DISTRIBUTION AND ABUNDANCE OF PEARY CARIBOU (*Rangifer tarandus pearyii*) AND MUSKOXEN (*Ovibos moschatus*) ON SOUTHERN ELLESMERE ISLAND, MARCH 2015

MORGAN ANDERSON[1]

And

MICHAEL C. S. KINGSLEY[2]

7 August 2015

[1]Wildlife Biologist High Arctic, Department of Environment
Wildlife Research Section, Government of Nunavut Box 209 Igloolik NU X0A 0L0
[2]Box 3, 3300-357 São Martinho da Cortiça, Portugal
mcskingsley@gmail.com

STATUS REPORT 2015-01
NUNAVUT DEPARTMENT OF ENVIRONMENT
WILDLIFE RESEARCH SECTION
IGLOOLIK, NU

ᐊᕕᒃ ᑐᖅᓯᒪᓂᖏᑦ ᖃᓄᕐ ᓗ ᐅᓄᖅᑎᒋᓂᖏᑦ ᑐᒃ ᑐᐃᑦ
ᐅᒥᖕ ᒪᐃᑦ ᓗ ᐅᒥᖕ ᒪᑦ ᓄᓈᑕᓂᒋᐊᓂ, ᒫᔾ ᔨ 2015

ᒧᐊᒐᓐ ᐋᓐᑐᓴᓐ[1]

ᐊᒻ ᒪᓗ

ᒪᐃᑯᓪ C. S. ᑭᖕᔅ ᓖ[2]

7 ᐋᒡᒋᓯ 2015

[1]ᐆᒪᔪᓂᒃ ᖃᐅᔨᓴᖅᑎ ᖁᑦ ᑎᒃ ᑐᖅ ᐅᑭ ᐅᖅᑕᖅᑐᒥ, ᐊᕙᑎᓕᕆᔨᒃ ᑯᑦ
ᐆᒪᔪᓂᒃ ᖃᐅᔨᓴᖅᑏᑦ, ᓄᓇᕗᑦ ᒐᕙᒪ ᖓBox 209 Igloolik NU X0A 0L0
[2]Box 3, 3300-357 São Martinho da Cortiça, Portugal
mcskingsley@gmail.com

ᖃᓄᐃᓕᖓᓂᖓᓂ ᐅᓂᒃ ᑳᖅ 2015-01
ᓄᓇᕗᒻ ᒥ ᐊᕙᑎᓕᕆᔨᒃ ᑯᑦ
ᐆᒪᔪᓂᒃ ᖃᐅᔨᓴᖅᑏᑦ
ᐃᒡ ᓗᓕᒃ, ᓄᓇᕗᑦ

Anderson, M. and M. C. S. Kingsley. 2015. Distribution and abundance of Peary caribou (*Rangifer tarandus pearyii*) and muskoxen (*Ovibos moschatus*) on southern Ellesmere Island, March 2015. Nunavut Department of Environment, Wildlife Research Section, Status Report, Igloolik, NU. 49 pp.

Summary

We flew a survey of southern Ellesmere, Graham, and Buckingham islands by Twin Otter in 50 hours between March 19 and 26, 2015, to update the population estimate for caribou and muskoxen in the study area. Previous survey attempts in April and August 2014 were cancelled due to weather. Severe winter weather in the early 2000s, resulted in poor condition and low muskox numbers during the previous survey in 2005, although the area supported relatively high densities of muskoxen in the past. This survey found that muskoxen had recovered from the previous population crash and caribou continued to persist at low densities, as seen in previous surveys.

Muskoxen were abundant north of the Sydkap Ice Cap along Baumann Fiord, north of Goose Fiord, west and north of Muskox Fiord, and on the coastal plains and river valleys east of Vendom Fiord, although they were also seen on Bjorne Peninsula and the south coast from Harbor Fiord to Jakeman Glacier. Short yearlings (10-month old) made up 22% of the population in March 2015. We observed 1146 muskoxen, and calculated a population estimate of 3200 ± SE 602. Although this is the highest estimate recorded for surveys of the area, most previous surveys covered only part of the area, included other areas, or provided only minimum counts. However, the muskox population does appear to have recovered from the low of 312-670 (95% CI) recorded in 2005.

We only saw 38 Peary caribou during the March survey. They were concentrated on the north tip of Bjorne Peninsula and Graham Island, although not as many as had been seen there in 2005. We saw another group east of Vendom Fiord and a group between Bird Fiord and Sor Fiord. That area is also where we saw 2 groups totaling 8 caribou in the August 2014 survey attempt (neither of the 2014 survey attempts covered most of the areas where caribou were expected to be, and none were seen in April 2014). The low number of observations and large variance, making it difficult to tell whether the population has declined from 2005, when 109-442 caribou (95% CI) were estimated to inhabit the same study area. We estimated 183 ± SE 128 caribou, so the population is likely stable at low density on southern Ellesmere Island.

ᐋᓐᑐᓴᓐ, ᐊᒻ ᒪ ᑭᖕᔅ ᓵ. 2015. ᐊᕕᒃ ᑐᖅᓯᒪᓂᖏᓐ ᖃᓄᕐ ᓘ ᐅᓄᖅᑎᒋ ᓂᖏᓐ ᑐᒃ ᑐᐃᑦ ᐅᒥᖕᒪᐃᓪᓗ ᐅᒥᖕᒪᑦ ᓄᓈᑦᑕ ᓂᒋᐊᓂ, ᒫᔾᓱ 2015. ᓄᓇᕗᒻᒥ ᐊᕙᑎᓕᕆᔨᒃᑯᑦ, ᐆᒪᔪᓂᒃ ᖃᐅᔨᓴᖅᐲᑦ, ᖃᓄᐃᓕᖕᓂᖕᓂ ᐅᓂᒃ ᑳᖅ, ᐃᒡ ᓘᓕᒃ, ᓄᓇᕘᑦ. 49 pp.

ᓇᐃᓈᖅᓯᒪᓂᖓ

ᖃᖓᑕᓪ ᓗᑕ ᖃᐅᔨᓴᓚᐅᖅᑐᒍᑦ ᐅᒥᖕᒪᑦ ᓄᓈᓐᓂ, ᒍᕼᐊᒻ, ᐸᑭᖕᕼᐋᒻ ᓗ ᕿᑭᖅᑕᖏᓐᓂᒃ ᒪᕐᕈᓕᒃ ᑯᑦ 50 ᐃᑲᕐ ᕋᓄᑦ ᒫᔾᓱ 19-ᒥᑦ 26-ᒧᑦ, 2015, ᓄᑖᙱᓕᐊᕈᒪᓪ ᓗᒍᑦ ᖃᓄᖅ ᐅᓄᖅᑎᒋᓐᓂᖏᓐᓂᒃ ᓇᓚᐅᑦ ᑖᕐ ᓂᖅ ᑐᒃ ᑐᒧᑦ ᐅᒥᖕᒪᖕ ᓄᓪ ᓗ ᖃᐅᔨᓴᕐ ᕕᐅᔪᒧᑦ. ᖃᐅᔨᓴᕋᓱ ᐊᓚᐅᖅᑑᒐ ᓗᐊᑦ ᐊᐃᕐ ᓇᓕ ᐊᒻ ᒪ ᓗ ᐋᒎᓯ 2014-ᒥᑦ ᑭᓯᐊᓂ ᓄᖅᑲᖅᑎᑕᐅᓚᐅᖅᑐᑦ ᓯᓚ ᐱᔾ ᔪᑎᒋᓪ ᓗᒍᑦ. ᐅᑭᐅᖅ ᓯᓚᕈᔫᑲᑦᒃ ᑎᓪ ᓗᒍᑦ 2000-ᖑᓕᕌᖅ ᔪᓂ, ᖃᐅᔨᓴᕈᑕᐅᑦ ᑎᐊᓚᐅᙳᖅ ᐅᒥᖕᒪᐃᓪ ᓗ ᐅᓄᙵ ᔪᑎᒃ ᖃᐅᔨᓴᕐ ᓂᐅᓚᐅᖅᑐᒥᑦ 2005-ᖑᑎᓪ ᓗᒍᑦ, ᐊᒥᓲ ᕙᓚᐅᕋ ᓗᐊᖅ ᔪᑎᒃ ᐅᒥᖕᒪᐃᑦ ᑕᐃᑲᓂ. ᖃᐅᔨᓴᖅᑎᓪ ᓗᑎᑦ ᖃᐅᔨᓚᐅᖅᑐᑦ ᐅᒥᖕᒪᐃᑦ ᐅᓄᖅᓯᒃ ᑲᓐ ᓂᕐ ᓂᖏᓐᓂᒃ ᐅᓄᕈᓐ ᓃᕐ ᓂᐅᓚᐅᖅᑐᒥᑦ ᑐᒃ ᑐᐃᓪ ᓗ ᐅᓄᖅᓯ ᓗᐊᙶᓇᖅ ᔪᑎᒃ, ᑕᐃᒫᒃ ᖃᐅᔨᔭᐅᓯᒪᔪᖅ ᖃᐅᔨᓴᖅᑕᐅᖃᑦ ᑕᕐ ᓂᑯᓂ.

