First scientific data on herd size and population dynamics of the Torngat Mountains caribou herd.

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Torngat Joint Fisheries Board
Torngat Wildlife and Plants Co-Management Board
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Torngat Wildlife, Plants and Fisheries Secretariat

The primary responsibilities of the Torngat Wildlife and Plants Co-management Board and the Torngat Joint Fisheries Board are to establish total allowable harvests for non-migratory species of wildlife and for plants, recommend conservation and management measures for wildlife, plants, and habitat in the Labrador Inuit Settlement Area (LISA) and to make recommendations in relation to the conservation of species, stocks of fish, aquatic plants, fish habitat, and the management of fisheries in the Labrador Inuit Settlement Area.

The Secretariat is the implementation agent of the Torngat Joint Fisheries Board and the Torngat Wildlife and Plants Co-Management Board. The Secretariat is a team of professionals based in Happy Valley-Goose Bay that provide financial management, logistical, project management and analytical support to both boards.

Torngat Omajunik, Piguttunik Oganniaganillu Suliangit

Suliagigumajangit Torngat Omajunik, Piguttunillu AulatsiKatigengita AngajukKauKatigengit ammalu Torngat Ikajuttiget Oganniatuligijingita AngajukKauKatigengit sakKititsigiamut pijaugunnatunik katillugit aullaigatsatagiamut nokataKattangitunik omajunik ammalu piguttunik, uKautjigiajut asikKitailigiamut ammalu aulatsigiamut omajunik, piguttunik, ammalu inigiKattajanginnik Labradorimi Inuit Satusasimajanginni Nunani (LISA) ammalu uKautjigiagutinik ilingajunik asikKitailigiamut omajunik, oganniaganik, piguttunik, oganik, ammalu aulatsigiamut oganniaganik Labradorimi Inuit Satusasimajanginni Nunani.

SuliaKattet atuliaKititsigumajut kiggatuttinganik Torngat Ikajuttiget Oganniatuligijingita AngajukKauKatigenginnik ammalu Torngat Omajuligijinginnik Piguttunillu AulatsiKattajut AngajukKauKatigenginnik, sunatuinnanik, suliatsanik aulatsigiamut ammalu ikajutsitaullutik tamâginnut angajukKauKatigenut.

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Executive Summary

Inuit of Nunavik and Nunatsiavut have known for decades that a small caribou population was living year-round in the Torngat Mountains region. It was their “local” caribou as opposed to the migratory caribou belonging to the George River herd that visited the Torngat Mountains for part of the year. Few scientific studies have been completed on Torngat caribou and it was only recently that biologists recognized the Torngat Mountains caribou herd as distinct. Recognizing its unique status, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) identified the Torngat caribou as one of eleven living Designatable Units for caribou conservation across Canada. This recognition emphasises the importance of properly managing and conserving this significant component of biodiversity in Canada.

The need for more information about the Torngat caribou has been discussed by stakeholders for many years and a technical committee formed in 2013 to address research needs. This committee is comprised of representatives from the Government of Quebec, the Government of Newfoundland & Labrador, the Nunatsiavut Government, Makivik Corporation, Nunavik Parks, Parks Canada, and Torngat Wildlife, Plants and Fisheries Secretariat (on behalf of the Torngat Wildlife and Plants Co-management Board, hereafter the Secretariat). The Secretariat received funding from the federal Department of Aboriginal Affairs and Northern Development to conduct a population census of the Torngat caribou herd. A helicopter census was then performed in March 2014 and this report presents results of the first census ever completed on this caribou herd. A novel census technique based on distance sampling was executed along line transects flown at slow speed and low altitude. Moreover, as there were radio-collars on caribou at the time of the census, it was also possible to use Lincoln-Petersen method to estimate herd size.

Four observers recorded caribou groups and other mammal species seen on a total of 81 transects spaced 4 kilometres apart. Weather conditions and visibility were excellent during flying days. Total transect length was 7,057 kilometres and census area covered 30,689 km^2 between Okak Bay and Killiniq Island. One pack of three wolves and relatively few wolf tracks were recorded, eleven polar bears were seen and there were numerous observations of red fox. Fifty caribou groups were observed on-transect for a total of 269 caribou. Group size varied from 1 to 18 caribou. Recruitment was good with calves representing 17.2% of the herd. No caribou were observed south of Hebron Fjord, while most of the groups were seen north of Nachvak Fjord. The main census method using distance sampling gave a herd size estimate of 930 caribou with a confidence interval ranging from 616 to 1453. The Lincoln-Petersen method provided similar herd size estimates. Annual survival rate were estimated from radio-collared caribou. Although sample sizes were small, most annual survival rates were so low that they were likely associated with a declining population. Since 2011, hunting mortality seems to be higher than natural mortality.

AngajukKaunet Naillitisimajanga

Inuit Nunavimmiut Nunatsiavummilu Kaujimasimalittut jârigiallatânut ikittuit tuktuit tamâneKattaninginnik jâri nâdlugu Tornat KakKasuanginni. Taikkua "ininga" tuktuit asingititut ingiggaKattajuttitut tukuit kangiqsualujjuamiut aiKattamata Torngat KakKasuanginnut ilangani jârimi. Ikittut Kaujisanniusimajut pijagettausimalittut Torngat tuktunginnik ammalu mânnaKamik omajuligijet Kaujisimajut Torngat KakKasuanginni tuktuit adjiungininginnik. Kaujijaudlutik piusingit, katimajet Kanuilingausinginnik Ulugianattumejut Omajuit Canadami (COSEWIC) ulinnaitausimajut Torngat tuktungit ilangiuningit ailfanit omajunik Ulugianattumeningit tuktuit asikKitailigiangit ilonnâni Canadami. Tamanna Kaujijausimajuk uKautausimajuk pimmagiuninga kamagijautsiagiaKanningit asikKitailillugillu omajoningit Canadami.

KaujisajaugiaKanningit Torngat tuktungit uKâlautausimalittut ilauKatigejunut unuttuni jâriusimalittuni ammalu uKumaittunik katimajet âkKitaumajut 2013-mi kamagiamut Kaujisannisamut pigumajaujunik. Tâkkua katimajet ilauttisivut kiggatuttinik pisimajunik kavamanganit Quebec, kavamanganit Newfoundland Labradoriullu, Nunatsiavut kavamanganit, Makivikkunit, Nunavik SilakKijattuligijinginnit, Torngat Omajuligijinginnit, Piguttunik Oganniaganillu AngajukKauninginnit (kiggatudlutik Torngat Omajuligijinginnik Piguttunik AulatsiKatigenginnit AngajukKauKatigenit, taijaujut AngajukKaunet). AngajukKaunet tikitausimajut kenaujanik pisimajunik federal SuliaKapvinganit NunaKakKâsimajunik kamajinginnit kititsigiagiamut Torngat tuktunginnik. Kulimigok kititsisimalauttuk Mertz 2014-mi ammalu una Kaujititsiutik takutitsijuk sivullipâmi kititsinik pijagettausimaninganik tuktunik. Allatausimajut kamagidlugit Kaningitomejut ottugadlugit akKutinginni tingidlutik sukkaitumik ammalu pukkitoKattadlutik. Ammalu, Kungasimiutalet tuktuit taitsumani kititaudlutik, atugunnalaummijut Lincoln-Petersen atuKattatanginnik Katsiumangâta kititsidlutik tuktuninga Kanuk angitigimmangâta.

Sitamait ilauKatausimajut allasimajut tuktunik katingajunik ammalu asinginnik omajunik takujaminik katidlugit 81 akKutimesimajut 4 kilometresinik avittusimadlutik. Silak kamagidlugu ammalu takugunnaningit piujummagiulauttut tingigalagiamik. katidlugit takiniKasimajut 7,057 kilometresinik ammalu kittitaudlutik Kaningitigijumit 30,689 km² akungani OKak ammalu Killiniq. katingajuit pingasuit amaguit ammalu ikittunik tumitsidlutik allatausimajut, ailfanik nanunnik takudlutik ammalu unuttunik takuKattadlutik kajunik tigigannianik. 50 tuktuit katingajut takujausimajut akKutinginni katidlugit 269 tuktuit. katingajut ununningit adjigengitoKattalauttut atautsimit 18-nanut tuktuit. Tuktunik takusimangitut siKingani Hebron, ununningit takujauKattadlutik taggâni Nachvak. kititausimajut atudlutik Kaningitumi ottugautinik takusimajut tuktuit adjigenginingit anginingit 930 tuktuit akKutinginni 616-nanit 1453-nut. Lincoln-Petersen kitisiutik takutitsigunnasimavuk Kanuk angitigimmangâta tuktuit. Jâimi omanigiKattajangit uKautausimajut Kungasimmiutanginnit tuktuit. Ilangit mikijolaugaluattilugit, ununningit omasimajut ikittotillugit takutsait ikillivallialinningit kititangit. Taimanganit 2011-minit, omajunniatauKattajut tuKuKattavut ununnisaudlutik tuKuinnaKattajunit.

Sommaire

Les Inuit du Nunavik et du Nunatsiavut savaient depuis longtemps qu'une petite population de caribous vivait à l'année longue dans les Monts Torngat. C'était leur caribou « local » par opposition au caribou migrateur du troupeau de la Rivière George qui visitait ces montagnes une partie de l'année. Peu d'études scientifiques ont été réalisées sur le caribou des Torngat et ce n'est que récemment que les biologistes ont reconnu son caractère distinct. Le Comité sur la situation des espèces en péril au Canada (COSEPAC) a identifié le caribou des Torngat comme l'une des 11 unités désignables du caribou au Canada. Cette reconnaissance illustre l'importance d'une gestion adéquate afin de conserver cette composante significative de la biodiversité au Canada.

Le besoin d'acquisition de connaissances sur le caribou des Torngat a été depuis longtemps au coeur des discussions des parties intéressées et le Comité sur le caribou des Torngat fut créé en 2013. Le Comité regroupe divers organismes : Gouvernement du Québec, Gouvernement de Terre-Neuve et Labrador, Gouvernement du Nunatsiavut, Société Makivik, Parcs Nunavik, Parcs Canada et Torngat Wildlife, Plants and Fisheries Secretariat (représente le Torngat, Wildlife and Plants Co-management Board, ci-après le Secrétariat). Le Secrétariat a reçu une subvention du ministère fédéral des Affaires autochtones et Développement du Nord afin de réaliser un inventaire du troupeau des Torngat. Un inventaire en hélicoptère a donc été réalisé en mars 2014 et ce rapport fait état des résultats de ce premier inventaire réalisé sur ce troupeau. Une technique d'inventaire innovatrice basée sur l'échantillonnage par distance a été appliquée sur des transects aériens survolés à vitesse et altitude réduites. De plus, comme il y avait des caribous munis de colliers radio-émetteurs au moment de l'inventaire, ce fut aussi possible d'utiliser la méthode Lincoln-Petersen pour estimer la taille du troupeau.

Quatre observateurs ont noté les caribous et autres mammifères rencontrés sur un total de 81 transects espacés de quatre kilomètres. Les conditions météorologiques et la visibilité ont été excellentes durant les jours de vol. La longueur totale des transects a atteint 7 057 kilomètres et l'aire d'inventaire a couvert 30 689 km^2 entre Okak Bay et Killiniq Island. Quelques traces et une meute de trois loups ont été notées durant l'inventaire alors que les observations de renard roux ont été fort nombreuses et que 11 ours blancs ont été vus. Ce furent 50 groupes totalisant 269 caribous qui ont été observés sur les transects. La taille des groupes a varié entre un et 18 caribous. Le recrutement était moyen alors que les faons représentaient 17,2 % de la population. Aucun caribou n'a été observé au sud de Hebron Fjord alors que la majorité a été observée au nord de Nachvak Fjord. La méthode principale d'inventaire a fourni une estimation de 930 caribous avec un intervalle de confiance compris entre 616 et 1453. La méthode Lincoln-Petersen a produit des estimations similaires. La survie des adultes a été estimée grâce aux caribous munis de colliers radio-émetteurs. Malgré que le nombre de colliers était limité, il apparaît que la majorité des taux annuels de survie étaient si faibles que cela suggère une population en déclin. Depuis 2011, il semble que la mortalité par la chasse soit supérieure à la mortalité naturelle.

1. Introduction

Across its circumpolar range, *Rangifer tarandus* exhibits tremendous variations in morphology, ecology and behaviour and is the most variable of the Cervidae (deer) family (Geist 1998). *Rangifer tarandus* is the scientific name given by biologists to describe caribou in North America but also reindeer in Eurasia. Because *Rangifer* are so variable across their range it has been difficult to categorize them, which is essential for management and conservation actions. In fact, the caribou taxonomy and sub-species designation proposed by Banfield (1961) are invalid particularly for caribou in eastern Canada (Geist 1998). Banfield's (1961) subspecies, although often quoted as the de facto *Rangifer* subspecies categorizations, did not consider genetic difference, life history and behavioural differences. Instead of relying on such arguable subspecies designations, Bergerud (1988) proposed the use of ecotypes to categorize caribou for management and conservation. Three main ecotypes of caribou are described: sedentary (also called forest-dwelling, woodland or boreal caribou); migratory (also called barren-ground or tundra caribou); and montane.

The sedentary caribou live at low population densities in the boreal forest and remains south of the treeline year-round. They exhibit seasonal movements (~10-100s km), and disperse or "space out" from conspecifics at calving to reduce calf predation risks. The migratory ecotype lives at high population densities, undertakes large-scale seasonal migrations (~1,000s km) between boreal forest and tundra, aggregates on distinct calving ranges on the tundra, and "space-away" to reduce calf predation risk. In northern Quebec and Labrador, two migratory caribou herds are found: the Leaf River herd roaming in the northwest region and the George River herd living in the northeast portion of the peninsula (Bergerud et al. 2008). In the last two decades, the George River herd experienced one of the largest ungulate population crash ever recorded in the world declining from 776,000 caribou in 1993 (Couturier et al. 1996), to 385,000 caribou in 2001 (Couturier et al. 2004), to 76,000 in 2010, 27,600 in 2012 and 14,200 in 2014 (QC Government and NL Government, unpubl. data).

The montane ecotype applies to those small caribou populations whose annual migrations are altitudinal (i.e., from low to high altitudes between seasons to avoid predation and facilitate foraging). Inuit of Nunavik and Nunatsiavut have known for decades that a small caribou population was living year-round in the Torngat Mountains region. It was their "local" caribou as opposed to the migratory caribou belonging to the George River herd that visit the Torngat Mountains for part of the year. It was only recently that biologists recognized the Torngat Mountains caribou herd (hereafter Torngat caribou) as distinct based on space use monitoring by radio-telemetry (Schaefer and Luttich 1998; Couturier, S., QC Government and Makivik Corporation, unpubl. data), genetic analysis (Boulet et al. 2007), and morphological and behavioural (movement rate) criteria (Couturier et al. 2010). The Torngat caribou belong to the montane ecotype and along with the Gaspésie caribou herd in southeastern Québec (St-Laurent et al. 2009), are the only montane caribou found east of the Rockies. Because these three ecotypes differ greatly in their ecology and behaviour, their monitoring and management techniques may also vary.

