and the related economy, and enrich the tourist economy;
- cultural benefits: Newfoundland residents place value on caribou existence and have a long association with caribou physically and symbolically.

PUBLIC TRUST

Recognizing that wildlife is a public trust resource, that is, a resource collectively owned by the public and held in trust by government for the benefit of the public, a secondary goal for Newfoundland caribou management is to act on behalf of citizens in a manner consistent with

current and future public interest. Management undertaken on behalf of the public interest requires open communication, meaningful public engagement, and accountability and transparency in decision-making.

KEY CONSIDERATIONS FOR SUSTAINABLE CARIBOU MANAGEMENT

A RICH BODY OF EVIDENCE IS AVAILABLE TO INFORM MANAGEMENT DECISIONS

The Newfoundland caribou population is among the best-studied wildlife populations in the world. Few jurisdictions in North America have invested as many resources over so many decades to develop such an intimate understanding of a single wildlife population. Resulting from these efforts, our understanding of the major factors influencing caribou vigor and abundance in Newfoundland is broad and deep, providing a firm base for sustainable population management.

Over the last few decades, population monitoring and historic research documented the recurrence of a long-term pattern of rapid population increase followed by rapid population decline and a protracted period of low but stable abundance for Newfoundland caribou. The mechanisms, influences and causative agents have been identified through scientific investigation and evaluation of empirical evidence. Although Newfoundland, partly by nature of being an island, harbors a unique set of ecological and cultural circumstance which has profound effects on management practices, the general pattern described is not unique to Newfoundland caribou. Similar patterns occur in other populations of caribou and reindeer, and indeed these patterns are recorded in many species across the globe.

Given the rich body of evidence, now compiled and summarized through the Caribou Data Synthesis project, and the ecosystem-level research of the recent caribou study, many of the foundational questions respecting caribou ecology have been addressed. In the absence of significant ecological change, the Government of Newfoundland and Labrador holds sufficient

scientific knowledge to focus on sound caribou population management for Newfoundland without further studies of the magnitude of scale seen in the recent study.

A Relational Data Base Exists

As a result of the Caribou Data Synthesis efforts to compile, synthesize and evaluate all of the scientific information available for Newfoundland caribou, hundreds of data files were amalgamated. Relational data bases were developed during the five-year caribou initiative in order to manage the vast amount of spatial data for caribou and predators and the data collected for various inter-related component projects.

These existing data bases can support queries to generate data sets for specific analyses and thus be used to safeguard against duplicative or repetitive investigations and to assess if and when research of emerging issues is required. Additionally, continued development could allow for broader inclusion of the existing historic data and support the addition of new data as they are collected.

Analysis of Data is Not Fully Completed

The volume of data collected during the research and monitoring activities since 2008 precluded the ability to evaluate all these data to the full extent of their use within the time constraints of the program. These data, however, continue to be analyzed and evaluated by departmental personnel directly and in collaboration with external expertise. In particular, some graduate students conducting sophisticated analyses of caribou and predator interactions have not yet completed thesis work. New insights and conclusions arising from current and future investigations may provide additional knowledge and further inform management activities. Although this document will provide a sound basis for sustainable caribou management,

principles of adaptive management should result in modifications to management and conservation activities where appropriate.

Some Scientific Research will Still be Required

Continued monitoring and strategic research initiatives will be needed to address knowledge gaps, provide current metrics for models, to test and evaluate new methods or techniques and to investigate new or unanticipated phenomena. Research should, to the maximum appropriate extent, build on the current level of understanding while striving for continuous improvement, innovation and leadership in management approaches and outcomes.

Current known knowledge gaps include, but are not limited to:

- the similarity of the Avalon peninsula region caribou population dynamics to the rest of Newfoundland;
- the influence of social aggregation decisions, particularly by females with and without calves, on the accuracy of herd composition surveys;
- the role of parasites in Newfoundland caribou population dynamics and the anticipated influence of climate change;
- implications of individual caribou avoidance of human activity and infrastructure at the population level;
- establishing whether wolf occurrence in Newfoundland is a new phenomenon or simply a newly-detected one, and, the implications for caribou, coyote and other aspects of the ecosystem if re-establishment occurs; and,
- geographically and demographically explicit knowledge of the human relationship to caribou.

POPULATION STRUCTURE HAS MULTIPLE SCALES

Evaluations of telemetry and genetic data indicate that the Newfoundland caribou population is isolated from continental caribou populations, thereby existing as a separate and distinct entity.

Within Newfoundland, four sub-populations (Northern Peninsula, southwest region, Middle Ridge, and Avalon) can be identified from annual movement and spatial affiliations and validated by genetic structure. In particular, caribou distribution during the rut and in winter supports a model of four regional subpopulations.

The distribution of female caribou and calves during the calving season, and the relatively high year-to-year fidelity to calving areas, demonstrates that the traditional identification of herd units is not arbitrary. The Newfoundland caribou population is sensitive to changes in juvenile survival and the calving and summer seasons are the period during which calves are most vulnerable to mortality, further validating the relevance of the herd scale.

The scale appropriate for management, however, is not determinate or static. Different management goals, objectives and concerns may be best approached at different scales. The regional geographic overlap between some herds and observed synchrony in demographic trends across herds provides an opportunity for resource efficiency.