ᐅᒥᖕᒪᑦ ᐊᒥᓲᓚᐅᖅᑐᑦ ᓯᕐ ᒥᕈᓘᒃ ᓱᕋᒃ ᑎᕐ ᓂᐅᑉ ᐅᐊᖕᓇᖕᓂ ᐸᐅᒥᓐ ᑲᖏᖅ ᔪᐊᓂ, ᑲᖑᑉ ᐅᐊᖕᓇᖕᓂ, ᐅᒥᖕᒪᐅᑉ ᑲᖏᖅ ᔪᐊᑕ ᐱᖕᖑᖅ ᓇᖕᓂ ᐅᐊᖕ ᓇᖕᓂᓗ, ᖃᖏᖅ ᔪᐊᓘᓪ ᓗ ᐱᖕᖔᑦᑕ ᓯᒡ ᔭᖕᓂ ᑰᖕᓂᓗ, ᑕᑯᔭ ᐅᓚᐅᕆᓪ ᓗᑎᒡ ᓗ ᑰᒐᓇᓺᑉ ᐃᓚᖕᓂ ᕼᐅᐳ ᑲᖏᖅ ᔫᓪ ᓗ ᓂᒋ ᐊᑕ ᓯᒡ ᔭᖅᐸᓯ ᐊᓂᑦ ᓯᕐ ᒥ ᐊᓗᖕ ᒧᑦ. ᓄᕐ ᕋᐃᑦ (ᖁᓕᓂᒃ ᑕᖅᑭ ᓵᑦ) 22%-ᖑᓚᐅᖅᐳᑦ ᐅᓄᖅᑎᒋ ᓂᖏᓐ ᒫᔾᓱ 2015-ᒥᑦ. ᑕᑯᓚᐅᖅᑐᒍᑦ 1146 ᐅᒥᖕᒪᖕ ᓂᑦ, ᐅᓄᖅᑎᒋ ᓂᖏᓐ ᓂᓪ ᓗ ᓇᓚᐅᑦ ᑖᖅ ᔪᑕ 3200 ± SE 602. ᑖᓐ ᓇ ᐅᓄᕐ ᓂᖅᐹᖑᒐ ᓗᐊᖅ ᑎᓪ ᓗᓂ ᓇᓚᐅᑦ ᑖᖅ ᑕᐅᓯᒪᔪᒥᑦ ᖃᐅᔨᓴᕐ ᕕᐅᖃᑦ ᑕᖅᓯᒪᔪᒥᑦ, ᖃᐅᔨᓴᖅ ᑕᐅᓯᒪᔪᓕᒫ ᑲᓴᑦ ᑕᒪ ᑐᒪ ᓄᓇᐅᑉ ᐃᓚᐃᓐ ᓇᖕᓂᐅᕗᖅ, ᐱᖃᓯ ᐅᑎᓪ ᓗᓂ ᐊᓯᖕᓕ ᓄᓇᐃᑦ, ᐅᓄᙳᓂᓪ ᓘᓐ ᓅᑦ ᓈᓴ ᐃᓯᒪᑐᐃᓐ ᓇᖅ ᔪᑎᒃ. ᑭᓯᐊᓂᓕ, ᐅᒥᖕᒪᑦ ᐅᓄᖅᑎᒋ ᓂᖏᓐ ᐅᓄᖅᓯᒋ ᐊᖅᐹᓪ ᓕᖅᓯᒪᔪᑦ ᐊᒥᓲᙱᑎ ᔪᒥᑦ 312-670 (95% CI) ᓇᐃᓴ ᖅᑕᐅᓂᑯᑦ 2005-ᒥᑦ.

38-ᖏᓐ ᓇᕐ ᓂᒃ ᑐᒃ ᑐᓯᓚᐅᖅᑐᒍᑦ ᒫᔾᓱᒥ ᖃᐅᔨᓴᖅᑎᓪ ᓗᑕ. ᑰᒐ ᓇᕉᑉ ᐃᒪᖕᑕ ᐅᐊᖕᓇᖕᓂ ᐊᒻ ᒪ ᒍᕼᐊᒻ ᕿᑭᖅᑕᖕᓂ, ᑕᐃᒫᒃ ᓱᓕ ᐅᓄᖅᑎᒋ ᓚᐅᙱᑲ ᓗᐊᖅ ᔪᑎᒃ 2005-ᒥᑦ. ᑐᒃ ᑐᓂᑦ ᑕᑯᓚᐅᕐ ᒥᔪᑦ ᑲᖏᖅ ᔪᐊᓗᖕᒥ ᑕᑯᒃ ᑲᓐ ᓂᓇᓪ ᓗᑕ ᑎᖕᒥᐊᑦ ᑲᖏᖅ ᔪᐊᓂ ᐊᒻ ᒪ ᓱᐊ ᑲᖏᖅ ᔪᐊᓂ. ᑕᐃᑲ ᓂᔅ ᓴᐃᓐ ᓇᖅ ᑕᑯᓚᐅᕐ ᒥᔪᑦ ᒪᕐ ᕘᓕᖕᖁᓂᑦ ᑲᑎᔅ ᔪᒋᑦ 8 ᑐᒃ ᑐᐃᑦ ᐋᒎᓯ 2014-ᒥᑦ ᖃᐅᔨᓴᕕᐅᓇᓱ ᐊᓚᐅᖅᑐᒥᑦ (2014-ᒥᑦ ᖃᐅᔨᓴᕈᑕᐅᓇᓱ ᐊᓚᐅᖅᑐᑦ ᑕᒪ ᐅᓈᓗᐊᓚᐅᙲᑦ ᓄᓇᒃ ᑯᑦ ᑐᒃ ᑐᓄᑦ ᐃᓂᒋ ᓗᐊᕋᓱᒋᔭᐅᔪᓄᑦ, ᑕᑯᓚᐅᕋᑎᒡ ᓗ ᐊᐃᕐ ᓇᓕ 2014-ᒥᑦ). ᐊᒥᓲᙱᓂᖏᓐ ᑕᑯᔭᐅᔪᑦ ᖃᓄᐃᑦ ᑐᑯ ᓘᔭ ᐅᓂᖏᓐ ᓂᓪ ᓗ, ᓇᓗᓇᕈᑕᐅᓚᐅᖅᐳᖅ ᐅᓄᕈᓐ ᓅᓇᐊᕐ ᒪᖔᑦ 2005-ᒥᑦ, 109-442 ᑐᒃ ᑐᐃᑦ (95% CI) ᓇᓚᐅᑦ ᑖᖅ ᑕᐅᓚᐅᖅᑎᓪ ᓗᒋᑦ ᑕᐃᑲ ᓂᔅ ᓴᐃᓐ ᓇᖅ ᖃᐅᔨᓴᕐ ᕕᐅᔪᒥᑦ. ᓇᓚᐅᑦ ᑖᓚᐅᖅᑐᒍᑦ 183 ± SE 128 ᑐᒃ ᑐᖃᕋᓱ ᖏᓐ ᓈᓪ ᓗᑕ, ᐅᓄᕈᓐ ᓅᖅᐸᓪ ᓕᐊᓗᐊᕌ ᓗᙱᑦ ᑐᒃ ᓴᐅᔪᑦ ᐅᒥᖕᒪᑦ ᓄᓈᑦᑕ ᓂᒋᐊᓂ.