Identification of significant conservation units represents the first step in biodiversity conservation. Up to 2004, eight "nationally significant populations" for caribou were identified by the Committee on the status of endangered wildlife in Canada (COSEWIC) on a case by case basis to fulfill and prioritize conservation needs. More recently, an extensive multi-criteria analysis was completed by COSEWIC (2011) to define the Designatable Units (DU) to establish long-term biological foundations for the conservation of caribou in Canada. By establishing DU in advance, conservation efforts can be directly targeted towards assessment status instead of DUs recognition. COSEWIC (2011) established 12 DUs (including one extinct) for caribou in Canada (Figure 1) based on scientific criteria and five lines of evidence: (1) phylogenetics, (2) genetic diversity and structure, (3) morphology, (4) movements, behaviour, and life history strategies, and (5) distribution. DU designations were assessed on multiple lines of evidence and the majority of the 12 DUs met at least two criteria each for discreteness and significance. Recognizing its unique status, COSEWIC (2011) identified Torngat caribou as one of eleven living DU in caribou conservation across Canada (Figure 1). This recognition emphasises the importance of properly managing and conserving this significant component of biodiversity in Canada. Both governments and users must value the Torngat caribou and ensure that their long-term conservation is guaranteed.

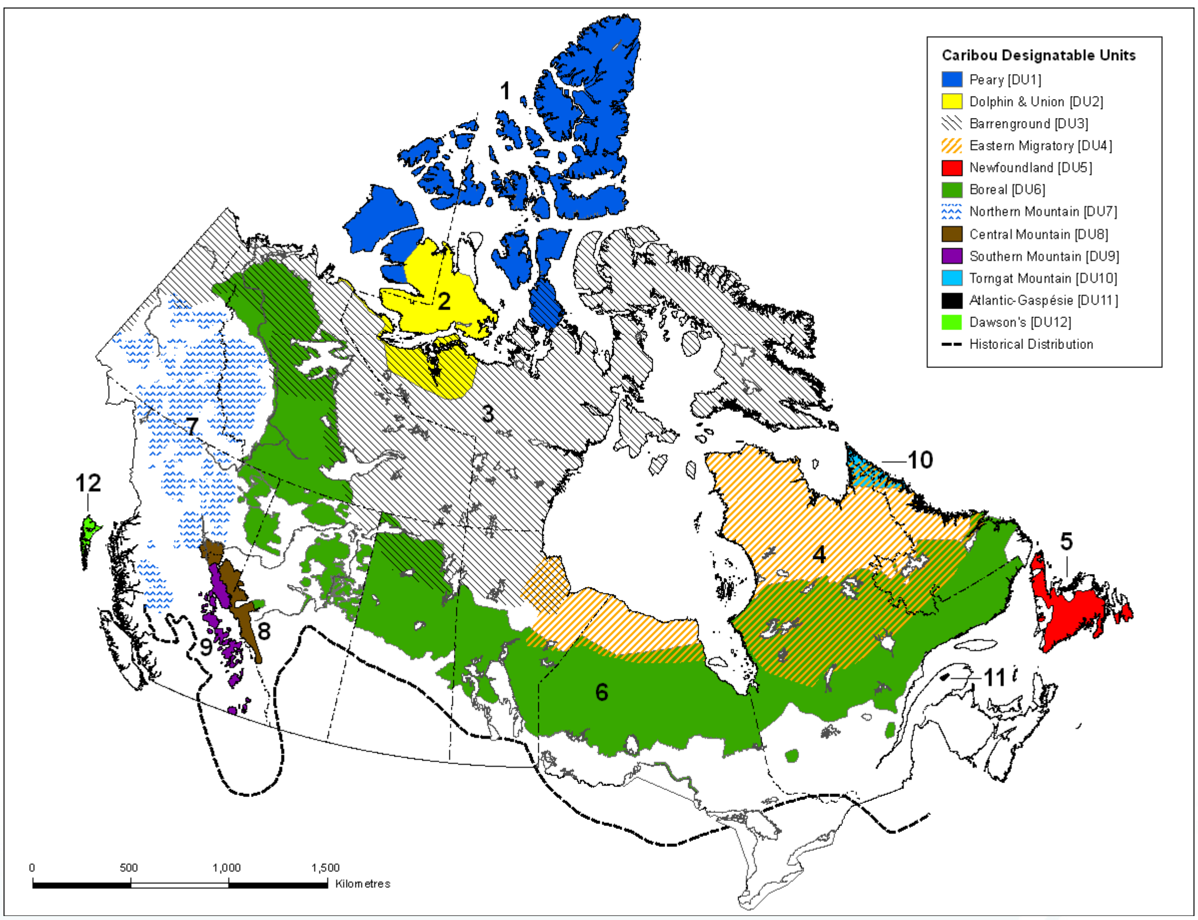


Figure 1. Designatable units (DUs) of conservation for caribou in Canada as adopted by COSEWIC. Source: COSEWIC (2011).

Few scientific studies have been completed on Torngat caribou. Herd space use has been partly described for the period 1988-1997 (Schaefer and Luttich 1998) and for the period 1997-1999 (Couturier, S., QC Government and Makivik Corporation, unpubl. data). Since 2011, a satellite radio-tracking study has contributed significantly to our understanding of this herd. The information collected during these projects prove to be essential for management and have confirmed that although range overlap may occur with the neighbouring George River herd, Torngat caribou are associated year-round with the alpine habitat found in the Torngat Mountains. These mountains are part of the Arctic Cordillera ecozone which extends North to Devon and Ellesmere islands in Canada's High Arctic. The harsh ecological conditions and the elevation gradients in the Torngat Mountains likely contribute to the distinctiveness of the Torngat caribou.

Regarding the herd size and population dynamics, little information exists and no systematic census was ever undertaken. It is hard to determine how many caribou were present in the Torngat herd historically and the situation is complicated by seasonal range overlap with the George River herd during previous decades. When this large migratory herd was near its peak level, a calving census in June 1993 confirmed the presence of thousands of migratory females during calving in the Torngat Mountains as far north as Abluviak Fjord (Couturier et al. 1996, see their Fig. 2). From a distance, it is difficult or impossible for caribou biologists or hunters to distinguish George River caribou from Torngat caribou. Hence, even local information collected by Aboriginal knowledge-holders or biologists can be misleading about the abundance of Torngat caribou. In a meeting with users (February 1997, Kangiqsualujjuaq), Inuit knowledge-holders reported that it was impossible in the field to discriminate George River from Torngat caribou (Couturier, S., unpubl. data). In that context, rare information about the number of caribou in the Torngat herd is found in Bélanger and Le Henaff (1985):

> *"In 1980, a reconnaissance survey indicated that the herd contained approximately 5,000 individuals. Although little information is available, it would seem that a group other than that of the George River is involved here."*

Both caribou biologists and users agree that there is a lack of information on Torngat caribou but most observers believe that Torngat caribou are less abundant than before. Mortality of radio-collared caribou, including those lost through hunting, was very high during a preliminary collaring project between 1997 and 1999 (Couturier, S., QC Government and Makivik Corporation, unpubl. data). The four radio-collared females lived an average of 338 days before dying from predation (n= 2) or hunting (n= 2). Mortality from natural cause and from hunting was also high during the current collaring project that started in 2011. This information on heavy mortality of radio-collared caribou suggests that the herd could have been declining in the last two decades which requires further investigation.

One of the most important steps in the process of wildlife management is to estimate the animal population size. It is particularly crucial when wildlife species are harvested and when Aboriginal people depend on the resource. However, it may be difficult to get precise and unbiased estimates of wildlife population size. Most wildlife populations are managed based on population size estimates obtained from sampling. In North America, most moose (*Alces alces*), white-tailed deer (*Odocoileus virginianus*) and caribou populations are estimated with various sampling designs adapted to ecological differences among species or ecotypes and tailored to landscape conditions of the species range. Migratory caribou herd size in Quebec-Labrador was estimated from photo-sampling of calving females on their calving grounds in the 1980s and early 1990s (Couturier et al. 1996) and from photo-census of the dense aggregations in summer following insect harassment since the early 1990s (Russell et al. 1996; Rivest et al. 1998; Couturier et al. 2004) and until recently (QC Government, NL Government, 2010-2014, unpubl. data). In each of these methods, it was impossible to have a complete coverage of the range used by migratory caribou and herd size estimation depended on sampling. The Torngat caribou herd belongs to the montane ecotype and do not aggregate on traditional calving grounds like the George River herd. As well, the Torngat caribou do not aggregate following insect harassment in the summer as migratory ecotype do. Instead, they depend on different strategies, including moving in altitude or using snow patches to cope with insects. This was confirmed during a reconnaissance flight conducted in the Torngat Mountains in July 2013 (Nash 2013). The insect avoidance strategy of the montane ecotype is more individually centred while the migratory caribou use a more group-oriented behaviour. In combination, these differences explain why it is impossible to use census methods developed for the migratory ecotype on Torngat caribou.

The need for more information about the population dynamics of the Torngat Mountains caribou herd was discussed within the Torngat Caribou Committee (hereafter the Torngat Committee) in the last few years. This committee is comprised of representatives from Quebec Government, Newfoundland & Labrador Government, Nunatsiavut Government, Makivik Corporation, Nunavik Parks, Parks Canada, and Torngat Wildlife, Plants and Fisheries Secretariat (hereafter the Torngat Secretariat). On several occasions the Committee discussed the need for a survey design that would be scientifically sound, would fit the timeframe and budget available, and would meet the objectives of all the Torngat Committee members. In 2013-2014 fiscal year, the Secretariat received funding from the federal Department of Aboriginal Affairs and Northern Development to conduct a population census of the Torngat Mountains caribou herd. A census project was then proposed (Couturier et al. 2013) and later accepted by the Committee in December 2013. The census procedure was applicable in winter to the special ecological and landscape context of the Torngat caribou. It was then proposed to use two independent census methods during an aerial survey in March 2014. The first main method involved aerial line-transect distance sampling (Buckland et al. 2001, 2004) while the second complementary method relied on the Lincoln-Petersen technique (White and Garrott 1990) to estimate herd size. During the planning and field program of the census, it was also possible to collect and analyse some demographic data like survival rate, recruitment and adult sex-ratio, to investigate further population dynamics of this unique herd. An aerial census was performed in March 2014 and this report presents some population dynamics findings as well as the results of the first census ever done on this caribou population.

2. Methods

An aerial survey was completed over the annual range of the Torngat Mountains caribou herd in March 2014 using a Bell Long Ranger helicopter chartered from Universal Helicopters Newfoundland and Labrador Limited Partnership based in Happy Valley-Goose Bay, NL.

2.1 Distance sampling

The main census method is based on distance sampling which is briefly described below.

2.1.1 Distance sampling: an overview

Distance sampling is an extensively used method for estimating the density and abundance of wildlife. The main method is based on collecting field observations from line transects and uses analytical techniques that correct for imperfect detection of animals during census (Buckland et al. 2001). This method is very similar to the traditional fixed strip window survey technique except that the perpendicular distance from the survey line to the animals is recorded and the strip survey width is not fixed but theoretically infinite (Buckland et al. 2001, 2004). This sampling technique has been used successfully for an assortment of taxa, including trees, amphibians, birds, fish, and mammals (Buckland et al. 2001, 2004; Marques et al. 2006, 2007; Williams and Thomas 2009). Recently, distance sampling has been used during caribou census on southern Baffin Island (Jenkins et al. 2013) and on the island of Newfoundland (Fifield et al. 2012). This technique was also used on Peary caribou and muskoxen in the High Arctic, Nunavut (Jenkins 2007, 2008, 2009; Jenkins et al. 2011). However, the application of this census technique on large mammals in Quebec and Labrador was novel.

Line-transect distance sampling is based on a number of parameters including sampling effort, the number of wildlife observations detected from the transect line, the size of the group or cluster of animals detected, and the distance of each observation away from the transect line. Intuitively, one would expect that it is easier to see objects closer to the line and that animals become harder to detect with increasing distance. The method assumes that all animals located directly on transect are detected and that the probability of visual detection diminishes as the distance from transect increases. Based on this and an assumption of uniform distribution, distance sampling analysis estimates density and abundance of animal populations using these parameters while correcting for missed animals by fitting a detection function to the observed distances (Buckland et al. 2001). In this way, distance sampling is superior to traditional strip sampling which assumes 100% detection within the strip.

Fifield et al. (2012) successfully used distance sampling for the first time in a census of a caribou herd on the island of Newfoundland. They presented a list of advantages for distance sampling over fixed strip transect survey or total counts:

• In Total Count or Strip Transect Surveys, some animals are inevitably missed and it is usually difficult to estimate how many were missed. Both methods assume 100% detection.
• Distance sampling corrects for missed animals and is cost effective.
• Distance sampling provides an absolute estimate with confidence intervals whereas total counts provides a value with no measures of confidence.
• Double counting is allowed in distance sampling when transects overlap which may occur during census due to weather related problems for example.
• Difference in observer ability, type of aircrafts, landscape configuration, transect orientation and other covariates can be statistically controlled for while this can create problems with strip transect surveys.

The three main assumptions of distance sampling (Thomas et al. 2010, p. 6) are identified below and addressed through our census design and analysis:

1. All animals directly on the transect are detected.
2. Animal do not move in response to the observer before they can be detected or animal movement is slow relative to the observer movement.
3. Distances are measured accurately.

2.1.2 Distance sampling: data analysis

Most of the analytical techniques related to distance sampling were completed using Distance software. Specifically, density and abundance were estimated using the program Distance 6.2 Release 1 which is free and available on-line (Thomas et al. 2010; see also http://distancesampling.org). Following instructions given in the User's Guide (RUWPA 2014), the program Distance 6.2 was used to model the detection function and estimate the density of caribou using Conventional Distance Sampling (CDS) and Multi-Covariate Distance Sampling (MCDS) techniques. The detection function models (key function/series expansion) recommended by Buckland et al. (2001) and Thomas et al. (2010) were used to analyze the data and selection of models was based on Akaike information criterion (AIC). Moreover, parsimonious models were accepted only if the fitting was good as estimated from visual examination of the quantile-quantile (Q-Q) distribution function plots and from probability values for goodness of fit tests: Chi^2, Kolmogorov-Smirnov (K-S), and Cramer-von Mises (C-v-M) (Buckland et al. 2001, 2004). The last two tests are available because exact perpendicular distances (not rounding approximations by intervals) were collected during this census. During both CDS and MCDS analysis, the default selection method for the adjustments term was selected. However, it was set to a maximum of five terms for CDS and two terms for MCDS analysis.