MANY POPULATION CHARACTERISTICS CHANGE IN ADVANCE OF POPULATION NUMBERS

Delays between sample-collection or monitoring surveys and production of data and indices can result in an unavoidably delayed decision-making process. The recent caribou research, however, identified some population indices which changed in advance of the decline and could be useful in future as early-warning signals of population change.

Population growth rate showed high variability but with no apparent trend during the early phase of population growth, but began to show a consistent decreasing trend about 12 to 15 years

before the caribou population reached peak numbers. Similarly, body size measures declined in advance of the population peak. Monitoring trends and changing trend patterns in these characteristics could be very informative for predicting changes in the caribou population.

TRENDS IN INDICATORS ARE MORE INFORMATIVE THAN ISOLATED NUMERIC VALUES

The Newfoundland caribou population, like other caribou and reindeer populations, shows variation in year-to-year (or point-to-point) measures of demographic rates, body size and condition, and habitat use, among others. Data from license returns is similarly variable at a year-to-year scale. The large amount of statistical error typically associated with point-estimates of any characteristic of a wild population often obscure year-to-year differences (this is not a problem unique to Newfoundland; it is a common challenge when studying or monitoring natural systems). When viewed at multi-year and decadal scales, however, the Newfoundland caribou population displays significant trends in abundance and demographics despite point-to-point fluctuations.

The current point-value of demographic rates and other population characteristics are important for understanding present population status. The direction of trends, the magnitude and/or timing of changes in trends, and the synchrony (or lack thereof) in multiple trends is more informative than the isolated numeric values associated with the trends.

In some cases, multiple characteristics are highly coordinated or synchronized. There is scientific value and prudence in monitoring independent characteristics to validate trends, but synchronization also denotes the opportunity for flexibility in monitoring schedules (not all traits need to be monitored all of the time in all areas) and thus provides an avenue for resource efficiency.

Predictive Models Can Be a Tool for Management Planning

Population models can be used to predict the population effects of alternative options for management or to estimate appropriate targets for herd composition, proportional harvest, and distribution of harvest effort. The models, of course, need to be informed by data (where available), estimates based on professional literature where necessary, and realistic expectations where data do not exist.

Well-constructed population models are accurate for predicting population abundance several years in advance and can be used to reduce the frequency of expensive census and survey work. Models can enable harvest management to be planned 3-5 years in advance allowing for anticipatory management mitigating lags between changing population trends and changing harvest regimes.

From and economic and tourism perspective, the capacity for business forecasting would benefit outfitting and associated industries. Advanced license allocation could increase planning time for hunting trips and may improve stability in both resident and non-resident harvest participation. This continuity of an engaged hunting public during periods of low caribou density is vital in creating a hunting public capable of hunting heavily during periods of high population growth.

If the Caribou Population Recovers to Peak Numbers, it Will Likely Crash Again

When viewed as a whole, the cumulative evidence of reduced caribou stature, relaxed range fidelity, changes in habitat affiliations and spatial behaviour, increased tooth wear at-age and increased reliance on low-value food items strongly indicate a population which could not be sustained at high numbers. The recovery of the Newfoundland caribou population to the extreme abundance of historic peaks would almost certainly result in a repeated decline of the population.

The extreme peaks and valleys of caribou numbers may be preventable if it is more desirable socially and economically, and acceptable ecologically. At present, the caribou population continues to decline and still displays signs of poor range quality. A few decades from now, however, we should anticipate an opportunity to mitigate population growth through high harvest pressure to attempt to avoid the next peak, thereby avoiding the next major decline.

Long-term data indicate that signals of adverse density-dependent characteristics began to occur when the population reached 55-60,000 caribou. Although this may be a good estimate of the upper limit of caribou abundance which can be sustained by Newfoundland, changes in the ecosystem or environment could result in a higher or lower sustainable limit.

RANGE-QUALITY AND AVAILABILITY IS THE PRIMARY LIMIT OF NEWFOUNDLAND CARIBOU

High density populations which result in overcrowding of caribou or overgrazing of the range tend to be unsustainable for lengthy periods. The Newfoundland caribou decline was mediated by a vulnerability to predation, but triggered by food limitation. In the absence of wolves (a predator capable of killing healthy adult caribou in addition to the young and the compromised), Newfoundland's caribou population is, perhaps more than most, affected by forage resources. Long-term management of this caribou population should be primarily focused on range quality and availability.

Ultimately, safeguarding the population will require that sufficient quantities of space remain available for caribou's basic ecological needs.

SUMMER FORAGE RESOURCES ARE PARTICULARLY IMPORTANT

Body condition, diet analyses, and behavioural observations are consistent with nutritional deficits through summer. Patterns of annual fidelity of female caribou indicate that spring and

summer ranges are of particular importance. Changes in habitat use point to a decline in summer range quality specifically as contributor to population decrease.

THE MAJORITY OF LAND TRADITIONALLY OCCUPIED BY NEWFOUNDLAND'S CARIBOU REMAINS RELATIVELY INTACT.

