Results of a spring 2017 aerial survey of the Torngat Mountains Caribou Herd.

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In collaboration with the Torngat Caribou Technical Committee:
Government of Quebec, Newfoundland & Labrador Government, Nunatsiavut Government, Parks Canada, Makivik Corporation and Kativik Regional Government (Nunavik Parks).

Torngat Wildlife and Plants Co-Management Board

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.

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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Ryan Merkuratsuk from Nain, Nunatsiavut (NL) and Tommie Unatweenuk from Kangiqsualujjuaq, Nunavik (QC) provided invaluable assistance in the field. Their knowledge of the land contributed to the success of the survey. Also, pilot Steve Lodge provided safe operation of the helicopter during a long field study in this remote and often harsh region. The survey protocol was presented in March 2017 during two public meetings held in Kangiqsualujjuaq and Nain. We would like to thank people who took this opportunity to exchange information with us about the status of their local caribou. Special thanks to Charlie Munick, Kuururjuaq Park Director who let us use the Qurlutuarjuq facilities as a base camp for several days. The Kuururjuaq Park Director also provided housing facilities for the team in Kangiqsualujjuaq during the first leg of the survey. Also, thanks to the Parc national Kuururjuaq's staff Darrel Emak, Jessie Baron, Cecilia Emudluk, Jari Leduc and Olivier Paradis who were gracious in sharing the Qurlutuarjuq camp with us. The survey lasted about a month and many people assisted with the operation in the field: Tummasi Itua Annanack, Henry Lyall, Charlie Munick and others both in Kangiqsualujjuaq and Nain. Thanks to Étienne Caron from Héli-Boréal (Sept-Îles, QC), Peter Duncan from Nunavik Rotors (Kuujjuaq, QC) and Matthew Emudluk (Kangiqsualujjuaq, QC) for their help with fuel deployment.

This project represents the best of co-management with partners representing seven institutions coming together at a technical and operational scale to accomplish a monumental task prioritised by the people of Nunavik and Nunatsiavut. The commitment of all partners to see this project through to completion was a defining factor in the success of this endeavour.

Executive Summary

Inuit of Nunavik and Nunatsiavut have long known that a small caribou population was living year-round in the Torngat Mountains. Recognizing its unique status, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has recently identified the Torngat caribou as one of eleven units for caribou conservation across Canada. In 2016, COSEWIC assessed the status of the Torngat caribou as Endangered based largely on the inherent risk associated with its small population size.

An informal Torngat Caribou Technical Committee was established in 2013 to address research needs. The Torngat Committee is a coalition of interested parties and it includes representatives from the Government of Quebec, the Government of Newfoundland & Labrador, the Nunatsiavut Government, Makivik Corporation, Kativik Regional Government (Nunavik Parks), Parks Canada, and the Torngat Wildlife, Plants and Fisheries Secretariat (on behalf of the Torngat Wildlife and Plants Co-management Board). Following discussion among the Torngat Committee, the first aerial population survey of the Torngat Mountains Caribou Herd was carried out in March 2014 (Couturier et al. 2015), and estimated the herd size at 930 caribou. To continue the scientific monitoring of the herd, all members of the Torngat Committee dedicated funds and/or in-kind contributions to support a second systematic population survey of the Torngat caribou herd. This was carried out in March and April 2017 following a similar distance sampling technique as was employed in 2014.

The study area was divided into two geographic strata, north and south, along a line located on latitude 58° 55′ N. It was expected that caribou density would be higher in the northern stratum, therefore more sampling effort was devoted there. Parallel transects ran east-west and were separated by 3 km in the north and 4 km in the south. Observers recorded caribou groups and other mammal species seen on a total of 91 transects flown at slow speed and low altitude. Weather conditions and visibility were excellent during flying days. Total transect length was 7,722 km and the survey area covered 30,625 km^2 between Okak Bay and Killiniq Island. Three packs of wolves (8 wolves), fourteen polar bears, and one arctic fox were observed. Fifty-eight caribou groups were observed on-transect for a total of 610 caribou. Observed group size varied from 1 to 38 caribou with a mean of 10.5 caribou per group. Group size in 2017 was almost twice that reported in 2014 (5.4). As in 2014, recruitment was high, with calves accounting for 23.1% of the animals observed, which would theoretically allow for a growing population under typical demographic conditions. No caribou were observed south of Hebron Fjord, while most of the groups were seen north of Nachvak Fjord. The distance sampling method estimated Torngat Herd size in 2017 at 1,326 caribou (including calves) with a confidence interval ranging from 912 to 1,986. The strata sampling design yielded estimates of 1,045 and 281 caribou in the north and south strata, respectively. However, while these results may seem encouraging for the Torngat Herd, this survey confirmed that it is still small and needs careful attention from managers and users.

AngajukKauniujuit Kaujititsiutinga Nailittisimajuk

Inuit Nunavimmi, Nunatsiavummilu akuninit KaujimasimalikKut unuttolungituit tuttuit jâri nâdlugu iniKaKattaninginnik Tungait KakKasuanginni. Ilitagidlugu tamanna adjiusialugani ilusiujuk, katimajiujuit kamajiudlutik Canadami Omajunik Nungutautuinnagiangit Ilimanattumejunik (COSEWIc) mânnaKamiulauttuk ulinnaisilaukKut tamakkuninga Tungait tuttuKutinginnik ilangiunninginnik ailfaujuit immigolingallutik tuttuKutiujunik Canadami kamagijautsiagialinnik nungutauttailikKulugit. 2016-nami, tamakkua COSEWIC-kut KaujiutiKalaukKut tamakkua Tungait tuttungit Nungutautuinnagiangit Ilimanattumenninginnik pitjutiKallutik ununningit ikiluadlalimmata ulugianattumenninginnik.
Pimmagiulungikkaluallutik Tungait TuttuKutinginnik kamajitsaulutik katimajet pigiasittitaulaukKut 2013-nami kamakKulugit KaujisautiKagajannimik atuttaugiaKagajattunik. Tungait katimajingit katimajiuvut kamaKataugumatsiajuit, ilauKatautillugit kiggatuttiujuit Quebec-iup kavamanganit, Niufulâlu, Labradoriullu kavamanganit, Nunatsiavut kavamanganit, Makivikkut kuapanganit, kativikkut kavamanganit (Nunavimmi SilakKijapviligijingit), Canadami SilakKijapviligijingit, Tungait Omajuligijingita, Pigutsiagijet, Ugannaituligijellu Aulatsivingalu (kiggatullutik Tungait Omajuligijingita Pigutsialigijingita ikajuttigellutik kamajiullutik katimajinginnik). Tungait katimajingit uKâlautikKâtillugit, sivullipâmik tingijokkut Kaujisapviusimajuit allasimavut ovani (Couturier et al. 2015), nalautsâgutigillugillu tuttuit ununningit 930-tiulaukKut. Suli Kaujisautigigumallugit kamagumallutik tuttunik, ilonnaita ilaliutijuit Tungait katimajinginnut aittotiKalaukKut kenaujanik ammala/ubvalu tunijidlutik aippânik Kimiggugumallutik Tungait tuttuKutingita ununninginnik. Tamanna kajusittitaulaukKuk Mertz-imi Âprelimilu 2017-nami atudlutik adjigalanganik Kaninginingata atulauttangata 2014-nami.
Tamanna KaujisautiKannimi inigilauttanga aviukKasimalaukKuk magguilingatillugu nunanguami, taggâni, siKinganilu, nunanguami titigasimajumi 58 55′ N. NigiunnalaukKuk tuttuit ununningit taggânenitsaugajanninginnik, taimaimmalu tappâni kamalualaukKut. Adjigettumik ikâttanimmi kitânit kangimut aiKattalauttuit avisimautinniKadlutik 3 kilometers-itut taggânit, 4 kilometers-itullu siKinganit. kamaKataulauttuit takulaukKut tuttunik katingajunik asinginnilu omajunik katidlugit 91-naittudlutik ikâttanimmi sukkaisâdlutik, pukkitodlutillu. Silak piujolauttuk takunnânatsiadlunilu tingilanannita ullunginni. Ikâttadluta tingigalannivut KaninginiKalaukKuk 7,772 kilometers-itut, Kimigguvigijavullu ininga anginiKattilugu 30,625 kilometers-itut akungani OkKaup kangidluata killiniullu Kikkitanganit. TakulaukKugut pingasunik amagunik katingajunik (âttat amaguit), 14-nanik nanunnik, atautsimillu tiggiganniamik. TakulaukKugut 58-tinik tuttunik katingajunik ikâgalannitini katillugillu 610-ninik tuttunik. takuKattajavullu katingaKattatallugit

ununniKaKattalauttuit atautsimit, 38-tinut tuttunik, taggalu ununniKaKattadlutik tuttuit katingautijuit 10.5-itut.

katinggautiKattajuillu 2017-nami ununniKaKattalauttuit magguitulluangukasâdlutik uKautaulauttunit 2014-nami (5.4). Sollu 2014-nami, unutsivallisimalaukKut, nuggangit unutsivallisimattilugit 23.1%-itut, takulauttattini, taggalu takutitsidluni unutsiumisimanninginnik unutsiumisongunningit malillugu. Tuttunik takululaungituit Nachvâp kangidluata siKingani, ununningillu katingajuit takujautillugit Nachvâp kangidluata taggâni. Kaninginga takunnâlugu kamasiulauttulu Tungait tuttuKutingita ununningit 2017-nami 1,326-iulaukKut (ilauKasiutillugit nuggait) taggalu katsungaittogasualluni akunganegajakKut 912-et 1,986-imut. Kaujisanniulauttumi atuttaulauttuk takunnâlugu nalautsâgajakKut 1,045-init 281-nanut tuttunik taggâni, siKinganilu, katillugit. Taimaigaluattilugu, tamakkua Kaujijaulauttuit piggonakKogaluattilugit Tungait tuttungit pillugit, tamanna Kaujisanniulauttuk takutitsigunnatuk suli ikittoninginnik kamagijautsiagiaKanninginillu angajukKauniujunut, tuttuniaKattatunullu.

ᓀᓪᓚᑎᕐᓯᒪᔪᖅ ᑐᓴᕐᑎᓯᒍᑎᒃ

ᓄᓇᕕᒻᒥᐅᑦ ᓄᓇᑦᓯᐊᕘᒻᒥᐅᓗ ᐃᓄᐃᑦ ᖃᐅᔨᒪᓂᑐᕐᑫᑦ ᑐᑦᑐᐃᑦ ᐃᑭᑦᑐᐃᑦ ᐊᕐᕿᒍᓕᒫᒥ ᑑᕐᖏᑦ ᖃᕐᖃᖏᓐᓃᓲᖑᕆᐊᖏᑦ. ᐃᓕᑕᕐᓯᓱᑎᒃ ᐊᑦᔨᐅᖏᑦᑐᒥᒃ ᑌᒫᓕᖕᒪᐅᓯᖃᕐᑎᓗᕆᑦ, ᑲᑎᒪᕕᐊᕖᑦ ᑲᓇᑕᐅᑉ ᓂᕐᔪᑎᓂᒃ ᐊᑦᑕᓇᕐᑐᒦᓪᓕᕐᓂᕋᕐᑕᐅᔪᑦ ᑲᑎᒪᔩᖏᓐᓄᑦ (COSEWIC) ᓇᓗᓀᕐᓯᖃᒻᒥᖅ ᑑᕐᖏᑦ ᑐᑦᑐᖕᓂᒃ ᐃᓚᒋᔭᐅᓂᕕᑦᓱᑎᒃ 11-ᓄᑦ ᐊᓯᑦᑕᐅᑌᓂᑎᑕᐅᒍᓯᕐᓄᑦ ᑲᓇᑕᒥ. 2016-ᖑᑎᓪᓗᒍ, COSEWIC-ᑯᑦ ᖃᐅᔨᕆᐊᕐᑐᕕᓃᑦ ᑑᕐᖏᑦ ᑐᑦᑐᖏᓐᓂᒃ ᐊᑦᑕᓇᕐᑑᓐᓂᕋᕐᑕᐅᒍᑎᖏᓐᓂᒃ ᑐᖕᖓᕕᖃᓗᐊᖕᖑᐊᓱᑎᒃ ᓇᖏᐊᕐᓇᑑᓐᓂᑯᖏᓐᓄᑦ ᐱᑦᔪᑎᓕᒻᒥᒃ ᐃᑭᑦᑑᓂᑯᖏᓐᓄᑦ.

ᑑᕐᖏᑦ ᑐᑦᑐᖏᑦᑕ ᐱᓪᓗᑯᑎᐊᓕᓕᕆᓂᕐᒧᑦ ᑲᑎᖕᖓᔨᐊᐱᖏᑦ ᐃᓂᓪᓚᑕᐅᓯᒪᔪᑦ 2013-ᖑᑎᓪᓗᒍ ᑲᒪᕐᑯᔭᐅᑦᓱᑎᒃ ᖃᐅᔨᓴᕐᑕᐅᒍᑎᒋᒋᐊᓕᖏᓐᓂᒃ. ᑑᕐᖏᑦ ᑲᑎᖕᖓᔨᐊᐱᖏᑦ ᑲᑐᑦᔨᖃᑎᒌᒍᑕᐅᔪᑦ ᐃᓚᐅᒍᒪᔪᓄᑦ ᐊᒻᒪᓗ ᑭᒻᒪᑐᕐᑎᖃᕐᓱᑎᒃ ᑯᐯᒃ ᑲᕙᒪᖓᓂᒃ, ᓂᐅᕙᐅᓛ ᐊᒻᒪᓗ ᓛᐸᑐᐊ ᑲᕙᒪᖓᓂᒃ, ᓄᓇᑦᓯᐊᕘᑦ ᑲᕙᒪᖓᓂᒃ, ᒪᑭᕝᕕᒃᑯᓂᒃ, ᑲᑎᕝᕕᒃ ᓄᓇᓕᓕᒫᑦ ᑲᕙᒪᖓᓂᒃ (ᒥᕐᖑᐃᓯᕐᓂᓕᕆᕕᖏᑦ), ᑲᓇᑕᐅᑉ ᒥᕐᖑᐃᓯᕐᓂᓕᕆᕕᖓᓂᒃ, ᐊᒻᒪᓗ ᑑᕐᖏᑦ ᓂᕐᔪᑎᓕᕆᕐᒧᑦ, ᐱᕈᕐᑐᓕᕆᓂᕐᒧᑦ ᐊᒻᒪᓗ ᐃᖃᓪᓕᐊᓂᓕᕆᕐᒧᑦ ᐊᓪᓚᕕᖕᖓᓂᒃ (ᑭᒻᒪᑑᑦᔨᓱᑎᒃ ᑑᕐᖏᑦ ᓂᕐᔪᑎᓕᕆᓂᕐᒧᑦ ᐊᒻᒪᓗ ᐱᕈᕐᑐᓕᕆᓂᕐᒧᑦ ᐊᐅᓚᑦᓯᖃᑎᒌᓐᓂᒧᑦ ᑲᑎᖕᖓᔨᖏᓐᓂᒃ). ᑑᕐᖏᑦ ᑲᑎᖕᖓᔨᐊᐱᖏᑦ ᐅᖃᖃᑎᒌᓚᐅᑎᓗᑎᑦ, ᓯᕗᓪᓕᐹᖅ ᖃᖓᑦᑕᔫᒃᑯᑦ ᖃᑦᓯᐅᓂᖏᓐᓂᒃ ᕿᒥᕐᕈᓂᖅ ᐋᖁᑎᓯᒪᔪᖅ ᑑᕐᖏᑦ ᖃᕐᖃᖏᑦᑕ ᑐᑦᑐᖏᓐᓂᒃ ᒫᑦᔨ 2014-ᖑᑎᓪᓗᒍ (Couturier ᐊᒻᒪᓗ ᐊᓯᖏᑦ 2015), ᐊᒻᒪᓗ ᖃᑦᓯᐅᓂᖏᑦ ᐃᒪᖃᐅᔮᕐᑕᐅᓯᒪᔪᑦ 930 ᑐᑦᑐᐃᑦ. ᑲᔪᓯᑎᓗᒍᑦ ᓱᑯᐃᓂᓂᑎᒍᑦ ᖃᐅᔨᒪᒐᓱᐊᕐᓂᖅ ᖃᑦᓯᐅᓂᖏᓐᓂᒃ, ᑭᒻᒪᑐᕐᑎᓕᒫᑦ ᑑᕐᖏᑦ ᑲᑎᖕᖓᔨᐊᐱᖏᑦ ᑮᓇᐅᔭᕐᑖᓯᒪᔪᑦ ᐊᒻᒪᓘᓐᓃᑦ ᐃᑲᔪᕐᓯᓯᒪᓂᒃᑯᑦ ᐱᓇᓱᐊᕐᕕᒥᑎᒍᑦ ᐃᑲᔪᕐᓂᐊᓱᑎᒃ ᑐᖕᖓᓕᐊᓂᒃ ᑭᓯᑕᐅᒍᑎᖏᓐᓂᒃ ᑑᕐᖏᑦ ᑐᑦᑐᖏᓐᓂᒃ. ᑕᒪᓐᓇ ᐋᑐᑎᓂᖃᓚᐅᔪᖅ ᒫᑦᔨ ᐊᒻᒪᓗ ᐁᑉᐸᓕ 2017-ᒥ ᑌᒪ ᑭᖑᓂᐊᒍᑦ ᑌᒫᑦᓴᓇᓚᓚᒃ ᖃᓂᖕᖏᑐᒦᑦᓱᑎᒃ ᖃᐅᔨᓴᕐᓂᕆᓯᒪᔭᓯᑎᑐᑦ 2014-ᒥ ᐋᑐᑎᓂᖃᕐᓯᓱᑎᒃ.