Contents

List of Figures

List of Tables

Introduction

Peary caribou (*Rangifer tarandus pearyi*) are a small, light-coloured subspecies of caribou/reindeer inhabiting the Canadian Arctic Archipelago in the Northwest Territories and Nunavut from the Boothia Peninsula in the south to Ellesmere Island in the north. They are sympatric with muskoxen (*Ovibos moschatus*) over much of their range although diet, habitat preferences, and potentially interspecific interactions separate the two species at a finer scale (Resolute Bay Hunters and Trappers Association [HTA] and Iviq HTA, pers. comm.). Arctic wolves (*Canis lupus*) occur at low densities throughout Peary caribou range, but the most significant cause of population-wide mortality appears to be irregular die-offs precipitated by severe winter weather and ground-fast ice that restricts access to forage (Miller et al 1975, Miller and Gunn 2003, Miller and Barry 2009).

Peary caribou have been surveyed infrequently and irregularly on Ellesmere Island since Tener's 1961 survey extrapolated 200 animals for the island (Tener 1963). Weather issues prevented a full systematic survey of the island however, and the reliability of this estimate is questionable. Riewe (1976) flew unsystematic surveys primarily north of the Sydkap Ice Cap, along Baumann and Vendom Fiords and on the Svendsen, Raanes, and Bjorne peninsulas in 1973, with minimum counts of 150 caribou. In 1989, surveys on southern Ellesmere estimated 89 ± SE 31 caribou, including the Svendsen Peninsula (Case and Ellsworth 1991). In 2005, the GN systematically surveyed southern Ellesmere and Graham islands, with an estimate of 219 caribou (95% CI=109-244). Central and northern Ellesmere Island were surveyed in 2006, with an estimate of 802 caribou (95%CI=531-1207). Residents of Grise Fiord have not noticed a marked increase or decline in caribou where they hunt, primarily on Graham Island, the Bjorne Peninsula, the head of Muskox Fiord, and Baumann Fiord from Okse Bay to Stenkul Fiord. They have noticed some changing distribution patterns, with caribou caught in 2014 and 2015 on northeast Devon Island (Iviq HTA and Wildlife Officer J. Neely, pers. comm.).

Muskoxen are generally surveyed at the same time as caribou. Ellesmere Island was estimated by Tener (1963) to have more muskoxen, about 4000, than the rest of the Queen Elizabeth Islands combined. Southern Ellesmere Island, being largely comprised of ice fields, mountains and fiords, has historically had a much smaller muskox population than the Fosheim Peninsula and Lake Hazen areas further north (Tener 1963, Jenkins et al. 2011). The coastal lowlands along Baumann Fiord support some of the highest densities of muskoxen south of the Svendsen Peninsula (Iviq HTA pers. comm., Case and Ellsworth 1991, Inuit Qaujimajatuqangit [IQ] in Taylor 2005). In ground surveys of the Jones Sound region in 1966-67, Freeman (1971) counted 470 muskoxen on southern Ellesmere Island. In July 1973, Riewe (1973) estimated 1060 muskoxen north of the Sydkap Ice Cap, and on the Bjorne Peninsula, Raanes Peninsula, Svendsen Peninsula, Graham Island, and Buckingham Island. Of these, 260 muskoxen were estimated on Bjorne Peninsula alone (Riewe 1973). Case and Ellsworth (1991) estimated 2020 ± SE 285 muskoxen (including calves) on southern Ellesmere Island, including the Svendsen Peninsula, in July 1989. In May 2005, the population was estimated at only 456 (95%CI 312-670) 1+ year-old muskoxen south of Baumann and Vendom Fiords, including Graham and Buckingham islands, and many muskoxen seen on the survey were in poor condition (Campbell and Hope 2006, Jenkins et al. 2011). Residents of Grise Fiord recall freezing rain and ground-fast ice in fall/winter 2005, causing many muskox to starve (Iviq HTA, pers. comm.).

The Peary caribou and muskoxen of northern Devon Island, southern Ellesmere Island, and Graham Island are vitally important to the community of Grise Fiord. Muskoxen have been hunted in the area since the government ban on muskox hunting was lifted in 1969, and tags are currently set aside for domestic/commercial use and sport hunts. Caribou have been regularly hunted in the region since Grise Fiord was established in 1953, with most harvest since 1964 focusing on the Bjorne Peninsula, south shore of Baumann Fiord, and Graham Island (Riewe 1973, IQ in Taylor 2005, Iviq HTA pers. comm.). Petroleum exploration in the 1970s is believed to have caused caribou to shift their ranges and movements, and there is concern that future industrial activity could be detrimental to the herds as well (Iviq HTA, pers. comm.) This survey was conducted to update the population estimates, demographic characteristics, and distribution of Peary caribou and muskoxen on southern Ellesmere Island and Graham Island.

ᐱᒋᐊᕈᑎᖓ

ᑐᒃᑐᐃᑦ ᒥᑭᔩᕗᑦ, ᑕᖅᓴᑭᓐᓂᖅᓴᐅᓪᓗᑎᒃ ᑐᒃᑐᒋᔭᐅᔪᓂᑦ ᑲᓇᑕᐅᑉ ᐅᑭᐅᖅᑕᖅᑐᖓᓂ ᓄᓇᑦᓯᐊᕐᒥ ᓄᓇᕘᒻᒥᓗ ᐊᓚᕐᓈᕐᔪᖕᒥᑦ ᓂᒋᐊᓂᑦ ᐅᒥᖕᒪᑦ ᓄᓈᓐᓂ ᐊᐅᓐᓇᖕᒪᓃᑦ. ᓄᓇᖃᑎᒌᑦ ᑕᖅᑐᑦ ᐅᒥᖕᒪᖕᓂᑦ ᐃᓂᑦᔭᒥᓂᑦ ᑭᓯᐊᓂᓕ ᓂᕆᑦᑎᒃ ᑕᖕᓂᖏ, ᐃᓂᑦᔪᒪᔭᖕᖏ, ᓂᕐᔪᑎᐅᖃᑎᖃᕐ ᓂᕐᓗ ᐊᕕᒃᓯᓯᒪᔪᑦ ᑕᒪᒃᑯᓂᖓ ᒥᑭᓐᓂᖅᓴᒃᑯᑦ (ᖃᐅᓯᐃᑦ ᑑᑉ ᐊᖑᓇᓱᐊᒃ ᑐᓕᕆᔩᒃᑯᖏ [ᐊᖑᓱᒃ ᑐᓕᕆᔩᑦ ᐊᒻᒪᓗ ᐊᐃᕙᒃ ᐊᖑᓇᓱᒃ ᑐᓕᕆᔩᒃᑯᑦ, pers. comm.). ᐊᒪᖅᑯᑦ ᐱᑕᖃᖃᑦ ᑕᖅᐸᑦ ᐊᒥᒫᙯᖅᑎᒃ ᑐᒃᑐᑦ ᐃᓂᑦᔭᖕᖑᓂ, ᑭᓯᐊᓂ ᐅᓄᕈᓐ ᓅᖅᐹᓕ ᓕᕈᑕᐅᓂᐊᖅᐹᖑᔪᖅ ᓯᓚᕈᔪᒃ ᐅᑭᐅᒃᑯᑦ ᓄᓇᓗ ᕿᕿᑎᖃᑦ ᑕᕐ ᓂᖕᒪᓃᑦ ᓂᑎᔭᒃᓴᖕᖏ ᐃᓄᓕᖅᑲᓂᐅᒃ (ᒥᓗ ᐃᑦ ᐅᐃᓪ 1975, ᒥᓗ ᐊᒻᒪ ᒐᓐ 2003, ᒥᓗ ᐊᒻᒪ ᐱᐅᑎ 2009).