Caribou require large contiguous landscape. Caribou are known to go through geographic shifts in distribution and thus the land currently occupied may represent only a portion of the long-term land requirements for caribou.

At present, space is not an issue for Newfoundland caribou. Calving and summer foraging areas are relatively remote and unfragmented. The amount of overlap between caribou and human land-use varies across herds, but generally there is relatively low intrusion in caribou-occupied areas. Alternatively, current caribou distribution may be an artefact of the avoidance of human activity. Nevertheless, large contiguous landscape remains available for caribou.

AN OPPORTUNITY STILL EXISTS TO PLAN HUMAN LAND-USE AND ACTIVITY IN A WAY THAT IS COMPLIMENTARY TO CARIBOU CONSERVATION AND MANAGEMENT

In other parts of North America where human development has infringed heavily on caribou ranges, caribou populations are under intense adverse pressure related to space, competition from encroaching herbivores and disproportionate predation pressure (Sleep 2007). While cumulative effects of continued development and activity can reasonably be expected, the pace of change will not be instant; unlike the circumstance in the highly developed landscapes of other jurisdictions, this province has the time and ability to adapt, plan and intercede to conserve a viable caribou population in perpetuity. A significant portion of land remains undisturbed in a

permanent way, much of which coincides with caribou distribution, including the heavily used wintering area on the south coast of Newfoundland

Several intensive investigations over the last 30 years resulted in well-documented effects of human land use activity and infrastructure in Newfoundland (summarized in Mahoney and Weir 2009). These studies spanned multiple types of industrial development and activity occurring within the ranges of most major Newfoundland herds. Although individual behavioural changes were recorded, there is no evidence that human land use – at the level of occurrence in Newfoundland – has profound effects at the population level. Activity, however, appears to have greater implications than infrastructure, at least at current levels.

Since the human footprint in caribou-occupied areas of Newfoundland is relatively small at present, knowledge gaps exist around cumulative effects of development on caribou populations. Future planning needs to be informed by caribou tolerance for range incursion and population-level implications of a range of potential land-use models.

Research reports, GIS tools and substantial data sets exist to allow for conscientious planning of future development is such a way as to protect caribou from the kind of landscape fragmentation endangering caribou in other jurisdictions.

Reductions in Hunting Opportunities Increase the Risk of Losing an Engaged Hunting Public

Hunting is one of the most valuable tools for wildlife population management as it is one within the direct control of management agencies. Further, hunting can be used to collect rich population data for relatively low costs. Varying harvest allocations (percent of population, proportion of male and either-sex licenses, and geographic distribution of hunting effort) is a primary method of responding to changes in population numbers, demographics, or distribution. As such, a common management reaction to major declines in game populations, and indeed a

legislated approach under severe declines (Species At Risk Act, SC 2002, c 29; Endangered Species Act SNL 2001, c E-10.1), is to reduce harvest quotas or close hunting. While hunting closures can be necessary to preserve wildlife, if these are geographically broad and in place over many years may result in the loss of an engaged hunting public. The loss of hunting opportunity can endanger a primary management tool: hunting skills decline, new hunters do not enter the system, and the cultural value of hunting declines.

As an important note, there is presently low to no danger to the Newfoundland caribou population in maintaining a hunt. Population models indicate that although the magnitude of decrease is amplified by hunting pressure, the direction of population trends is not affected. Further, there is no risk of Newfoundland caribou extinction, with or without hunting, in the next 15 years (Randall et al. 2012).

Snow Machines and ATVs may Pose Unprecedented Challenge for Caribou

Of particular caution, however, the effects of snow machine and ATV disturbance on caribou in Newfoundland could be profound. Caribou respond to snow machines by disruption to normal activity (including feeding) even if they do not flee from the disturbance (Mahoney et al. 2001). The lack of an obvious fright response (such as running away) could lead snow machine operators to believe caribou are not bothered by their presence. ATV users express uncertainty about the extent of the environmental impact ATVs have on wildlife or wildlife habitat (Waight 2014).

The primary uses for ATVs (presumably also snow machines) in Newfoundland are transportation, hunting and wood collection; overly restrictive regulations for recreational vehicle could be detrimental to the well-being of residents (Waight 2014). Off-road motorized vehicle use is increasing in Newfoundland and Labrador (van Vierssen Trip 2014). Road infrastructure associated with resource extraction and development has increased the ability for people to access previously remote areas, potentially increasing interaction and conflict between

people and caribou. Clearly, unmitigated intrusions of recreational vehicles in caribou ranges can have negative impacts. Used and regulated well, however, there is potential to use this type of traffic to coexist with caribou and even aid management (e.g. distribution of harvest effort).

MANIPULATION OF PREDATOR POPULATIONS COULD BENEFIT CARIBOU UNDER SPECIFIC CIRCUMSTANCES

Although predators have a clear influence on survival, particularly of juvenile caribou, the evidence suggests predators as an agent rather than a cause of declining caribou numbers. Caribou predators in Newfoundland exist at relatively low densities but they can have profound effects on calf survival and caribou population size. None of the major predators rely solely on juvenile caribou as a food source, thus their populations can remain high despite declining caribou numbers and may have a disproportionately large impact on caribou. Given evidence for possible specialization of individual predators on caribou calves, black bear reductions conducted in calving areas would be most effective if conducted concurrent with calving season; removal efforts at other times of year could remove individuals that do not participate in calf predation and fail to remove those that do.