ᓄᓇ ᖃᐅᔨᓴᕐᕕᐅᔪᖅ ᐊᕕᑦᑐᑕᐅᓯᒪᓂᖃᓚᐅᕐᑐᖅ ᒪᕐᕿᓕᖕᖓᑎᑕᐅᑦᓱᓂ, ᐊᑐᐊᕐᓂᒥ ᐊᒻᒪᓗ ᖃᕙᖕᖓᓂᕐᒥ, ᑎᑎᕐᑕᐅᓯᒪᔪᖅ 58° 55′ N ᕐᑯᓛᓂ. ᓂᕆᐅᒋᔭᐅᓚᐅᔪᖅ ᑐᑦᑐᐃᑦ ᐊᒥᓲᓂᕐᓴᐅᓚᔪᕆᐊᖏᑦ ᐊᑐᐊᕐᓂᖕᖓᓂ, ᑌᒪᒪᑦ ᖃᐅᔨᓴᕐᑕᐅᓂᕐᓴᐅᑎᑕᐅᓚᐅᔪᖅ ᑌᑲᓂ. ᐊᑐᐊᕐᓂᒥᒃ ᖃᐅᔨᓴᕐᓂᖅ ᓴᓂᕋᑦᓯᕆᑦᑐᓂᒃ ᕿᒥᕐᕈᔭᐅᑎᑕᐅᓚᔪᖅ ᓂᒋᕐᒧᑦ ᐊᒻᒪᓗ ᐅᐊᓐᓂᒧᑦ 3 ᑮᓕᒥᑕᓂᒃ ᖃᓂᖕᖏᑎᕆᓐᓂᖃᕐᑎᑕᐅᔪᓂᒃ ᐊᒻᒪᓗ ᖃᔭᖕᖓᓂᕐᒥᒃ ᖃᐅᔨᓴᕐᓂᖅ 4 ᑮᓕᒥᑕᓂᒃ ᖃᓂᖕᖏᑎᕆᓐᓂᖃᕐᑎᑕᐅᑎᓪᓗᒍ. ᕿᒥᕐᕈᔪᐃᑦ ᑭᓯᑦᑐᕕᓃᑦ ᑐᑦᑐᓂᒃ ᑲᑎᖕᖓᔪᓂᒃ ᐊᒻᒪᓗ ᐆᒪᔪᕐᓂᒃ ᐊᓯᖏᓐᓂᒃ ᑕᑯᔭᕐᒥᓂᒃ. 91 ᕕᑦᓱᑎᒃ ᓴᓂᕋᑦᓯᕆᑦᑐᓂᒃ ᐅᑎᕐᑕᑐᕕᓃᑦ ᓱᒃᑫᑑᑦᓱᑎᒃ ᐊᒻᒪᓗ ᓇᕿᑦᑐᒥ ᖃᖓᑕᑦᓱᑎᒃ. ᓯᓚᐅᑉ ᐱᐅᓯᖓ ᐊᒻᒪᓗ ᓂᑦᑕᓂᖓ ᐱᐅᔫᒪᕆᐅᓚᐅᔪᖅ ᐅᓪᓗᓂ ᖃᖓᑕᓂᖏᓐᓂ. ᑲᑎᓕᒫᕐᓱᑎᒃ ᓴᓂᕋᑦᓯᕆᑦᑐᓂ ᐅᑎᕐᑕᕕᕕᓂᖏᑦ 7,722 ᑮᓕᒥᑕᐅᓚᐅᔪᑦ ᐊᒻᒪᓗ ᖃᐅᔨᓴᕐᕕᓕᒫᖓ 30,625 ᑮᓕᒥᑌᑦ ᓱᒃᑭᑕᓪᓗᐊᖑᑦᓱᑎᒃ Okak Bay ᐊᒻᒪᓗ Killiniq Island ᐊᑯᓐᓂᖏᓐᓂ. ᐱᖓᓱᐃᑦ ᐊᒪᕈᐃᑦ ᐃᓚᕆᑦ (8 ᐊᒪᕈᐃᑦ), 14 ᓇᓄᐃᑦ, ᐊᒻᒪᓗ ᐊᑕᐅᓯᖅ ᑎᑎᓚᓐᓂᐊᒃ ᖁᑯᕐᑕᖅ ᑕᑯᔭᐅᓚᐅᔪᑦ. 58-ᕕᑦᓱᑎᒃ ᑐᑦᑐᐃᑦ ᐃᓚᕆᑦᑐᑦ ᑕᑯᔭᐅᓚᐅᔪᑦ ᓴᓂᕋᑦᓯᕆᑦᑐᓂᒃ ᐅᑎᕐᑕᓂᕐᒥ ᑲᑎᓕᒫᕐᓯᑎ 610 ᑐᑦᑐᐃᑦ. ᑐᑦᑐᐃᑦ ᐃᓚᕆᑦᑐᑦ ᑕᑯᔭᐅᔪᑦ ᖃᑦᓯᐅᓂᖏᑦ ᐊᑦᔨᕆᓚᐅᔫᖕᖏᑐᑦ 1-ᒥᑦ 38-ᓄᑦ ᑎᑭᖃᑦᑕᓱᑎᒃ ᒥᑦᓯᖃᕐᓱᑎᒃ 10.5-ᓂᑦ ᑐᑦᑐᓂᒃ ᐃᓚᕆᑦᑎᑐᓂᒃ. ᑐᑦᑐᐃᑦ ᐃᓚᕆᑦᑎᑐᑦ 2017-ᒥ ᒪᕐᕈᕕᓪᓗᐊᑐᒥᒃ ᐊᒥᓲᓂᕐᓴᒪᓴᓚᐅᕐᑐᑦ 2014-ᒥᓂᑦ (5.4). 2014-ᒥ, ᑭᓯᑕᐅᒪᓂᖏᑦ ᐅᓄᕐᓂᓴᐅᓚᐅᔪᑦ, ᓄᕋᖏᑦ ᐃᓚᐅᑎᓪᓗᒋᑦ 23.1 ᐳᓴᓐᑎᐅᓱᑎᒃ ᐆᒪᔪᕐᓂ ᑕᑯᔭᐅᔪᓂ, ᑌᒣᑐᐊᕐᐸᑦ ᐃᓱᒪᓇᖕᖑᐊᑐᖅ ᐊᒥᓱᖕᖑᐸᓪᓕᐊᓚᔭᕐᓂᖏᓐᓂᒃ ᖃᐅᔨᓴᕐᑕᐅᒍᑎᕕᓂᖏᑦ ᐃᑉᐱᕆᑦᓱᕆᑦ. ᑐᑦᑐᐃᑦ ᑕᑯᔭᐅᓚᐅᔫᖕᖏᑐᑦ ᖃᕙᖕᖓᓂᖕᖓᓂ, ᑐᑦᑐᐃᑦ ᐃᓚᕆᓈᕐᑎᑐᑦ ᑕᑯᔭᐅᕙᓪᓗᓱᑎᒃ Nachvak Fjord ᐊᑐᐊᕐᓂᖕᖓᓂ. ᖃᓂᖕᖏᑐᒥ ᑭᓯᑕᐅᒍᑎᕕᓂᖏᑦ ᑑᕐᖏᑦ ᑐᑦᑐᖏᑦ 2017-ᖑᑎᓪᓗᒍ 1,326 ᖑᓚᐅᔪᑦ (ᓄᕋᖏᑦ ᐃᓚᐅᑎᓪᓗᒋᑦ) ᓱᕐᑯᐃᓯᐊᕐᑎᓗᒋᑦ ᑭᓯᑕᐅᒪᓂᖏᑦ 912-ᒥᑦ 1,986. ᐃᒻᒥᒎᓈᕐᑎᑐᓂᒃ ᖃᐅᔨᓴᕐᓂᖅ ᐃᒪᖃᐅᔮᕐᓂᖃᕐᑎᓗᒍ 1,045ᓂᒃ ᐊᒻᒪᓗ 281ᓂᒃ ᑐᑦᑐᓂᒃ ᐊᑐᐊᕐᓂᒥ ᐊᒻᒪᓗ ᖃᕙᖕᖓᓂᐅᑉ ᐃᒻᒥᒎᓈᕐᑎᑎᑕᐅᓂᖏᑦ, ᐃᒻᒥᒍᑦ. ᑌᒪᓗᐊᕐᑎᓗᒍ, ᑭᓯᑕᐅᔪᐃᑦ ᓴᑑᒪᓇᕐᑑᓱᑎᒃ ᑑᕐᖏᑦ ᑐᑦᑐᖏᑦ, ᑕᒪᓐᓇ ᖃᐅᔨᓴᕐᑕᐅᓂᖓ ᓱᕐᑯᐃᓯᓚᐅᕐᑐᖅ ᐃᑭᑦᑑᕆᐊᖏᓐᓂᒃ ᐊᒻᒪᓗ ᐃᑉᐱᕆᔭᐅᑦᓯᐊᕆᐊᖃᕐᓱᑎᒃ ᐊᐅᓚᑦᓯᔪᓄᑦ ᐊᒻᒪᓗ ᑐᑦᑐᓲᓄᑦ.

Sommaire

Les Inuit du Nunavik et du Nunatsiavut savaient qu'une petite population de caribous séjournait à l'année longue dans les Monts Torngat. Reconnaissant le statut unique de cette population, le Comité sur la situation des espèces en péril au Canada (COSEPAC) a récemment identifié le caribou des Monts Torngat comme l'une des 11 unités de conservation au Canada. En 2016, en se basant principalement sur les risques inhérents associés à la faible taille de cette population, le COSEPAC jugeait que le caribou des Monts Torngat était en voie de disparition.

En 2013, un comité informel a été créé pour discuter des besoins de recherches sur le caribou des Torngat. Le comité Torngat caribou est constitué d'une coalition de groupes intéressés et inclut des représentants du gouvernement du Québec, du gouvernement de Terre-Neuve et Labrador, du gouvernement du Nunatsiavut, de la corporation Makivik, du gouvernement régional Kativik (Parcs Nunavik), de Parcs Canada, ainsi que du Torngat Wildlife, Plants and Fisheries Secretariat (représentant le Torngat, Wildlife and Plants Co-Management Board). À la suite de discussions au sein du comité, le premier inventaire aérien a été effectué en mars 2014 et a permis d'estimer la taille de cette population à 930 caribous (Couturier et al. 2015). Afin de poursuivre le suivi scientifique de cette population, les membres du comité ont dédié des fonds et/ou des contributions en espèces à la réalisation d'un second inventaire systématique du troupeau de caribous des Monts Torngat. Cet inventaire a été effectué en mars/avril 2017 suivant une méthode similaire à celle employée en 2014, soit l'échantillonnage par distance.

L'aire d'étude a été scindée en deux strates géographiques (nord et sud) à la latitude 58° 55′ N. Comme il était prédit que la densité de caribous serait plus élevée dans la strate nord, un effort d'échantillonnage supérieur a été alloué à cette strate. Des transects parallèles est-ouest étaient espacés de 3 km dans la strate nord et de 4 km dans la strate sud. Les observateurs ont noté les groupes de caribous ainsi que les autres mammifères vus sur 91 transects survolés à basse altitude et vitesse réduite. Lors des jours de survols, les conditions météorologiques et la visibilité ont été excellentes. La longueur totale des transects était de 7 722 km alors que l'aire d'étude totalisait 30 625 km^2 entre Okak Bay et l'île Killiniq. Trois meutes de loups (8 loups), 14 ours blancs ainsi qu'un renard arctique ont été observés durant l'inventaire. Ce furent 58 groupes de caribous qui ont été notés sur les transects pour un total de 610 caribous. La taille des groupes a varié de 1 à 38 caribous avec une moyenne 10,5 caribous par groupe. La taille des groupes a presque doublé en 2017 par rapport à celle de 2014 (5,4). À l'instar de 2014, le recrutement était élevé avec une estimation de 23,1% de faons dans la population ce qui théoriquement permet une croissance démographique. Aucun caribou n'a été observé au sud du fjord Hebron, tandis que la majorité a été enregistrée au nord du fjord Nachvak. La taille du troupeau des Torngat a été estimée à 1 326 caribous (incluant les faons) pour un intervalle de confiance compris entre 912 et 1 986 caribous. L'échantillonnage stratifié par distance a estimé les caribous présents dans les strates nord et sud respectivement à 1 045 et 281 bêtes. Toutefois, bien que ces résultats puissent sembler encourageants pour le troupeau des Monts Torngat, cet inventaire a confirmé que ce troupeau est toujours petit et que cela demande une grande attention de la part des gestionnaires et des usagers.

1. Introduction

In North America, at least three caribou (*Rangifer tarandus*) ecotypes are used by biologists to describe differences in the ecology and behaviour of caribou living in various boreal, sub-arctic and arctic landscapes and habitats. We employ this classification system for convenience, and as convention, recognizing that it is not necessarily shared by Indigenous Peoples. Sedentary caribou, also called forest-dwelling, woodland or boreal caribou, are found in low density south of tree-line, primarily in boreal forest landscapes. Migratory caribou, also referred to as barren-ground or tundra caribou, can occur at high density and typically undertake large-scale annual migrations between boreal forests and Arctic tundra. In the 1980s and 1990s, migratory caribou of the George River Herd (GRH) were plentiful and roamed across 800,000 km^2 of boreal and arctic habitats in Labrador and Northern Quebec. The GRH decreased from 823,000 caribou in 1993 (Couturier et al. 1996), to 385,000 in 2001 (Couturier et al. 2004), and to 76,000 in 2010, 27,600 in 2012, 14,200 in 2014 and to 8,900 caribou in 2016 (QC Government and NL Government, unpubl. data). A third ecotype that was described by biologists refers to small caribou populations living in mountainous landscapes and which make small-scale migrations between various elevations to fulfill their ecological needs during different seasons. The Torngat Mountains Caribou Herd (hereafter Torngat caribou or Torngat Herd) located in northern Labrador and northern Quebec near the Ungava Bay belongs to this ecotype. The range of the GRH overlapped with that of the Torngat Herd during the 1980s and 1990s but is presently believed to range south of the Torngat Herd (Bélanger 2017a,b). The sedentary ecotype in Labrador and Quebec is located in the boreal forests to the south and do not overlap with the Torngat herd.

Noted differences in space use (Schaefer and Luttich 1998; QC Government and NL Government, unpubl. data), movement rate, body size and shape (Couturier et al. 2010) and genetics (Boulet et al. 2009) have been postulated as evidences to support the identification of the Torngat caribou as distinct from migratory and sedentary caribou living in the region. An Inuit Knowledge study heard that Inuit could identify Torngat caribou by their location, habitat, appearance, taste and behaviour (Wilson et al. 2014). In 2011 the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recognised the Torngat Mountains Caribou Herd as one of eleven living Designatable Units for caribou conservation across Canada (COSEWIC 2011). In December 2016, based on population and demographic assessment criteria, COSEWIC declared the status of the Torngat Mountains Caribou Herd as Endangered.

Due to an annual range that spans over Nunavik, Nunatsiavut, and Nunavut, the Torngat Mountains Caribou Herd is of interest for two provinces, six governments, two parks and two Co-Management Boards. Out of necessity and this shared interest, an informal Torngat Caribou Technical Committee (hereafter the Torngat Committee) has been in place since 2013. The shared goal of the Torngat Committee is to deliver a coordinated effort to generate information about the herd, with the hopes that this information and the ties built through working together will lead to coordinated management of the herd in the future. The informal Torngat Committee includes representatives from the Government of Quebec, the Government of Newfoundland &

Labrador, Nunatsiavut Government, Makivik Corporation, Kativik Regional Government (Nunavik Parks), Parks Canada, and Torngat Wildlife and Plants Co-Management Board.

The Torngat Wildlife and Plants Co-Management Board hosted a Torngat Mountains caribou workshop in 2008. Many of the specific research priorities that eventually materialized were first identified here. In the several years that followed, the Board conducted exploratory work including reconnaissance flights and interviews with Indigenous Knowledge-holders. Research questions, priorities, and approaches were refined through these processes, through continuing dialogue with the communities of Kangiqsualujjuaq and Nain, and through the partnerships that emerged.

In 2013, Wilson et al. (2014) completed a comprehensive Inuit Knowledge study that provided important information to support research and management. Most participants interviewed by Wilson et al. (2014) expressed some level of concern about the future of Torngat caribou. The majority of participants considered over-hunting to be a cause for concern, while several participants also believed that other threats such as predators, disturbance, development activity and a changing environment could also be detrimental to Torngat caribou sustainability.

From 2011 to 2013, the Quebec and Newfoundland and Labrador governments in partnership with the Torngat Wildlife and Plants Co-Management Board deployed 35 satellite radio-collars on adult caribou of the Torngat Herd. This radio-telemetry study has significantly added to our understanding of space-use and survival of Torngat caribou (Bélanger 2017a,b). In addition, telemetry has described a decline in range overlap between 1990 and 2015 with the GRH, from almost 50% of the range in the early 1990s to less than 10% between 2010 and 2015. Little range overlap exists now between these two herds.

Based on specific requests made by both communities and following discussion at the Torngat Committee, the first aerial population survey ever for Torngat caribou was carried out in March 2014 (Couturier et al. 2015). That survey estimated herd size at 930 caribou (confidence interval: 616 to 1,453).

The Torngat Committee held consultations with the communities of Kangiqsualujjuaq and Nain and those discussions were used to develop a research approach that was responsive to the received community input. The need for a second survey was expressed as early as 2016. The survey was discussed within the Torngat Committee and the design was refined based on previous consultations, Inuit Knowledge, radio-telemetry data, and lessons learned in the first aerial survey in 2014. Latest public consultation meetings were held in early March 2017 in Kangiqsualujjuaq and Nain to consider additional studies of Torngat caribou based on demographic indicators and satellite telemetry. To investigate the current status of the Torngat caribou, two studies and their respective goals were presented and led to an open discussion with local people interested in caribou. First, the aerial survey project was strongly supported by Inuit from both communities. The study area for this survey was refined based on comments provided during these consultations, with significant additional coverage added to the southeast of

Kangiqsualujjuaq. Second, the Torngat Committee also presented a proposal to place tracking collars on 25 caribou in order to document space use and survival and to support future surveys. This proposal received mixed support, with most individuals from one community supporting the study, while most participants from the other were opposed to the work. Based on this feedback it was decided not to proceed with the collaring project.

A second aerial survey was performed in March and April 2017 with close collaboration of all partners of the Torngat Committee interested in the conservation of Torngat caribou. This report summarizes technical and biological information gathered during the Torngat Herd aerial survey. As it was in September of 2014 following the first population survey, it is planned to share the final survey results during public consultations in the Inuit communities of Nain and Kangiqsualujjuaq.

2. Methods

An aerial survey was completed in March and April 2017 using an A-Star AS350 B2 helicopter (Figure 1) chartered from Universal Helicopters Newfoundland and Labrador Ltd. A detailed timeline of the survey project including daily flying time is reported in Appendix A.

Figure 1. Project field team of the Torngat Mountains Caribou Herd survey, spring 2017. From left to right: Serge Couturier, wildlife biologist consultant; Steve Lodge, helicopter pilot; Aaron Dale, project manager for the Torngat Wildlife and Plants Co-Management Board; Tommie Unatweenuk, Inuit expert from Kangiqsualujjuaq, QC; and Ryan Merkuratsuk, Inuit expert from Nain, NL.