ᑐᒃᑐᐃᑦ ᖃᐅᔨᓴᖅᑕᐅᒐᔪᓗᐊᙳᑦ ᐅᒥᖕᒪᑦ ᓄᓈᓐᓂ ᑕᐃᒪᙵᑎᓄ 1961-ᒥᑦ ᖃᐅᔨᓴᓚᐅᕋᒥᑦ 200 ᓂᕐᔪᑎᓂᒃ ᕿᑭᖅᑕᒥ (ᑎᓄ 1963). ᓯᓚ ᐱᓪᓗᒍᑦ ᓈᒪᔪᒥ ᖃᐅᔨᓴᕈᓐᓇᓚᐅᙱᑦᑐᑦ ᕿᑭᖅᑕᒥ ᑭᓯᐊᓂᓕ, ᑕᑎᒋᔭᒃᓴᐅᓂᖓ ᑕᒪᑐᒪ ᓇᓚᐅᑦ ᑖᖅᑕᐅᔫᑉ ᐊᐱᖅᑯᑎᒋᔭᒃᓴᐅᕗᖅ. ᑎᐅ (1976) ᖃᖓᓪᓗᓂ ᖃᐅᔨᒐᓰᖃᑦ ᑕᓚᐅᖅᑐᖅ ᓯᕐᒥᕈᓗᒃ ᓱᕋᒃ ᑎᕐ ᓂᐅᑉ ᐅᐊᖕ ᓇᖕᒪᓂ, ᐸᐅᒥᓐ ᐊᒻᒪ ᑲᖖᓱᐊᓗᖕᒥᓪᓗ ᐊᒻᒪ ᔅ ᕕᓐᓴᓐ, ᕋᓐᔅ, ᑰᒐᓇᔩᑉ ᐃᓚᖕᒥᓪᓗ 1973-ᒥᑦ, ᐅᓄᙶᖕᒪ ᓈᓴᐅᕙᒃ ᓱᓂ 150 ᑐᒃᑐᓂᑦ. 1989-ᒥᑦ, ᖃᐅᔨᓴᖅᑎᓪᓗᒋᑦ ᐅᒥᖕᒪᑦ ᓄᓈᑦᑕ ᓂᒋᐊᓂ ᓇᓚᐅᑦ ᑖᓚᐅᖅᑐᑦ 89 ± SE 31 ᑐᒃᑐᖃᕋᓱᒋᓐᓈᓪᓗᑎᒃ, ᐱᖃᓯᐅᑎᓪᓗᓂᔅ ᕕᓐᓴᓐ (ᑲᐃᔅ ᐊᒻᒪ ᐃᐅᓪᔅ ᕗᑦ 1991). 2005-ᒥᑦ, ᓄᓇᕗᑦ ᒐᕙᒪᖓᐊᑕᖕᖑ ᓗᑎᒃ ᖃᐅᔨᓴᓚᐅᖅᑐᑦ ᐅᒥᖕᒪᑦ ᓄᓈᑦᑕ ᓂᒋᐊᓂ ᒍᕌᕼᐊᒻ ᕿᑭᖅᑕᖕᖑ ᓂᓪᓗ, ᓇᓚᐅᑦ ᑖᖅᑯᑎᒃ 219-ᓂᒃ ᑐᒃᑐᖃᕋᓱᒋᓐᓈᓪᓗᑎᒃ (95% CI=109-244). ᕿᑎᖅᐸᓯ ᐊ ᐅᐊᖕ ᓇᖕᒐ ᐅᒥᖕᒪᑦ ᓄᓈᑦᑕ ᖃᐅᔨᓴᖅᑕᐅᓚᐅᖅᑐᑦ 2006-ᒥᑦ, ᓇᓚᐅᑦ ᑖᖅᑯᑎᒃ 802ᓂᒃ ᑐᒃᑐᖃᕋᓱᒋᓐᓈᓪᓗᑎᒃ (95%CI=531-1207). ᐊᐅᓯᐃᑦ ᑐᕐ ᒥᐅᑦ ᐅᔾ ᓵᕈᓯᙳᑐᖅ ᐅᓄᖅᓯᒋᐊᕐ ᒪᖔᕙ ᐅᓄᕈᓐ ᓅᑎᐊᕐ ᒪᖔᕙ ᑕᔫᓐ ᓅᑦ ᑐᒃᑐᐃᑦ ᑐᒃᑐᓐ ᓇᓯᒡ ᕕᒋᑫ ᑕᖕᖑ ᓂ, ᐱᓗᐊᙹᖅᑐᒥᑦ ᒍᕌᕼᐊᒻ ᕿᑭᖅᑖᓂ, ᑰᒐᓇᔩᑉ ᐃᓚᖕᒥ, ᐅᒥᖕᒪᐅᑉ ᑲᖖᓱᐊᑕ ᐃᓯᑎᐊᕐ ᕕᐊᓂ, ᐸᐅᒥᓐ ᑲᖖᓱᐊᓂᓪ ᓗ ᐆᒃᔅ ᒥᑦ ᔅ ᑎᓐ ᑯᓪ ᑲᖖᓱᖕ ᒍᑦ. ᐅᔾ ᓵᕈᓯᒃ ᓯᒪᓕᖅᑐᑦ ᐊᕕᒃ ᑐᖅᓯᒪᓂᖕᖏ ᐊᓯᔾ ᓵᖅᐸᓪᓕᐊᓂᖕᖑ ᓂᒃ, ᑐᒃᑐᑕᐅᓯᒪᔪᑦ 2014 ᐊᒻᒪ 2015-ᒥᑦ ᑕᓪᓗᕈᑦ ᑲᓇᖕᓈᓂ (ᐊᐃᕙᖅ ᐊᖑᓇᓱᒃ ᑐᓕᕆᔩᒃᑯᑦ ᐊᒻᒪᓗ ᐆᒪᔪᓕᕆᔩᒃᑯᑦ J. ᓅᓕ, pers. comm.).