We derived density estimates from line-transect data and detection function models as recommended by Buckland et al. (2001) and Thomas et al. (2010). Readers can consult these keynote references for more information on model selection and density estimation. For all distance sampling parameters and estimates, the notation presented in Distance 6.2 was applied in this report where:

n= Numbers of caribou groups detected during the census
W= Width of line transect (highest distance recorded during census)
L= Total length of census transects
ESW: Effective strip width (ESW= W*p)
p: Probability of detecting a caribou group during the census
E (S)= Caribou group size estimated by Distance using regression
ER: Encounter rate (ER= n/L)
D: Estimate of density of caribou per km^2
CV: Coefficient of variation

2.2 Study area and survey design

The study area includes the Labrador Peninsula which straddles the Torngat Mountains between northern Labrador in Nunatsiavut and northeastern Quebec in Nunavik (58°30′N-60°20′N; 62°W-66°W). The area covers the annual range of the Torngat caribou and was delineated from the recent satellite radio-collaring projects that started with deployment of ten collars in 2011, three collars in 2012 and an additional twenty-two in 2013 (Mitchell Foley, J., unpubl. data). The census area of about 30,000 km^2 was compared to Inuit Knowledge (IK) held by the Inuit of the region which confirmed recent late winter caribou distribution in the Torngat range (Wilson et al. 2014). Scientific data suggests a reduction in the Torngat caribou range since the 1990s and an increasing density from the south to the north (Schaefer and Luttich 1998; QC Gov. and NL Gov., unpubl. data). It was decided to efficiently prioritize the current range use in the proposed census design. However, it was also decided to extend southward the southern limit of the study area to include the region between Hebron Fjord and Okak Bay as this area has been used in the past following IK (Wilson et al. 2014) and scientific data (Schaefer and Luttich 1998).

Using a Geographical Information System (GIS) (ArcMap 10.0, www.esri.com), we designed a systematic line-transect aerial survey with a random starting location. Transect lines were oriented East-West (E-W) and positioned 4 km apart over the entire census area (Figure 2) for a total of 81 transects. All transects were flown and total transect length was measured in ArcMap 10.0 as the sum of the length of all transects. Survey lines run E-W from coast to coast across the Torngat mountains, and parallel to the valleys but perpendicular to expected caribou density gradients which satisfy statistical requirements (Buckland et al. 2001). This design provided a high number of transects, which is statistically meaningful when deriving an abundance estimate. Fifield et al. (2012) reported that at least 30-40 sample lines are required to adequately estimate sampling variances.

Our survey design is sufficient to assume randomization, efficient and unbiased sampling coverage and independent selection of transects (Buckland et al. 2001). It should also be noted that movements of Torngat caribou are limited in March and April (<1.5 km/week, QC Gov., unpubl. data) which decreases the likelihood of caribou movements from one transect to another during census period.

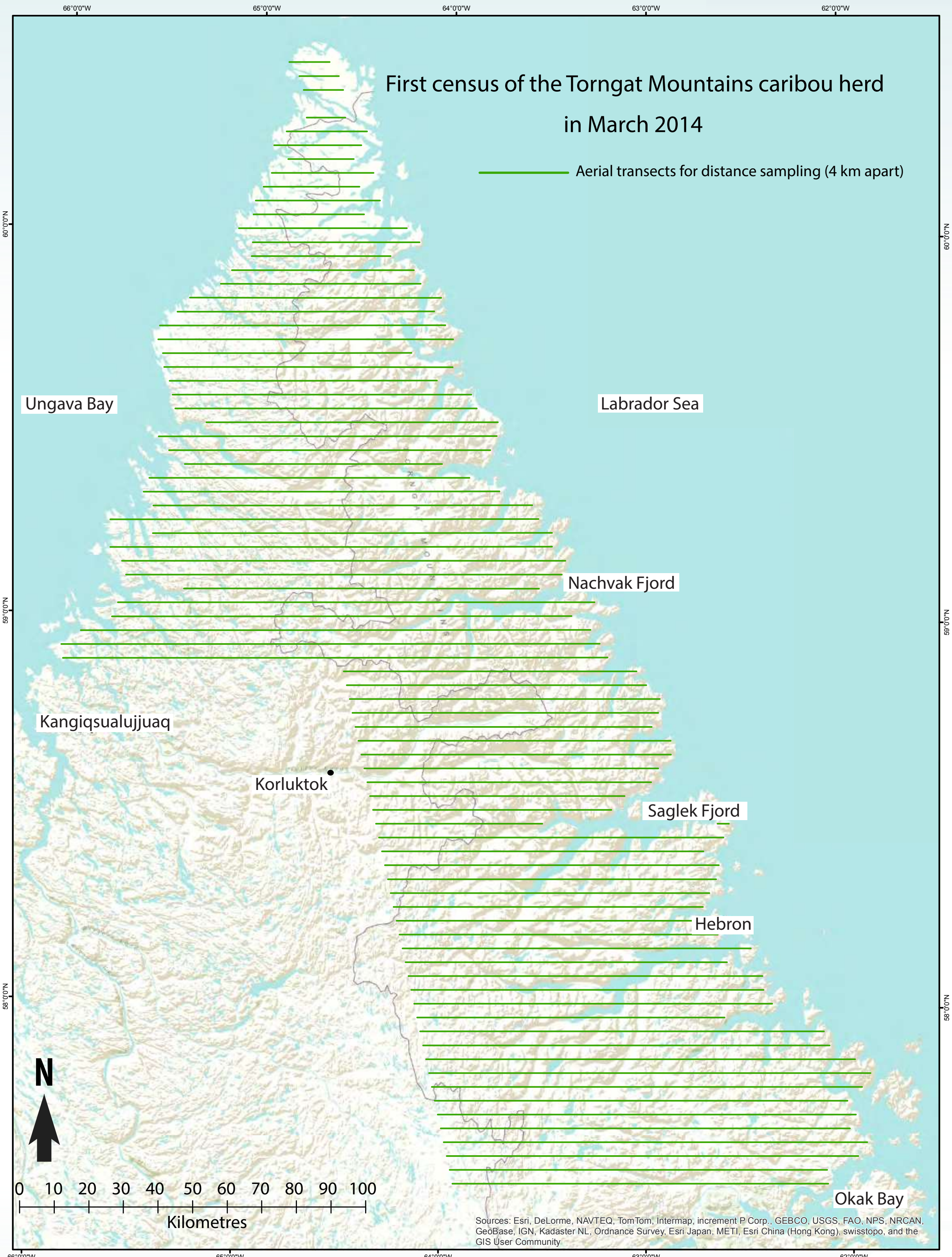


Figure 2. Census area and line transects (n= 81, spaced 4 km apart) flown during the first aerial census of Torngat Mountains caribou herd, March 2014.

2.3 Census implementation

The census team of four people (including the pilot) was based in two remote camps during most of the field work to save ferrying time to and from transects. The team was first based in Hebron Fjord cabin for seven days and second in the Korluktok camp for two days (Figure 1). During the rest of the census period, census team was based in Nunavik Park's house in Kangiqsualujjuaq (Appendix A). The helicopter company provide rear door bubble windows and set up a custom made system (i.e., flexible pipe) to keep them frost-free. The helicopter GPS (Garmin GPSMAP 276) received all positional data (transect, waypoints, etc.) and provided pilot with navigational information over transects. Throughout the survey, helicopter position data was automatically recorded on two other hand-held GPS units (Garmin GPS Map 62S) every 2 seconds to produce detailed track logs of each flight. For data safety, all spatial data was collected continuously and each day these data were copied to an external hard drive and the GPS memory cleared. Notably, it was also possible to follow census team progress in real time over the internet using an Iridium satellite tracking and messaging device (InReach SE, DeLorme, ME).

The aerial survey progressed systematically from the south to the north (Figure 2). Transects were flown at approximately 150 meters above ground level to provide efficient caribou detection. Following Jenkins et al. (2013), no a priori truncation width was set and the survey protocol allowed all detections of caribou to be recorded regardless of distance from the transect line. This approach maximizes sample size and permits truncation of the strip width if needed during post census data analysis.

To maximize detectability, ground speed was reduced to 150 km/h (about 80 knots) over transects. The helicopter acted as a single sampling platform (see Buckland et al. 2001), with four observers, including the pilot, searching for caribou. The observers remained the same and used the same seats during the entire census period.

Upon detection, all caribou clusters (a group of caribou 1 or greater in size) were approached to record locations with hand held GPS units and to count and classify caribou by sex and age. Specifically, the helicopter flew off-transect to the caribou and recorded their location with GPS. If the caribou moved during the approach, we collected the location where the animals were first seen using tracks in the snow. To ensure that no sections of the line were missed, the helicopter then circled back on transect line to continue the survey. The perpendicular straight-line distance from the caribou cluster to the transect line was estimated later in a GIS using the GPS location and the transect represented by the actual flight line data (Marques et al. 2006). In the actual survey, the transect line is the helicopter flight track, so there is no error associated with not being able to fly exactly over the pre-established line (Marques et al. 2006). A key assumption in line-transect sampling is that perpendicular distances are collected without errors. Our method to measure perpendicular distance from GPS locations taken over animals appeared to be very accurate, unbiased, and more efficient than another method based on estimating sighting angle and aircraft above ground level altitude (Marques et al. 2006).

Two covariates describing habitat structure were noted for each caribou observation. Slope and snow cover were recorded at two spatial scales: the coarse scale represents the area extending 1000 m around the caribou observation while the local scale represents the area within 100 m of the observation. The habitat slope score was coded as 1 for flat terrain, as 2 for moderately sloped or rolling habitat, and as 3 for mountainous or steep terrain. The snow cover was visually estimated by the front left observer as percentage of white cover at both scales and do not take into account snow depth variations. Due to strong winds prevailing in this area, some areas were showing rocks and bare ground even in mid-winter. In March 2014, the Labrador coast (<10-15 km from the coast) had less snow cover than along the Ungava Bay coast. Most of the Torngat Mountains region are found in tree-less arctic tundra.

At the beginning of each transect, the visibility conditions and percent cloud cover were estimated. Visibility condition was recorded as 3 for excellent (≥40 km), 2 for good (10-40 km) and 1 for poor (≤10 km). If visibility conditions changed during the survey flight, it was recorded.

Caribou clusters observed while flying off transect (e.g. ferrying to camps, transects or fuel caches) were recorded as off-transect and not included in herd size estimation. However, these caribou clusters were included in the sex and age classification to compute herd demographic parameters.

The census team noted tracks and observations of wolf (*Canis lupus*), polar bear (*Ursus maritimus*), red fox (*Vulpes vulpes*), arctic fox (*Alopex lagopus*), and arctic hare (*Lepus arcticus*).

2.4 Complementary census method

As some satellite radio-collared caribou were present in the Torngat herd, it was possible to use the Lincoln-Petersen method (also called Capture-recapture method) to estimate herd size. This complementary census method was independent from the main census method based on distance sampling. As required by the Lincoln-Petersen method (White and Garrott 1990), observers were not aware of the radio-collar locations during the census. When a cluster of caribou was detected, observers noted visually how many radio-collared animals were found in the group. Observations were later confirmed using photographs taken during classification. No telemetry scanning was done on transects during the aerial survey.

2.5 Population dynamics monitoring

It was originally suggested (Couturier et al. 2013) that sex and age classification would be completed for every second caribou cluster to save flying time while maintaining an accurate systematic sampling design for population dynamics data collection. Classification from the helicopter using voice-recorders while chasing caribou was proposed. However, due to the rugged landscape in most of the census area, the classification method was changed. Instead every caribou group was photographed with a hi-resolution digital camera (Nikon D600) coupled with a GPS (di-GPS, Dawn Technology Ltd, Hong Kong) and a 70-300 mm telephoto zoom lens (Nikkor). As animal care and safety were a priority, the photographic method kept observation time to a minimum and reduced caribou disturbance. This classification method decreased low-altitude flying time over caribou and it was generally possible to take photographs of the group in less than 30 seconds; less than 20 seconds for smaller groups. Moreover, the use of a telephoto zoom lens made it possible to photograph caribou at farther distances and thus further reduced stress on the animals. Detailed analysis of photographs permitted even more accurate classification by sex and age than would have been possible with live classification. On average, five to seven photographs were taken per group. Photographs were later enhanced for exposure and colour rendering with Lightroom 4 (Adobe Systems Canada, Ottawa, Canada). Caribou were classified in one of the following sex-age classes based on head and body size, presence of vulvae or penis, and antler condition: 1- adult antlered female, 2- adult unantlered female, 3- adult antlered male (younger), 4- adult unantlered males (older) and 5- calves. Photographs were also analysed carefully to confirm radio-collars presence or absence on caribou.

From a compilation of all caribou observations (on and off transects), it was possible to compute the ratio of calves per 100 adult females (hereafter calf/cow ratio) and the percentage of calves in the population. These recruitment parameters measured in late winter or early spring are essential in population dynamics investigations to determine the population trajectory. From the photographic classification, it was also possible to compute the ratio of males per 100 females (hereafter adult sex-ratio) to investigate possible skewed sex proportion. These population dynamic parameters are comparable to ratios estimated in April and July 2013 (Torngat Secretariat, Nash, P., unpubl. data).

2.6 Adult survival

The rates at which animals die are critical parameters of wildlife management. Adult survival is one of the most important demographic parameters in caribou management. However, very few methods exist that can provide reliable and unbiased estimation of adult caribou survival. Radio-collaring is one of the most commonly used methods to estimate adult survival rate in migratory caribou (e.g., Rasiulis et al. 2014) and in woodland caribou (e.g., Losier et al. 2014).

A total of 48 radio-collared adult caribou (38 females, 10 males) were monitored between November 1988 and May 2014 in the Torngat Mountains caribou herd (QC Gov., NL Gov., and Torngat Secretariat, unpubl. data). As exact knowledge of the fate of the radio-collars was essential for using the Lincoln-Petersen census method, we analysed carefully radio-collar data and estimated survival rate using the method described by Heisey and Fuller (1985) for radio-telemetry studies. This method computes survival from total number of transmitter days and number of deaths during an interval. The interval retained for survival estimation was the biological year starting on June 1st. As the program Micromort is no longer available, formulae described in Heisey and Fuller (1985) have been included in an Excel file (Microsoft, Redmond, USA) to calculate annual survival rate for adult caribou monitored by radio-telemetry. Causes of death were divided in three classes: (1) Hunting, (2) Natural, and (3) Unknown.

3. Results

Between March 11 and March 29, 2014, including travel time from and to Happy Valley-Goose Bay, a team of four observers (including pilot) performed the first census of the Torngat caribou. The census team flew an area of 30,689 km^2 (Figure 2) across northern Quebec (Nunavik) and Labrador (Nunatsiavut). As planned, a total of 81 transects were flown systematically from the south to the north for a total transect length of 7,057 km (see Appendix A). The census was completed in late winter when the Torngat caribou herd was isolated from the George River herd. This was confirmed by the daily monitoring of about 80 radio-collared George River caribou and 14 radio-collared Torngat caribou of both sexes (QC Gov., unpubl. data).