2.1 Study area and survey design

The 2017 survey area was similar to that of 2014 (see Couturier et al. 2015 for details) as it was designed to cover the population's historic range, based on the findings of Schaefer and Luttich (1998) and Inuit knowledge. The Torngat caribou range appears to have retracted northward in the last few decades (Wilson et al., 2014; Bélanger 2017a). The survey area was discussed with Inuit hunters, including during the pre-survey consultations of March 2017. Early during the planning, the Torngat Committee discussed restricting the survey to the northernmost part of the range (e.g. north of Hebron Fjord), where it was expected to find most of the Torngat caribou, based on radio-collaring data and on Inuit Knowledge. Although the available information from the 2014 survey and other observations suggested that few Torngat caribou are found south of Hebron Fjord, it was decided to include again this area in 2017 to further investigate whether Torngat caribou are currently present in the southern part of their historical range.

Bounded by the Labrador Sea in the east and Ungava Bay in the west, the landscape of the Torngat Mountains is characterized by a highly fragmented coast with numerous fiords and river valleys. To standardize the survey area size determination, we used all external transects and calculated a hull polygon using a Geographical Information System (GIS) (ArcMap 10.0, www.esri.com). A 1-km buffer was added to this polygon to take the approximate distance of line of sight during the survey into consideration.

Two minor additions were made to the 2014 study area following comments received from Torngat Wildlife and Plants Co-Management Board members and Inuit experts during pre-survey consultations in March 2017 (Figure 2). First, the study area was slightly increased with the westward extension of six transects (transect 31 to 36) by about 22 kilometers each. Also, two transects (37 and 38) were extended westward to add survey effort northeast of Kangiqsualujjuaq and to provide better coverage of the Kuururjuaq Park (Figure 2). These two westward extensions represent an increase of 1,234.6 km^2 compared to 2014, yielding a total study area of 30,624.8 km^2 in 2017.

To increase sampling effort in the northern part of the study area, where higher densities of caribou were expected, the sampling design was modified from the method used in 2014. Instead of 4-km spacing throughout, as in 2014, transects in the north were spaced 3-km apart in 2017, which increased the sampling intensity in the higher density stratum. The study area was then divided in two geographic strata along a line midway between transects 39 and 40 on latitude 58° 55′ N (Figure 2) for data analysis in distance sampling modelling.

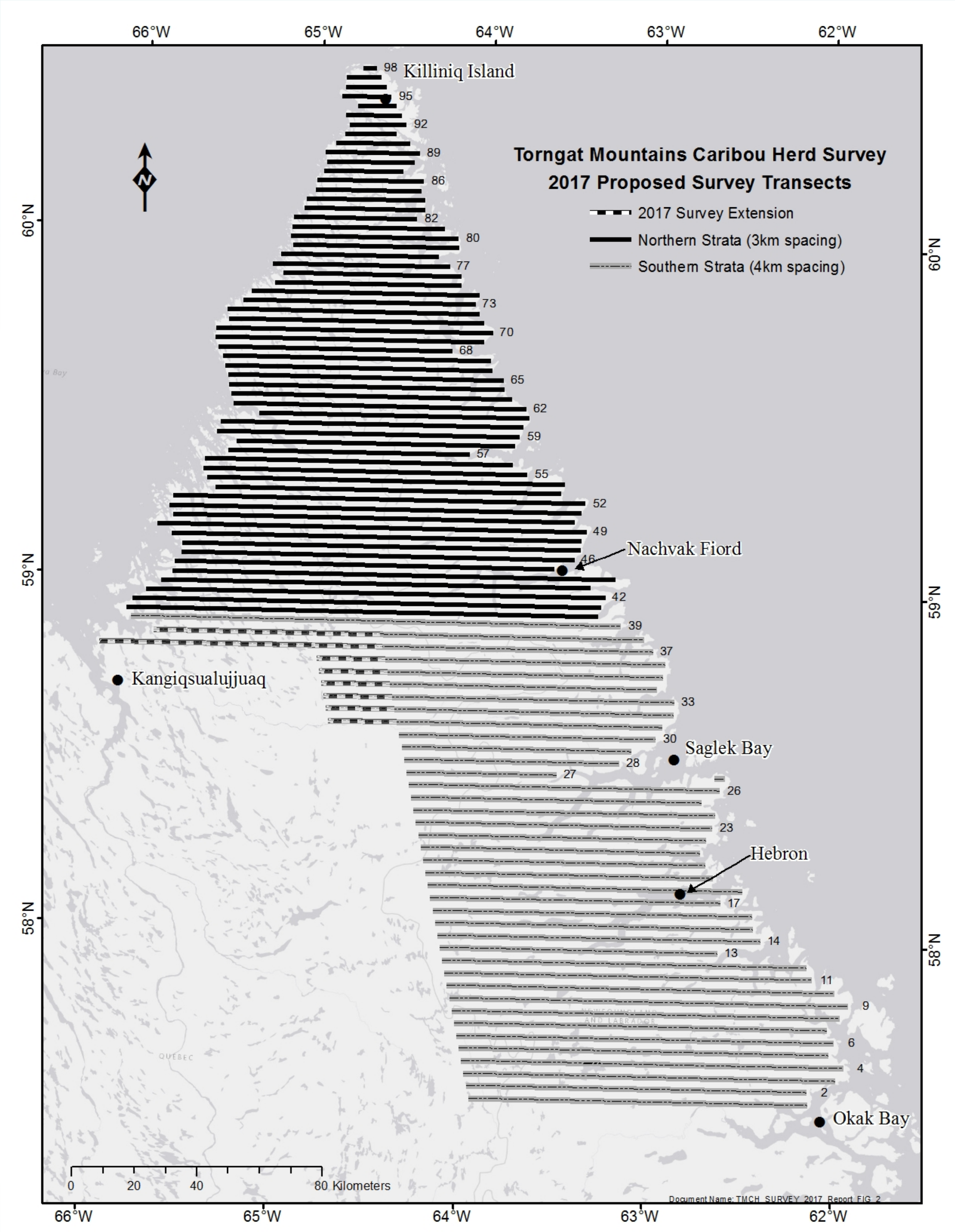


Figure 2. Map of the study area and transects planned during the spring 2017 survey of the Torngat Mountains Caribou Herd. The dashed lines show new areas added in 2017 (1,235 km²).

2.2 Distance sampling

The Torngat caribou herd range is located in the Arctic Cordillera ecozone and comprised of open tundra and alpine habitats offering excellent visibility during aerial survey. As in 2014, the 2017 survey method is based on distance sampling, which presents some benefits over fixed-width strip survey, notably an embedded visibility correction factor (see Couturier et al. 2015 for details). Distance sampling is similar to conventional fixed-width strip survey 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). Le Moullec et al. (2017) reported that Distance sampling is currently one of the most widely used monitoring methods to estimate animal population size in the world. In their study of Svalbard reindeer, they showed that Distance sampling population estimates were not statistically different from known population sizes, confirming the efficiency of the Distance sampling method. They also reported that in the open tundra landscape, the detection of reindeer should in principle only vary with distance from the transect line because visibility is good. Distance sampling was also used to estimate populations of caribou in Nunavut (Jenkins et al. 2013; Campbell et al. 2015) and in Newfoundland (Fifield et al. 2013), muskox (*Ovibos moschatus*) in Nunavut (Jenkins et al. 2011), moose (*Alces alces*) in British Columbia (Thiessen 2010; McNay 2013), and polar bear (*Ursus maritimus*) in the Barents Sea (Aars et al. 2009).

Distance sampling generates a density estimate from the number of groups detected on transect, the perpendicular distance from the transect line, and the mean size of the groups that were detected. Each caribou observation contributes to estimating the density in a study area. The detection of animals by the observers is expected to decrease with their distance from the aircraft, so it is presumed that distant groups are more likely to be overlooked than nearby groups. Distance sampling compensates for this effect by modeling how detectability decreases with distance. Then, this detection function is used to estimate the proportion of the caribou that were likely present but which were not detected by the observers. The estimated caribou density is later converted to a herd size estimate based on the area surveyed.

Buckland et al. (2001, 2004, 2015) recommend that Distance sampling fulfill these basic statistical assumptions:

1. A large number of transects are randomly allocated in the study area independently of the animal distribution of interest.
2. All animals directly on transect are detected.
3. Animals do not move in response to the observer before they can be detected or animal movement is slow relative to the observer movement.
4. Distances are measured accurately.

In order to extrapolate observations from transects to the entire study area, including areas that were not surveyed, transect lines must be established in an unbiased design via random or systematic sampling. Distance sampling requires that a large number of transects are sampled (>40 according to Fifield et al. 2013), and that their location is independent of the animals' locations. In the 2014 Torngat caribou survey, transects were systematically allocated from a random starting latitude in the south of the study area (Couturier et al. 2015). In 2017, it was decided to use the same transect grid for the southern stratum and to switch to a 3-km spacing in the northern stratum. Systematic placement with a random start point is more efficient than a completely random design. Parallel transect lines were spaced every 3 or 4 kilometers running east/west. Increased sampling effort was allocated in the northern stratum because the available information suggested that caribou density was higher in that area. The sampling effort of the southern stratum with 4-km spacing between transects was similar to the design used in 2014.

As suggested by Marques et al. (2006), perpendicular distances were estimated during post-survey analysis with a GIS. It is difficult for the helicopter pilot to fly exactly over the transect line during the survey. Therefore, the perpendicular distance of each group of caribou from the actual flight track was measured, and not the distance from the theoretical transect line. This was based on actual flight tracks monitored every second and overhead GPS positions of caribou clusters. This distance measurement method is more accurate than the other method based on sighting angle and aircraft altitude (Marques et al. 2006).

Descriptive statistics analysis were performed in software JASP version 0.8.2 for Macintosh (JASP Team 2017) while all statistical analysis related to Distance Sampling were done using the software Distance Version 7.1 Release 1, free and available on-line (http://distancesampling.org). This software was used to model detection functions and estimate density with Conventional Distance Sampling (CDS) and Multiple Covariate Distance Sampling (MCDS). Using CDS, the probability of detecting a caribou group (i.e. the detection function) was modeled based solely on perpendicular distance from the flight track. In order to see if variables other than distance alone affected the detection probability, MCDS was also used. Snow and slope covariates (see next section for more details) evaluated at local scale (i.e. about 100 m) were tested individually and in concert during MCDS model fitting.

In Distance 7.1, CDS and MCDS engines were run to test detection function models recommended by Marques et al. (2007) and Thomas et al. (2010). These models and their abbreviations are described by their key functions and adjustment terms in Table 1. Both MCDS models were run with two covariates alone and together. A total of six models were fit with the CDS engine while six models were fit using the MCDS engine.

Distance 7.1 can automatically select the number of adjustment terms using a model selection method based on Akaike Information Criteria (AIC). In CDS, the maximum number of adjustment terms was set to five. As recommended by Marques et al. (2007), we limited the number of adjustment terms to two in MCDS. The chance of fitting an implausible detection function is decreased with fewer adjustment terms in MCDS. Adjustment terms and covariates are performing similar tasks; explaining patterns in detectability not explained by the key function (Rexstad, E., pers. comm.).

Density estimates were derived from line-transect data and detection function models as recommended by Buckland et al. (2001) and Thomas et al. (2010). Best models were selected on their AIC values. Readers can consult these keynote references for more information on model selection and density estimation. In line transect sampling, the variance of the encounter rate estimator usually dominates the overall variance of the object density, and it is also the more difficult component to estimate (Thomas et al. 2010). Fewster et al. (2009) presented a simulation study comparing some density variance estimation methods. In general, considering both estimator performance and simplicity, it is recommended to use density variance estimation method O2 for systematic parallel line placement design like in our study (Thomas, L., pers. comm.). Instead of using the default setting method R2, the variance estimation method O2 was selected during all analyses in Distance 7.1. For all distance sampling parameters the notation presented in Distance 7.1 was applied in this report where:

n: Number of caribou groups detected during the survey
k: Number of transects
W: Width in meters of line transect (highest distance recorded during survey)
L: Total length in km of survey transects
ESW: Effective strip width in meters (ESW= W*p)
p: Probability of detecting a caribou group during the survey
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

Table 1. Distance sampling detection function recommended by Thomas et al. (2010) and Marques et al. (2007) that have been used in data analysis of the 2017 Torngat Mountains Caribou Herd aerial survey. Models are described by their key functions and adjustments terms.

Model description in CDS and MCDS (key + adjustment terms)	Covariates	Abbreviations
CDS Uniform key with cosine		CDS Unif Cos
CDS Half-normal key with cosine		CDS HN Cos
CDS Half-normal key with simple polynomial		CDS HN Poly
CDS Half-normal key with Hermite polynomial		CDS HN Herm
CDS Hazard-rate key with simple polynomial		CDS HR Poly
CDS Hazard-rate with Hermite polynomial		CDS HR Herm
MCDS Hazard-rate key with simple polynomial	snow	MCDS HR Poly snow
MCDS Hazard-rate key with simple polynomial	slope	MCDS HN Poly slope
MCDS Hazard-rate key with simple polynomial	snow slope	MCDS HN Poly snow slope
MCDS Half-normal key with cosine	snow	MCDS HN Cos snow
MCDS Half-normal key with cosine	slope	MCDS HN Cos slope
MCDS Half-normal key with cosine	snow slope	MCDS HN Cos snow slope

2.3 Survey implementation

In the field, the survey method was based on the following criteria (as in 2014):

- helicopter flew at 150 km/h (about 80 knots) and 150 metres of altitude;
- four main observers including pilot;
- photos and GPS location taken of each group of caribou observed.

The helicopter acted as a single sampling platform (see Buckland et al. 2001), with four observers, including the pilot, searching for caribou. The four observers remained the same during the entire fieldwork to maintain the uniformity over the survey period. During the period when the survey team was based out of Kangiqsualujjuaq, it was possible to add a fifth person (TU) that was sitting in the middle of the back seat. The fifth person was present over transects 98 to 49, located in stratum North (Figure 2). When the helicopter was based elsewhere, the load capacity of the helicopter made it impossible to carry a fifth person. Four caribou groups were recorded at the same time by the fifth person and by another observer while two groups were reported only by the fifth person. It must be noted that visibility is excellent in this type of aircraft and that it is not unusual for more than one observer to detect a caribou group at the same time. Considering the need for uniformity during the entire survey and to avoid possible bias in observer probability detection between strata, it was decided to remove these two caribou groups that were observed only by the fifth person from the herd size estimation. However, these two groups were considered in the sex and age classification.

Upon detection, all caribou clusters (groups of one or more caribou) were approached to record their location. Specifically, the helicopter flew off-transect to the caribou and recorded their location with handheld GPS. If the caribou moved during the approach, the location where the animals were first seen based on tracks in the snow was recorded. Caribou that were more than 100 meters apart were considered separate groups.

Low snow cover and steep slopes could reduce the probability of detecting caribou groups, so as in 2014, snow and slope were included as covariates in our MCDS models. Slope and snow cover were recorded at two spatial scales for each group of caribou observed: the coarse scale represents the area extending 1,000 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, 2 for moderately sloped or rolling habitat, and 3 for mountainous or steep terrain. The snow cover was visually estimated as percentage in 11 category classes (i.e. 0%, 10%, 20%, 30%, etc.) at both scales.

Visibility, temperature and percent cloud cover were estimated on each transect. Visibility was recorded as 3 for excellent (≥40 km), 2 for good (10-40 km) and 1 for poor (≤10 km).

Compared with methods used in 2014, one small improvement was made during the GPS tracking of the flight. Instead of two second intervals, the tracking interval of the two handheld Garmin GPSmap 62S was set to one second. This improvement represents a better smoothing of the tracking and higher precision during post-survey perpendicular distance measurements.

Observations of other mammal species such as polar bear, wolf (*Canis lupus*), arctic fox (*Vulpes lagopus*), and moose were also recorded during the survey.

2.4 Recruitment and sex ratio

To estimate recruitment and the adult sex ratio, the classification method was similar to the method developed in 2014 during the population survey (Couturier et al. 2015). Each caribou group recorded on and off transect was photographed with a hi-resolution digital camera (Nikon D600; 24.3 megapixel FX-format full-frame 24X36 mm) coupled with a GPS and a 70-300 mm telephoto zoom lens (Nikkor). It was generally possible to take 8 to 10 photos of a group in less than 30 seconds, which allowed quick, accurate measurement of the number of caribou regardless of group size. The use of a telephoto zoom lens made it possible to stay farther from the caribou, further reducing disturbance. Analysis of georeferenced photographs also permitted additional accuracy of classification by sex and age than would have been possible with live classification in the field from the helicopter. Digital photographs were enhanced for exposure and color using Lightroom 6 (Adobe Systems Canada, Ottawa, Canada).

Caribou were classified in six categories based on presence of vulvae or penis, head and body size, and antler condition (i.e. present or casted, one or two antlers, velvet on calf spike antlers, etc.): 1- adult antlered female, 2- adult unantlered female, 3- adult antlered male (younger, some may have casted one antler), 4- adult unantlered males (older), 5- calves, and 6- unknown sex and age. The later unknown class occurred when caribou were mostly found in unsafe areas (i.e. risk of falling in rocky area), when a group split during the short chase, or when fuel limitations restricted the time devoted to the classification. Photographs were also inspected for evidence of radio-collars on caribou.

From a compilation of all caribou observations (on and off transect), it was possible to compute the ratio of calf/100 cows, the percentage of calves in the population, and the adult sex ratio as male/100 cows. These demographic parameters are fundamental in the monitoring of a caribou herd as they provide information to determine the population trend, a comparison of the sex specific survival rates and a precise indication of productivity.

3. Results

An aerial survey was completed in spring 2017 over the historical range of the Torngat Mountains Caribou Herd. The fieldwork lasted 26 days from March 20 to April 14 2017 (the complete timeline is presented in Appendix A). It was decided to start the survey in the north and to proceed southwards to better follow the expected decreasing density gradient from north to south. Nine full or partial days were lost due to weather conditions. Once the aerial survey began, snowfalls and blowing snow occurred on April 1st, April 6th, April 8th, April 10th, and April 12th. The new snow covered old tracks and provided a good visibility contrast with caribou and their fresh tracks.

Visibility was excellent during most transects (Appendix B). Of 91 transects, 82 had excellent visibility during the survey, while eight transects had good visibility and only one was poor (94). In the northern part of the study area where transects were spaced 3-km apart, and with excellent visibility, it was sometimes possible to have complete coverage of the area with maximum visibility between 1,500 and 2,000 metres on each side of the aircraft. This means that a group could be detected close to the next transect. This also means that the 3-km spacing is the minimum value that could be fitted in this study area to a Distance sampling design or even to a fixed-width transect design. Less than 3 km could represent a confusing situation where it could become difficult to determine if groups had been already recorded on a previous transect.