ᐅᒥᖕᒪᐃᑦ ᖃᐅᔨᓴᖅᑕᐅᒐᔪᒃᐸᑦ ᐊᑕᐅᑦᑎᒃ ᑰᖃᑎᖃᖅᑐᑎᒃ ᑐᒃᑐᓂᑦ. ᐅᒥᖕᒪᑦ ᓄᓈ ᓇᓚᐅᑦ ᑖᖅᑕᐅᓚᖅᑐᖅ ᑎᓅᑉ (1963) ᐅᒥᖕᒪᖃᕐ ᓂᖅᓴᐅᓂᕋᖅᓱᓂᐅᒃ, 4000-ᓗᐊᑦ, ᐅᓄᕐ ᓂᖅᓴᑦ ᑲᑎᓚᖅᓱᒋᑦ ᑯᐃᓐ ᐃᓕᓴ ᐱᐅᑉ ᕿᑭᖅᑕᙳᓃᑦ ᑐᑦ. ᐅᒥᖕᒪᑦ ᓄᓈᑦᑕ ᓂᒋᐊᓂ, ᐱᖁᖃᐅᖅᓱᓂ, ᖃᖅᑲ ᖃᐅᖅᓱᓂ ᑲᖖᓱᖃᐅᖅᓱᓂᓗ, ᑭᖑᓂᖕᓂᑦ ᐅᒥᖕᒪᑦ ᐅᓄᙶᓂᖅᓴᐅᕙᓚᐅᖅᑐᑦ ᕗᓴ ᐃᓪ ᒥᑦ ᕼᐋᓯᓐ ᑕᓯᖖᑕ ᐅᐊᖕ ᓇᖕᒪ (ᑎᓄ 1963, ᔨᓐ ᑭᓐᔅ ᐃᑦ ᐃᐅᓪ. 2011). ᓯᒡ ᔭᖅᐸᓯᖓ ᐸᐅᒥᑦ ᑲᖖᓱᐊᓂ ᐅᒥᖕᒪᖕᖏ ᐅᓄᕐ ᓂᖅᐹᖑᖃᑕᐅᕗᑦ ᔅ ᕕᓐᓴᓐ ᓂᒋᐊᓂ (ᐊᐃᕙᖅ ᐊᖑᓇᓱᒃ ᑐᓕᕆᔩᒃᑯᑦ pers. comm., ᑲᐃᔅ ᐊᒻᒪ ᐃᐅᓪᔅ ᕗᑦ 1991, ᐃᓄᐃᑦ ᖃᐅᔨᒪᔭᑐᖃᖏ [IQ] ᑕᐃᓗᒥᑦ 2005). ᓄᓇᒃ ᑯᑦ ᖃᐅᔨᓴᖅᑎᓪᓗᒋᑦ ᔩᓐᔅ ᓴᐅᓐ ᒥᑦ 1966-67-ᒥᑦ, ᕗᕇᒪᓐ (1971) ᓈᓴ ᐃᓚᐅᖅᑐᖅ 470 ᐅᒥᖕᒪᖕᓂᑦ ᐅᒥᖕᒪᑦ ᓄᓈᑦᑕ ᓂᒋᐊᓂ. ᔪᓚᐃ 1973-ᒥᑦ, ᑎᐅ (1973) ᓇᓚᐅᑦ ᑖᓚᐅᖅᑐᖅ 1060-ᓂᒃ ᐅᒥᖕᒪᖃᕋᓱᒋᓐᓈᓗᓂ ᓯᕐᒥᕈᓗᒃ ᓱᕋᒃ ᑎᕐ ᓂᐅᑉ ᐅᐊᖕ ᓇᖕᒪᓂ, ᑰᒐᓇᔩᓪᓗ ᐃᓚᖕᒥ, ᕋᓐᔅ, ᔅ ᕕᓐᓴᓐ, ᒍᕌᕼᐊᒻ ᕿᑭᖅᑕ, ᐊᒻᒪ ᐸᑭᖕᕼᐊᒻ ᕿᑭᖅᑕᖕᒥ. ᑕᒪᒃ ᑯᓂᖓ 260-ᓂᒃ ᐅᒥᖕᒪᖃᕋᓱᒋᓐᓈᓚᐅᖅᑐᖅ ᑰᒐᓇᔩᑉ ᐃᓚᖕᒥᑐᐊᖅ (ᑎᐅ 1973). ᑲᐃᔅ ᐊᒻᒪ ᐃᐅᓪᔅ ᕗᑦ (1991) ᓇᓚᐅᑦ ᑖᓚᐅᖅᑐᑦ 2020 ± SE 285 ᐅᒥᖕᒪᖃᕋᓱᒋᓐᓈᓪᓗᑎᒃ (ᐱᖃᓯᐅᑎᓪᓗᑎᒃ ᓄᕐ ᕋᑦ) ᐅᒥᖕᒪᑦ ᓄᓈᑦᑕ ᓂᒋᐊᓂ, ᐱᖃᓯᐅᑎᓪᓗᓂᔅ ᕕᓐᓴᓐ, ᔪᓚᐃ 1989-ᒥᑦ. ᒪᐃ 2005-ᒥᑦ, ᐅᓄᖅᑎᒋᓂᖏ 456-ᑐᐃᓐ ᓇᐅᓇᓯᒋᔭᐅᓚᐅᖅᑐᑦ (95%CI 312-670) 1+ ᓄᑲᑐᒐᐃᑦ ᐸᐅᒥᓐ ᓂᒋᐊᓂ ᑲᖖᓱᐊᓗᖕᒥᓪᓗ, ᐱᖃᓯᐅᑎᓪᓗᑎᒃ ᒍᕆᕼᐊᒻ ᐸᑭᖕᕼᐊᒻᓗ ᕿᑭᖅᑕᖕᖏ, ᐊᒥᓱᓪᓗ ᐅᒥᖕᒪᑦ ᑕᑯᔭᐅᔪᑦ ᖃᐅᔨᓴᖅᑎᓪᓗᒋᑦ ᑕᑯᒥᓇᓚᐅᙱᑦᑐᑎᒃ (ᑳᒻᐹᓪ ᐊᒻᒪ ᕼᐆᐸ 2006, ᔨᓐ ᑭᓐᔅ ᐃᑦ ᐃᐅᓪ. 2011). ᐊᐅᓯᐃᑦ ᑐᕐ ᒥᐅᑦ ᐅᔾ ᓵᕈᓯᒃ ᑐᑦ ᒪᖁᒃᑦ ᑕᓚᐅᕐ ᓂᖕᓂᑦ ᓄᓇᓗ ᕿᕿᑎᓚᐅᕐ ᓂᖕᓂᑦ ᐅᑭᐊᒃ ᓴᖅ/ᐅᑭᐅᖅ 2005-ᒥᑦ, ᐊᒥᓱᑦ ᐅᒥᖕᒪᑦ ᐱᕐ ᓕᓕᖅᓱᑎᒃ (ᐊᐃᕙᖅ ᐊᖑᓇᓱᒃ ᑐᓕᕆᔩᒃᑯᑦ, pers. comm.).

ᑐᒃ ᑐᐃᑦ ᐅᒥᖕᒪᐃᓪ ᓗᑕᓪ ᓗᕈᑦ ᐅᐊᖕ ᓇᖕᓂ, ᐅᒥᖕᒪᑦ ᓄᓈᑦ ᑕᓂᒋ ᐊᓂ, ᐊᒻᒪ ᒍᕆᓴᐊᒻ ᕿᑭᖅᑕᖕᓂ ᐱᒻᒪᕆᐅᕗᑦ ᐊᐅᓯ ᐃᑦᑐᕐ ᒥᐅᓄᑦ. ᐅᒥᖕᒪᒐᓯ ᖃᑦ ᑕᖅᑐᑦ ᑕᐃᑲᓂ ᑕᐃᒪᖖᒐ ᒐᕙᒪ ᐅᑉ ᓄᖅᑲᖅᑎᑦ ᑎᓯᒪᔪᓐ ᓅᕋᒥᑦ ᐅᒥᖕᒪᒐᓯᒍᓐ ᓇᕐ ᓂᕐ ᒥᑦ 1969-ᒥᑦ, ᓂᕙᖖᑏ ᑐᑕᓃᖅᓱᑎᓪ ᓗ ᓄᓇᓕᖕ ᓂᕐ ᒥᐅᑦ /ᑮ ᓇᐅᔾ ᔭᒃ ᓴᓇᓯ ᐊᖅᑐᑦ ᐊᖑᓇᓯᑎ ᐊᖅᐸᒃ ᑐᓄᓪ ᓗ. ᑐᒃ ᑐᓐ ᓇᓯᖃᑦ ᑕᐃᓐ ᓇᖅᐳᑦ ᑕᐃᒪᖖᒐ ᐊᐅᓯ ᐃᑦ ᑐᖅ ᓄᓇᓕᖖᖑᖅᑎᑕᐅᒐᒥ 1953-ᒥᑦ, ᑐᒃ ᑐᓯᒪᓂᖅᐹᖑᓕ ᓗᑎᒃ 1964-ᒥᑦ ᑖᒐᓇᔩᑉ ᐃᓚᖕᓂ, ᐸᐅᒥ ᑲᖏᖅᓱᖕᓂ ᓂᒋᐊᑕ ᓯᒡ ᔭᖕᓂ, ᒍᕆᓴᐊᒻ ᕿᑭᖅᑕᖕᓂᓪ ᓗ (ᑎᐅ 1973, ᐃᓄᐃᑦ ᖃᐅᔨᒪᔭᑐᖃᖏᑦ ᑕᐃᓗᒥᑦ 2005, ᐊᐃᕙᖅ ᐊᖑᓇᓯᒃ ᑐᓕᑎᔩᒃ ᑯᑦ pers. comm.). ᐅᖅᓯᐊᓗᖕ ᓂ ᕿᓂᖅᑐᖃᖅᑎᓪ ᓗᑯᑦ 1970-ᖕᖏ ᓂᑦ ᑐᒃ ᑐᓄᑦ ᐊᓯᔾ ᔮᔾ ᔭᑕᐅᓇᓯᒋᔭᐅᕗᖅ ᓇᓃᓐ ᓂᖕᖏ ᓂᒃ ᐃᖕᖏ ᕋᓂᖕᖏ ᓂᓪ ᓗ, ᐃᓯᒫ ᓘᑕᐅᓪ ᓗᓂᓗ ᓯᕗᓂᒃ ᓴᑦ ᑎᓐ ᓂ ᖃᓄᐃᓕᐅᕈᑕᐅᔭᑦ ᐱᐅᔭᓐ ᓃᕈᑕᐅᕚᓪ ᓕᐊᓂᐊᕐ ᓂᖕᓂ ᑐᒃ ᑐᓄᑦ (ᐊᐃᕙᖅ ᐊᖑᓇᓯᒃ ᑐᓕᑎᔩᒃ ᑯᑦ, pers. comm.) ᖃᐅᔨᓴᓚᐅᖅᑐᑦ ᓄᑖᖖᒍᐊᖅᓯᔭᒪᓪ ᓗᑎᒃ ᖃᓄᖅ ᐅᓄᖅᑎᒋ ᓇᓯᑎᔭ ᐅᖕᒪᖖᒋᑦ, ᓄᓇᒦᑉ ᕙᑎᔭᖕᖏ ᖃᓄᐃᓕᖖᒍᖕᒪᖖᒋᑦ, ᐊᕙᒃ ᑐᖅᓯᒪᓂᖕᖏ ᓗ ᑐᒃ ᑐᐃᑦ ᐅᒥᖕᒪᐃᓪ ᓗ ᐅᒥᖕᒪᑦ ᓄᓈᑦ ᑕᓂᒋ ᐊᓂ ᒍᕆᓴᐊᒻ ᕿᑭᖅᑕᖕᓂᓪ ᓗ.