No caribou were observed on the first 11 transects (south of Hebron Fjord), while 3 groups were observed between Hebron Fjord and Saglek Fjord. Most of the groups were detected north of Nachvak Fjord (59° N). Caribou were detected in highly aggregated groups, ranging from 1 to 18 animals (means ± SE= 5.4 ± 3.8). Fifty groups with a total of 269 caribou were seen on-transect while 3 additional groups (22 caribou in total) were detected opportunistically while flying off-transect. Combining on and off-transect observations, photographic classification determined 170 antlered females, 6 unantlered females, 47 antlered males, 18 unantlered males and 50 calves (see Appendix B). Using these totals, the calf-cow ratio was 28.4 while the percentage of calves in the population reached 17.2%. The adult sex-ratio was 36.9. Among the adult female segment of the population, 3.4% were unantlered.

Numerous observations of red fox were recorded during the census. A total of 11 polar bears were also recorded while only three wolves in one pack and few tracks were observed on and off-transect during the caribou census.

Visibility was excellent during most of the flying time on-transect (see Appendix C). Of the 81 transects flown, two were coded 2 for good visibility (10-40 km) while 79 transects were coded 3 for excellent visibility (≥40 km) (see Appendix A and C). Overall, cloud cover varied from 0 to 50% and averaged 16% (n= 81). Sky conditions were particularly clear during the aerial survey. No precipitation was recorded during our transect flights except some small isolated patches of ice crystals which only slightly reduced visibility (Appendix A). However, snow occurred from time to time during the field program and forced the census team to wait periodically at base camp (see transect flying timeline in Appendix A). Snow was observed on March 12 (day before the census started), on March 16-17, on March 21, 22 and 23, and on March 27, 2014. Periodic snowfall erased old animal tracks and provided fresh snow on which caribou or their tracks can be more easily detected. For the 50 caribou groups seen on-transect, snow cover averaged 82% (range 50 - 100%) at the local scale (i.e., 100 m) and 91% (range 60-100%) at the coarse scale (i.e., 1000 m). At the local scale, slope was estimated at 1 (flat) for 19 groups (38%), at 2 (moderately sloped or rolling habitat) for 28 groups (56%) and at 3 (steep) for 3 groups (6%). At the coarse scale, slope was estimated at 1 for 2 groups (4%), at 2 for 33 groups (66%) and at 3 for 15 groups (30%).

3.1 Exploratory analysis

As recommended by Thomas et al. (2010), exploratory analysis was carried out to aid understanding of the data and identify potential problems. Our investigation of group size and perpendicular distance did not detect any problems with a possible correlation that may suggest a significant group size bias which happens when larger groups are more easily detected at larger distance than smaller groups. The Pearson correlation coefficient is close to zero between group size and distance (r^2= 0.04, Figure 3). As the size of the group had no influence on detection probability, we did not include group size in the covariate analysis during distance sampling model fitting.

We plotted histograms of the distance data with many cutpoint intervals (bin size of 100 m, 139 m and 200 m) and found no major distribution problems that would suggest possible bias or failure of distance sampling assumptions (Figure 4). As expected, the number of observations declined with distance from the transect line but some increases were noted in the right side of the distribution. This is due to the small sample size where some groups at larger distances have been found by chance.

Because local and coarse scales were correlated for slope and snow covariates, only local values of each covariate were used in the models. Due to the low number of observations in the slope covariate, the highest value coded 3 for mountainous or steep terrain was merged with the value coded 2 for moderately sloped or rolling habitat. For the 50 caribou groups, 19 observations were seen in category 1 (slope described as flat) and 31 observations were recoded in category 2 (slope described as moderately sloped or steep).

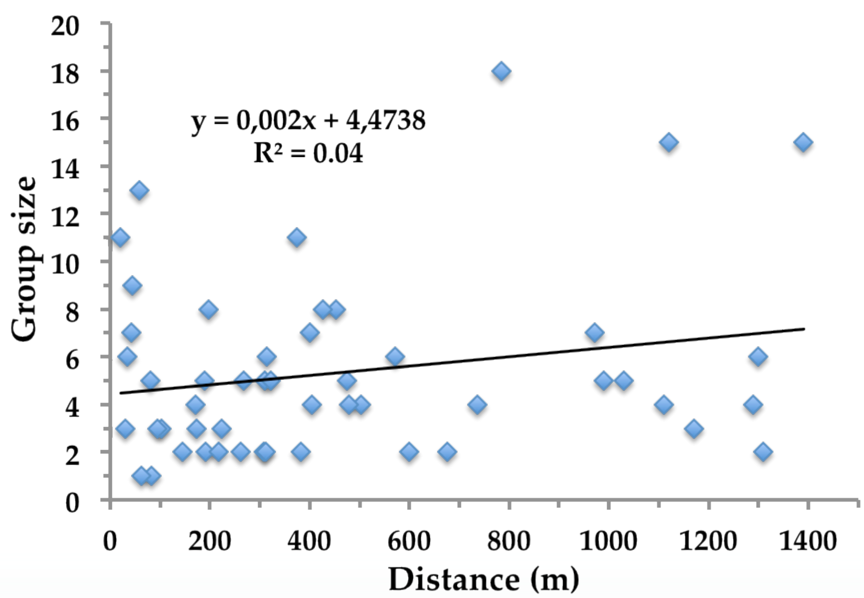
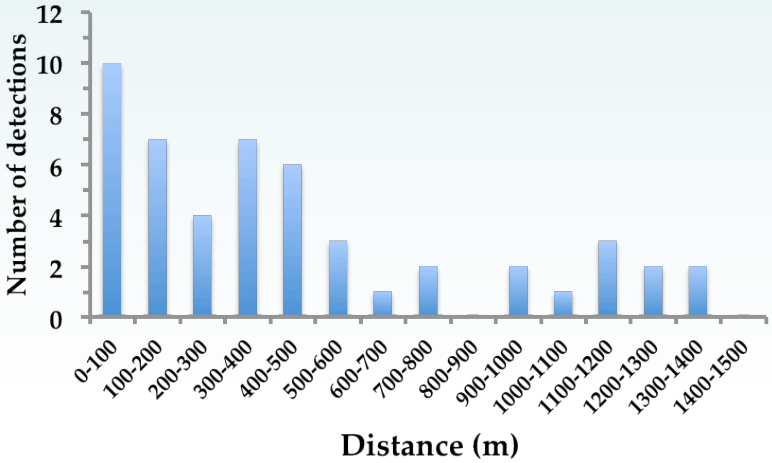
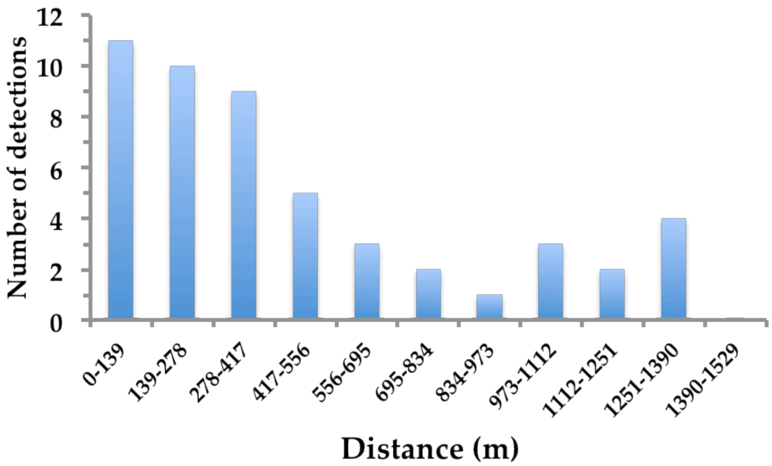


Figure 3. Relationship between group size and the perpendicular distance (m) from the transect for 50 groups of caribou seen on transects during the Torngat Mountains caribou herd census in March 2014.

A.



B.



C.

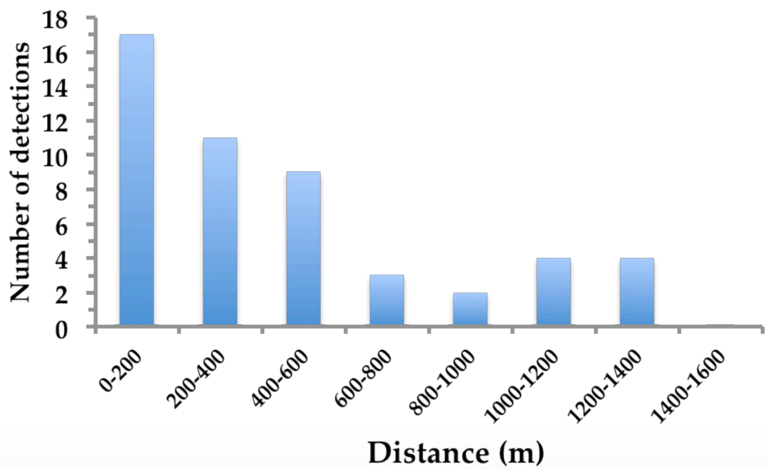


Figure 4. Distribution of perpendicular distances collected (n= 50) during the Torngat Mountains caribou herd census in March 2014 using three bin sizes: A. 100 m, B. 139 m, and C. 200 m.

3.2 Model fittings in distance sampling

A total of 50 caribou groups were recorded on-transect during the Torngat Mountains caribou herd census. Perpendicular distances were 464 m on average and ranged from 21 to 1390 m. Using these results, model fittings were done in Distance 6.2 to identify the best detection function that can be used in herd size estimation.

3.2.1 Effect of distance truncation

As the frequency distribution of observations was showing some unexpected increases at longer distance, the data truncation effect was explored using CDS engine in Distance 6.2. As the sample size was relatively small with 50 observations, it was not mandatory to do right-censoring and it was worthwhile to explore the effect of such truncation. Simulations were done using different truncation distances. For each truncation distance, nine models were tested using a combination of three key functions and three series adjustments (or expansion terms). Hence, models with uniform (unif), half-normal (hn) and hazard rate (hr) key functions were tested where each function were fitted with one series adjustment among cosine (cos), simple polynomial (poly) and Hermite (Herm) polynomial (Buckland et al. 2001). These nine models include the six models recommended by Buckland (2001, p. 47) and the four models recommended by Thomas et al. (2010, p. 12).

The maximum observed distance was 1390 m in the full dataset and the simulation used truncation distances of 1200 m, 1100 m, 1000 m and 973 m. The latter truncation distance corresponded to the pooling of frequencies proposed by Distance 6.2 when analysing the full dataset. The sample size decreased from 50 for the full dataset to 41 for models tested at 973 m truncation distance (Table 1). Choosing the lowest AIC in each truncation simulation, the best model out of the nine tested with each truncation distance was selected and these results are presented on Table 1. Most census parameters were similar and did not vary much for all truncation distances tested in the simulation. Density estimates and their CVs were remarkably similar among different truncation scenarios with caribou densities ranging from 0.0246 to 0.0277 and CV from 0.2747 to 0.2974 (Table 1).

Table 1. Preliminary analysis of Torngat Mountains caribou herd census data to investigate possible effects of data truncation at longer perpendicular distance (right censoring) done in Distance 6.2. with Conventional Distance Sampling (CDS) engine on census parameters: estimated caribou group size (E (S)), effective strip width (ESW) in meters, detection probability (p) and its associated CV, and caribou density per km² (D) and its associated CV.

Best models (lowest AIC) [a]	Truncation distance	n (groups)	E (S)	ESW	p	p CV	D	D CV
hn+cos(2)	None	50	4.57	584	0.420	0.171	0.0277	0.2924
unif+cos(1)+cos(2)	>1200 m	46	4.58	573	0.478	0.162	0.0260	0.2959
unif+cos(1)+cos(2)	>1100 m	43	4.58	494	0.449	0.142	0.0282	0.2974
unif+cos(1)	>1000 m	42	4.63	559	0.559	0.074	0.0246	0.2754
unif+cos(1)	>973 m	41	4.63	524	0.539	0.066	0.0256	0.2747

[a] Key functions: unif= uniform; hn= half-normal. Series expansion: cos(x)=cosine of order x. Formulae for these functions are provided in Buckland et al. (2001), p. 47.

3.2.2 Conventional distance sampling (CDS)

As recommended in Buckland et al. (2001) and in Thomas et al. (2010), it is more appropriate to start distance sampling analysis with simpler models and to continue later on with more complex model fittings. Using CDS engine in Distance 6.2, same nine models as described above were fitted with the full data set (no truncation) using three key functions (uniform, half-normal and hazard rate), each fitted with one of the three series adjustments (cosine, simple polynomial and Hermite polynomial). Modeling results are sorted by delta-AIC on Table 2 and the first five models have less than 2 AIC value differences. The first three best supported models were almost identical with delta-AIC of less than 0.75. These three models were showing very similar estimates for effective strip width (range: 567.6-593.8), detection probability (range: 0.408-0.427), estimated group size (range: 4.57-4.60), and ultimately for density (0.0274-0.0286), as well as for their respective CVs (Table 2). All three models were showing a good visual fit on the Q-Q distribution plots and their GOF tests probability were very high ($p \geq 0.84$). All models reported in Table 2, except Models 4 and 8, were suggested by Buckland et al. (2001, p. 47) as useful models to be fit in a variety of situations. Moreover, Models 1, 2, 5 and 7, were suggested by Thomas et al. (2010, p. 12) as models that perform well.

For all models shown on Table 2, parameters were constrained to obtain monotonicity as reported in warning messages issued by Distance 6.2. The monotonicity warnings happen often where you have a relatively small dataset and just by chance when there is a slight increase at some distance as observed in our dataset. In this situation, Distance 6.2 would try to fit an extra adjustment term and will issue the monotonicity constraint warning (Thomas, L., pers. comm.). This warning does not seem to pose a major issue in our analysis.

Models 7 and 8 showed larger delta-AIC (Table 2). Their parameters estimates varied from the better fitting models and their CVs were generally smaller; an example of the bias-precision trade off. The three better fit models (Model 1 to 3) had lower precision (high CV) and smaller bias (better fit) while the worse models (Model 7 and 8) showed high precision (low CV) and possibly higher bias (poor fit) as suggested by the Q-Q plots and by lower goodness of fit tests probability values (Table 2).

When some models are reporting very low delta-AIC values (less than 1 or typically less than 2), model selection can be problematic. If choice of model is uncertain and, more importantly, if choice of model is influential on parameters estimates, model averaging can be done with variance estimation computed by bootstrapping instead of empirically (Thomas et al. 2010). Most of our CDS estimates presented in Table 2 are similar and model selection is then not so influential on density estimates. Nevertheless, we used CDS engine in Distance 6.2 to perform model averaging and bootstrap resampling, selecting the best model using AIC at each step. Model averaging results for the first three and for the first five models are presented in Table 2. The group size and density estimates were almost equal when compared to estimate reported for the individual models. The main difference brought by model averaging was an increase in the density CV. In model averaging, resulting variances and CV reflect model selection uncertainty that brings then lower precision (higher CV) (Thomas et al. 2010).