The fieldwork lasted longer than expected because of uncontrolled factors including helicopter-related problems and weather. Nevertheless, the survey team successfully covered the whole study area as planned from transect 98 situated to the north near Killiniq, to transect 1 in the south near Okak Bay (Figure 2). A total of 8,701.3 km of transects were planned during the aerial survey. The survey team flew 7,721,9 km or 89% of the total transect length that was planned (Appendix C and Figure 3). It was decided in the field to skip every second transect south of transect 13 because the maintenance schedule of the helicopter would have forced the aircraft to go back to Happy Valley - Goose Bay for two days or more. The high cost of fuel in the Hebron area also contributed to the decision to skip some transects south of transect 13; both the helicopter maintenance delay and the high cost of fuel would have had a strong budgetary impact. Further, it was expected that few Torngat caribou would be present south of Hebron: no caribou were observed south of transect 19 in March 2014 (Couturier et al. 2015). Consequently, it was decided to skip even numbered transects from 12 to 2, (Total 717.8 km, Appendix C and Figure 3) while maintaining the full extent of the study area.

A total of 128.1 km were not flown on transect because of localized weather problems. Some transects were truncated by a few kilometers during flight due to weather, mostly caused by localized low clouds and fog patches near the seacoast (Appendix C and Figure 3). Also, transect 92 was skipped (18.1 km) because of low clouds and fog patches created by nearby open water (Figure 3).

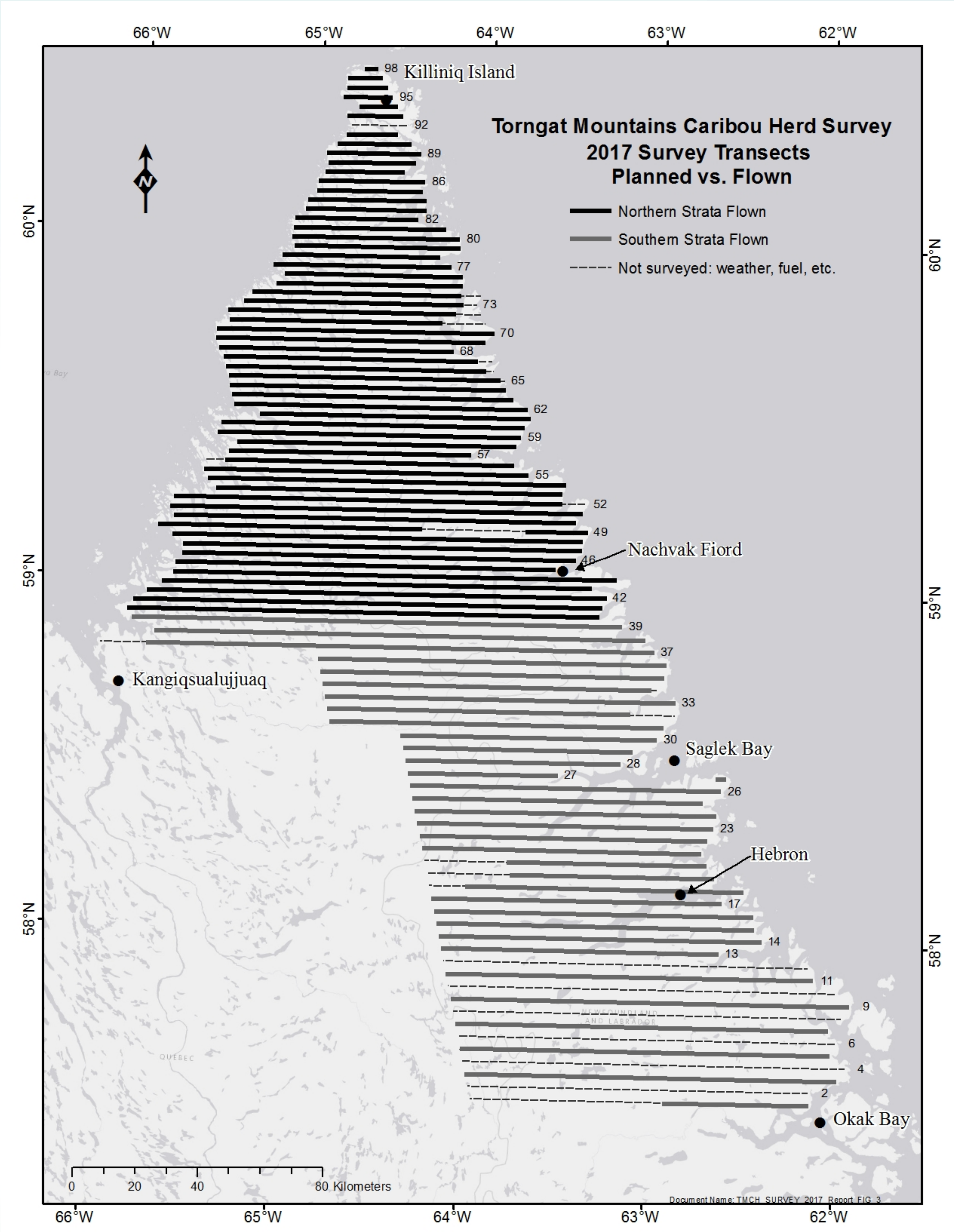


Figure 3. Map of the study area and its geographic strata used during the 2017 spring survey of the Torngat Mountains Caribou Herd. This map also shows transects that were not surveyed due to weather problems, fuel limitations or other causes (see text for explanations).

For group 45, which included 17 caribou, it was not possible to approach the animals because the helicopter was low on fuel therefore we could not take the GPS location. Instead, the survey team stayed on transect and took two lateral photographs of the group to be able to count the number of caribou. Using these lateral photos, it was also possible to estimate the perpendicular distance of the group from the helicopter with the pinhole camera model that describes the mathematical relationship between the size of an object and its projection onto the image plane of a camera. This model has shown that the ratio of the size of the object on the sensor (i.e. 24 X 36 mm in the Nikon 600 model) and the size of the object in real life is the same as the ratio between the focal length and distance to the object. Based on the typical body length of Torngat caribou (mean = 200.3 cm; Couturier et al. 2010), the perpendicular distance was estimated at 352 and 360 meters on first and second photos, respectively, and the average (356 m) was used in the Distance sampling analysis. This agrees with notes taken based on a visible landmark during the survey.

The sampling effort of 240.1 km flown over transect per 1,000 km^2 of the study area was high in 2014, and was slightly higher in the 2017 survey at 252.1 km/1,000km^2 (Table 2). Total number of transects was also higher in 2017, with 91 transects flown due to the 3-km spacing between transect in the North stratum.

With the small increase of sampling effort, it was expected that the number of caribou observed possibly could be slightly higher in 2017. However, the actual increase was proportionally higher than the increase in the sampling effort. In 2017, a total of 610 caribou in 58 groups were recorded on transect, which was more than double the 269 caribou observed in 2014 (Table 3). It is also noteworthy that the average observed group size almost doubled in 2017 compared to 2014 (10.5 vs 5.4).

Other mammal species were also recorded during the survey. Eight wolves in three packs, fourteen polar bears and one arctic fox were seen. One moose was also seen on transect 1 near Okak Bay. During the previous survey in 2014, there were observations of three wolves, 11 polar bears, and more than fifty arctic foxes, while no moose were seen (Couturier et al. 2015).

Table 2. Technical information related to the helicopter survey of the Torngat Mountains Caribou Herd in spring 2017 and comparison with previous survey done in 2014 (Couturier et al. 2015).

	2014 [a b]			2017		
	North	**South** [c]	**Total** [b]	**North**	**South** [c]	**Total**
Study area (km^2)	13,441.4	15,948.8	29,390.2	13,835.7	16,789.1	30,624.8
Line transect flown (km)	3,157.8	3,899.6	7,057.4	4,403.0	3,318.9	7,721.9
Sampling effort (km/1000 km^2)	234.9	244.5	240.1	318.2	197.7	252.1
Transect spacing	4 km	4 km		3 km	4 km	
Number of transects	42	39	81	58	33	91
Number of days in the field			19			26
Helicopter flying time (h)			90.8			85.3

[a] Study area has been divided in two strata along a line midway between transect 39 and 40.

[b] In 2014, total survey area was estimated at 30,689.4 km^2 using a different method.

[c] For the south stratum (transects 1 to 39), most transects were identical in both 2014 and 2017 survey.

Table 3. Biological information obtained from the helicopter surveys of the Torngat Mountains Caribou Herd in spring 2014 and 2017 (see also Couturier et al. 2015).

	2014 [a]			2017 [a]		
	North	South	Total	North	South	Total
• ***On-transect only data***						
Number of caribou photographed	255	14	269	512	98	610
Number of groups	46	4	50	49	9	58
Southernmost transect where caribou have been recorded [b]			19			24
Observed group size						
Mean	5.5	3.5	5.4	10.4	10.9	10.5
Standard-error (SE)	0.6	0.6	0.5	1.2	2.1	1.1
Range (min – max)	1 – 18	2 – 5	1 – 18	1 – 38	1 – 19	1 – 38
• ***On and off transect data*** [c]						
Total classified by sex and age	266	25	291	540	98	638 [d]
Calf %	18.0	8.0	17.2	24.6	15.6	23.1
Calf/ 100 cows	30.2	11.8	28.4	47.4	26.8	43.6
Male/100 cows	37.1	35.3	36.9	45.0	44.6	45.0
Adult female unantlered %	2.5	11.8	3.4	2.0	0.0	1.6

[a] Study area was divided in two strata along a line midway between transect 39 and 40.
[b] In the south (transect 1 to 39), most transects were identical in both 2014 and 2017 survey.
[c] Three and 4 groups were recorded off-transects in 2014 and 2017, respectively.
[d] Includes 59 caribou that were recorded as unknown during sex and age classification.

3.1 Exploratory data analysis

Exploratory data analysis was done to verify that the dataset fulfills the basic statistical assumptions identified by Buckland et al. (2001, 2004, 2015). Assumption 1 was likely fulfilled in our survey. The number of transects was large in both stratum, and the systematic allocation of transects from a random location was independent of caribou locations. It is difficult to test assumption 2 with a sampling design involving a single platform as in our survey. However, this assumption can be investigated during an analysis of the frequency distribution of the perpendicular distance of the groups from the line of flight. In the frequency distribution of distance for 58 groups recorded during the survey, the gradual decline of caribou observations with increasing distance suggests that assumption 2 was met (Figure 4). The first distance class always had more observations than the second class. Moreover, the A-Star AS350 B2 helicopter provided excellent visibility during the survey. It is one of the best aircraft to do visual survey, and the front seats offer particularly good visibility in flight. Not seeing all caribou directly on transect would have been noted in distance frequency distribution and it would have produced a density estimate that is low biased (Buckland et al. 2001, 2004). A left truncation can be used to compensate for that bias when the detection function shows that animals located under or near the aircraft were missed (see McNay 2013), mostly when observers concentrate on the distance or if they have a blind spot. No left truncation of data was applied, as it was likely that the visibility directly in front of and under the helicopter was sufficient. All caribou directly on the transect line (i.e. at distance= 0) were likely detected while the probability of detection declines with increasing distance from the line. Although the survey design did not allow us to fully test assumption 2, all these observations suggest that it was met.

Most of the caribou groups moved as the helicopter approached, but it was easy to spot their initial location based on snow tracks. The GPS location was taken over the initial location of caribou. Assumption 3 is then fulfilled. Our method to measure perpendicular distance was accurate and followed recommendations by Marques et al. (2006). Assumption 4 is then fulfilled.

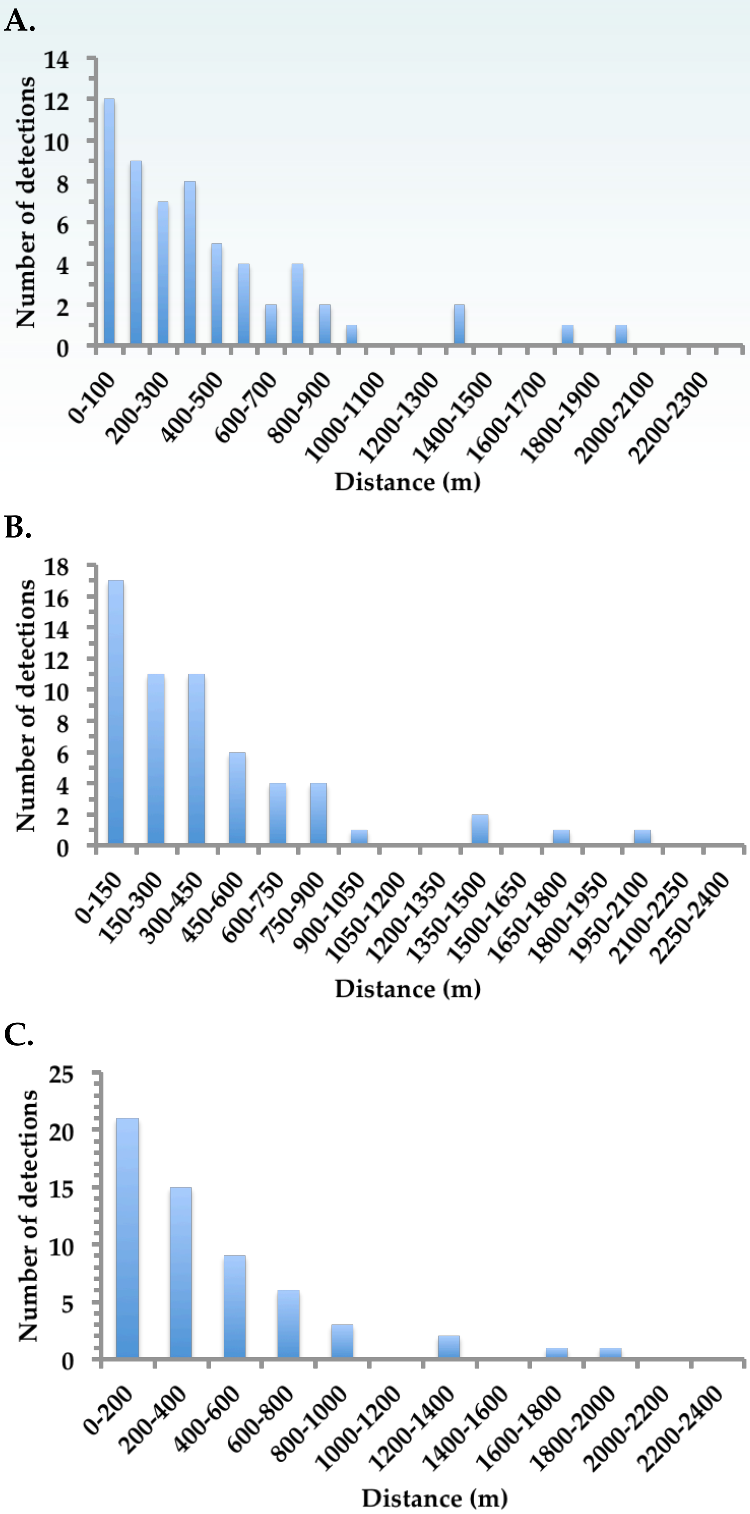


Figure 4. Frequency distribution of perpendicular distances of caribou groups (n= 58; before data censoring) detected during the Torngat Mountains Caribou Herd survey in spring 2017 using three bin sizes: A. 100 m, B. 150 m, and C. 200 m.

Testing for a relationship between perpendicular distance and group size could also help evaluate whether distance-sampling guidelines were met. For example, regression analysis might suggest that distant groups are more likely to be missed if they are smaller. If so it would be important to use the regression method to estimate expected cluster size (E(S)) or, if group size effect is strong, to include group size as a covariate in the MCDS modelling (see section 3.3). Regression of group size (y) as a function of perpendicular distance (x) suggests that any such relationship was weak and non-significant ($p = 0.103$, $r^2 = 0.047$; Figure 5). Nevertheless, it must be acknowledged that regression of observed cluster size against distance is not really informative in this regard. The problem with hypothesis tests is that they do not just verify the biological significance of a relationship (i.e. group size vs distance), but also test the sample size (Thomas, L., pers. comm.). In comparison, the R^2 regression coefficient was 0.04 for the 2014 survey dataset reported by Couturier et al. (2015) because small groups were also detected at far distances which suggested that distance was not having a strong effect on group size.

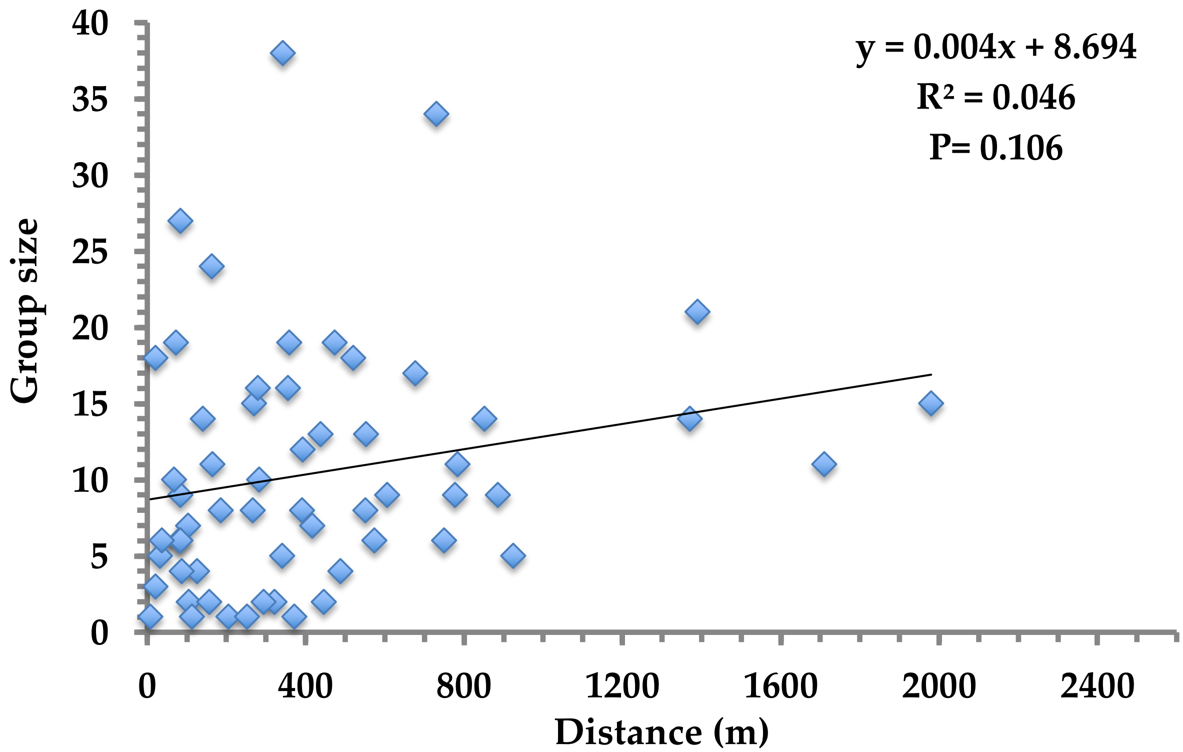


Figure 5. Relationship investigation between group size (y) and the perpendicular distance in metres (x) for 58 groups of caribou seen on transects during the Torngat Mountains Caribou Herd survey in spring 2017 (before data censoring). The relationship is weak and non-significant ($p>0.05$).