Experimental work suggests that the distraction and removal or removal-only of predators can benefit caribou calf survival rates. The reverse experiment has not been conducted, but it would be reasonable to expect that if decreases in predator density improve calf survival, increases in predator density could reduce calf survival. The high mobility and low density of predators on the landscape and the large areas over which caribou calves are found make predator manipulation a very costly activity, thus may be best reserved for highly localized conservation urgencies.

In 2014, The Newfoundland Caribou Population was Assessed as a Species of Special Concern by the Committee on the Status of Wildlife in Canada

In 2014, the Committee on the Status of Wildlife in Canada (COSEWIC) assessed the status of the Newfoundland caribou population. The 68 per cent decline in numbers since the previous COSEWIC assessment met criteria for at-risk status of Threatened or Endangered. However, due to evidence of natural population fluctuations the magnitude of decline was not considered to be of concern, particularly in light of indications that calf survival is improving and that the Province has taken action to mitigate the decline. COSEWIC did express concern about the level of uncertainty around future impacts of the coyote population and as a result, assessed the population as a Species of Special Concern.

This assessment triggers federal Species At Risk legislation and provincial Endangered Species legislation. Once the COSEWIC assessment of Special Concern is formally recommended, the responsible federal minister and responsible provincial minister must consider designating the population as a Species of Special Concern or Vulnerable, respectively. If listed by either or both levels of government, the status will require the development of a management plan, but does not result in any prohibitions (for example, hunting would still be permitted).

The Ecology of Newfoundland will Change

The natural world is not static: even in the absence of human development or interference, ecological systems change. Forests mature, wetlands expand or contract, fire and insect cycles occur, new species arrive and other species disappear. Some changes have subtle impacts on the system, others initiate changes which result in major impacts. Newfoundland is subject to these dynamics in addition to that which we have some control over (land-use and development, human activities, etc.).

In recent years, evidence of Labrador wolf presence in Newfoundland has been confirmed. Although there is no current evidence of a breeding population of wolves on the island, the presence of at least a few individual wolves raises the possibility of wolf recolonization. Wolf presence could exacerbate population decline (adult mortality from wolf predation could have significant adverse consequences) or may be neutral or positive for caribou despite predation risk (could result in reduced coyote, bear and/or moose populations).

Climate change is expected, among other items, to improve conditions for some caribou parasites (Gunn and Skogland 1997; Vors and Boyce 2009) due to higher mean daily temperature (Finnis 2013). Although the current decline is primarily caused by limited forage resources in summer, increases in severe weather events and increased incidence of freeze-thaw cycles (Finnis 2013) may have implications for winter forage conditions in future. Changes in weather patterns, in turn, will likely favour increased coyote predation and decreased bear predation (Bastille-Rousseau 2015). These, and other yet unknown changes have the potential to influence caribou populations.

CARIBOU MANAGEMENT IS A MULTI-DISCIPLINARY ACTIVITY

Full management and conservation of wildlife populations, habitat and ecological systems requires participation from multiple sources. In Newfoundland, there is a cross-departmental nature to caribou management, including responsibilities for wildlife research and population management, sustainable development of resource extraction industries, and enforcement of legal obligations and regulatory and policy compliance.

TAKING ACTION

The insights and knowledge gains achieved as a result of dedication to high quality research on the Newfoundland caribou population improves the capacity of government to manage caribou in a sustainable manner. The release of this report is consistent with a commitment to knowledge-based decision-making, openness and transparency.

The information gained from recent investments in caribou research is already being used in an adaptive manner to make informed decisions for current and future caribou management in Newfoundland. Information from evaluations of research and monitoring aids in determining short-term and long-term objectives for caribou abundance, setting appropriate harvest plans, and identifying areas of high sensitivity for caribou.

The key considerations discussed in the report provide a base for decisions which will allow us to act wisely, act efficiently and act collaboratively to provide better service to Newfoundland and Labrador residents and conduct proactive management for the long-term sustainability of caribou. Sustainable caribou management requires cooperation from multiple sectors including natural resource industries, outfitting and tourism operators, hunters and the non-hunting public. Continuing to build collaborative relationships with stakeholders and meaningful engagement of the public in decision-making is a priority. This document provides guidance as the Department continues to consult and collaborate with stakeholders during the development of management goals and objectives for the caribou population.

ACKNOWLEDGEMENTS

Although this document captures the essential outcomes of the 2008-2013 caribou initiative, it does not demonstrate the richness and complexity of the effort that was required to produce these results. The magnitude of the program undertaken on behalf of Newfoundland's caribou was immense and required the dedication of a large number of people for the development, implementation and completion of this work.