Study Area

The March 2015 aerial survey was flown to cover the same study area as the previous 2005 survey (Jenkins et al. 2011), which included Ellesmere Island south of Vendom Fiord, excluding the Svendsen Peninsula, and also including Graham and Buckingham islands. The area south of Jakeman Glacier to King Edward Point was originally included in the survey area but could not be flown due to weather. North Kent Island was circled in a reconnaissance flight but not surveyed systematically. Neither area was included in the 2005 survey.

The survey area is predominantly polar desert and semi desert, with more rugged topography along the mountains and fiords of the south coast which rise from sea level to 1000 m, transitioning to rolling terrain in the north along Baumann Fiord and the Bjorne Peninsula. Mountains dominate the eastern edge of the study area along the ice sheets, which, along with the Sydkap Ice Cap at almost 1500 m AMSL, are the highest points in the study area. Cryptogam herb barrens, cushion forb barrens, unvegetated bedrock and talus, and icefields dominate south of the Sydkap Ice Cap, mostly with <5% vegetation cover and less than 100 g/m^2 vegetation biomass (Gould et al. 2003, Walker et al. 2005). Further north, along Baumann Fiord and Bjorne Peninsula, vegetation cover increases to 5-50% and biomass increases to 100-500 g/m^2 (Gould et al. 2003). Prostrate dwarf shrub and herb tundra dominates, extending north and west of the study area on Svendsen Peninsula (Walker et al. 2005). The north end of Bjorne Peninsula also includes sedge and grass wetlands and large areas of graminoid, dwarf prostrate shrub, and forb tundra (Walker et al. 2005), with 50-80% vegetation cover (Gould et al. 2003). Exposed carbonate and non-carbonate bedrock is common along the edges of ice sheets at the eastern edge of the study area. Graham and Buckingham islands are typified by flat to rolling terrain below 150 m AMSL and relatively lush graminoid, forb, and cryptogam tundra, with areas of sedge and grass wetland, particularly on southwest Buckingham Island (Walker et al. 2005). Prostrate dwarf shrub-lichen tundra, which is not found elsewhere is the study area, is found on Graham and Buckingham islands (Gould et al. 2003). Vegetation cover is 5-50% on the islands, with primary productivity 100-500 g/m^2 (Gould et al. 2003).

Mean July temperatures are 3-5°C on the west side of the study area and 5-7°C in the east (Gould et al. 2003 and references therein). In March 2015, the average daily low temperature was -33.4°C and the average daily high temperature was -25.4°C (Environment Canada weather data for Grise Fiord, available http://climate.weather.gc.ca/index_e.html). There was very little snow throughout the study area, with 0-5 cm snow recorded on the ground at Grise Fiord in March, and 22.9 mm of precipitation (Environment Canada weather data).

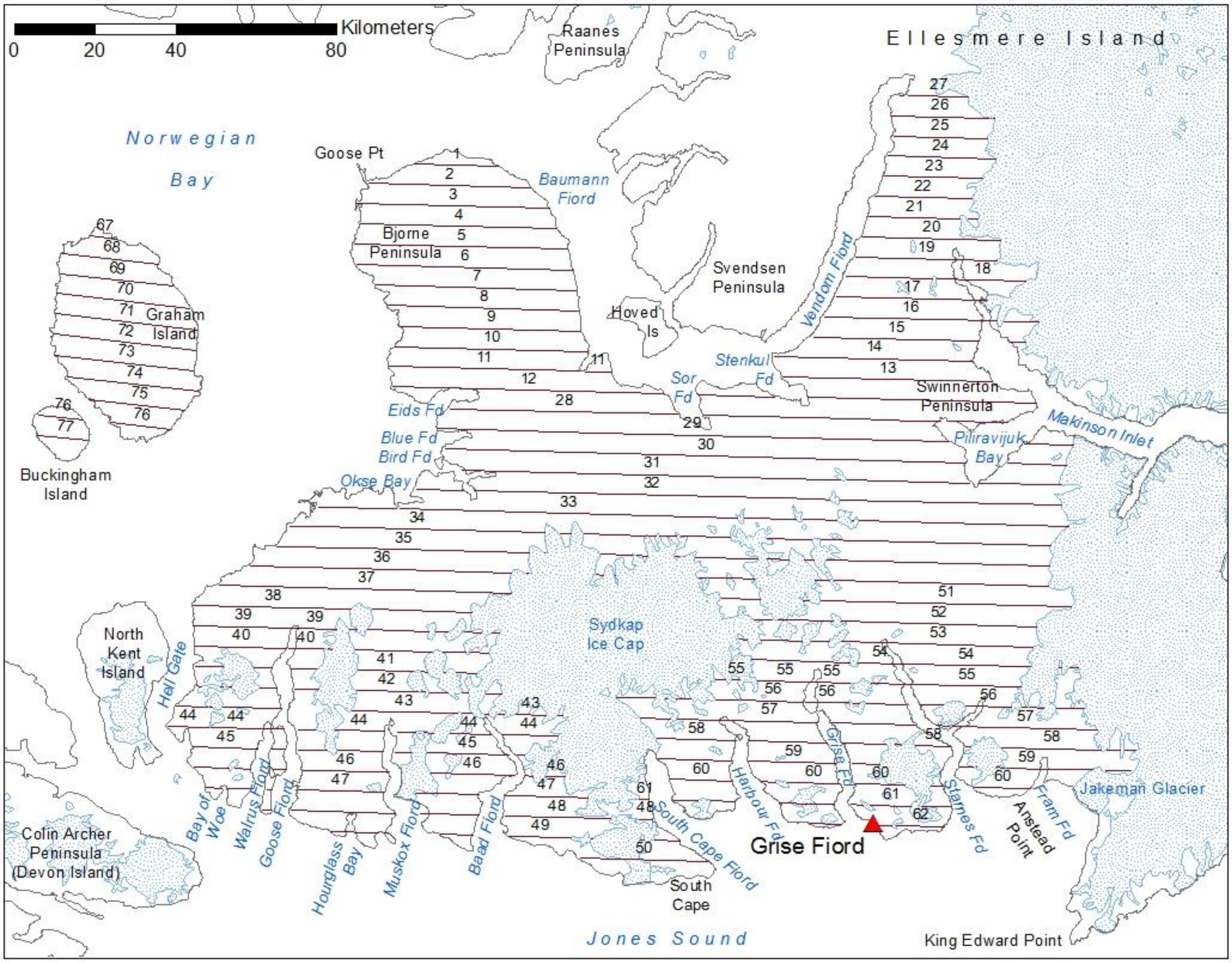

Figure 1. Transects over the study area, excluding ice caps (stippled blue), in dark red with numbers noted above the transects, running east-west, 5 km apart.

Methods

Aerial Survey

Although originally planned for April 2014, we were unable to complete the survey due to fog and wind. The survey was rescheduled in August, when caribou would be visible against the snow-free ground, but again weather prevented survey completion. Summaries of the April and August 2014 survey methodology and results are given in Appendix 1 and 2 but were not used in the analyses presented here. The survey was successfully flown March 19-26, 2015.