Because local (i.e. about 100 m around caribou group) and coarse (i.e. about 1,000 m) scales were correlated for slope and snow covariates, only local values of each covariate were used in Distance sampling model fitting. The range of snow cover varied from 10% to 100% with a mean of 74% (n= 58, SE= 18%). This is slightly less than snow conditions reported in 2014 with a mean of 82%

(range: 50-100%) (Couturier et al. 2015). Due to the low number of observations of the slope covariate in the steepest terrain (n= 5), the highest value coded 3 for mountainous or steep terrain was merged with the covariate value coded 2 for moderately sloped or rolling habitat. Following recoding, 33 caribou observations were done in flat habitat at local scale while 25 were recorded in sloped or steep terrain.

3.2 Possible overlap with George River Herd

Historically, the George River Herd (GRH) overlapped part of the seasonal ranges of the Torngat caribou. In the 1980s and 1990s, when the GRH population peaked in size, range overlap occurred primarily during summer and fall. Recently, Bélanger (2017b) reported that range overlap decreased greatly as the population of the GRH declined to less than 9,000 caribou as of July 2016 (Newfoundland & Labrador Government 2016 press release). However, in recent years some GRH animals are known to have been present in the area of the Kiglapait Mountains (Government of Newfoundland and Labrador, unpublished data) close to the southern portion of the 2017 survey area. This presents some possibility of limited overlap between the two herd ranges in the area around Okak Bay and south of Hebron Fiord.

GRH movements and distribution are monitored primarily from radio-collared animals (Government of Quebec and Government of Newfoundland and Labrador). At the time of the survey, only two radio-collared GRH animals (of about 70) were located within the study area. One GRH radio-collared caribou died in late March near the eastern end of transect 18 and it is not known if this animal was associated with a group of caribou. No caribou or tracks were recorded in this area during the survey on April 13th, 2017. The second GRH radio-collared caribou within the Torngat study area (ID 13288) moved north from the latitude of transect 11 on March 17th to transect 13 on March 27th. On April 10th, this caribou returned south to reach latitude of transect 6 (see Figure 2 for transect numbers). While flying over transect 5 on April 13th, the survey team recorded 1 day-old tracks of a group of ~6-8 caribou that were moving in a straight, south-westerly direction 7 km southeast of the radio-collar location recorded on April 10th. On April 14th, 2017, the survey team saw another set of 1 day-old caribou tracks of ~6-8 caribou on transect 1, 17 km southwest of the tracks recorded the previous day, and again these tracks were moving in a straight, south-westerly line. As these two sets of tracks were the only caribou tracks seen south of Hebron during the survey, these tracks could likely belong to a small group associated with the GRH radio-collared caribou (ID 13288).

Five radio-collared adult females were still monitored in the Torngat Herd during the aerial survey. Some radio-collared Torngat caribou were located in Saglek Fjord area while others were ranging near Nachvak Fjord. The survey team was unaware of recent radio-collar locations at the time of the fieldwork and no radio tracking was done during the aerial survey. Four of these five radio-collars were almost white while another was orange (ID 2013040). Three of these radio-collared caribou had coloured ear tags while two others did not (ID 2013037 and 2013040). One of the five active radio collared Torngat caribou was detected on the photos during the survey. On March 31st, one collared caribou was visible in classification photos of group 36, which was located off-transect near the eastern end of transect 54 north of Nachvak Fjord (59.26970° N, 63.70490° W). This adult female caribou with a calf at heel was wearing a white collar and a pink ear tag number 323. This was caribou ID 2013034. From this limited data set, it seems that all these five active Torngat radio-collared caribou were still using their traditional range.

During the aerial survey, the southernmost presumed Torngat caribou group was located on transect 24 near Saglek Fjord. This group and all other groups located farther north were not showing linear movements based on their convoluted tracks, as would be more typical of the migratory ecotype. Instead, their movements appeared to typify winter range use, which is generally more localised for the montane caribou ecotype (Couturier et al. 2010). Thus, based on both the movements of radio collared caribou from both herds and visual observations of caribou and tracks, it is presumed that no significant numbers of George River caribou were present in the Torngat Herd study area during the time of the 2017 survey.

3.3 Density and herd size estimation in Distance Sampling

During the planning of the survey, it was expected from survey data and Inuit Knowledge that caribou density would be higher in the north than in the southern portion of the traditional Torngat Herd range. Based on this anticipated density gradient, geographic post-stratification was used in Distance 7.1. This approach should yield a more precise density estimate, and also could generate stratum-specific density estimates for management purposes. As we only observed nine caribou groups in the southern stratum (Table 3), we used all the observations to estimate a global detection function and total cluster size, and applied these to estimate density in each stratum, as recommended by Marques et al. (2007). The Global density estimate was then calculated as the mean of the stratum estimates, weighted by stratum area. This approach assumes that detection probability and caribou group size were similar in the northern and southern strata, which seemed reasonable.

Visual assessment of model fit was performed by examining histograms and quantile-quantile (Q-Q) plots. Model fit was also checked with Chi^2 and Kolmogorov-Smirnov (K-S) goodness of fit tests. K-S is a good test for data that are continuous and measured accurately like in our study, while Chi^2 test is more appropriate for data collected in distance classes. However, the use of p-value is no longer efficient once you have a good fit to the data, which is to say above 0.10 (Buckland, S., pers. comm.). For example, it would not be valid to state that a model with K-S p of 0.90 would be showing a better fit than another model with a K-S p of 0.60.

A visual examination of Figure 4 suggests that a right censoring would be useful to compensate for an undesired increase of the detection function at a far distance. Censoring data in distance sampling is common practice and improves the prediction performance of the model but at the cost of reducing the sample size. Various truncation distances were evaluated to obtain the best trade-off between model fitting and reasonable CV. The truncation distance W=1,390 m was selected (Table 4). Otherwise, extra adjustment terms may be needed to fit spurious bumps in the tail of the detection function. This right censoring addresses outlier effects and possible group size bias at longer distance. Right truncating at 1,390 m removed only two groups or 3.4% of our dataset and thus had little effect on the estimates. These two groups of 11 and 15 caribou were recorded respectively at perpendicular distances of 1,710 and 1,980 m (Figure 5). The choice of truncation distance had little influence on the density estimates provided by the best models (Table 4). The truncating distance of 1,390 m made the transect width equal to the length of the detection function (W) recorded during the 2014 Torngat caribou survey. The truncation at 1,390 m provided the most parsimonious model. Hence, no extra adjustment term was required with truncation at 1,390 m, contrary to the extra term needed at 1,710 m and without truncation distance (Table 4). The number of parameters (m) was then smaller at distance 1,390 m with the best models CDS HN Cos(0). No extra term was needed at 1,000 m but the best model required two parameters.

Table 4. Preliminary analysis of the Torngat Mountains Caribou Herd survey data to investigate effects of right-truncation. Analysis were done in Distance 7.1 with Conventional Distance Sampling (CDS) and Multiple Covariate Distance Sampling (MCDS) methods to compute sampling parameters: number of caribou groups (n), number of parameters (m), effective strip width in meters (ESW), detection probability (p), estimated caribou group size (E(S)), density and its associated coefficient of variation (D and D CV).

Truncation distance	Models [a b c]	n	m	Delta AIC	ESW	p	E(S)	D	D CV
None	MCDS HN Cos(1) snow	58	3	0,00	559,1	0,282	8,24	0,0480	0,252
	MCDS HN Cos(1) slope snow	58	4	1,99	558,9	0,282	8,24	0,0480	0,252
1710 m	CDS HN Cos(1)	57	2	0,00	550,4	0,322	8,25	0,0481	0,253
	MCDS HN Cos(1) slope	57	3	0,55	549,1	0,321	8,20	0,0479	0,252
1390 m	CDS HN Cos(0)	56	1	0,00	622,2	0,448	8,63	0,0433	0,239
	MCDS HR Poly(0) slope	56	3	1,55	592,4	0,426	9,21	0,0485	0,248
1000 m	MCDS HN Cos(0) slope	54	2	0,00	539,8	0,540	9,44	0,0528	0,255
	CDS HN Cos(0)	54	1	1,45	559,1	0,559	8,78	0,0474	0,256

[a] Key functions: Half-normal (HN), Hazard rate (HR)

[b] Series expansions: Cosine of order x (Cos(x)), Simple polynomial of order x (Poly(x)). The notation (0) means that no adjustment term was selected following AIC comparison.

[c] The fit of all models was estimated as good based on Kolmogorov-Smirnov and Chi^2 tests ($p>0.10$) and visual analysis of histograms and Q-Q plots.

Size of the cluster or group size is essential in the population density estimation in Distance sampling. Though the mean group size observed during the survey was 10.4 (n = 56, after truncation), the default setting in Distance 7.1 for estimating mean group size is the size bias regression method, in which log group size is regressed on estimated probability of detection. This is designed to remove group size bias that may happen if larger groups are easier to detect at larger distances (Thomas et al. 2010). Following standard practices for CDS, Distance 7.1 was then set to use the size bias regression method to compute expected cluster size denoted by E(S) that were used in our analyses. Experience has shown that the intercept of this regression is not much, if any, less precise than the straight mean cluster size (Thomas, L., pers. comm.).

From the 12 models that were tested (Table 1), four models received warnings from Distance 7.1 about monotonicity and/or high correlation between parameters. These four models were dropped during subsequent analyses. Six of the eight remaining models had similar explanatory power, having delta AIC scores of less than 2 and all showed good fit based on goodness of fit tests ($p > 0.10$; Table 5). Q-Q plots also showed good fit for these models. Exploratory analysis indicated that the detection distance function followed a monotonically decreasing distribution, thereby satisfying a key distributional expectation of the Distance sampling. However, it seems that slightly more groups than expected were detected from zero to mid-distances. The effect is limited and has little effect on fit. This could have been caused by small sample size of groups detected.

Within these six models having delta AIC <2, density estimates varied little from 0.0433 to 0.0485 caribou/km^2, suggesting that model choice had little effect on density estimates (Table 5). Two models received identical results and had the lowest AIC: CDS HN Cos(0) and CDS HN Poly(0). The (0) notation means that no adjustments term was applied following AIC comparisons, which made both models identical as being only a half-normal model. The model CDS HN Cos(0) was selected and later used for density estimation. The detection function created by Distance 7.1 of this model showed a monotonically decreasing detection probability with distance (Figure 6). The effective Strip Width (ESW= W*p) of the best model is 622.2 m and it is plotted on Figure 6. The ESW is the distance for which as many animals are detected at distance greater than ESW as are missed closer to the line than ESW (Buckland et al. 2015). The detection probabilities of these two situations are equal as shown by the same size of the shaded areas on Figure 6. The best model estimated probability of detection of caribou groups at p= 0.4476 (CV= 0.082), expected group size at E(S)= 8.63 (CV= 0.150), and density at 0.0433 caribou/km^2 (CV= 0.239; Table 5).

Table 5. Torngat Mountains Caribou Herd 2017 survey results (n= 56 caribou groups) of the fitted detection models provided by Conventional Distance Sampling (CDS) and by Multiple Covariate Distance Sampling (MCDS) methods in Distance 7.1. Covariates snow cover and slope were tested, while truncation distance was set at 1,390 m in a two strata sampling design. Columns report number of parameters (m), Delta AIC (Akaike's Information Criteria), effective strip width in meters (ESW), probability of detection (p), coefficient of variation of p (p CV), estimated group size (E(S)), density of caribou per km^2 (D), coefficient of variation of D, (D CV), and two goodness of fit test probability values (Chi^2 and Kolmogorov-Smirnov (K-S)).

Model name abbreviations [a b c]	m	Delta AIC	ESW	P	P CV	E(S)	D	D CV	Chi^2-p [d]	K-S p [d]
CDS HN Cos(0) [e]	**1**	**0,00**	**622,2**	**0,4476**	**0,082**	**8,63**	**0,0433**	**0,239**	**0,763**	**0,652**
CDS HN Poly(0)	1	0,00	622,2	0,4476	0,082	8,63	0,0433	0,239	0,763	0,652
MCDS HR poly(0) slope	3	1,55	592,4	0,4262	0,105	9,20	0,0485	0,248	0,502	0,874
MCDS HN cos(0) slope	2	1,72	620,4	0,4463	0,101	8,60	0,0433	0,246	0,662	0,685
MCDS HN cos(0) snow	2	1,79	620,8	0,4466	0,103	8,63	0,0434	0,247	0,661	0,665
MCDS HR poly(0) snow	3	1,86	627,7	0,4516	0,103	9,05	0,0451	0,246	0,510	0,697
MCDS HR poly(0) slope snow	4	3,34	608,5	0,4377	0,106	9,20	0,0472	0,249	0,388	0,843
MCDS HN cos(0) slope snow	3	3,53	619,0	0,4453	0,104	8,62	0,0435	0,247	0,538	0,736

[a] Key functions: HN= half-normal; HR= hazard rate. See Buckland et al. (2001), p. 47.

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

[c] From a total of 12 models tested, only the eight best models run with no warnings are presented here.

[d] The fit of all models was estimated as good based on those p values but also on visual analysis of histograms and Q-Q plots.

[e] The best model is shown in bold and will be later used in herd size estimation.

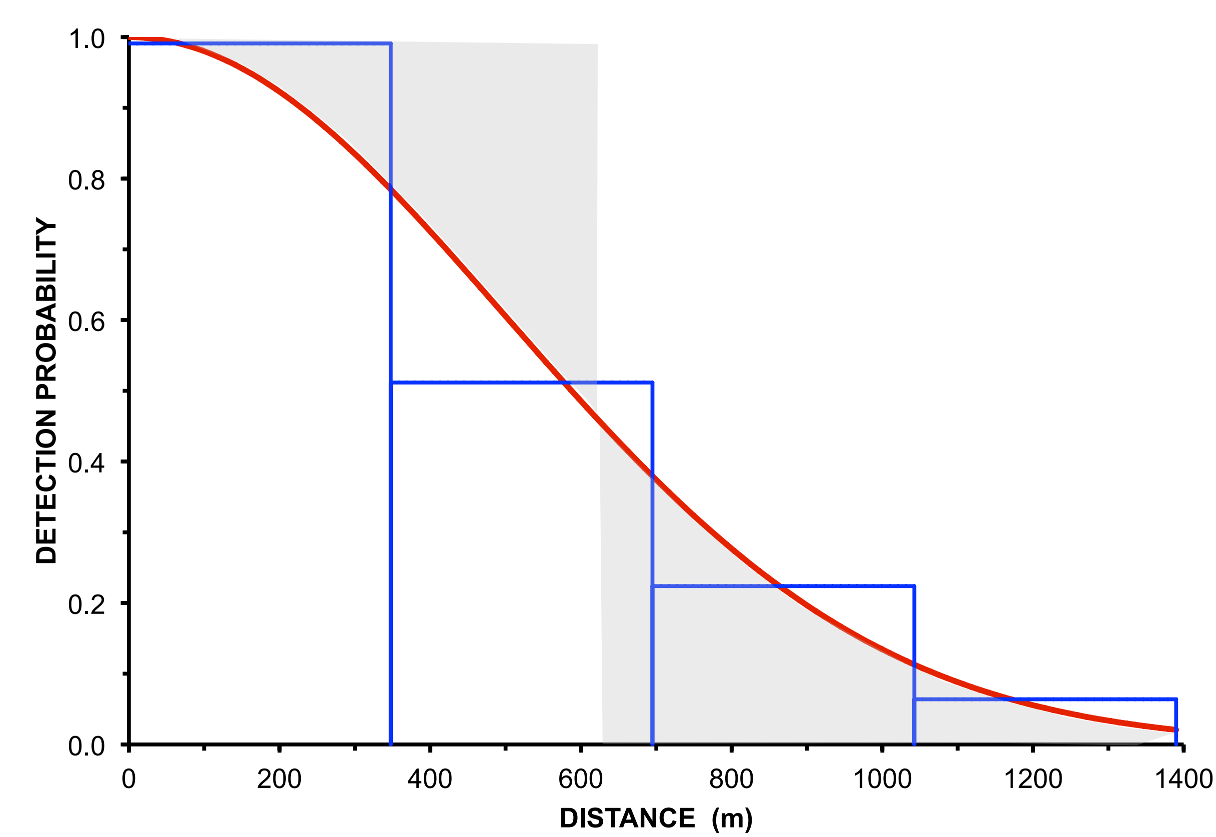


Figure 6. Detection probability function (continuous red line) and histogram of perpendicular distances (m) from the transect line of caribou groups recorded during the Torngat Mountains Caribou Herd survey, spring 2017. This detection function was created by the program Distance 7.1 using the best model in Conventional Distance Sampling (CDS): Half-Normal Cosine with no adjustment term. Bin size is 348 m. Two shaded areas of equal size were added to illustrate the equal detection probability below and above the Effective strip width (ESW=W*p) of 622 m in this model (see text).

The best estimate of herd size provided by Distance sampling was 1,326 caribou, including 11-month old calves, with a coefficient of variation CV= 0.239 and a 90% level confidence interval of 912 to 1,986 (Table 6). The lower confidence interval was 31.2% below the estimate and the upper confidence interval was 49.7% above the estimate. The best estimate of the sub-population size for the northern stratum was 1,045 caribou, while this was estimated at 281 caribou for the southern stratum (Table 6). These herd size estimates include 11-month old calves because it was assumed that the survival of these short-yearlings is close to adult survival. If only 23-month-old and older caribou are considered, the adult population size is estimated at 1,020 caribou based on the ratio of calves to adults estimated from photo classification (i.e. 23.1%, see next section).