The Department of Environment and Conservation is grateful to the personnel who did the heavy lifting from project development and design, logistic coordination, field work for data collection, complex data management, analysis, interpretation of results, education, training, contract management, communication, liaison, coordinating graduate student projects, and disseminating updates and result. The caribou program was led by the Sustainable Development and Strategic Science Division (SDSS) under the direction of Shane Mahoney and jointly delivered by SDSS and Wildlife Division. Many thanks to Chris Baldwin, Wayne Barney, Gary Beaton, John Blake, Fran Dinn, Christine Doucet, Casidhe Dyke, Sabrina Ellsworth, David Fifield, Ross Firth, Steve Gullage, Peter Hearns, Tyler Hodder, Dave Jennings, Keith Lewis, Glenn Luther, Olive Marsh, Jason McGinn, Kim Morgan, Andrew Mouland, Tamara Murphy, John Neville, Frank Norman, Rob Otto, Truman Porter, Heather Randell, Kim Saunders, Paul Saunders, Karyn Smith, Jonathan Strickland, Colleen Soulliere, Pete Tremblett, Mariana Trindade, Jackie Weir, and Gerry Yetman for their contributions. Shawn Morrison, an external contractor, had a key role in the evaluation and interpretation of the Caribou Data Synthesis. Over the tenure of the work, we were grateful of the support of Ministers Charlene Johnson, Ross Wiseman, Terry French, Joan Shea, Vaughn Granter and Minister Dan Crummell and the guidance and commitment of Deputy Ministers Bruce Hollett, Bill Parrott, and Jamie Chippett.

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Brinkman, Daniella Dekelaita, Hance Ellington, Isaac Hebert, Doug MacNearney, Sarah McCarthy, Matt Mumma, Nathaniel Rayl, Maggie Sutherland, Kathy Unger, Lindsey Webb, and Chris Zieminski made substantial scientific contributions to our understanding of the Newfoundland caribou population and the ecology of the island. We are particularly grateful to Chris Zieminski's well-trained dogs Marvin and Jetson, for their tireless efforts in searching for and finding predator tissue for diet and DNA analyses. Many of the students were supervised by academic team members, but the expertise and influence of Rita Anderson, Paul Krausman, Lisette Waits, Carolyn Walsh, and Robert Weladji were also vital to the graduate work.

Caribou Resource Committee members Blair Adams, Wade Bowers, Barbara Case, Keith Deering, Jim Evans, Ross Firth, Bruce Gilbert, Wayne Holloway, Juanita Keel-Ryan, Brad Leyte, Ted Miller, Bruce Porter, Sheila Robinson, Dave Schneider, Mary Taylor-Ash, Eugene Tiller, and Ken White delivered a valuable service by providing an engaged and enthusiastic exchange between the caribou program team and crucial stakeholders.

Safari Club International Foundation dedicated substantial funds to support field and laboratory activities related to predator-prey research, along with providing research advice and connections with other projects and programs with similar goals.

This report was drafted by Colleen Soulliere. Graphical figures in this document were produced by Chris Hammill.

Glossary of Terms

abundance	the number of individuals in a defined population (e.g. the number of caribou in Newfoundland or the number of black bear in a calving area during spring)
age structure	the distribution of individuals in a population across ages or age-classes; this is usually represented by the proportion or percentage of the population belonging in each age or age-class
census	a survey of the population in order to collect data which can be used to estimate abundance
cumulative effects	the combined and additive effects of multiple changes to the environment over time
demographics	characteristics of a population related to the age and sex structure which have implications for abundance and vigor (e.g. birth rate, adult survival, male : female ratio)
density	abundance per unit area; a measure of how crowded a population is on the landscape
diversionary feeding	providing supplementary food which provides a high caloric reward for little effort in order to distract predators from making use of a prey resource in the same area
DNA	deoxyribonucleic acid is a material found in the cells of nearly all organisms and carries genetic information; because genetic code is unique to individuals, it can be used to identify and discriminate between individuals
ecosystem	an interacting network animals, plants, and microbes linked to each other and environment through processes such as energy flow and nutrient cycling
fidelity	the degree of habitual use (“faithfulness”) of a specific place in subsequent seasons; fidelity is measured by the distance distance in one year of an animal’s location to the same animal’s location on the same date in the previous year
fragmentation	the process of reducing large, continuous landscapes into patches separated by alterations to the environment (human-induced or natural)

	related:
	unfragmented refers to landscape which is intact; has not been subject to substantial fragmentation
forage	vegetative food items, particularly those which are browsed (like leaves, twigs or other high-growing vegetation) or grazed (like grass, lichen, or other low-growing vegetation)
growth rate	the amount of increase (positive growth) or decrease (negative growth) that a population goes through over a specified time period, usually a year
herd composition survey	a survey of the population sub-units (herds) to determine the distribution of individuals across age and sex categories and support estimates of demographic rates
licence returns	hunters and trappers are required by law to submit a licence return whether or not successful harvest took place; this return includes a questionnaire which provides substantial data that can be used for monitoring hunter success and behaviour as well as wildlife population characteristics
preference	when an animal uses a resource in a greater proportion than its occurrence, this is recognized as a preference; e.g. if forests represent 20 per cent of the landscape but are used more than 20 per cent of the time, this is interpreted as a preference for forest
range	the geographic area over which a population normally ranges throughout an annual cycle that contains the set of conditions appropriate for natural occurrence of the species
	related:
	home range refers to the geographic area over which an individual animal ranges throughout an annual cycle
	seasonal range refers ot the area over which a population normally ranges during a specified season
	range quantity refers to the availability of space which provides conditions appropriate for the natural occurrence of the species whether or not it is currently occupied by a population
	range quality refers to the relative ability of a geographic space to statisfy the needs of a specific population; the relative suitability, availability and excellence of resources within a range