Survey transects (n=77, Appendix 3) followed the transects established for the 2005 distance sampling helicopter survey parallel to lines of latitude, with 5 km spacing and a 500 m strip on either side of the aircraft. Ice caps were excluded, and we did not detect any caribou, muskoxen, or their tracks on any ice caps during ferry flights. The area of southeastern Ellesmere Island from Jakeman Glacier to King Edward Point was originally included in the survey area, but persistent wind and fog in the area prevented flying the 4 short transects there. The area was not included in the 2005 survey. We flew reconnaissance around

North Kent Island since hunters had found caribou at the north end in previous years, but it was not systematically surveyed (nor was it surveyed in 2005), and we saw no caribou, muskoxen, or tracks. No caribou or muskoxen were present on North Kent Island when it was last surveyed in 2008.

To define the transect width for observers, we marked survey aircraft wing struts following Norton-Griffiths (1978):

$$w = W\left(\frac{h}{H}\right)$$

where W is the strip width, H is the flight height, h is the observer height when the plane is on the ground and w is measured and marked on the ground to position wing strut marks (Figure 2).Multiple distance bins can be incorporated and marked on the wing strut, but for this survey we only used 1 mark representing 500 m. Fixed-wing strip transect sampling has been successfully used in the high arctic since 1961.

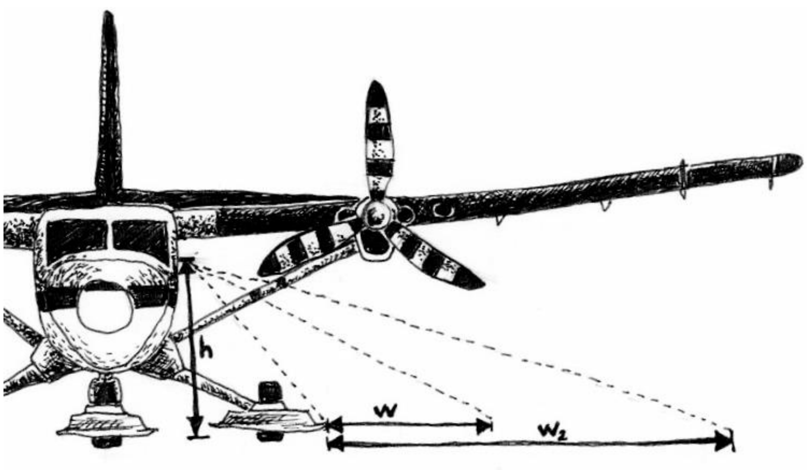

Figure 2. Derivation of wing strut marks for strip boundaries, where w and w_2 are calculated as described in the text, h is measured (2.2 m for Twin Otter on wheel-skis), and dotted lines indicate observer sightlines as modified from Norton-Griffiths (1978).

We did not stratify the study area because of changes to wildlife distributions and densities (confirmed by the April 2014 survey attempt) since the last survey 10 years ago and given the different habitat preferences for caribou and muskox,. We did, however, examine population estimates according to Case and Ellsworth's (1991) stratification for direct comparison of their July 1989 survey results (since no muskoxen were seen on transect on Graham/Buckingham islands, this part of the study area did not have to be added to the stratification).

Transects were flown at 150 km/hr (81 kts) with a DeHavilland Twin Otter. Surveys were only conducted on days with good visibility and high contrast to facilitate detection of animals, tracks, and feeding craters, as well as for operational reasons to ensure crew safety. Flight height was set at 500' (152 m), using a radar altimeter. In rugged terrain, the flight height was adhered to as closely as possible within the constraints of crew safety and aircraft abilities.

A Twin Otter with 4 passengers (2 front observers, 2 rear observers, one of whom was also data recorder) was used to follow a double-observer platform when possible (4 dedicated observers were not always available), which has been successful in the Kivalliq Region of Nunavut (see Campbell et al. 2012 for an overview of the methodology) and on Bathurst Island (Anderson 2014). In both the Bathurst Island survey and the South Ellesmere survey, front and rear observers were able to communicate and all observations by front and rear observers were lumped. Estimates of group size are a potentially large source of error in calculating population estimates, however Peary caribou are generally distributed in small groups where observer fatigue is likely to be a more important source of error (A. Gunn, pers. comm.). We found obvious benefits of using the platform where having the added observers not only increased the accuracy of age and sex classification, but also allowed for some crew members to classify with binoculars while others continued to scan for nearby groups and individuals.

All observations of wildlife and tracks were marked on a handheld Garmin GPSMAP 62STC global positioning system (GPS) unit, which also recorded the flight path every 30 seconds. Sex and age classification was limited, since the aircraft did not make multiple passes (to minimize disturbance), but adult/short yearling (calves from the previous spring, i.e. 10-11 months old) determination was often straightforward for muskox and aided by binoculars. Muskoxen were frequently spotted more than a kilometer off transect due to their large aggregations and dark colour in contrast to the snowy background. Depending on distance and topography, an accurate count could not always be determined for these groups. Newborn muskoxen were not present during the survey. GPS tracks and waypoints were downloaded through DNR Garmin and saved in Garmin GPS eXchange Format and as ESRI shapefiles. Data was entered and manipulated in Microsoft Excel and ArcMAP (ESRI, Redlands, CA).

Analysis

Flights linking consecutive transects were removed for population analysis, although survey speed and height were maintained and all observations recorded as if on survey. Similarly, sections of transect crossing inlets and ice fields were removed, as these areas were not included in the area used for density calculations. The study area was also stratified following Case and Ellsworth (1991) for direct comparison with their survey results (Figure 3). We considered stratifications by elevation and by treating the Bjorne Peninsula separately as well, to aid in future survey planning. Strata are summarized in Table 1.

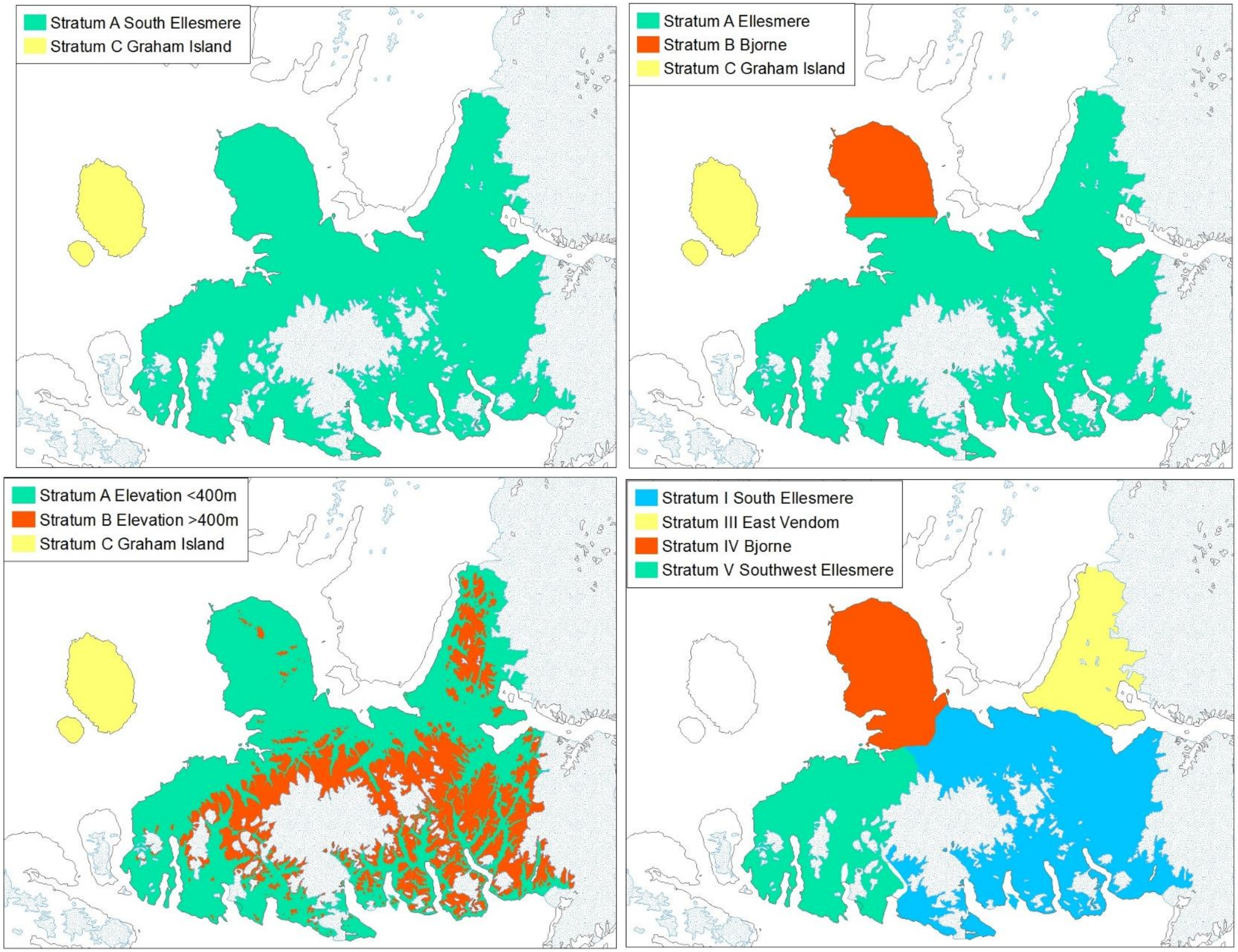

Figure 3. Several stratification regimes for the study area based on geography, elevation, and Case and Ellsworth's (1991) strata.