Variations of density estimate of the best model (CDS HN Cos(0)) was mostly influenced by the Encounter Rate (ER= n/L) in both strata (Table 7). Variations in ER contributed to 87.0% in the south stratum, possibly because of the small number of caribou groups recorded. In the north stratum, even with a larger sample size of groups recorded, the ER was still the greatest contributor to the uncertainty in density estimates with a variance component of 51.2%.

During the planning of the survey, it was decided to survey the southern areas of the south stratum to validate that there are no Torngat caribou there. The main reason for this inclusion was to ensure that the herd size was not low biased because the survey team did not cover all the range used by the herd. If the range varies from year to year, the survey team would still need to retain the larger study area each time. Then, it was suggested that we could later investigate the effect of study area delineation on the density estimate and ultimately on the herd size estimates, as we expected to see very few caribou in the southernmost portion of the survey area. No caribou observations were recorded south of transect 24 in spring 2017 (Table 2). For this investigation, we first ran the best model (CDS HN Cos; see Table 5) with a smaller data set that did not include 14 transects south of Hebron Fjord, where we did not observe any caribou. We retained data from transect 15 to 98 and used two geographic strata (south and north) again. In this analysis, the number of caribou groups remained the same at 56 following truncation at W=1,390 m, but the number of transects was reduced to 83 transects, while transect length was reduced by 11%, from 7,721.9 km to 6,880.6 km (Table 8). Another similar simulation was done with the removal of more southern transects where no caribou were recorded. In this second simulation, transects south of transect 23 were not considered. These two simulations indicate that inclusion of the southern area, where no caribou were seen, does not have a strong effect on estimated herd size (Table 8). However, since the number of caribou observations remained the same in a smaller study area, the estimated density is higher for the smaller study area. Applying this density to a smaller area yielded a herd size estimate of 1,273 and 1,269 caribou, which are both only 4% smaller than the estimate of 1,326 using all transects of the study area (Table 8).

The distance sampling method is based on a theoretically infinite transect strip width. The detection function shown on Figure 6 computes the effective strip width (ESW= W*p). If we assumed that 622.2 m was the half-strip width of a hypothetical fixed-width strip survey, it is then possible to use this value obtained from Distance sampling to estimate density and population size following the fixed-width transect method. This value of 622.2 m is close to the width of 500 m usually retained during caribou surveys (Nishi and Buckland 2000; Anderson 2016). Hence, if ESW is taken as the strip width, it is possible to count the number of caribou that were recorded within 622.2 m on both side of the aircraft, and later to compute caribou density. This simulation provided a population estimate of 1,405 caribou (Table 9), only 6% higher than the herd size of 1,326 computed from distance sampling (Table 6). Continuing along this simulation about fixed-width transect method, it is also possible to explore what could be the effect of the inclusion of the southern transects where no caribou were recorded. Applying same study areas as shown on Table 8 and still using fixed-width strip survey method, the herd size were estimated at 1,235 and 1,204 caribou, respectively 7% and 9% lower than the distance sampling estimate of 1,326 (Table 9). It must be noted that these fixed-width method estimates were not corrected for sightability and then assumed sightability of 1.0 within 622 m. In this open tundra habitat covered by snow, sightability within 622 m from an helicopter flying at low altitude and slow speed was likely very high (see Le Moullec et al. 2017). Nevertheless, there are no means to estimate sightability factor in the current situation of the Torngat Mountains Caribou Herd as there are not enough radio-collars still monitored in the herd range.

Table 6. Estimates of density, herd size (N), coefficient of variation (CV) and confidence interval at p= 0.10 (CI) for the Torngat Mountains Caribou Herd survey, spring 2017.

Geographic strata	Density (caribou/km^2)	N
South (16,789.1 km^2)		
• Estimate	0.0167	281
• CV	0.475	0.475
North (13,835.7 km^2)		
• Estimate	0.0756	1,045
• CV	0.245	0.245
Pooled strata (30,624.8 km^2)		
• Estimate	0.0433	1,326
• CV	0.239	0.239
• Confidence interval (at p=0.10)		912 – 1,986 (31.2% – 49.7%)

Table 7. Variance components of density estimate computed by the best model (Conventional Distance Sampling Half-Normal Cosine(0)) fitted to data recorded during the survey of the Torngat Mountains Caribou Herd, spring 2017.

Variance components	South stratum	North stratum
Detection probability (p)	3.0%	11.2%
Encounter rate (n/L)	87.0%	51.2%
Group size estimated by regression (E(S))	10.0%	37.6%
Total	100.0%	100.0%

Table 8. Investigation of the effect of the study area size using the Spring 2017 survey data for the Torngat Mountains Caribou Herd. In Distance 7.1 software, the best model CDS HN Cos(0) was run for all three study area using two geographic strata (north and south).

	Whole study area [a, b]	Transect 15 and north [a, c]	Transect 23 and north [a, c]
Area (km²)			
South strata	16,789.1	10,145.4	7,178.3
North strata	13,835.7	13,835.7	13,835.7
Pooled stratum	30,624.8	23,981.1	21,014.0
Number of transects (k)			
South strata	33	25	17
North strata	58	58	58
Pooled stratum	91	83	75
Transect length (L, km)			
South strata	3,318.9	2,477.6	1,780.2
North strata	4,403.0	4,403.0	4,403.0
Pooled stratum	7,721.9	6,880.6	6,183.2
Covered area (2WL, km²)			
South strata	9,226.5	6,887.7	4,949.0
North strata	12,240.3	12,240.3	12,240.3
Pooled stratum	21,466.9	19,128.1	17,189.3
Survey effort (%)			
South strata	55.0%	67.9%	68.9%
North strata	88.5%	88.5%	88.5%
Pooled stratum	70.1%	79.8%	81.8%
Density (D, per km²)	0.0433	0.0531	0.0604
D CV	0.239	0.237	0.237
Herd size (N)	1326	1273	1269

[a] All other Distance sampling parameters remained identical in all three comparisons: W= 1,390 m, ESW= 622.2 m, p= 0.4476 and E(S)= 8.63.

[b] The whole study area corresponds to the historical range of the Torngat Herd (from Killiniq to Okak) and include southern areas where no caribou have been recorded during 2014 and 2017 surveys.

[c] These two other study area scenarios correspond to the range used recently by the Torngat Herd and remove some areas in the south (see Figure 2 for transect numbers).

Table 9. Herd size estimation using fixed-width transect method computed from Distance sampling results obtained during the aerial survey of the Torngat Mountains Caribou Herd in spring 2017.

	Whole study area	Transect 15 and North	Transect 23 and North
Area (km^2)	30,624.8	23,981.1	21,014.0
Transect length (L, km)	7,721.9	6,880.6	6,183.2
Strip half-width: Effective strip width (ESW, km)	0.6222	0.6222	0,6222
Number of caribou recorded closer than ESW (n)	441	441	441
Covered area (2*ESW*L, km^2)	9,609.1	8,562.2	7,694.4
Herd size estimate using fixed-width strip transect computation method: (n/2 ESW L)* Area	1,405	1,235	1,204

3.4 Recruitment and sex ratio

The raw classification data are presented in Appendix D. The spring calf recruitment (i.e. proportion of 11-month old calves in the population) was good in 2014 at 17.2%, and higher in 2017 at 23.1% (Table 2). At 43.6, the calf/100 cows ratio is also very high for a spring classification done near the end of the biological year of the caribou. High recruitment figures such as these, if sustained, are typically associated with an increasing population trend of the herd in biological year 2016-2017. Such potentiality needs to be interpreted with caution though as recruitment can vary significantly year to year. Moreover, the adult survival rate is unknown and therefore the population's trend cannot be assessed annually but only relative to previous surveys (i.e. 2014). The adult sex ratio of 45 males/100 cows was typical for a caribou population and within the range of 43 to 72 reported by Bergerud (1980).

4. Discussion

Based on this survey using distance sampling, the best estimate of the size of the Torngat Mountains Caribou Herd in spring 2017 is 1,326 caribou including calves (CI: 912 – 1,986), which is 1.43 times that of spring 2014 (see Couturier et al. 2015). The population increase since 2014 represents an annual finite population increase (lambda) of 1.13 or 13% per year since 2014, which is in the high end of values reported for caribou populations. Still, excellent recruitment rate estimates in 2014 and 2017 are consistent with the observed population increase and suggest that any increase is at least in part due to high productivity. No recruitment data were collected in 2015 and 2016, but the high estimate of annual growth suggests that productivity was also high for those years. Higher caribou calf survival is normally associated with a low predation rate. Only eight wolves were recorded during the survey, which suggests a relatively low wolf density in the Torngat Mountains Caribou Herd range. Only three wolves were recorded during the previous survey in 2014 (Couturier et al. (2015).

Like the first survey in 2014, the second Torngat caribou population survey was done with a relatively intensive sampling effort (Tables 2). A total of 21,467 km^2 was covered (2WL) in 2017 with Distance sampling, which represented 70% of the entire study area (Table 8). However, it was not intended to be a full-coverage survey with a total count of the population, so statistical analyses (i.e. mostly using Distance sampling) were needed to extrapolate the observations to estimate total population size. However, even a comparison of raw data may offer some insight into population trend. Compared to 2014, our study area was 4% larger and the length of transect surveyed increased by 9% in 2017 (Table 1). Thus if the population had remained stable we should still have expected to record more caribou than were seen in 2014 due simply to this increased survey effort. However, 2.27 times more caribou were recorded on transect in 2017 than in 2014, a far greater increase than the one that would be expected based on the slight increase in the sampling effort, suggesting that the size of the herd had increased.

The survey team saw no evidence of caribou migratory movements during the survey period and no directional tracks in the snow between transects were observed. Most snow track networks around caribou observations suggested that the caribou had remained in a localised area for a number of days. Consequently we believe that the likelihood of duplicate observations of individual groups of caribou that had moved from one transect to another is small. Further, based on visual observations and on the radio-collared caribou monitoring from the GRH and Torngat Herd, we can conclude that no significant numbers of George River caribou were present in the Torngat Herd study area during the 2017 survey.

With only two systematic surveys completed, it is still too early to predict if the increasing population trend of the Torngat caribou will continue in the short term. In North America, caribou have shown population variations of large amplitude; therefore estimating trends from only two herd size estimates is premature.

Pioneering work done in the 1970s and 1980s suggested that Torngat Herd was more abundant at that time. An approximate herd size estimation of 5,000 caribou by Bélanger and Le Henaff (1985) has often been quoted to suggest that Torngat Herd size was larger in the 1980s. However, that estimate was not obtained from a systematic survey but from simple reconnaissance surveys. Consequently this 5,000 figure should not be considered as a herd size estimate because of the reconnaissance nature of the surveys. It was not planned or conducted to produce an estimate at the population scale. Another important limitation of caribou number estimates from the 1970s-1980s in the Torngat Mountains Herd range relates to the large range overlap between the Torngat Herd and the George River Herd from 1970 to 2000 (Bélanger 2017a,b). For example, the extensive aerial surveys done in June 1993 during the George River Herd photo-survey showed that thousands of caribou from the George River Herd were observed within the traditional Torngat caribou range as far north as Abluviak Fiord (59°N; Couturier et al. 1996). In addition to Bélanger and Le Henaff (1985), there are other technical reports on some surveys carried out in the Torngat Herd range in the 1970s-1980s. Some were opportunistic or erratic searches, while others were systematic surveys along transects planned with partial knowledge of the population's range or inadequate sampling effort. For example, Le Henaff (1977) flew 1,010 km in a fixed-wing aircraft along transects spaced every 16 km over 13,000 km^2 in the Torngat herd range between April 8 and April 15 of 1976. They covered almost the entire Torngat Herd range located north of Nachvak Fjord. They recorded 168 caribou in 19 groups for a mean group size of 8.8 caribou. Based on these data and estimating a fixed total detection width of 500 m on each side of the aircraft (often used as transect width for caribou, see Nishi and Buckland 2000, Anderson 2016), it is possible to estimate the Torngat Herd size at about 2,200 caribou in the spring of 1976. However this crude estimate, as well as that of Bélanger and Le Henaff (1985), should be used cautiously because these casual observations were not intended to generate rigorous estimates of the size of the Torngat Mountains Caribou Herd.

4.1 Survey area, transect and sampling design

The presence of caribou in the areas added since the 2014 survey showed that they were important. These transects represented an increase of 1,234.6 km^2 (4%) in the area surveyed and yielded 2% of the caribou observed in 2017 (groups 110 and 121 of 2 and 11 caribou). Inclusion of this area also improved coverage of Kuururjuaq Park area, which Inuit with local knowledge suggested was important.

The 3-km spacing in the north stratum provided improved coverage of the study area and therefore the probability of detecting caribou, and if resources permit should be considered for future surveys. As the Torngat Herd is a small wildlife population, estimating its herd size will always be vulnerable to statistical problems related to small sample sizes; the sampling method should be tailored to sample the highest proportion of caribou and therefore reduce the confidence interval to a minimum within the budgetary capacities.

If all knowledge confirms that Torngat caribou no longer use the areas south of Hebron during winter, removing this region from the study area of future surveys would not influence the population estimate. It must be acknowledged that keeping a larger study area increases the costs of any survey done on the Torngat caribou. This budgetary factor is an important consideration with implications for the feasibility of future monitoring. As shown by the budget summary presented in Appendix E, these aerial surveys are expensive.

4.2 Density estimation in Distance Sampling

Two geographic strata were used in a systematic design to estimate Torngat Herd size in Spring 2017. Buckland et al. (2001, p. 233) advocated systematic sampling survey designs because they give better spatial coverage and precision. Fewster et al. (2009) also reported that systematic survey designs are more efficient and they conclusively favour the use of post-stratification to reduce bias in estimates of the encounter rate (n/L) variance for systematic designs. Our results support the use of two strata and the strata delineation method was appropriate.

Variance estimation method O2, described by Fewster et al. (2009), was used to compute density in Distance 7.1 (see Methods). Following tests during analyses, it appears that this method provided better accuracy than the default settings R2 method often used in Distance 7.1. The best model retained in the density estimation, CDS HN Cos(0), provided density and herd size CV estimates of 0.257 and 0.239 (Table 5) for R2 and O2 methods respectively. In the 2014 survey, density variance was estimated following default settings R2 method and the best model has density CV of 0.264, which gave herd size confidence interval from 616 to 1,453 (Couturier et al. 2015). Using data set collected in 2014, variance was again estimated using O2 method resulting in a smaller CV of 0.233, which would have provided slightly smaller herd size confidence interval from 645 to 1,369. It is recommended to use the O2 variance estimation method in future systematic parallel transects design surveys (Thomas, L., pers. comm.).

Relationship between perpendicular distance and group size was weak and non-significant. The default settings used in Distance 7.1, based on size bias regression method to estimate expected cluster size (E(S)), were efficient to deal with such weak effect. It was evaluated that the use of cluster size as a covariate in MCDS modelling was not required in the analysis of the 2017 survey results (Thomas, L., pers. comm.).

4.2.1 Sample size

The 2017 survey CV and confidence intervals were similar to those reported during the 2014 survey. Variance estimates were relatively high and characteristic of a small sample size. Sample size was 50 caribou groups in 2014 but it increased slightly to 58 in 2017. Most of the variance in density estimates came from Encounter rate (n/L, Table 7)) and researchers would only know after the survey is completed the number of groups of animals located on transects.

During a survey of Newfoundland caribou, Fifield et al. (2013) suggested that at least 30-40 transect lines and at least 70-100 detections (groups of caribou) were required to adequately estimate sampling variance in Distance sampling. The number or length of transects required depends on the number of expected detections per transect. If caribou are rare, transect length has to be longer in order to generate an estimate with comparable variance. Buckland et al. (2001) proposed that 60-80 groups of animals are a good sample for Distance sampling. In a distance sampling study involving walked line-transect, Glass et al. (2015) suggested that sample size to achieve good precision in Distance sampling could be higher than previously suggested. They obtained precision better than the desired CV= 0.20 (Buckland et al. 2001) when ~200 animal clusters were observed and their greatest precision of CV= ~0.13 was achieved when ~400 clusters were recorded.

We increased the number of randomly allocated systematic transects in the 2017 survey. We flew 91 transects, which is close to the maximum number of transects that could be placed in this study area using an east/west oriented transect design. Based on this experience with 3-km spacing, we now feel that this is the minimum spacing distance that could be efficiently used in the north stratum while still using distance sampling. With an increased sampling effort, we were also expecting more caribou groups than in 2014. Unfortunately, the number of groups only increased slightly although the mean group size was almost twice that observed in 2014. Group sizes are important in density estimation, but since the groups are the observation unit in distance sampling, group size does not influence sample size.

If group size had remained the same as the one in 2014, the total number of caribou seen on transect would have represented 113 groups in 2017, a sample size larger than most recommendations. It is difficult to explain why caribou group size has changed so much from 2014 to 2017. Snow conditions were similar in both surveys and no significant icing events were noted. Timing of both surveys was also comparable although delayed by about two weeks. If we consider only period of fieldwork when caribou were recorded over transects (e.g. excluding days of preparation and days flying southern transects with no caribou), photographic classification was done between March 13 and 29 during the survey in 2014 (Couturier et al. (2015) and between March 27 and April 9 in 2017 (Appendix D). It is possible that only a two-week difference could partly explain that caribou grouping behaviour changed toward higher group size in 2017.

Studying a small population like the Torngat Herd, researchers do not have much control on sample size, whatever the survey method they choose. Fixed-width transect method with many transects with zero caribou would also provide high variance and large confidence intervals. Using Distance sampling, we increased survey effort in 2017 but the number of groups still was relatively small. In the next survey, increasing likelihood of observing more caribou groups could be done again through an increased survey effort in the Torngat Herd range. Some areas south of Hebron fjord could be removed from the survey area if Torngat caribou no longer use them in recent years. Flying effort saved in this southern area could be re-allocated between current transect 15 and 38 by flying 3-km spacing instead of 4-km as flown in 2017. The next survey could then have 3-km spacing between transects over the entire study area.