recruitment	the portion of the population comprised of young-of-the-year; for Newfoundland caribou this is typically measured in fall (calves 4-5 months old) and late winter (calves 10-11 months old) and is recorded as a percentage of the population made up of juveniles
resource competition	when a number of individuals (same or different species) require the same resource in the same place, particularly where that resource is in short supply
telemetry	the wireless transmission and reception of a signal; in wildlife studies, collars affixed to animals which send radio or satellite signals provide telemetry data which indicate the location of these animals at defined intervals
survival rate	the likelihood that an individual from the described class (e.g. newborn calf or adult female) will survive for a specified time period, usually a year
sustainability	the capacity for a population, system or process to endure; in the context of sustainable development, the capacity for a resource to endure over many generations while protecting ecological, social and economic aspects related to the resource

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APPENDIX: ADDITIONAL REPORTS AND PRODUCTS

The Report on Newfoundland Caribou provides an overview of the knowledge gains, insights, and accomplishments of the 2008-2013 activities. The report condenses and summarizes a vast amount of scientific results and interprets the **more detailed reporting arising from individual component project reports. Below are a list of the reports and articles available (at the time of printing) and a listing of all associated graduate student projects associated (some remaining incomplete at the time of printing).**

Technical Bulletins (available in PDF and hard-copy), internal reports, and unofficial copies of student theses can be obtained by contacting the Department of Environment and Conservation at:

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709-729-2664 or 1-800-563-6181.

Peer-reviewed articles and official copies of student theses and dissertations can be obtained through inter-library loans, or may be available for download from internet sources

SUSTAINABLE DEVELOPMENT AND STRATEGIC SCIENCE - TECHNICAL BULLETIN SERIES

The SDSS technical bulletin series forms the basis for describing and interpreting the results of the caribou research and is structured to present a detailed review of specific components of the work. As such, these reports are heavily referenced throughout this Summary Report document.

Hard copies or PDF copies of all reports in the Technical Bulletin Series are available by request.

No.	Title	Date
001	Caribou Data Synthesis – Progress Report	2009
002	Caribou Calf Mortality Study 2003-2007	2011
003	Projection of woodland caribou populations in Newfoundland (Leslie-Matrix)	2012
004	Population projections of Newfoundland caribou using Population Viability Analysis.	2012

No.	Title	Date
005	Application of distance sampling to determine calving ground abundance and aggregation of parturient females in the Middle Ridge herd, June 2012.	2013
006	Noninvasive genetic sampling and predator density estimates for black bear and coyote in Newfoundland 2009-2011.	2013
007	Spatial ecology of black bear, coyote, and lynx in Newfoundland.	2013
008	Caribou Data Synthesis – Progress Report #2.	2014
009	Caribou survival, fate, and cause of mortality in Newfoundland: a summary and analysis during a period of rapid population decline, 2003-2012	2014
010	Experimental manipulations of black bear (*Ursus americanus*) and Eastern coyote (*Canis latrans*) to improve caribou calf survival in Newfoundland 2010-2013.	2014

PEER-REVIEWED ARTICLES IN PROFESSIONAL LITERATURE

Bastille-Rousseau, G., D. Fortin, C. Dussault, R. Courtois, and J.P. Ouellet. 2011. Foraging strategies by omnivores: are black bears actively searching for ungulate neonates or are they simply opportunistic predators? Ecography 34: 588-596.

Bastille-Rousseau, G., J.R. Potts, M.A. Lewis, E.H. Ellington, N.D. Rayl, S.P. Mahoney, T.K. Fuller, J.F. Organ, J.A. Schaefer, and D.L. Murray. 2015. Unveiling trade-offs in resource selection of migratory caribou using a mechanistic movement model of availability. Ecography 38: 1-11.

Ellington, E. H., Bastille-Rousseau, G., Austin, C., Landolt, K. N., Pond, B. A., Rees, E. E., Robar, N. and Murray, D. L. 2014. Using multiple imputation to estimate missing data in meta-regression. Methods in Ecology and Evolution 6:153-163.

Hebert, I. and R.B. Weladji. 2013. The use of coniferous forests and cutovers by Newfoundland woodland caribou. Forest Ecology and Management 291: 318-325.

Mahoney, S.P., J.N. Weir, J.G. Luther, J.A. Schaefer, and S.F. Morrison. 2011. Morphological change in Newfoundland caribou: Effects of abundance and climate. Rangifer 31: 21-34.

Mumma, M. A., Zieminski, C., Fuller, T. K., Mahoney, S. P., and Waits, L. P. 2015. Evaluating noninvasive genetic sampling techniques to estimate large carnivore abundance. Molecular Ecology Resources 15:1133–1144.

Mumma, M.A., C.E. Soulliere, S.P. Mahoney, and L.P. Waits. 2013. Enhanced understanding of predator–prey relationships using molecular methods to identify predator species, individual and sex. Molecular Ecology Resources14:100-8.