3.2.3 Multi-covariate distance sampling (MCDS)

Multi-covariate distance sampling is generally superior to CDS when covariates are assumed to affect the rate at which detectability decreases as a function of distance (Buckland et al. (2004). The addition of covariates in our analysis proved to be efficient as most MCDS models were showing a better fit than CDS models (Table 3). The best CDS model ranked sixth in this comparison. Moreover, most MCDS models were run without any warnings from Distance 6.2 (Table 3) while all CDS models had one or more warnings issued (mostly related to monotonicity). However, some MCDS models had poor data fit. The lowest AIC model was "MCDS hn cos(2) slope snow" which included both covariates. However, this model showed a poor fit to our data as indicated by poor visual fitting on the Q-Q distribution plot and by lower probability values in goodness of fit tests (Chi^2 0.72; Kolmogorov-Smirnov p= 0.41; Cramer-von-Mises p>0.50). The second best model according to AIC rankings is "MCDS hn cos(2) slope" with a delta-AIC of 1.65. It shows both a better visual fit in the Q-Q plot and higher probability values for the goodness of fit tests (Chi^2 0.86; Kolmogorov-Smirnov p= 1.00; Cramer-von-Mises p>0.90). This model "MCDS hn cos(2) slope" included slope as covariate and was retained as the best model in our analysis. The detection probability function is shown on Figure 5. In this model, the component percentage of variance of the density was 19% caused by detection probability (p), 64% by encounter rate (n/L or here 50/7057) and 17% by group size (E (S)). This model estimated that the effective strip width (ESW) was 541 m (95% CI: 428 – 683), the expected group size (E (S), or cluster size) was 4.6 (95% CI: 3.7 – 5.7), the probability of detecting a caribou group (p) was 0.39 (95% CI: 0.31 – 0.49), and the density of caribou was 0.033 caribou/km^2 (95% CI: 0.018 – 0.051).

To verify potential effects of right truncation on our results further analysis were undertaken (see Table 4). The first two models in the MCDS analysis presented in Table 3 (“MCDS hn cos(2) slope snow” and “MCDS hn cos(2) slope”) were re-run using the same truncation distances as previously used (see Table 1). Most census parameters were similar and did not vary much for all truncation distances tested in the simulation. Density estimates and their CVs were remarkably similar among different truncation scenarios with densities ranging from 0.027 to 0.033 and CV from 0.264 to 0.292 (Table 4). Using pair-wise comparisons with AIC, the second model in the full dataset analysis (see also Table 3) became the best fit model in all truncation distance analysis although delta-AIC values were small and less than 2 (Table 4). This suggested that these two models exhibited almost similar fitting capabilities with our data.

3.2.4 Herd size estimation from distance sampling

Model 2 in Table 3 showing MCDS results was retained as the best fitted model and it was used to compute population size. The model “MCDS hn cos(2) slope” estimated Torngat Mountains caribou herd size at 930 caribou with a CV of 0.264. The asymmetrical confidence interval (CI) at p= 0.10 indicates that herd size was between 616 (33.8%) and 1453 (56.2%) caribou in March 2014 (Table 5). This population estimate includes calves because the survival rate of 10-month old calves is close to adult survival.

To investigate possible impact of the study area delineation on the herd size estimation, we rerun the selected model “MCDS hn cos(2) slope” with a smaller data set that do not include 11 transects located south of Hebron Fjord where no caribou was detected. We removed the 11 transects located in the south and recalculated at 25,405 km^2 the new smaller study area (in comparison to 30,689 km^2). Here are the results with only 70 transects as well as its comparison with the results presented above for 81 transects:

Density: 0.0372 vs 0.0329 caribou/ km^2

Herd size: 945 vs 930 caribou

Coefficient of variation: 0.259 vs 0.264

3.3 Lincoln-Petersen method

During the census, there were 14 functioning radio-collars on live adult caribou. Moreover, the status of three more radio-collared adult caribou was unknown as their collars stopped transmitting in 2013 before the census (Jutras, C., pers. comm.). The fate of the radio-collared caribou wearing these malfunctioning collars was unknown. During the census, it was 269 caribou that were seen on-transect (i.e., captured in the sense of the Lincoln-Petersen technique). Among these caribou, five radio-collared adult caribou were observed (i.e., recaptured in the sense of the Lincoln-Petersen method) by the census team and later confirmed with photographs. Another radio-collared caribou was seen during flight off-transect but it was not considered in the Lincoln-Petersen analysis. During post-census analysis using accurate satellite data locations, it was possible to identify five out of six radio-collared caribou detected visually during census. The only radio-collared caribou that was not identified by satellite tracking data was seen in the group 10 on March 24th, 2014. It was likely one of the three malfunctioning radio-collars (2 males and 1 female). Using information like collar type and colour, sex and age of the caribou (male of 4+ years), ear tag colour and position (pink tag on right ear) and the last location transmitted on Nov. 10, 2013 (approx. 30 km travelled in about 4 months), it was possible to identify the radio-collared caribou seen in group 10 as the adult male caribou ID 2013035 (PTT 119389) which was indeed one of the malfunctioning collars (Jutras, C., pers. comm.). The minimum number of radio-collared caribou was then 15 and the Torngat Mountains caribou herd size was computed using two scenarios, one assuming that the other two unknown radio-collared caribou were dead, another assuming that they were both alive at the time of the census. The number of marked caribou was then 15 or 17 following each of these scenarios (Table 5).

If there were 15 radio-collars active in the population, the estimated population size would be 719 caribou with symmetrical confidence interval between 362 and 1076 (49.6%, at p= 0.10). However, if the number of active collars was 17 instead, the herd size of 809 caribou with symmetrical confidence interval of 51.2% ranging from 395 to 1223 is estimated (Table 5). Confidence intervals for both Lincoln-Petersen estimates overlapped the asymmetrical confidence interval computed earlier from distance sampling (Table 5). As there is no radio-collar deployed on the calf segment of the population, these Lincoln-Petersen herd size estimates should be considered for the adult population only (not including calves).

3.4 Adult survival

Table 6 presented a summary of the fate of the radio-collared caribou monitored since 1988. Since 2011, more deaths happened from hunting than from natural cause while this was the opposite between 1988 and 1999 (Table 6). Of the 22 caribou that were radio-collared in April 2013, seven or 32% caribou died within days of the capture operation. For these animals, the mean duration of life after capture was eight days ranging from 1 to 16 days (based on satellite data). Six of these caribou died from hunting while another died from predation. It is noteworthy that following mortality events that occurs shortly after the April 2013 capture session, no additional mortality were recorded and 15 caribou captured in April 2013 were alive on Nov. 6, 2013. A total of 20 active radio-collars were on live caribou and still functioning on Nov. 6, 2013 (i.e., during the planning of the census) but only 14 were still alive and transmitting in March 2014 (Jutras, C., pers. comm.). A total of 11 radio-collared caribou were alive on May 31st, 2014.

Annual survival rate were estimated from the 48 radio-collared caribou for 13 biological years between 1988-1989 and 2013-2014 (Figure 6). The annual survival rates were variable which is likely related to small sample size of radio-collars. In 1999 and before, sample sizes were very small but they were larger starting in 2011 (Table 6). Annual survival rates were very low for 10 years out of 13 years monitored. The survival rates were 58%, 32% and 66% for 2011-2012, 2012-2013 and 2013-2014 respectively (Figure 6). These survival rates are far below what is normally expected for a long-living mammal like caribou.

Table 2. Torngat Mountains caribou herd distance sampling census results of the fitted detection models provided by Conventional distance sampling (CDS) engine in Distance 6.2: number of parameters (m), Akaike Information Criteria (AIC) values, effective strip width (ESW) in meters, detection probability (p) and its associated coefficient of variation (p CV), estimated caribou group size (E (S)), density of caribou per km^2 (D) and its associated coefficient of variation (D CV), and three goodness of fit test probability values (Chi^2, Kolmogorov-Smirnov (K-S) and Cramer-von-Mises (C-v-M) tests.

Models [a b]	Fit [c]	m	Delta-AIC	AIC	ESW	p	p CV	E (S)	D	D CV	Chi^2	K-S	C-v-M
1. hn+cos(2)	Good	2	0	707.44	584	0.420	0.171	4.57	0.0277	0.2924	0.87	0.99	p>0.90
2. unif+cos(1)+cos(2)+cos(3)	Good	3	0.64	708.08	568	0.408	0.168	4.58	0.0286	0.2905	0.85	0.99	p>0.90
3. hr+cos(2)	Good	3	0.75	708.18	594	0.427	0.162	4.60	0.0274	0.2868	0.84	0.99	p>0.90
4. hn+poly(4)+poly(6)	Good	3	1.22	708.65	616	0.443	0.150	4.61	0.0265	0.2802	0.85	0.98	p>0.90
5. hr+poly(0)	Good	2	1.35	708.79	537	0.386	0.311	4.59	0.0303	0.3918	0.67	0.95	p>0.90
6. unif+poly(2)+poly(4)+poly(6)+poly(8)	Good	4	2.79	710.22	607	0.436	0.158	4.62	0.0270	0.2845	0.70	0.99	p>0.90
7. hn+Herm(0)	Poor [d]	1	5.82	713.25	835	0.601	0.098	4.81	0.0204	0.2560	0.28	0.21	p>0.10
8. unif+Herm(2)+Herm(4)	Poor [d]	2	6.42	713.85	856	0.616	0.124	4.83	0.0200	0.2670	0.25	0.16	p>0.05
Averaging Models 1 to 5								4.67	0.0297	0.5073			
Averaging Models 1 to 3								4.64	0.0278	0.4302			

[a] Key functions: unif= uniform; hn= half-normal; hr= hasard rate. See Buckland et al. (2001), p. 47.

[b] Series expansion: cos(x)=cosine of order x; poly(x)= simple polynomial of order x; Herm(x)= Hermite of order x. See Buckland et al. (2001), p. 47. The notation (0) means that no adjustments term was selected following AIC comparison.

[c] For all models shown, parameters were constrained to obtain monotonicity as reported by Distance 6.2.

[d] In models G and H, some parameters were highly correlated as reported by Distance 6.2.

Table 3. Torngat Mountains caribou herd distance sampling census results of the fitted detection models provided by Multiple Covariate Distance Sampling (MCDS) and Conventional Distance Sampling (CDS) engines in Distance 6.2 using covariates describing slope (flat, steep) and snow (% of ground covered by snow): number of parameters (m), Akaike Information Criteria (AIC) values, effective strip width (ESW) in meters, detection probability (p) and its associated coefficient of variation (p CV), estimated caribou group size (E (S)), density of caribou per km² (D) and its associated coefficient of variation (D CV), and three goodness of fit test probability values (Chi², Kolmogorov-Smirnov (K-S) and Cramer-von-Mises (C-v-M) tests).

Models [a b c]	Fit	m	Delta-AIC	AIC	ESW	p	p CV	E (S)	D	D CV	Chi²	K-S	C-v-M
1. MCDS hn cos(2) slope snow	Poor	4		702.58	521	0.375	0.122	4.66	0.0317	0.267	0.72	0.41	p>0.50
2. MCDS hn cos(2) slope	Good	3	1.65	704.23	541	0.389	0.117	4.63	0.0329	0.264	0.86	1.00	p>0.90
3. MCDS hn cos(2) snow	Good	3	1.84	704.42	540	0.388	0.121	4.59	0.0301	0.267	0.85	0.83	p>0.90
4. MCDS hn poly(4) slope snow	Poor	4	2.63	705.21	675	0.490	0.420	4.87	0.0256	0.484	0.39	0.60	p>0.50
5. MCDS hn Herm(0) slope snow	Poor	3	4.15	706.73	714	0.514	0.117	5.02	0.0249	0.265	0.25	0.65	p>0.50
6. CDS hn cos(2)	Good [d]	2	4.86	707.44	584	0.420	0.171	4.57	0.0277	0.292	0.87	0.99	p>0.90
7. MCDS hr cos(2) slope	Good	4	5.32	707.91	528	0.380	0.129	4.61	0.0310	0.270	0.73	0.98	p>0.90
8. CDS unif cos(1,2,3)	Good [d]	3	5.50	708.08	568	0.408	0.168	4.58	0.0286	0.291	0.85	0.99	p>0.90
9. CDS hr cos(2)	Good [d]	3	5.60	708.18	594	0.427	0.162	4.60	0.0274	0.287	0.84	0.99	p>0.90
10. CDS HN poly(4,6)	Good [d]	3	6.07	708.65	616	0.443	0.150	4.61	0.0265	0.280	0.85	0.98	p>0.90
11. CDS hr poly(0)	Good [d]	2	6.21	708.79	537	0.386	0.311	4.59	0.0303	0.392	0.67	0.95	p>0.90
12. MCDS hr poly(0) slope	Good	3	6.24	708.82	588	0.423	0.130	4.74	0.0286	0.270	0.53	1.00	p>0.90
13. MCDS hr Herm(0) slope	Good	3	6.24	708.82	588	0.423	0.130	4.74	0.0286	0.270	0.53	1.00	p>0.90
14. MCDS hr cos(2) snow	Poor	4	6.61	709.19	531	0.382	0.118	4.59	0.0306	0.265	0.70	0.66	p>0.60
15. MCDS hr poly(4) slope	Poor	3	6.86	709.44	734	0.528	0.642	4.89	0.0236	0.684	0.41	0.45	p>0.30
16. MCDS HN Herm(4) slope	Poor [e]	2	6.88	709.46	783	0.563	0.105	5.03	0.0227	0.259	0.37	0.29	p>0.20
17. MCDS HN poly(4) snow	Poor	3	6.96	709.54	730	0.525	0.561	4.69	0.0228	0.609	0.42	0.42	p>0.30
18. MCDS HN Herm(0) snow	Poor	2	7.13	709.71	784	0.564	0.110	4.83	0.0220	0.261	0.31	0.34	p>0.20
19. MCDS hr cos(2) slope snow	Poor	5	7.18	709.76	510	0.367	0.140	4.64	0.0322	0.276	0.56	0.69	p>0.70
20. MCDS hr poly(4) snow	Good	4	7.75	710.33	598	0.430	0.180	4.70	0.0278	0.297	0.80	0.94	p>0.90
21. MCDS hr Herm(0) snow	Good	3	8.23	710.81	619	0.445	0.122	4.68	0.0268	0.267	0.53	0.92	p>0.90
22. MCDS hr poly(0) slope snow	Good	4	8.26	710.84	671	0.483	0.133	4.78	0.0252	0.272	0.36	0.85	p>0.70
23. MCDS hr Herm(0) slope snow	Good	4	8.26	710.84	671	0.483	0.133	4.78	0.0252	0.272	0.36	0.85	p>0.70

[a] Key functions: unif= uniform; hn= half-normal; hr= hasard rate. See Buckland et al. (2001), p. 47.