4.2.2 Distance truncation

In Distance sampling, right-truncation is a common procedure that removes some observations at a larger distance. Otherwise extra adjustment terms may be needed to fit a long tail to the detection function. Thomas et al. (2010) suggested that the most distant 5% of observations should be truncated. In a similar caribou survey over tundra habitat in South Baffin Island, Jenkins et al. (2013) used a truncation distance (W) of 2,800 m to censor two observations or 1.4% of 143 groups recorded. Fifield et al. (2013) truncated observations > 1,000 m from their sample of 394 caribou groups in partially forested habitat. Thiessen (2010) recorded 339 groups during a moose survey and truncated the largest 5% of distance. Observations >1 km from transects (representing the most distant 2% of observations) were also truncated following an aerial survey of moose in open forested habitat in British Columbia (McNay 2013), while in an aerial polar bear survey truncation of the most distant 5% of observations (W= 1,068 m, n= 189 groups) was adequate to fit the tail of the detection function (Aars et al. 2008). During the 2014 survey of the Torngat Herd as the frequency distribution was showing some unexpected increases at longer distance, the data truncation effect was explored (Couturier et al. (2015). It was found that truncation did not have a substantial effect on density estimates. Consequently it was decided not to truncate the most distant observations (maximum= 1,390 m) because of issues related to the small sample size (Couturier et al. 2015).

Achieving a good model fit combined with a low CV is the recommended strategy when investigating truncation distance, as there is no cookbook to guide researchers (Rexstad, E., pers. comm.). When sample size is small, the trade-off is particularly painful because truncation increases the confidence interval. Distance sampling experts tend to favour less truncation rather than more provided the fit is good (e.g. $p \geq 0.10$; E. Rexstad, pers, comm.). We followed this recommended strategy and right-censored at W= 1,390 m, resulting in the removal of two observations (1,710 m and 1,980 m) or 3.4% of our dataset. Other truncation distances tested provided similar density estimates suggesting that truncation was not so influential on density estimates. Moreover, dataset truncated at 1,390 m showed a better model fit and decreased the number of models that received warnings in Distance 7.1, mostly for monotonicity (e.g. “Parameters are being constrained to obtain monotonicity”) and high correlation issues (e.g. “Some parameters are very highly correlated”). Truncating at 1,710 m would have required extra adjustment terms to fit spurious bumps in the tail of the detection function while truncating at 1,000 would require an additional parameter. When compared with these truncation distances, right censoring at 1,390 m provided the most parsimonious models. This right censoring at 1,390 m addresses outlier effects and possible group size bias at longer distance.

4.3 Recruitment and sex ratio

Our surveys indicate that recruitment was high in spring of 2014 and 2017, when calves represented 17.2% and 23.1% of the caribou observed, respectively. The ratios of calf/100 cows were respectively 28.4 and 43.6 in 2014 and 2017. Spring classification data for the Torngat Herd were not conducted in 2015 or 2016. The high recruitment measured in spring 2014 and 2017 suggest that the Torngat Herd was likely increasing in these two years. However, the absence of data in 2015 and 2016 makes it impossible to draw solid conclusion about herd growth potential in recent years. Further monitoring is required to draw sound conclusions on any population trend.

Torngat Herd recruitment figures from 2014 and 2017 compare favourably to observations from other caribou populations. For example, for 22 sedentary herds, Bergerud (2000) reported that the recruitment needed to balance adult mortality was 15.6%. In Alaska, Valkenburg et al. (1996) reported that spring recruitment of the Delta Herd varied from 21 to 51 calves/100 cows (mean= 37.1) from 1982-1988, a period when the population was increasing by 5% per year. Studying the Qamanirjuaq migratory caribou herd, Campbell et al. (2010) suggested that 25 calves/100 cows during spring classification could serve as an approximate index of a stable population. They reported spring recruitment figures varying from 17 to 50 calves/100 cows between 1979 and 2008. During a period of rapid herd growth from 1976 to 1984, Couturier et al. (1990) reported that spring percentage of calves in the GRH was 15.3% on average. During the same period, they also reported that the annual survival was high at 89%.

Timing of spring classification is an important factor to consider when caribou researchers want to collect unbiased data on recruitment and sex ratio. Couturier et al. (1990) warned against doing spring classification later than April for migratory caribou first because the mother-calf bond is usually broken between April and June but also because of the spring migration. For the Torngat Herd, part of the same rationale could be applied and both classification and survey should be done between March 10th and March 31st before caribou start to increase their daily movement rates (Couturier et al. 2010).

5. Conclusion and recommendations

The aerial survey done in spring 2017 over the entire historical range of the Torngat Mountains Caribou Herd estimated the population size at 1,326 caribou including 11-month old calves (CI: 912 – 1,986). In contrast with the declining numbers observed in other caribou herds across the Quebec-Labrador peninsula in recent years, this study suggests that the Torngat caribou Herd increased by 13% per year since 2014 and that high recruitment was indicative of herd growth both in 2014 and 2017. The crash of the GRH and the rapid decline of the Leaf River Herd (LRH) have caused social and economic challenges in the region, particularly for Indigenous Peoples who depend on caribou for their food security and their culture. However, while these results may seems encouraging for the Torngat Herd, this survey also confirmed that this herd is still small compared to past population estimates of its migratory neighbours the Leaf River Herd and the George River Herd. The 2014 and 2017 population surveys both described the small size of the Torngat Herd at about one thousand animals and such confirmation will require continuous and careful attention from managers and users.

It can be hypothesized that the Torngat Herd has persisted at low density for decades and even centuries. Belonging to the montane ecotype, Torngat caribou depend on these mountainous habitats so may not be able to expand their range substantially beyond the region. The marked differences in ecology and population biology between the montane Torngat Herd and the migratory (GRH and LRH) herds are such that the Torngat Herd is likely to remain a small population.

Every caribou herd faces different limiting factors (predation, habitat quality, human disturbances, insect harassment, hunting, etc.) and environmental conditions (snow, icing events, etc.). These limiting factors and environmental conditions are likely to change over time, so it is difficult to predict herd trends from one year to the next, or to extrapolate population dynamics estimates from one herd to another. If budgets allow it and if it is justified based on management needs, an efficient multi-year monitoring system could include an annual spring classification, an annual estimation of adult survival through radio-collaring (see Rasiulis et al. 2014, Losier et al. 2015), an annual monitoring of harvest and a periodic survey (e.g., every third year) to estimate herd size. Managers could then have an annual estimation of the population trends when using population dynamics parameters like recruitment and adult survival, along with a recent population size estimate to model population trends between survey years. The survey findings support a valid herd size estimate and other essential population dynamics parameters that will help managers monitor this important resource for Inuit of Nunavik and Nunatsiavut. This information can now serve as a baseline for further monitoring in support of management considerations.

For the monitoring of the Torngat Herd, it is recommended to:

- Work with Inuit Knowledge-Holders in Kangiqsualujjuaq and Nain to identify research priorities and strategies;
- Update the population abundance estimate in 2020 in a study area identified through Inuit and scientific knowledge;
- Measure recruitment annually by a spring photo classification (i.e. March 10^{th}-31^{st}) by flying randomly selected transects used in 2017 (i.e. no opportunistic or erratic flying);
- Monitor the harvest;
- Develop methods to better understand space-use and survival, in collaboration with Inuit Knowledge-Holders.

References

Aars, J., Marques, T. A., Buckland, S. T., Belikov, S., Boltunov, A. & Wiig, O. (2009). Estimating the Barents Sea polar bear subpopulation size. *Marine Mammal Science, 25(1),* 35–52.

Anderson, M. (2016). Distribution and abundance of muskoxen (*Ovibos moschatus*) and Peary caribou (*Rangifer tarandus pearyi*) on Prince of Wales, Somerset, and Russell Islands, August 2016. Department of Environment, Wildlife Research Section, Government of Nunavut, Igloolik, NU. Status report 2016-06 27 p.

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.

Bélanger, É. (2017a). Habitat use of Torngat Mountains caribou – Results update of the Torngat Mountains caribou research. Report submitted to the Torngat Secretariat. Université Laval, Québec, QC.

Bélanger, É. (2017b). Sélection de l'habitat, dynamique de population et utilisation de l'espace du caribou des Monts Torngat. M. Sc. Thesis, Université Laval, Québec, QC. 64 p + 9 Appendix.

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.

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.

Buckland, S. T., Rexstad, E. A., Marques, T. A. & Oedekoven, C. S. (2015). Distance sampling: Methods and applications. Springer.

Campbell, M., Goorts, J., Lee, D. S., Boulanger, J. & Pretzlaw, T. (2015). Aerial abundance estimates, seasonal range use, and spatial affiliations of the barren-ground caribou (*Rangifer tarandus groenlandicus*) on Baffin Island – March 2014. Government of Nunavut, Department of Environment. Technical Report Series - No: 01–2015.

Campbell, M., Nishi, J. & Boulanger, J. (2010). A calving ground photo survey of the Qamanirjuaq migratory barren-ground caribou (*Rangifer tarandus groenlandicus*) population – June 2008. Government of Nunavut, 129 p.

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

Couturier, S., Brunelle, J., Vandal, D. & St-Martin, G. (1990). Changes in the population dynamics of the George River caribou herd, 1976-87. *Arctic, 43,* 9–20.

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.

Couturier, S., Dale, A., Mitchell Foley, J., Snook, J., and Wood, B. (2015). First scientific data on herd size and population dynamics of the Torngat Mountains caribou herd. Torngat Wildlife, Plants and Fisheries Secretariat. Ser. 2015/43 + 9 p.

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.

Fewster, R. M., Buckland, S. T., Burnham, K. P., Borchers, D. L., Jupp, P. E., Laake, J. L. & Thomas, L. (2009). Estimating the encounter rate variance in Distance Sampling. *Biometrics, 65*, 225–236.

Fifield, D. A., Lewis, K. P., & Gullage, S. E. (2013). 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.

Glass, R., Forsyth, D. M., Coulson, G. & Fest-Bianchet, M. (2015). Precision, accuracy and bias of walked line-transect distance sampling to estimate eastern grey kangaroo population size. *Wildlife Research, 42*, 633–641.

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

JASP Team. (2017). JASP (Version 0.8.2) [Computer software]. Amsterdam, University of Amsterdam, Netherlands.

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. Department of Environment, Government of Nunavut, Pond Inlet, NU. 184 p.

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.

Le Henaff, D. (1977). Vérification des principales aires hivernales du caribou (*Rangifer tarandus*) dans le secteur de Waco (Basse Côte-Nord) et au Nouveau-Québec, avril 1976. Ministère du

Tourisme, de la Chasse et de la Pêche, Service de la recherche biologique, Québec. QC. 30 p.

Le Moullec, M., Pedersen, A. O., Yoccoz, N. G., R, Tufto, J. & Hansen, B. B. (2017). Ungulate population monitoring in an open tundra landscape: distance sampling versus total counts. *Wildlife Biology*, DOI: 10.2981/wlb.00299.

Losier, C., Couturier, S., St-Laurent, M.-H., Drapeau, P., Dussault, C., Rudolf, T., Brodeur, V., Merkle, J. A., & Fortin, D. (2015). Adjustments in habitat selection to changing availability induce fitness costs for a threatened ungulate. *Journal of Applied Ecology*, *52*, 496–504.

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.

McNay, S., Webster, D. & Sutherland, G. (2013). BC Boreal Caribou Implementation Plan – Aerial Moose Survey in North East BC 2013. Science and Community Environmental Knowledge, 25 p + appendices.

Newfoundland and Labrador Government. (2016). Press release 28 August 2016 at http://www.releases.gov.nl.ca/releases/2016/ecc/0829n02.aspx.

Nishi, J. & Buckland, L. (2000). An aerial survey of caribou on western Victoria Island (5-17 June 1994). Department of Resources, Wildlife, and Economic Development, Government of the Northwest Territories, Volume 128. 88 p.

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.

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.

Thiessen, C. (2010). Horn River Basin moose inventory January/February 2010. Ministry of Environment, Fort St-John, BC. 26 p + appendices.

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.

Appendix A

Timeline of the Torngat Mountains Caribou Herd survey in spring 2017.

Date	Route/ Transect / Comments	Flying time (h)	Group	Number of groups	Base camp [a]
March 20, 2017	Departure is delayed because of strong winds in the North	0			H V-G B
March 21, 2017	Leaving H V-G B to the North but must return to Nain	2.0			Nain
March 22, 2017	Nain	0			Nain
March 23, 2017	Nain	0			Nain
March 24, 2017	Leaving Nain to the North: must landed at 8 km of Kangiqsualujjuaq	2.8			Kangiq.
March 25, 2017	Weather day	0			Kangiq.
March 26, 2017	Weather day: helicopter is back in Kangiqsualujjuaq	0.2			Kangiq.
March 27, 2017	Transects 98 to 81 (skipped 92: weather)	6.9	1 to 21	21	Kangiq.
March 28, 2017	Transects 80 to 71	6.3	22 to 28	7	Kangiq.
March 29, 2017	Transects 70 to 63	6.6	29 to 30	2	Kangiq.
March 30, 2017	Transects 62 to 55	6.9	31	1	Kangiq.
March 31, 2017	Transects 54 to 51 (group 33 Off transect)	5.7	32 to 45	13	Kangiq.
April 1, 2017	Weather day	0			Kangiq.
April 2, 2017	Transects 50 to 43 (western section)	6.4	101 to 109	2	Kangiq.
April 3, 2017	Working on fuel caches	2.7			Kangiq.
April 4, 2017	Moving to Qurlutuarjuq and transects 37 to 42 (northward, western section)	4.5	110 to 113	3	Qurlu.
April 5, 2017	Transects 48 to 39 (eastern section)	7.4	114 to 117	4	Qurlu.
April 6, 2017	Weather day	0			Qurlu.
April 7, 2017	Transects 38 to 31	8.1	118 to 121	4	Qurlu.
April 8, 2017	Weather day	0			Qurlu.
April 9, 2017	Transects 30 to 21	7.2	122 to 125	4	Qurlu.
April 10, 2017	Weather day	0			Qurlu.
April 11, 2017	Weather delay and moving to Hebron	0.5			Hebron
April 12, 2017	Weather day	0			Hebron
April 13, 2017	Transects 18 to 5 (12, 10, 8, 6 were skipped)	8.5			Hebron
April 14, 2017	Transects 5 to 1 (4 and 2 were skipped) and leaving south to H V-G B	4.7			H V-G B
	TOTAL	**87.4**		**61**	

[a] Kangiq.= Kangiqsualujjuaq, Qurlu.= Qurlutuarjuq, H V-G B= Happy Valley-Goose Bay

Appendix B

Transect related information (visibility (3: excellent, 2: good, 1: poor), temperature, clouds percentage, precipitation) including groups of caribou detected, base camp [a] used and flying time on transect during the Spring 2017 population survey of the Torngat Mountains Caribou Herd.

Trans.	Start Date/Time	End Date/Time	Time on trans. (h)	Vis. class	T. (°C)	Clouds (%)	Precipitation	Groups (n)	Base camp	Comments
98	17-03-27 11:43	17-03-27 11:48	0.083	2	-19	60%	none	1	KQ	
97	17-03-27 11:49	17-03-27 11:54	0.083	2	-19	60%	none	2	KQ	
96	17-03-27 11:58	17-03-27 12:04	0.100	2	-18	70%	none	0	KQ	
95	17-03-27 12:05	17-03-27 12:12	0.117	2	-18	70%	none	0	KQ	
94	17-03-27 12:13	17-03-27 12:19	0.100	1	-17	80%	ice crystal	0	KQ	
93	17-03-27 12:21	17-03-27 12:30	0.150	2	-16	50%	none	1	KQ	
92			0.000						KQ	skipped: fog
91	17-03-27 12:35	17-03-27 12:44	0.150	3	-16	40%	none	0	KQ	
90	17-03-27 12:46	17-03-27 12:56	0.167	3	-16	20%	none	1	KQ	
89	17-03-27 12:58	17-03-27 13:10	0.200	3	-17	40%	none	0	KQ	
88	17-03-27 14:35	17-03-27 14:47	0.200	2	-16	80%	none	1	KQ	
87	17-03-27 14:50	17-03-27 15:03	0.217	3	-16	20%	none	2	KQ	
86	17-03-27 15:05	17-03-27 15:23	0.300	3	-15	0%	none	3	KQ	
85	17-03-27 15:25	17-03-27 15:44	0.317	3	-15	10%	none	3	KQ	
84	17-03-27 15:46	17-03-27 16:04	0.300	3	-16	0%	none	2	KQ	1 off-transect
83	17-03-27 16:05	17-03-27 16:23	0.300	3	-16	0%	none	1	KQ	
82	17-03-27 16:25	17-03-27 16:34	0.150	3	-16	10%	none	1	KQ	
81	17-03-27 16:43	17-03-27 17:05	0.367	3	-16	10%	none	1	KQ	
80	17-03-28 11:08	17-03-28 11:32	0.400	3	-13	40%	none	2	KQ	
79	17-03-28 11:34	17-03-28 11:56	0.367	3	-16	50%	none	0	KQ	
78	17-03-28 11:58	17-03-28 12:18	0.333	3	-13	30%	none	0	KQ	
77	17-03-28 12:20	17-03-28 12:41	0.350	3	-16	40%	none	0	KQ	
76	17-03-28 12:43	17-03-28 13:17	0.567	3	-12	10%	none	5	KQ	
75	17-03-28 13:19	17-03-28 13:42	0.383	3	-12	10%	none	0	KQ	
74	17-03-28 14:39	17-03-28 15:06	0.450	3	-10	40%	none	0	KQ	
73	17-03-28 15:08	17-03-28 15:35	0.450	3	-10	40%	none	0	KQ	
72	17-03-28 15:37	17-03-28 16:08	0.517	2	-12	40%	none	0	KQ	
71	17-03-28 16:15	17-03-28 16:42	0.450	3	-15	70%	none	0	KQ	
70	17-03-29 09:13	17-03-29 09:50	0.617	3	-13	0%	none	1	KQ	
69	17-03-29 09:53	17-03-29 10:26	0.550	3	-15	0%	none	0	KQ	
68	17-03-29 11:12	17-03-29 11:46	0.567	3	-14	0%	none	0	KQ	
67	17-03-29 11:50	17-03-29 12:21	0.517	3	-13	0%	none	0	KQ	
66	17-03-29 13:18	17-03-29 14:00	0.700	3	-13	0%	none	1	KQ	
65	17-03-29 14:02	17-03-29 14:38	0.600	3	-10	0%	none	0	KQ	
64	17-03-29 15:08	17-03-29 15:43	0.583	3	-12	0%	none	0	KQ	
63	17-03-29 15:45	17-03-29 16:22	0.617	3	-11	0%	none	0	KQ	
62	17-03-30 09:49	17-03-30 10:24	0.583	3	-15	0%	none	0	KQ	
61	17-03-30 10:26	17-03-30 11:00	0.567	3	-8	10%	none	0	KQ	
60	17-03-30 11:35	17-03-30 12:12	0.617	3	-13	0%	none	0	KQ	