Rayl, N.D., T.K. Fuller, J.F. Organ, J.E. McDonald, Jr., R.D. Otto, G. Bastille-Rousseau, C.E. Soulliere, and S.P. Mahoney. 2015. Spatiotemporal variation in the distribution of potential predators of a resource pulse: black bears and caribou calves in Newfoundland. Journal of Wildlife Management 79(7):1041-1050.

Rayl, N.D., T.K. Fuller, J.F. Organ, J.E. McDonald, S.P. Mahoney, C.E. Soulliere, S.E. Gullage, T. Hodder, F. Norman, T. Porter, G. Bastille-Rousseau, J.A. Schaefer and D.L. Murray. 2014. Mapping the distribution of a prey resource: neonate caribou in Newfoundland. Journal of Mammalogy 95: 328-339.

Rayl, N.D., T.K. Fuller, J.F. Organ, J.E. McDonald, R.D. Otto, and S.P. Mahoney. 2014. Den abandonment and transitional day bed use by black bears (Ursus americanus) in Newfoundland. Wildlife Biology 20: 222-228.

Saunders, P.W. 2013. Delineation of landcover boundaries in areas used or avoided by female woodland caribou (Rangifer tarandus caribou) using publicly available spatial datasets. Wildlife Biology in Practice 9: 40-62.

Schaefer, J.A. and S.P. Mahoney. 2013. Spatial dynamics of the rise and fall of caribou (Rangifer tarandus) in Newfoundland. Canadian Journal of Zoology 91: 767-774.

OTHER REPORTS

Title and Report Type	Year
Predator control literature review. Wildlife Division internal report	2008
Effects of sample size on home range delineation for woodland caribou (Rangifer tarandus caribou) in Gaff Topsails, NL. Wildlife Division internal report.	2009
Bias inherent in the current caribou classification protocol and suggestions for their elimination. Wildlife Division internal report.	2009
Review of predator reduction, removal and control methods and recommendations for experimental reduction of predation pressure on caribou calves in Newfoundland, Canada. SDSS internal report.	2009
Body condition of Newfoundland's woodland caribou: A factor in current population declines? Wildlife Division internal report.	2009
Object-oriented classification used to determine landscape utilization of woodland caribou (Rangifer tarandus caribou) in Gaff Topsails, Newfoundland. Wildlife Division internal report.	2011
Caribou Distribution on the Island of Newfoundland. Wildlife Division internal report.	2011
Summary and interpretation of demographic and hunter trends for Newfoundland caribou. Caribou Data Synthesis Report (SDSS).	2014

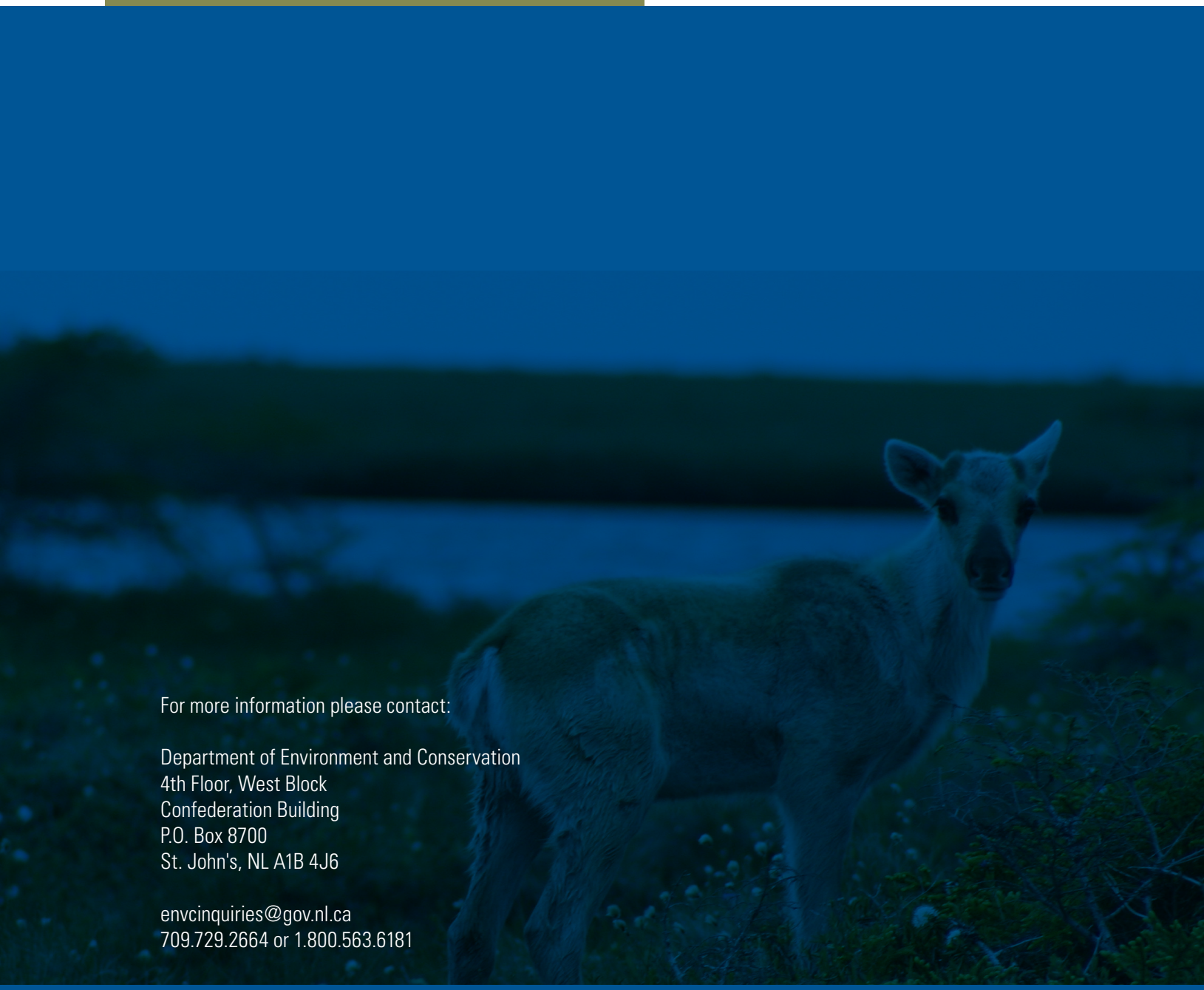
ASSOCIATED GRADUATE STUDENT RESEARCH PROJECTS