[b] Series expansion: cos(x)=cosine of order x; poly(x)= simple polynomial of order x; Herm(x)= Hermite of order x. See Buckland et al. (2001), p. 47. The notation (0) means that no adjustments term was selected following AIC comparison. Slope (flat, steep) and snow (% ground cover) were two covariates in the analysis.

[c] Only the five best CDS models are presented here.

[d] Warning message by Distance 6.2: "Parameters are being constrained to obtain monotonicity."

[e] Warning message by Distance 6.2: " Estimation routine failed to converge as some estimates of the pdf are negative in iteration 30."

Table 4. Investigation of possible effects of data truncation at longer perpendicular distance (right censoring) done in Distance 6.2. with Multiple Covariates Distance Sampling (MCDS) engine on census parameters: Akaike information criteria (AIC), estimated caribou group size (E (S)), effective strip width (ESW) in meters, detection probability (p) and its associated CV, and caribou density per km² (D) and its associated CV.

Truncation distance	Models [a]	n (groups)	AIC [b]	E (S)	ESW	p	p CV	D	D CV
None									
	MCDS hn cos(2) slope snow	50	702.58	4.66	521	0.375	0.122	0.032	0.267
	MCDS hn cos(2) slope	50	704.23	4.63	541	0.389	0.117	0.033	0.264
>1200 m									
	MCDS hn cos(2) slope snow	46	635.58	4.75	493	0.410	0.129	0.031	0.280
	MCDS hn cos(2) slope	46	634.01	4.75	499	0.416	0.127	0.031	0.280
>1100 m									
	MCDS hn cos(0) slope snow	43	585.58	4.77	536	0.487	0.120	0.027	0.288
	MCDS hn cos(0) slope	43	583.82	4.75	539	0.490	0.118	0.027	0.287
>1000 m									
	MCDS hn cos(0) slope snow	42	567.93	4.75	520	0.520	0.117	0.027	0.290
	MCDS hn cos(0) slope	42	565.99	4.74	521	0.521	0.114	0.027	0.290
>973 m									
	MCDS hn cos(0) slope snow	41	550.71	4.67	490	0.503	0.118	0.028	0.292
	MCDS hn cos(0) slope	41	548.72	4.68	490	0.503	0.115	0.028	0.291

[a] Key functions: hn= half-normal. Series expansion: cos(x)=cosine of order x. The notation (0) means that no adjustments term was selected following AIC comparison. Formulae for these functions are provided in Buckland et al. (2001), p. 47. Slope (flat, steep) and snow (% ground cover) were two covariates in the analysis.

[b] AIC values can be compared only within models using the same truncation distance because they are using the same dataset (see equal n).

Table 5. Lincoln-Petersen and distance sampling results of the Torngat Mountains caribou herd census done in March 2014.

Census Method [a]	Parameters	Herd size estimate	Confidence interval (CI) at p= 0.10	Lower CI limit	Upper CI limit
• Lincoln-Petersen					
Scenario 1	M=15; C= 269; R= 5	719	49.6%	362	1076
Scenario 2	M=17; C= 269; R= 5	809	51.2%	395	1223
• Distance sampling					
	A= 30,689.4 km2 n= 50 caribou groups E(S)= 4.626 caribou W= 1.39 km L= 7,057.4 km p= 0.38926	930	Lower CI= 33.8% Upper CI= 56.2%	616	1453

[a] The model "MCDS hn cos(2) slope" was selected to compute herd size with distance sampling.

Table 6. Summary of the fate of 48 radio-collared caribou from the Torngat Mountains caribou herd monitored from November 1988 to May 2014.

Project leader/ Agencies	Years	Number of collars [a]	Mortality cause				
			Natural	Hunting	Unknown	Still alive [b]	Technical failure
Luttich et al., NL Gov.	1988-1995	9 (0)	5	1	3		
Couturier et al., QC Gov. and Makivik	1997-1999	4 (0)	2	2			
QC Gov., NL Gov., and Torngat Secretariat	2011-	10 (2)	3	3	1	1	2
QC Gov., NL Gov., and Torngat Secretariat	2013- [c]	25 (8)	4	6	3	10	2
	TOTAL	48 (10)	14	12	7	11	4

[a] The number of adult males are in parenthesis.
[b] Still alive as of May 31, 2014.
[c] Included three radio-collars deployed in October 2012.

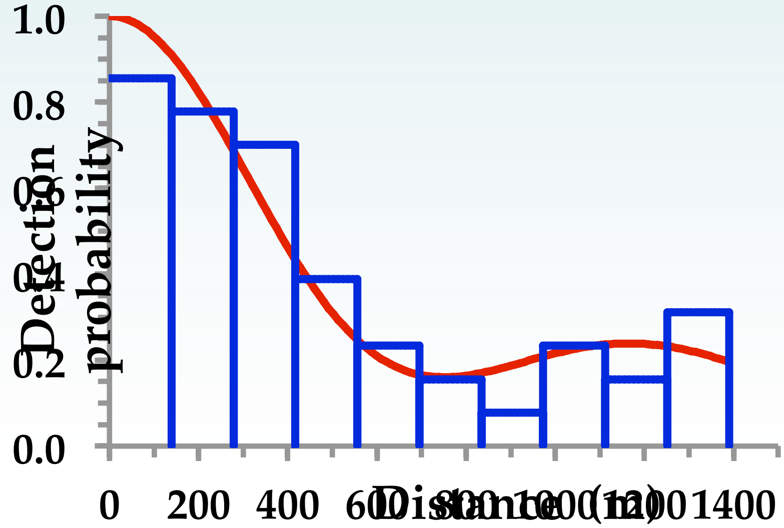


Figure 5. Detection probability function (continuous line in red) and histogram of perpendicular distances (m) from the transect line for caribou groups recorded during the Torngat Mountains caribou herd census in March 2014. The detection function is estimated using the MCDS model Half-normal Cosine with covariate slope. Bin size is 139 m.

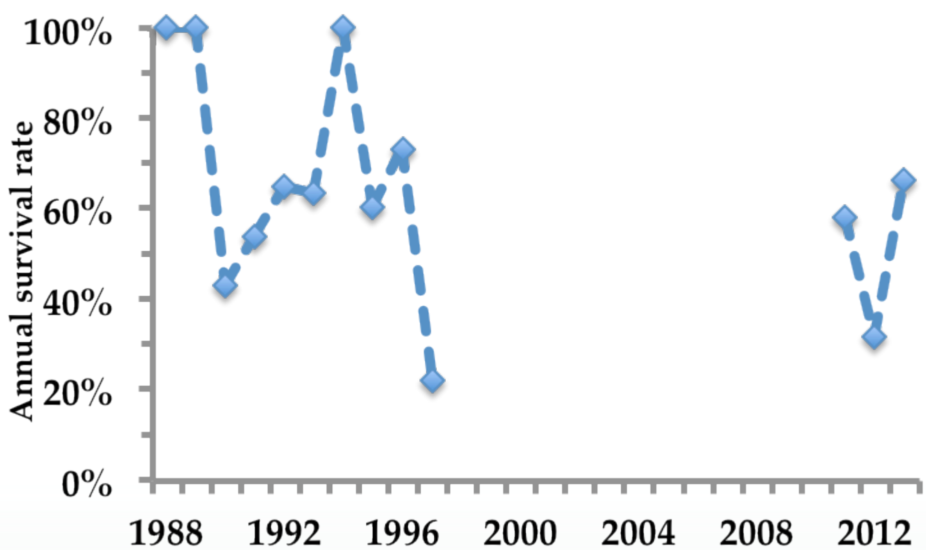


Figure 6. Annual survival rate of adult caribou from the Torngat Mountains caribou herd between 1988-1989 and 2013-2014. Note: 1988 is the biological year 1988-1989.

4. Discussion

A scientifically valid census was achieved using the proposed distance sampling method and it was accomplished within the estimated budget and time-frame presented in Couturier et al. (2013). The distance sampling estimate was similar to the Lincoln-Petersen method results. However, these herd size estimates were carrying large confidence intervals. Poor precision estimates are often obtained when studying low densities population. This is a well-known conservation challenge, because generally, the smaller the population, the harder it is to estimate its abundance from sampling methods (Williams and Thomas 2009). This should not be used as a reason for not trying to estimate wildlife populations that may be rare or at risk. Our low precision herd size estimate of 930 caribou is valuable as this is the first ever census done on this small caribou population. Our results shown that herd size is far from the 5,000 caribou suggested as a guess by Bélanger and Le Henaff (1985), the only other information available until now on herd size. The information collected will be essential to support the management of this unique caribou population.

4.1 Census area and transect design

The census area was based on recent satellite radio-tracking of adult females and from IK collected in the region. Some observers reported that caribou were no longer found in the area near Okak Bay along the Labrador Sea (Phillips, F., pers. comm.). To be sure that no significant aggregations of caribou would be missed on this former traditional range in the south (Schaefer and Luttich 1998), it was agreed during the planning process to increase the study area to include the region near Okak Bay (Couturier et al. 2013). The census team was able, within the allowed budget and time, to cover the extended annual range including this traditional winter range used by the Torngat caribou in 1980s and 1990s. No caribou and very few caribou tracks were seen in this area during the census, which confirms both IK and scientific knowledge (Wilson et al. 2014; QC Gov., and NL Gov., unpubl. data). Actually, no caribou were seen south of Hebron Fjord and this census confirmed that very few caribou live now in the south of the former herd range. It was essential to survey this area to make sure that no significant aggregations of caribou were missed.

Investigation of the effect of removing part of the census area located south of Hebron Fjord (i. e. removing 11 transects were no caribou were detected) has shown very small impact on herd size estimation. Our results suggested that census area delineation was not influential on herd size estimation. Nevertheless, the next census could be done within a smaller study area.

Our census design relied on flying a large number of randomly allocated line transects within the survey area and these lines were all successfully flown from the south to the north within a relatively short period of time. Movements of caribou were very limited during the census as shown by radio-collared caribou. It is then unlikely that caribou moved away from the census northward progression (moving south, negative bias) or moved to another transect lines where they could have been counted twice (moving north, positive bias). Observers remained the same and kept their seats throughout the entire census. Their extensive experience with caribou and this land suggest that detection probability was high and unbiased.

4.2 Distance sampling

The census fulfilled the three main assumptions of distance sampling (see Methods) (Thomas et al. 2010). Considering the excellent viewing conditions of the front seat in the helicopter, it is unlikely that caribou on the transect line would have been missed as both the pilot and the left front seat observer were looking forward with excellent visibility conditions during the census. Moreover, the extensive experience of all four observers must also be mentioned as well as the low altitude during the survey that was causing caribou to run when the helicopter was approaching making them more visible for the observers. It is very unlikely that caribou would not move when an helicopter is approaching for a direct over-flight at 150 m altitude. We did not judge it necessary to test for assumption 1 with a double observer approach because the detection conditions were excellent for caribou in this type of open tundra habitat (i.e., treeless) covered by snow. Assumption 1, therefore, was likely met. As the speed of the helicopter was high compared to caribou movements, we were able to collect rapidly GPS coordinates over locations where caribou were first spotted based on their tracks in the snow, so eliminating possible evasive movements of caribou and fulfilling assumption 2. Finally, as suggested by Marques et al. (2006), we estimated perpendicular distances accurately during post-census analysis within GIS as required by assumption 3. We used actual flight tracks monitored every 2 seconds (i.e. not the planned transect line) and overhead GPS position of caribou clusters to accurately compute perpendicular distances. Using this protocol we think that measurement error was negligible. Analysis of the distribution of perpendicular distance data did not detect any sign of violations of the assumption 3.

Model selection involved a variety of metrics, many including information-theoretic measures like AIC. These information-theoretic measures assess relative fit (i.e., comparing models within a set) and they should be used in conjunction with an absolute measure of fit (such as the goodness of fit tests found in Distance) and visual examination of the distribution function plot to get a complete picture of the model most appropriate for the survey data.

In this mountainous region, Couturier et al. (2013) were expecting that most detection distances would be less than 2 km while the mean distance could reach about 400-500 m. There was a small increase in frequency of observations in the right side of the distribution corresponding to larger distance. This was probably due to the small sample size of caribou clusters. The effect of right censoring was tested (Table 1 and 4) and it appeared that the truncation was not having a strong influence on the fit of models and on the density estimates and their coefficients of variation. Thus, it was decided to use the full data set instead of doing right truncation even if this is a common practice in distance sampling analysis (Thomas et al. 2010). Notably, truncation is not mandatory and its impact relates to a number of factors including data distribution, number of clusters and size bias. In the census of caribou in southern Baffin Island, Jenkins et al. (2013) used truncation to address size bias and outliers which facilitated data modeling and resulted in minimal data loss (<2%, two observations out of 143). Thomas et al.

(2010) reported that truncation could be made typically on about 5% of distances for transect sampling while Buckland et al. (2001) suggested that truncation could remove up to 5-10% of the objects detected. In similar caribou census, the detection function was truncated at 2800 m in Baffin Island tundra by Jenkins et al. (2013) and at 1000 m in a partly open habitat on the island of Newfoundland by Fifield et al. (2012).

As this is typical for census of small wildlife populations, our distance sample was small when compared to theoretical recommendations for a distance transect survey. Fifield et al. (2012) suggested that 30-40 transects lines and at least 70-100 groups of caribou are required in order to adequately estimate sampling variance. While Buckland et al. (2001, p. 231) recommended that a minimum of 60-80 observations is normally needed in distance sampling, they also stressed that sample size should be determined based on level of precision that is needed to achieve the research or management objective. Of course, studying small wildlife population or rare animals, it may be impossible to attain these theoretical sample size recommendations. For example, Williams and Thomas (2009) estimated the abundance of killer whales (*Orcinus orca*) with distance sampling while only 18 schools were recorded during the boat census. When looking at our results of the fitted models, it seems that the density estimates and respective CVs are similar which suggest that our data set is valid although small. Thomas et al. (2010) reported that high quality dataset will provide very similar estimates even when many possible model and adjustment combinations are fitted. This was well illustrated in our results when the best fitted models gave very similar estimates (see Table 2 and 3). This was one more line of evidence that suggests that our data set was robust.

Sample size in distance sampling is made up by two elements: the number of transects and the number of groups of caribou seen during the survey. We had control on the first element and with 81 transects we had a good sample size. However, we cannot control the latter and this problem is ubiquitous for researchers studying small or at risk populations (e.g., Williams and Thomas 2009). With a relatively small sample of 50 groups, we get larger CI and CV. Most densities and accordingly herd size estimates computed in Distance 6.2 came with CV of about 0.26 to -0.29 for the Torngat caribou herd (Table 3). As a comparison, Jenkins et al. (2012) during caribou census in South Baffin reported CV of about 0.17-0.22. Our CVs are higher but they are still reasonable. The 'variance components' summary in our distance analysis indicated that much of the uncertainty in our estimates comes from variability in encounter rate (n/L, 64%). Such variability is expected when many transects are found with no observations, and a few transects with many. This is simply a patchy distribution of wildlife which leads to greater uncertainty.