59	17-03-30 12:14	17-03-30 12:57	0.717	3	-7	10%	none	1	KQ	
58	17-03-30 13:51	17-03-30 14:32	0.683	3	-13	0%	none	0	KQ	
57	17-03-30 14:38	17-03-30 15:10	0.533	3	-11	10%	none	0	KQ	
56	17-03-30 15:12	17-03-30 15:50	0.633	3	-12	0%	none	0	KQ	
55	17-03-30 15:52	17-03-30 16:36	0.733	3	-6	10%	none	0	KQ	
54: 1	17-03-31 08:58	17-03-31 09:37	0.650	3	-10	10%	none	0	KQ	to fuel
53: 1	17-03-31 09:39	17-03-31 10:18	0.650	3	-12	0%	none	0	KQ	winds
52	17-03-31 11:24	17-03-31 12:28	1.067	3	-10	0%	none	1	KQ	1 off-transect
54: 2	17-03-31 12:31	17-03-31 12:54	0.383	3	-9	10%	none	2	KQ	
53: 2	17-03-31 12:55	17-03-31 13:17	0.367	3	-10	20%	none	2	KQ	1 off-transect
51: 1	17-03-31 13:21	17-03-31 13:58	0.617	3	-8	10%	none	6	KQ	1 off-transect; to fuel
51: 2	17-03-31 14:59	17-03-31 15:12	0.217	3	-11	50%	none	0	KQ	
50: 1	17-04-02 08:50	17-04-02 09:01	0.183	3	-12	0%	none	0	KQ	to fuel
50: 2	17-04-02 09:22	17-04-02 10:15	0.883	3	-12	0%	none	2	KQ	
49: 1	17-04-02 11:07	17-04-02 11:15	0.133	3	-15	0%	none	0	KQ	to fuel: no fuel
49: 2	17-04-02 12:44	17-04-02 13:05	0.350	3	-10	0%	none	0	KQ	to fuel
49: 3	17-04-02 13:54	17-04-02 14:05	0.183	3	-10	0%	none	0	KQ	
48 W	17-04-02 14:08	17-04-02 14:33	0.417	3	-10	0%	none	0	KQ	
47 W	17-04-02 14:35	17-04-02 14:56	0.350	3	-10	0%	none	0	KQ	
46 W	17-04-02 14:57	17-04-02 15:23	0.433	3	-11	0%	none	0	KQ	
45 W	17-04-02 15:24	17-04-02 15:45	0.350	3	-10	0%	none	0	KQ	
44 W	17-04-02 15:47	17-04-02 16:12	0.417	3	-11	0%	none	0	KQ	
43 W	17-04-02 16:13	17-04-02 16:39	0.433	3	-10	0%	none	0	KQ	
37 W	17-04-04 09:04	17-04-04 09:34	0.500	3	-9	0%	none	0	QQ	
38 W	17-04-04 09:36	17-04-04 10:11	0.583	3	-6	0%	none	1	QQ	
39 W	17-04-04 10:14	17-04-04 10:41	0.450	3	-10	0%	none	0	QQ	
40 W	17-04-04 10:42	17-04-04 11:13	0.517	3	-5	0%	none	1	QQ	
41 W: 1	17-04-04 11:17	17-04-04 11:39	0.367	3	-9	0%	none	0	QQ	to fuel
41 W: 2	17-04-04 12:34	17-04-04 12:49	0.250	3	-9	0%	none	1	QQ	
42 W	17-04-04 12:51	17-04-04 13:17	0.433	3	-6	0%	none	1	QQ	
48 E	17-04-05 09:59	17-04-05 10:42	0.717	3	-4	20%	none	0	QQ	
47 E	17-04-05 10:44	17-04-05 11:16	0.533	3	-3	10%	none	0	QQ	
46 E	17-04-05 11:18	17-04-05 11:44	0.433	3	-2	30%	none	0	QQ	
45 E	17-04-05 11:49	17-04-05 12:12	0.383	3	-5	30%	none	0	QQ	
44 E: 1	17-04-05 12:14	17-04-05 12:35	0.350	3	-4	40%	none	0	QQ	to fuel
44 E: 2	17-04-05 13:40	17-04-05 13:57	0.283	3	-4	40%	none	0	QQ	
43 E	17-04-05 13:59	17-04-05 14:41	0.700	3	-8	30%	none	3	QQ	
42 E	17-04-05 14:43	17-04-05 15:24	0.683	3	-4	20%	none	1	QQ	
41 E	17-04-05 15:25	17-04-05 16:09	0.733	3	-3	50%	none	0	QQ	
40 E: 1	17-04-05 16:10	17-04-05 16:34	0.400	3	-3	50%	none	0	QQ	to fuel
40 E: 2	17-04-05 17:23	17-04-05 17:32	0.150	3	-4	40%	none	0	QQ	
39 E	17-04-05 17:35	17-04-05 18:12	0.617	3	-8	30%	none	0	QQ	
38 E	17-04-07 08:47	17-04-07 09:22	0.583	3	-6	20%	none	0	QQ	
37 E	17-04-07 09:24	17-04-07 10:12	0.800	3	-4	50%	none	0	QQ	

36: 1	17-04-07 10:16	17-04-07 10:41	0.417	3	-4	40%	none	0	QQ	to fuel
36: 2	17-04-07 11:36	17-04-07 12:03	0.450	3	-6	10%	none	0	QQ	
35	17-04-07 12:07	17-04-07 13:07	1.000	3	-4	0%	none	2	QQ	
34	17-04-07 13:08	17-04-07 13:52	0.733	3	-4	80%	none	0	QQ	
33	17-04-07 15:12	17-04-07 16:06	0.900	3	-8	20%	none	2	QQ	
32	17-04-07 16:08	17-04-07 16:51	0.717	3	-4	50%	none	0	QQ	to fuel
31	17-04-07 17:37	17-04-07 18:16	0.650	2	-5	80%	none	0	QQ	
30	17-04-09 08:04	17-04-09 08:36	0.533	3	-7	10%	none	0	QQ	
29	17-04-09 08:39	17-04-09 09:15	0.600	3	-5	0%	none	2	QQ	
28	17-04-09 09:17	17-04-09 09:43	0.433	3	-7	0%	none	0	QQ	
27	17-04-09 09:52	17-04-09 10:13	0.350	3	-6	0%	none	1	QQ	
26	17-04-09 12:00	17-04-09 12:39	0.650	3	-6	0%	none	0	QQ	
25	17-04-09 12:45	17-04-09 13:31	0.767	3	-4	0%	none	0	QQ	
24	17-04-09 13:33	17-04-09 14:13	0.667	3	-6	0%	none	1	QQ	
23	17-04-09 15:15	17-04-09 15:55	0.667	3	-6	0%	none	0	QQ	
22	17-04-09 15:56	17-04-09 16:31	0.583	3	-6	10%	none	0	QQ	
21	17-04-09 16:33	17-04-09 17:07	0.567	3	-3	10%	none	0	QQ	
18	17-04-13 08:08	17-04-13 08:39	0.517	3	-16	60%	none	0	HF	
19	17-04-13 08:41	17-04-13 09:08	0.450	3	-9	0%	none	0	HF	
20	17-04-13 09:09	17-04-13 09:35	0.433	3	-14	20%	none	0	HF	
17	17-04-13 10:41	17-04-13 11:16	0.583	3	-9	10%	none	0	HF	
16	17-04-13 11:17	17-04-13 11:55	0.633	3	-13	10%	none	0	HF	
15	17-04-13 11:57	17-04-13 12:36	0.650	3	-8	0%	none	0	HF	
14: 1	17-04-13 12:38	17-04-13 12:58	0.333	3	-15	20%	none	0	HF	to fuel
14: 2	17-04-13 14:14	17-04-13 14:29	0.250	3	-10	0%	none	0	HF	
13	17-04-13 14:34	17-04-13 15:03	0.483	3	-8	0%	none	0	HF	
12			0.000							skipped
11	17-04-13 15:06	17-04-13 15:41	0.583	3	-15	10%	none	0	HF	
10			0.000							skipped
9	17-04-13 15:46	17-04-13 16:26	0.667	3	-13	0%	none	0	HF	
8			0.000							skipped
7	17-04-13 17:15	17-04-13 17:51	0.600	3	-15	0%	none	0	HF	
6			0.000							skipped
5: 1	17-04-13 17:57	17-04-13 18:22	0.417	3	-8	0%	none	0	HF	to fuel
5: 2	17-04-14 07:39	17-04-14 07:56	0.283	3	-17	0%	none	0	HF	
4			0.000							skipped
3	17-04-14 08:33	17-04-14 09:10	0.617	3	-17	40%	none	0	HF	
2			0.000							skipped
1	17-04-14 09:19	17-04-14 09:41	0.367	3	-15	0%	none	0	HF	
Means				**2.91**	**-10.4**	**18%**				
SE					**4.5**	**23%**				
Sum			**54.5**					**58**		

[a] Base camp: KQ: Kangiqsualujjuaq. QQ: Qurlutuarjuq (Base camp of Kuururjuaq Park) HF: Hebron Fjord (Labrador Wildlife Division cabin).

Appendix C

Description of transects done during the spring 2017 aerial survey of the Torngat Mountains Caribou Herd.

Transect	Planned length (km)	Cut-off during fieldwork (km)	Location of cut-off section	Reasons for cut-off	New length data (km)
98	4.2				4.2
97	11.1				11.1
96	13.0				13.0
95	15.9				15.9
94	12.4				12.4
93	17.8				17.8
92	18.1	18.1	See Note 1	Fog	0.0
91	16.4				16.4
90	23.6				23.6
89	30.0				30.0
88	28.1				28.1
87	25.4				25.4
86	34.0				34.0
85	33.7				33.7
84	37.9				37.9
83	38.7				38.7
82	39.5				39.5
81	48.8				48.8
80	53.7				53.7
79	53.2				53.2
78	50.5				50.5
77	56.9				56.9
76	56.8				56.8
75	59.6				59.6
74	73.1	6.4	E end	Low clouds	66.7
73	74.4	4.1	E end	Low clouds	70.3
72	80.5	7.8	E end	Low clouds	72.7
71	81.5	13.7	E end	Low clouds	67.8
70	88.5				88.5
69	86.1				86.1
68	74.9				74.9
67	85.9	4.5	E end	Big mountain	81.4
66	85.4	2.2	E end	Navigation confusion	83.2
65	88.3	1.5	E end	Navigation confusion	86.8
64	88.1				88.1

63	89.9				89.9
62	93.6				93.6
61	86.5				86.5
60	96.8				96.8
59	97.1				97.1
58	89.3				89.3
57	77.1				77.1
56	98.7	6.2	W end	Short on fuel	92.5
55	103.8				103.8
54	114.5				114.5
53	110.6				110.6
52	132.0	7.7	E end	Short on fuel	124.3
51	131.8				131.8
50	128.6				128.6
49	137.5	32.4	See Note 2	Fuel stolen in Nachvak	105.1
48	131.3				131.3
47	127.5				127.5
46	125.9				125.9
45	121.5				121.5
44	141.9				141.9
43	137.6				137.6
42	147.2				147.2
41	149.9				149.9
40	151.1				151.1
39	156.8				156.8
38	157.1				157.1
37	177.4	14.6	W end	Too close of Kangiqsualujjuaq	162.8
36	112.0				112.0
35	110.0				110.0
34	108.0	2.6	E end	Sea fog	105.4
33	112.0				112.0
32	111.0	13.8	E end	Sea fog	97.2
31	107.0				107.0
30	82.1				82.1
29	73.6				73.6
28	68.9				68.9
27	51.4				51.4
26	99.6				99.6
25	92.9				92.9
24	96.6				96.6
23	94.9				94.9
22	92.1				92.1
21	89.4				89.4

20	90.4	26.4	W end	Short on fuel	64.0
19	92.0	26.5	W end	Short on fuel	65.5
18	100.7	11.6	E end	Short on fuel	89.1
17	93.0				93.0
16	102.4				102.4
15	101.9				101.9
14	103.5				103.5
13	88.9				88.9
12	116.8	116.8	See Note 1	Fuel, budget, maintenance, etc.	0.0
11	117.6				117.6
10	124.0	124.0	See Note 1	Fuel, budget, maintenance, etc.	0.0
9	127.6				127.6
8	124.4	124.4	See Note 1	Fuel, budget, maintenance, etc.	0.0
7	119.3				119.3
6	120.9	120.9	See Note 1	Fuel, budget, maintenance, etc.	0.0
5	118.3				118.3
4	122.5	122.5	See Note 1	Fuel, budget, maintenance, etc.	0.0
3	119.0				119.0
2	109.2	109.2	See Note 1	Fuel, budget, maintenance, etc.	0.0
1	108.7	61.6	W end	Weather coming in	47.1
Total		**979.4**			
Total as planned	**8701.3**			**Total after survey**	**7721.9**
				% planned	**88.7%**

Note 1: This transect has not been surveyed during the Spring 2017 survey.

Note 2: Middle section of 49 has not been surveyed between 59.17490N 64.31619W and 59.18211N 63.73591W.

Appendix D

Sex and age classification of the caribou groups recorded on (58 groups) and off (4 groups) transects during the spring 2017 aerial survey of the Torngat Mountains Caribou Herd. Distance is the perpendicular distance in meters from the transect line (OFF refers to group recorded off-transect).

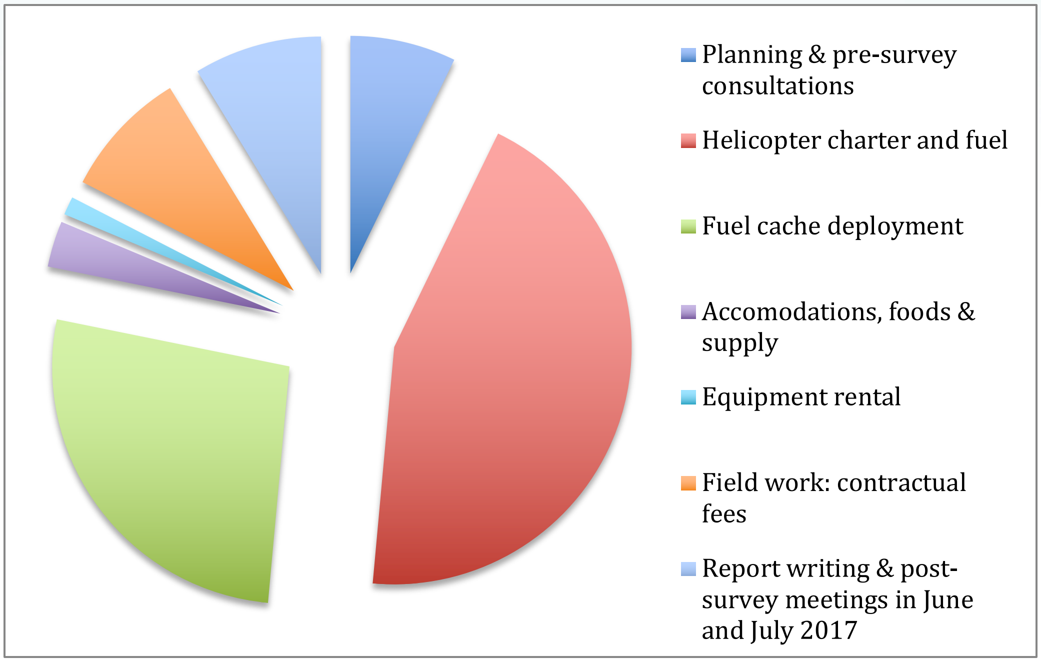
Date	Group	Distance	Fem. Antl.	Fem. Unantl.	Calves	Male Antl.	Male Unantl.	Unknown	Total
17-03-27	1	84	4	1	2	2			9
17-03-27	2	283	6		2	1		1	10
17-03-27	3	488	2		1	1			4
17-03-27	4	925	3		2				5
17-03-27	5	372	1						1
17-03-27	6	321				2			2
17-03-27	7	293			2				2
17-03-27	8	103	4		1	2			7
17-03-27	9	80	3		3				6
17-03-27	10	473	7		8	3	1		19
17-03-27	11	8				1			1
17-03-27	12	359	12		1	5		1	19
17-03-27	13	392	5	2	2	3			12
17-03-27	14	885	4		3	1	1		9
17-03-27	15	520	9		4	5			18
17-03-27	16	OFF				1	1		2
17-03-27	17	391	3		2	3			8
17-03-27	18	574	2		1	3			6
17-03-27	19	126	3			1			4
17-03-27	20	20	2		1				3
17-03-27	21	163	14		6	4			24
17-03-28	22	32	2		2	1			5
17-03-28	23	105					2		2
17-03-28	24	269	9		4	2			15
17-03-28	25	83	13		10	3		1	27
17-03-28	26	784	6		3	1		1	11
17-03-28	27	677	8		3	2		7	20
17-03-28	28	87	3		1				4
17-03-29	29	84	3		1	2			6
17-03-29	30	342	18		12	6	1	1	38
17-03-30	31	1370	9		4	1			14

17-03-31	32	157					2		2
17-03-31	33	OFF					6		6
17-03-31	34	205	1						1
17-03-31	35	37	4		2				6
17-03-31	36	OFF	5		1	1			7
17-03-31	37	185	3		2	3			8
17-03-31	38	438	7		3	2	1		13
17-03-31	39	749	5			1			6
17-03-31	40	605	4		4	1			9
17-03-31	41	280	5		4	7			16
17-03-31	42	OFF	7		3	3			13
17-03-31	43	551	6		1	1			8
17-03-31	44	341	5						5
17-03-31	45	356						17	17
17-04-02	101	67	7		3				10
17-04-02	102	417						7	7
17-04-04	110	445				2			2
17-04-04	111	1390	12		5	3		1	21
17-04-04	113	252	1						1
17-04-05	114	553	6		2	4	1		13
17-04-05	115	730	6	1	2	5		20	34
17-04-05	116	1980	7	1	6	1			15
17-04-05	117	777				2	7		9
17-04-07	118	113					1		1
17-04-07	119	1710	6		1	3	1		11
17-04-07	120	852	10		2	1	1		14
17-04-07	121	164	5		2	2	2		11
17-04-09	122	266	3		2	1		2	8
17-04-09	123	21	13		2	2	1		18
17-04-09	124	140	7		3	3	1		14
17-04-09	125	73	12		3	2	2		19
Total			**302**	**5**	**134**	**106**	**32**	**59**	**638**

Appendix E

Budget description of the Torngat Mountains Caribou Herd survey, spring 2017.

1. Total budget of $281,000 breakdown by items.



2. Total budget of $281,000 breakdown by partners