Copies of thesis and dissertation reports can be obtained through inter-library loan requests or by contacting IBES, SDSS or Wildlife Division as appropriate. Please note that at the time of

printing, not all graduate projects were complete, thus some theses may not be available immediately.

Name	Project	Degree	School
IBES Supported Graduate Projects			
(SDSS sponsored; varying additional support through SCIF funding, school-provided stipends, teaching and research assistantships , awards and/or merit scholarship)			
Guillaume Bastille–Rousseau	Caribou-habitat interactions in Newfoundland	Ph.D.	Trent University
Hance Ellington	The role of coyotes in caribou population dynamics in Newfoundland	Ph.D.	Trent University
Matthew Mumma	Determination of the population size and density, genetic diversity and structure, and predation habits of Newfoundland caribou calf predators	Ph.D.	University of Idaho
Nathaniel Rayl	Black bear spatial ecology in Newfoundland	Ph.D.	University of Massachusetts
Hannah Barron	The sequential dependence of habitat selection by caribou in Newfoundland	M.Sc.	Trent University
Beke Brinkman	The effects of hydroelectric corridors on Newfoundland caribou (Rangifer tarandus) distributions	M.Sc.	Trent University
Daniella Dekelaita	An examination of shifting caribou calving habitat in Newfoundland	M.S.	University of Montana
Douglas MacNearney	Review of habitat selection by caribou occupying Gros Morne National Park	M.Sc.F.	Lakehead University
Nathaniel Rayl	Use of caribou calving areas by black bears in Newfoundland	M.S.	University of Massachusetts
Maggie Sutherland	Human dimensions of black bears, caribou and coyotes on the island portion of Newfoundland and Labrador	M.Sc.	Memorial University of Newfoundland
Lindsey Webb	Use of clearcut forests by female and calf caribou on the Northern peninsula during calving and post-calving periods	M.S.	University of Montana
Christopher Zieminski	Spring and summer feeding habits of black bear, coyote and lynx in Newfoundland	M.S.	University of Massachusetts

Name	Project	Degree	School
Hugh Gilroy	Landscape attributes at mortality sites of predator-killed caribou calves in Newfoundland	B.Sc.	University of York, U.K.
Lena Jeha	Comparing field and veterinarian identification of predation on Newfoundland caribou calves	B.Sc.	University of York, U.K.
Stephen Mahant	Effects of snowmobile trails on caribou habitat selection	B.Sc.	Trent University
Genevieve Pugesek	Genetic evaluation of diversionary feeding on black bear predation of caribou calves	B.Sc.	University of Idaho
Megan Sadler	Spatial dispersion of Newfoundland caribou calves in relationship to timing and patterns of mortality	B.Sc.	University of York, U.K.
Catherine Sugden	Morphometrics of Newfoundland caribou calves in relationship to timing and patterns of mortality	B.Sc.	University of York, U.K.
SDSS / School Partnership Supported Projects			
Kathy Unger	Responses of Newfoundland caribou to visual cues of predation threat	M.Sc.	Memorial University of Newfoundland
Sydney Worthman	Vigilance and curiosity displayed by Newfoundland caribou in response to visual threat	B.Sc.	Memorial University of Newfoundland
Wildlife Division / School Partnership Supported Projects			
Courtney Drover	A re-evaluation of the status of brain worm in the caribou herds on the Avalon peninsula	M.Env. Sc.	Memorial University of Newfoundland
Isaac Hebert	Habitat preferences of Newfoundland caribou across range components and scales: implications for management.	M.Sc.	Concordia University
Sara McCarthy	The influence of landscape composition and configuration on Newfoundland caribou recruitment	M.Sc.	Concordia University
Paul Saunders	Delineation of land-cover boundaries in calving and post-calving ranges	M.Sc.	Manchester Metropolitan University



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