Williams and Thomas (2009) reported detection probability estimates that varied so much among different fitted models that they used model averaging to incorporate model uncertainty in the detection function. Our data set was different and model selection was not influential because our estimates were much more similar. As the model averaging was carrying the model selection uncertainty, our results were showing a lower precision (higher CV, see Table 2). As the model fitting improved within MCDS analysis as shown by smaller AIC values, it was then logical to use the results of the best fitted MCDS models shown on Table 3 to estimate density and population size. Again, very similar density estimates in MCDS best three models did not ask for model averaging.

When dataset is valid, competing models with small delta-AIC values produce very similar density estimates like it is noted in our analysis. To have small differences in delta-AIC but large differences in estimated density is an unusual situation and may indicate problems with the data (Rexstad, E., pers. comm.).

4.3 Lincoln-Petersen complementary method

Since natural and harvest mortality of radio-collared caribou has been very high in the recent years, only a small number of radio-collared animals was still alive in March 2014. The number of radio-collars decreased from 20 during the planning of the project in November 2013 to 14 at the time of the census. It must be acknowledged that this small sample size compromised the reliability of the herd estimates provided by the Lincoln-Petersen method.

Buckland et al. (2004, p. 350) were suggesting to establish routine consideration of combining line transect surveys and collection of mark-recapture data as part of research or monitoring program. The two types of data could be analysed separately to provide abundance and survival information. Although the number of active radio-collars was small in our study, it was possible to compute an estimate of herd size and also to compute survival rate estimation. The complementary Lincoln-Petersen method using radio-collar visual observation confirmed the herd size given by distance sampling which is valuable as these two methods are independent. The Lincoln-Petersen method provided herd size estimate following two scenarios based on the fate of two malfunctioning radio-collars. In both scenarios, the Lincoln-Petersen estimates were lower than the estimate provided by distance sampling but all three CI widely overlapped (Table 5). It must be remembered that the Lincoln-Petersen estimates does not include the calf segment of the population. Rivest et al. (1998) reported also that Lincoln-Petersen method tend to underestimate caribou population size.

4.4 Recruitment, sex-ratio and adult survival

The recruitment of the Torngat Mountains caribou herd was estimated at 17.2% during the census done in March 2014. The classification sample size is large for a small population (291 caribou classified from a population estimated at 930 animals) and the systematic transect line survey is robust as well as our photographic classification method (see Appendix C). This level of recruitment in late winter or early spring is good and close to the average for a caribou population. A recruitment rate of 15% is considered a threshold for a stable caribou population along with an 85% survival rate for adults (Bergerud 1980). In that context, a recruitment target of 15% was recently proposed in the woodland caribou Recovery Plan in Québec (ERCFQ 2013). At 17.2%, the addition of calves into the adult population should permit population growth if the adult survival is normal or above 85% (Bergerud 1980; Crête et al. 1996). However, if adult survival is below 80%, this level of recruitment is not likely sufficient to sustain caribou population growth.

Bergerud (1980) reported that the mean sex-ratio for caribou in North America is 56 males/100 females. This author reported that if caribou sex-ratio lies outside the range of 43 to 72, an explanation should be called for. The adult sex-ratio in the Torngat herd is low at 36.9. and possible causing factors for the low abundance of adult males include heavy predation, selective hunting and winter starvation (Bergerud 1980). The adult sex-ratio should be monitored closely in the future studies of the Torngat herd.

It must be acknowledged that most survival rate estimates were based on small number of radio-collars which limits the power of our findings. Nevertheless, the recent monitoring started in 2011-2012 provided larger sample sizes that could better support survival estimation. The annual adult survival was below 66% for three biological years starting in 2011-2012 (Figure 6) which was likely associated with a declining caribou population.

5. Conclusion and recommendations

Based on our March 2014 caribou census and on our detailed analysis we recommend that the distance sampling herd size result of 930 (CI: 616-1453) be used for management of the Torngat Mountains caribou herd. Although it must be acknowledged that our analysis of adult annual survival has many limitations due to the small number of radio-collars, we recommend caution in the management of this herd. Indeed, most annual survival rates are so low that they were likely associated with a declining population. Even the good recruitment recorded in March 2014 cannot compensate for such a magnitude of loss of adults. Since 2011, hunting mortality seems to be higher than natural mortality.

As we have now for the first time a herd size estimate, one of the management goals in the near future would be to monitor population trends. One way to investigate caribou population changes is to repeat census periodically over the annual range. Our census technique provides a systematic tool to monitor changes in abundance over time in Torngat caribou. Indeed, a sample of the same transects flown in March 2014 could be surveyed again after some years to estimate population trends using distance sampling. When the management goal is to monitor changes over time, greater precision is obtained by flying the same sample of transects at a later time (Buckland et al. 2001). However, it must be acknowledged that low precision estimates may be problematic when trying to compare census results to detect population trends. Indeed, the next census result could be within the confidence interval reported in March 2014 and not much would be learned then about population trends.

In a future census, a smaller study area can be redesigned if both scientific and IK data confirm that herd range continue to retract. This was useful to cover all the historic range during our census but for the next census, the study area should be re-evaluated. This may represent a reduction of study area and survey costs because the region south of Hebron Fjord, or even Saglek Fjord, may be removed if caribou continue to be rare in this area.

Population modelling represents another method that can track population changes but data on both survival of adults and recruitment of calves must be collected annually. Radio-telemetry is the best method to estimate survival rate of adult caribou but radio-collaring is seen by some observers as too invasive. It should be acknowledged that in the past radio-collars may have caused minor problems to some caribou particularly because former radio-collars were larger and heavier in the early stages of the technology. Former satellite radio-collars weighed up to 1.6 kg and they could have decreased slightly survival likelihood of some individual caribou of the George River Herd as suggested by Rasiulis et al. (2014). As reported by these authors, the detrimental effect was seen only for some animals carrying collars and was not involved in population level decline. More recently, satellite radio-collars are getting smaller and some models can weigh as little as 0.5 kg. One could ask if causing some minor inconveniences to some individual caribou is justified as radio-collaring brings many significant benefits to the whole herd management. A better knowledge of adult survival could result in more permissive harvesting plans because without this information managers must often be more conservative to avoid possible overharvest. Like shown in this study, radio-collaring not only gave a valuable tool to estimate survival, but it also provided a framework to estimate herd size. The Lincoln-Petersen census method is more powerful when the number of radio-collars is large (>25).

Annual survey of recruitment represents one of the first research activities done by biologists in the scientific monitoring of caribou populations in North America. Some variants exist in the methods and periods used but investigating the relative abundance of calves in March or early April during aerial population classification is the preferred method because most first year natural mortality had already happened. This means that the relative importance of calves in the population will not change much from March to June when they are about to join theoretically the adult population. For the Torngat herd, March or early April represents also the best timing to monitor recruitment because the risk of seasonal range overlapping with the neighbour George River herd is then minimal. The possibility of range overlapping must be investigated before doing any population classification on the Torngat herd and the use of radio-collar data is the preferred method to do so. In the field, researchers must find caribou aggregations and caribou biologists may use radio-collars data to locate caribou groups. This must be used with caution though if the sample of radio-collars is small or if it is not evenly distributed among sexes. Possible bias may occur if researchers target radio-collars deployed only or mostly on adult females as male-only groups would be likely missed (Ferguson and Elkie 2004). Erratic or opportunistic aerial searches can also be used to locate caribou groups but they are not systematic or repeatable. In the Torngat caribou monitoring, instead of doing opportunistic flying patterns to locate caribou groups by chance, or instead of searching for radio-collars, it would be more efficient to fly over a random line sample drawn from the same transect lines used in March 2014 north of Hebron Fjord (i.e., 70 transects lines). Each year, a sample of transect lines could be fly to locate caribou groups for the classification using the photo method described in this report. Doing so would not only provide group classification opportunities, but would also collect herd size data that could be used later in distance sampling to estimate population trends.

In conclusion and following our findings, we recommend that:

- another distance sampling census be repeated in March 2017 using the same method (same transects) but likely with a smaller census area if scientific and IK data confirm range retraction;
- spring classification be done every year in March or early April using photographs taken with telephoto lens from an helicopter flying over transect lines designed in March 2014;
- maintain 25 small (<0.8 kg) radio-collars in the Torngat Mountains herd during capture projects involving local people.

References

Banfield, A. W. F. (1961). A revision of the reindeer and caribou genus *Rangifer*. Ottawa, Canada, Dept. of Northern Affairs and National Resources. Bulletin No. 177. 137 p.

Bélanger, M. & Le Henaff, D. (1985). Distribution, abundance and regulation of caribou hunting in Quebec. Proc. Second North American caribou Workshop, Val Morin, QC, *McGill Subarctic Research Paper, 40*, 3–13.

Bergerud, A. T. (1980). A review of the population dynamics of caribou and wild reindeer in North America. *Proc. 2nd Int. Reindeer/Caribou Symposium*, 556–581, Roros, Norway.

Bergerud, A. T. (1988). Caribou, wolves and Man. *Trends Ecol. Evol., 3*, 68–72.

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

Boulet, M., Couturier, S., Côté, S. D., Otto, R. D., & Bernatchez, L. (2007). Integrative use of spatial, genetic, and demographic analyses for investigating genetic connectivity between migratory, montane, and sedentary caribou herds. *Mol. Ecol., 16*, 4223–4240.

Buckland, S. T., Anderson, D. R., Burnham K. P., Laake, J. L., Borchers, D. L., & Thomas, L. (2001). Introduction to distance sampling. Oxford University Press, London, 432 pp.

Buckland, S. T., Anderson, D. R., Burnham K. P, Laake, J. L., Borchers, D. L., & Thomas, L. (2004). Advanced distance sampling. Oxford, Oxford University Press. 416 pp.

COSEWIC (2011). Designatable units for caribou (*Rangifer tarandus*) in Canada. Ottawa, Committee on the status of Endangered Wildlife in Canada (COSEWIC).

Couturier, S., Courtois, R., Crépeau, H., Rivest, L. P., & Luttich, S. (1996). Calving photocensus of the Rivière George Caribou Herd and comparison with an independent census. In Proc. Sixth North American Caribou Workshop, Prince George, British Columbia. *Rangifer, Special Issue 9*, 283–296.

Couturier, S., Jean, D., Otto, R., & Rivard, S. (2004). Demography of the migratory tundra caribou (*Rangifer tarandus*) of the Nord-du-Québec region and Labrador. Min. Ressources naturelles, Faune et Parcs, Québec, QC.

Couturier, S., Nash, P., & Marriott, M. (2013). Census of the Torngat Mountains caribou herd in late winter 2014: Estimating herd size and population dynamics. Project proposal submitted to the Torngat Caribou Committee. Happy Valley-Goose Bay, NL. 14 p.

Couturier, S., Otto, R. D., Côté, S. D., Luther, G., & Mahoney, S. P. (2010). Body size variations in caribou ecotypes and relationships with demography. *Journal of Wildlife Management, 74*, 395–404.

Crête, M., Couturier, S., Hearn, B. J., & Chubbs, T. E. (1996). Relative contribution of decreased productivity and survival to recent changes in the demographic trend of the Rivière George herd. *Rangifer (Special Issue No. 9)*, 27–36.

Équipe de rétablissement du caribou forestier du Québec. (ERCFQ) (2013). Plan de rétablissement du caribou forestier (*Rangifer tarandus caribou*) au Québec — 2013-2023.

Québec, Qc, Ministère Développement durable, Environnement, Faune et Parcs, Québec. 110 pp.

Ferguson, S.H., & P.C. Elkie. 2004. Seasonal movement patterns of woodland caribou (*Rangifer tarandus caribou*). *J. Zool., Lond. 262*, 125–134.

Fifield, D. A., Lewis, K. P., & Gullage, S. E. (2012). Application of distance sampling to determine calving ground abundance and aggregation of parturient females in the Middle Ridge herd, June 2012. Dept. of Env. and Conserv., Sustainable Development and Strategic Science. St. John's, NL. Technical Bulletin No. 005: 17 p.

Heisey, D. M. & T. K. Fuller (1985). Evaluation of survival and cause-specific mortality rates using telemetry data. *Journal of Wildlife Management, 49*, 668–674.

Geist, V. (1998). Deer of the World: Their Evolution, Behavior, and Ecology. Mechanicsburg, PA, Stackpole Books. 421 p.

Jenkins, D. A. (2007). Estimating Peary caribou (*Rangifer tarandus pearyi*) and Muskox (*Ovibos moschatus*) numbers, composition and distributions on Ellesmere Island, Nunavut. Interim report. NWMB Project. Pond Inlet, NU, Department of Environment, Government of Nunavut. 02-06-08: 9.

Jenkins, D. A. (2008). The distribution and abundance of Peary caribou and Muskoxen across the North Western High Arctic Islands, Nunavut. Interim Report. Pond Inlet, NU, Department of Environment, Government of Nunavut.

Jenkins, D. A. (2009). The distribution and abundance of Peary caribou and Muskoxen across Devon Island, Nunavut. Interim Report. Pond Inlet, NU, Department of Environment, Government of Nunavut.

Jenkins, D. A., Campbell, M., Hope, G., Goorts, J., & McLoughlin, P. (2011). Recent trends in abundance of Peary caribou (*Rangifer tarandus pearyi*) and muskoxen (*Ovibos moschatus*) in the Canadian Arctic Archipelago, Nunavut. Wildlife Report. Pond Inlet, NU, Department of Environment, Government of Nunavut. 184 pp.

Jenkins, D. A., Goorts, J., & Lecomte, N. (2013). Estimating the Abundance of South Baffin Caribou - Summary Report 2012. Pond Inlet, Nunavut, Department of Environment, Government of Nunavut.

Losier, C., Couturier, S., St-Laurent, M.-H., Drapeau, P., Dussault, C., Rudolf, T., Brodeur, V., Merkle, J. A., & Fortin, D. 2014. Adjustments in habitat selection to changing availability induce fitness costs for a threatened ungulate. Submitted to Journal of Applied Ecology.

Marques, T. A., Andersen, M., Christensen-Dalsgaard, S., Belikov, S., Boltunov, A., Wiig, O., Buckland, S. T., & Aars, J. (2006). The use of Global Positioning Systems to record distances in a helicopter line-transect survey. *Wildlife Society Bulletin, 34,* 759–763.

Marques, T. A., Thomas, L., Fancy, S. G., & Buckland, S. T. (2007). Improving estimates of bird density using multiple- covariate distance sampling. *The Auk, 124,* 1229–1243.

Nash, P. (2013). July 2013 Reconnaissance flight Torngat Mountain caribou range – Draft. Happy Valley-Goose Bay, NL, Torngat Wildlife, Plants and Fisheries Secretariat.

Rasiulis, A. L., Festa-Bianchet, M., Couturier, S., & Côté, S. D. (2014). The effect of radio-collar weight on survival of migratory caribou. *The Journal of Wildlife Management, 78,* 953–956.

Research Unit for Wildlife Population Assessment. (RUWPA) (2014). User's Guide Distance 6.2 Release 1. 355 p.

Rivest, L.-P., Couturier, S., & Crépeau, H. (1998). Statistical methods for estimating caribou abundance using postcalving aggregations detected by radio telemetry. *Biometrics, 54,* 865–876.

Russell, J., Couturier, S., Sopuck, L. G., & Ovaska, K. (1996). Post-calving photo-census of the Rivière George caribou herd in July 1993. *Rangifer, Special Issue No. 9*, 319–330.

Schaefer, J. A., & Luttich, S. N. (1998). Movements and activity of caribou, *Rangifer tarandus caribou*, of the Torngat Mountains, northern Labrador and Québec. *Can. Field Nat., 112*, 486–490.

St-Laurent, M.-H., Ouellet, J. P., Mosnier, A., Boisjoly, D., & Courtois, R. (2009). Le parc national de la Gaspésie est-il un outil de conservation efficace pour maintenir une population menacée de caribou? *Le Naturaliste canadien, 133*, 6–14.

Thomas, L., Buckland, S. T., Rexstad, E. A., Laake, J. L., Strindberg, S., Hedley, S. L., Bishop, J. R. B., Marques, T. A., & Burhham, K. P. (2010). Distance software: design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology*, *47*, 5–14.

Williams, R., & Thomas, L. (2009). Cost-effective abundance estimation of rare animals: Testing performance of small-boat surveys for killer whales in British Columbia. *Biological Conservation, 142,* 1542–1547.

Wilson, K. S., Basterfield, M. W., Furgal, C., Sheldon, T., Allen, E., Communities of Nain and Kangiqsualujjuaq, & Co-operative Management Board for the Torngat Mountains National Park (2014). Across borders, for the future: Torngat Mountains caribou herd Inuit knowledge, culture, and values study. Nain, NL, Final report to the Nunatsiavut Government, Makivik Corporation, Parks Canada, and the Torngat Wildlife and Plants Co-Management Board: 72 p. & appendices.

White, G. C., & Garrott, R. A. (1990). Analysis of wildlife radio-tracking data. San Diego, USA, Academic Press Inc.

Appendix A

Transect related information (visibility, temperature, clouds percentage, precipitation) including base camp used and flying time.

Trans.	Start Date/Time	End Date/Time	Time (h)	Vis. class	T. (°C)	Clouds (%)	Precipitation	Base camp [a]	Comments
1	2014-03-13 14:52	2014-03-13 15:43	0.850	3	-20	10%	None	HF	
2	2014-03-13 15:50	2014-03-13 16:30	0.667	3	-21	10%	None	HF	
3	2014-03-13 17:07	2014-03-13 17:59	0.867	3	-15	10%	None	HF	
4	2014-03-13 18:03	2014-03-13 18:47	0.733	3	-19	10%	None	HF	
5	2014-03-14 10:19	2014-03-14 11:06	0.783	3	-23	10%	None	HF	
6	2014-03-14 11:40	2014-03-14 12:31	0.850	3	-17	10%	None	HF	
7	2014-03-14 12:35	2014-03-14 13:21	0.767	3	-25	10%	None	HF	
8	2014-03-14 14:11	2014-03-14 15:05	0.900	3	-15	10%	None	HF	
9	2014-03-14 15:11	2014-03-14 15:59	0.800	3	-25	10%	None	HF	
10	2014-03-14 16:46	2014-03-14 17:45	0.983	3	-17	20%	None	HF	
11	2014-03-14 17:48	2014-03-14 18:32	0.733	3	-25	0%	None	HF	
12	2014-03-14 18:39	2014-03-14 19:08	0.483	3	-16	0%	None	HF	
13	2014-03-15 10:47	2014-03-15 11:22	0.583	3	-21	0%	None	HF	
14	2014-03-15 11:32	2014-03-15 12:15	0.717	3	-17	0%	None	HF	
15	2014-03-15 12:18	2014-03-15 12:39	0.350	3	-22	0%	None	HF	
16	2014-03-15 14:36	2014-03-15 15:17	0.683	3	-16	0%	None	HF	
17	2014-03-15 15:19	2014-03-15 15:56	0.617	3	-20	0%	None	HF	
18	2014-03-15 15:59	2014-03-15 16:35	0.600	3	-15	0%	None	HF	
19	2014-03-15 16:38	2014-03-15 17:05	0.450	3	-20	0%	None	HF	
20	2014-03-15 18:04	2014-03-15 18:39	0.583	3	-17	0%	None	HF	
21	2014-03-15 18:43	2014-03-15 19:13	0.500	3	-17	0%	None	HF	
22	2014-03-18 10:02	2014-03-18 10:40	0.633	3	-17	30%	None	KK	
23	2014-03-18 12:42	2014-03-18 13:17	0.583	3	-17	30%	None	KK	
24	2014-03-18 13:20	2014-03-18 13:33	0.217	3	-12	20%	None	KK	
25	2014-03-18 15:55	2014-03-18 16:32	0.617	3	-13	20%	None	KK	
26	2014-03-18 16:38	2014-03-18 17:20	0.700	3	-12	10%	None	KK	
27	2014-03-18 17:54	2014-03-18 18:15	0.350	3	-19	0%	None	KK	
28	2014-03-18 18:22	2014-03-18 18:52	0.500	3	-13	20%	None	KK	
29	2014-03-19 09:41	2014-03-19 10:11	0.500	3	-20	30%	None	KK	
30	2014-03-19 10:15	2014-03-19 10:50	0.583	3	-13	30%	None	KK	
31	2014-03-19 11:33	2014-03-19 12:10	0.617	3	-20	30%	None	KK	
32	2014-03-19 12:12	2014-03-19 12:55	0.717	3	-13	30%	None	KK	
33	2014-03-19 12:57	2014-03-19 13:40	0.717	3	-16	30%	None	KK	
34	2014-03-19 13:44	2014-03-19 14:20	0.600	3	-13	30%	None	KK	
35	2014-03-19 15:22	2014-03-19 16:04	0.700	3	-16	20%	None	KK	
36	2014-03-19 16:06	2014-03-19 16:42	0.600	3	-12	40%	None	KK	
37	2014-03-19 17:15	2014-03-19 17:48	0.550	3	-12	10%	None	KK	
38	2014-03-19 17:52	2014-03-19 18:33	0.683	3	-12	10%	None	KK	

39	2014-03-20 14:08	2014-03-20 15:09	1.017	3	-12	10%	None	KQ	
40	2014-03-20 15:23	2014-03-20 17:08	1.750	3	-13	0%	None	KQ	fueling
41	2014-03-25 10:57	2014-03-25 12:03	1.100	3	-22	0%	Scattered ice crystal patches	KQ	
42	2014-03-25 12:06	2014-03-25 13:17	1.183	3	-17	0%	Scattered ice crystal patches	KQ	
43	2014-03-24 11:48	2014-03-24 12:44	0.933	3	-23	40%	None	KQ	
44	2014-03-24 12:53	2014-03-24 13:39	0.767	3	-16	40%	None	KQ	
45	2014-03-24 13:45	2014-03-24 15:33	1.800	3	-21	20%	None	KQ	fueling
46	2014-03-24 15:39	2014-03-24 17:18	1.650	3	-21	10%	None	KQ	fueling
47	2014-03-24 17:20	2014-03-24 18:22	1.033	3	-20	0%	None	KQ	
48	2014-03-24 18:24	2014-03-24 19:14	0.833	3	-19	0%	None	KQ	
49	2014-03-25 14:50	2014-03-25 15:37	0.783	3	-18	10%	None	KQ	
50	2014-03-25 15:39	2014-03-25 16:34	0.917	3	-15	0%	None	KQ	
51	2014-03-25 16:36	2014-03-25 17:55	1.317	3	-18	0%	None	KQ	fueling
52	2014-03-25 18:01	2014-03-25 18:40	0.650	2	-16	10%	Scattered ice crystal patches	KQ	windy
53	2014-03-26 10:01	2014-03-26 10:37	0.600	3	-15	10%	None	KQ	
54	2014-03-26 10:43	2014-03-26 11:40	0.950	3	-15	10%	Scattered ice crystal patches	KQ	
55	2014-03-26 11:42	2014-03-26 13:06	1.400	3	-15	0%	None	KQ	fueling
56	2014-03-26 13:08	2014-03-26 13:50	0.700	3	-19	0%	None	KQ	
57	2014-03-26 13:53	2014-03-26 14:35	0.700	3	-12	0%	None	KQ	
58	2014-03-26 14:36	2014-03-26 15:09	0.550	3	-13	0%	None	KQ	
59	2014-03-26 15:57	2014-03-26 16:37	0.667	3	-10	0%	None	KQ	
60	2014-03-26 16:40	2014-03-26 17:15	0.583	3	-12	0%	None	KQ	
61	2014-03-26 17:17	2014-03-26 17:47	0.500	3	-10	0%	None	KQ	
62	2014-03-26 17:52	2014-03-26 18:31	0.650	3	-13	0%	None	KQ	
63	2014-03-28 10:26	2014-03-28 10:57	0.517	3	-18	30%	None	KQ	fresh snow yesterday
64	2014-03-28 11:00	2014-03-28 11:33	0.550	3	-15	20%	Scattered ice crystal patches	KQ	
65	2014-03-28 11:35	2014-03-28 12:10	0.583	3	-19	10%	None	KQ	
66	2014-03-28 13:05	2014-03-28 13:42	0.617	3	-19	30%	Scattered ice crystal patches	KQ	windy
67	2014-03-28 14:48	2014-03-28 15:14	0.433	3	-17	20%	Scattered ice crystal patches	KQ	windy
68	2014-03-28 15:18	2014-03-28 15:44	0.433	3	-17	20%	Scattered ice crystal	KQ	

							patches		
69	2014-03-28 15:52	2014-03-28 16:15	0.383	2	-17	20%	Some blowing snow (ground)	KQ	windy
70	2014-03-28 16:16	2014-03-28 17:17	1.017	3	-17	20%	Some blowing snow (ground)	KQ	windy. fueling
71	2014-03-28 17:19	2014-03-28 17:32	0.217	3	-17	20%	None	KQ	windy
72	2014-03-28 17:34	2014-03-28 17:52	0.300	3	-19	10%	None	KQ	
73	2014-03-29 09:53	2014-03-29 10:08	0.250	3	-16	40%	None	KQ	
74	2014-03-29 10:10	2014-03-29 10:26	0.267	3	-15	40%	None	KQ	
75	2014-03-29 10:29	2014-03-29 10:39	0.167	3	-16	30%	None	KQ	
76	2014-03-29 10:40	2014-03-29 10:50	0.167	3	-16	50%	None	KQ	
77	2014-03-29 10:53	2014-03-29 11:05	0.200	3	-15	50%	None	KQ	
78	2014-03-29 11:07	2014-03-29 11:12	0.083	3	-15	50%	None	KQ	
79	2014-03-29 11:18	2014-03-29 11:22	0.067	3	-15	50%	None	KQ	
80	2014-03-29 11:24	2014-03-29 11:29	0.083	3	-15	50%	None	KQ	
81	2014-03-29 11:33	2014-03-29 11:37	0.067	3	-15	50%	None	KQ	
Means				**2.98**	**-16.7**	**16%**			
SE					**3.4**	**16%**			
Sum			**53.8**						

[a] Base camp
HF: Hebron Fjord cabin
KK: Korluktok camp
KQ: Kangiqsualujjuaq

Appendix B

Description of groups of caribou seen on and off transects during the Torngat Mountains caribou herd census in March 2014.

Date/ Time	Group #	Collar seen	Antlered Female	Unantlered Female	Antlered Male	Unantlered Male	Calf	Total
2014-03-15	1	1	2					2
2014-03-15	2	0	1	1			1	3
2014-03-18	3	1	5	1	4	1		11
2014-03-19	4	0	4		1			5
2014-03-20	5	1	3				1	4
2014-03-20	6	0				1		1
2014-03-24	7	0	4		1			5
2014-03-24	8	0	2				2	4
2014-03-24	9	0	12		4		2	18
2014-03-24	10	1				5		5
2014-03-24	11	0	11		3		1	15
2014-03-24	12	0	3				2	5
2014-03-24	13	0	1		2	1		4
2014-03-25	14	0	5				3	8
2014-03-25	15	1	1		1	3	1	6
2014-03-25	16	0	1				1	2
2014-03-25	17	1	9		5		1	15
2014-03-25	18	0	4				3	7
2014-03-26	19	0	1		1		1	3
2014-03-26	20	0			1	1		2
2014-03-26	21	0	2					2
2014-03-26	22	0	1	1			2	4
2014-03-26	23	0	3				1	4
2014-03-26	24	0	4		2			6
2014-03-26	25	0				1		1
2014-03-26	26	0	3					3
2014-03-26	27	0	2					2
2014-03-26	28	0	7		2		4	13
2014-03-26	29	0	3				2	5
2014-03-28	30	0	1				1	2
2014-03-28	31	0	1		1			2
2014-03-28	32	0	4		1		2	7

2014-03-28	33	0	1				2	3
2014-03-28	34	0	3		3			6
2014-03-28	35	0	2					2
2014-03-28	36	0	3					3
2014-03-28	37	0	6		2			8
2014-03-28	38	0	1		1		1	3
2014-03-28	39	0	4		2			6
2014-03-28	40	0	4				2	6
2014-03-28	41	0	9		2			11
2014-03-28	42	0	2					2
2014-03-28	43	0			2	3		5
2014-03-28	44	0	1				1	2
2014-03-28	45	0	2				2	4
2014-03-28	46	0	7				1	8
2014-03-28	47	0	5	1			3	9
2014-03-28	48	0	2		2		1	5
2014-03-28	49	0	3		1			4
2014-03-28	50	0	6	1	2	1	1	11
2014-03-29	51	0	4	1		1	1	7
2014-03-29	52	0	3				2	5
2014-03-29	53	0	2		1		2	5
Total		6	170	6	47	18	50	291

Appendix C

Examples of six caribou groups photographed during the Torngat Mountains caribou herd census in March 2014. Note that these selected photos are not necessarily those that have been used to classify caribou as some are presented to show landscape, snow and visibility conditions.

A. Group 7 (photo SC0_1824)

B. Group 9 (photo SC0_1854)

C. Group 23 (photo SC0_2030)

D. Group 24 (photo SC0_2045)

E. Group 29 (photo SC0_2080)

F. Group 48 (photo SC0_2273)