Table 1. Survey strata for southern Ellesmere Island, March 2015. Although 73 transects were flown, transects flown on the same latitude were combined as lines for further analysis (outlined in Appendix 3).

Stratification	Block ID	Location	Strata Area, Z (km^2)	Transect Spacing (km)	Transects Surveyed	Lines Surveyed	Survey Area, z (km^2)	Sampling Fraction, f (%)
All	A	South Ellesmere	21260	5	62	39	4896.0	0.199
	C[1]	Graham, Buckingham	1531	5	11	11	296.5	0.201
Elevation	A	South Ellesmere Low Elevation (<400 m)	13921	5	62	39	3322.5	0.195
	B[2]	South Ellesmere High Elevation (>400 m)	7339	5	54	38	1573.6	0.199
	C[1]	Graham, Buckingham	1531	5	11	11	296.5	0.198
Bjorne	A	South Ellesmere	18988	5	52	39	4439.1	0.201
	B	Bjorne Peninsula	2272	5	10	10	456.9	0.199
	C[1]	Graham, Buckingham	1531	5	11	11	296.5	0.265
Case and Ellsworth	I	South Ellesmere	10029	5	31	31	2657.9	0.201
	III	East Vendom	2865	5	17	17	576.0	0.202
	IV	Bjorne	3397	5	16	16	685.2	0.197
	V	Southwest Ellesmere	4969	5	18	18	977.0	0.230
	C[1]	Graham, Buckingham	1531	5	11	11	296.5	0.201

[1]For caribou estimates, Graham/Buckingham islands were both included and excluded, but no muskoxen were seen on transect there.
[2]No caribou were seen in the high elevation stratum.

Although Jolly's (1969) Method II is widely used for population estimates from surveys, it is designed for a simple random design, rather than for a systematic survey of a patchy population. For comparison, population calculations following Jolly's Method II are provided in Appendix 4, along with calculations following a systematic stratified survey design (Cochran 1977). The muskoxen and caribou detected in this survey were patchily distributed and serially correlated, not randomly distributed, and no stratification was applied based on population densities. For systematic samples from serially correlated populations, estimates of uncertainty based on deviations from the sample mean are expected to be upwardly biased and influenced by the degree of serial correlation; high serial correlation implies that there is less random variation in the unsurveyed sections between systematically spaced transects than if serial correlation were low (Cochran 1977). Calculating uncertainty based on nearest-neighbor differences incorporates serial correlation, and the upward bias in the uncertainty is expected to be less than if it were calculated based on deviations from the sample mean. Nearest-neighbor methods have been used previously to calculate variance around survey estimates on the unweighted ratio estimate (Kingsley et al. 1981, Stirling et al. 1982, Kingsley et al. 1985).

The model for observations on a transect survey following Cochran (1977) is:

$$y_i = Rz_i + \varepsilon_i\sqrt{z_i}$$

Where y_i is the number of observations on transect *i* of area z_i, R is the mean density and error terms ε_i are independently and identically distributed. In this model, the variance of the error term is proportional to the area surveyed. The best estimate of the mean density $\hat{R}$ is:

$$\hat{R} = \frac{\sum_i y_i}{\sum_i z_i}$$

The error sum of squares, based on deviations from the sample mean, is given by:

$$\left(\sum\nolimits_i \frac{{y_i}^2}{z_i}\right) - \frac{(\sum_i y_i)^2}{\sum_i z_i}$$

The finite-population corrected error variance of $\hat{R}$ is:

$$Var(\hat{R}) = \frac{(1-f)}{(n-1)\sum_i z_i}\left(\left(\sum\nolimits_i \frac{{y_i}^2}{z_i}\right) - \frac{(\sum_i y_i)^2}{\sum_i z_i}\right)$$

Where f is the sampling fraction and n is the number of transects (transects on the same latitude were combined for a total of 39 transects on Ellesmere Island and 10 transects on Graham and Buckingham islands). The sampling fraction also provides the scaling factor for moving from a ratio (population density) to a population estimate. It is calculated as $(\sum z_i)/Z$, where Z is the study area. The irregular study area boundaries mean that f varies from the 20% sampling fraction indicated by the 1-km survey strip and 5-km transect spacing (see Appendix 4 for comparative calculations with a stratified sampling regime based on transect width and spacing).

If we were to apply a model $y_i = Rz_i + \varepsilon_i$ instead, then the variance of the error term would be independent of z, so the variance would depend on the number of items in the sample, but not their total size. This would lead to a least squares estimate of R of $\sum zy / \sum z^2$, rather than the more intuitive density definition and model for R presented above.

To incorporate serial correlation in the variance, we used a nearest-neighbor calculation, with the error sum of squares given by:

$$\sum_{i=1}^{n-1}\left(\frac{y_i^2}{z_i}+\frac{y_{i+1}^2}{z_{i+1}}-\frac{(y_i+y_{i+1})^2}{z_i+z_{i+1}}\right)$$

i.e. the sum of squared deviations from pairwise weighted mean densities. The nearest-neighbor error variance of $\hat{R}$ is:

$$Var(\hat{R}) = \frac{(1-f)}{(n-1)\sum_i z_i}\sum_{i=1}^{n-1}\left(\frac{y_i^2}{z_i}+\frac{y_{i+1}^2}{z_{i+1}}-\frac{(y_i+y_{i+1})^2}{z_i+z_{i+1}}\right)$$

Both variance calculations were applied to several stratification regimes for the southern Ellesmere Island survey data. In addition, calculations for these strata based on Jolly's (1969) Method II and Cochran's (1977) systematic survey models are provided in the appendices for comparison. For the final estimate, we used the unstratified (Ellesmere plus Graham and Buckingham islands) estimate and the nearest neighbor variance. All distance measurements used North Pole Azimuthal Equidistant projection and area-dependent work used North Pole Lambert Azimuthal Equal Area, with central meridian at 85°W and latitude of origin at 76°N (centered over the study area for high precision).

Population growth rates were calculated following the exponential growth function, which approximates growth when populations are not limited by resources or competition (Johnson 1996):

$$N_t = N_0 e^{rt} \qquad \text{and} \qquad \lambda = e^r$$

Where N_t is the population size at time t and N_0 is the initial population size (taken here as the previous survey in 2005). The instantaneous rate of change is r, which is also represented as a constant ratio of population sizes, λ. When r >0 or λ >1, the population is increasing; when r <0 or λ <1 the population is decreasing. Values of r ~0 or λ ~1 suggest a stable population.

Results

We flew surveys on March 19, 20, 21, 23, 24, 25, and 26, 2015 for a total of 49.5 hours (35.6 h and 4521 km on transect). Daily flight summaries are presented in Appendix 5 and incidental wildlife sightings are presented in Appendix 6. Visibility was excellent for all survey flights with clear skies (visual estimates of <10% cloud) and high contrast. Some patches of low cloud and blowing snow were encountered near Piliravijuk Bay, but visibility on transect was not impaired. Temperatures ranged from -33°C to -14°C during the survey. We saw 38 caribou and 1146 muskoxen in total, including 36 caribou on transect and 636 muskoxen on transect. Spatial data presented here represents waypoints, so except for groups observed on the transect line, waypoints have error associated with the group's distance from the plane. While observations on transect are within 500 m, some muskox groups off transect were more than 2 km away.

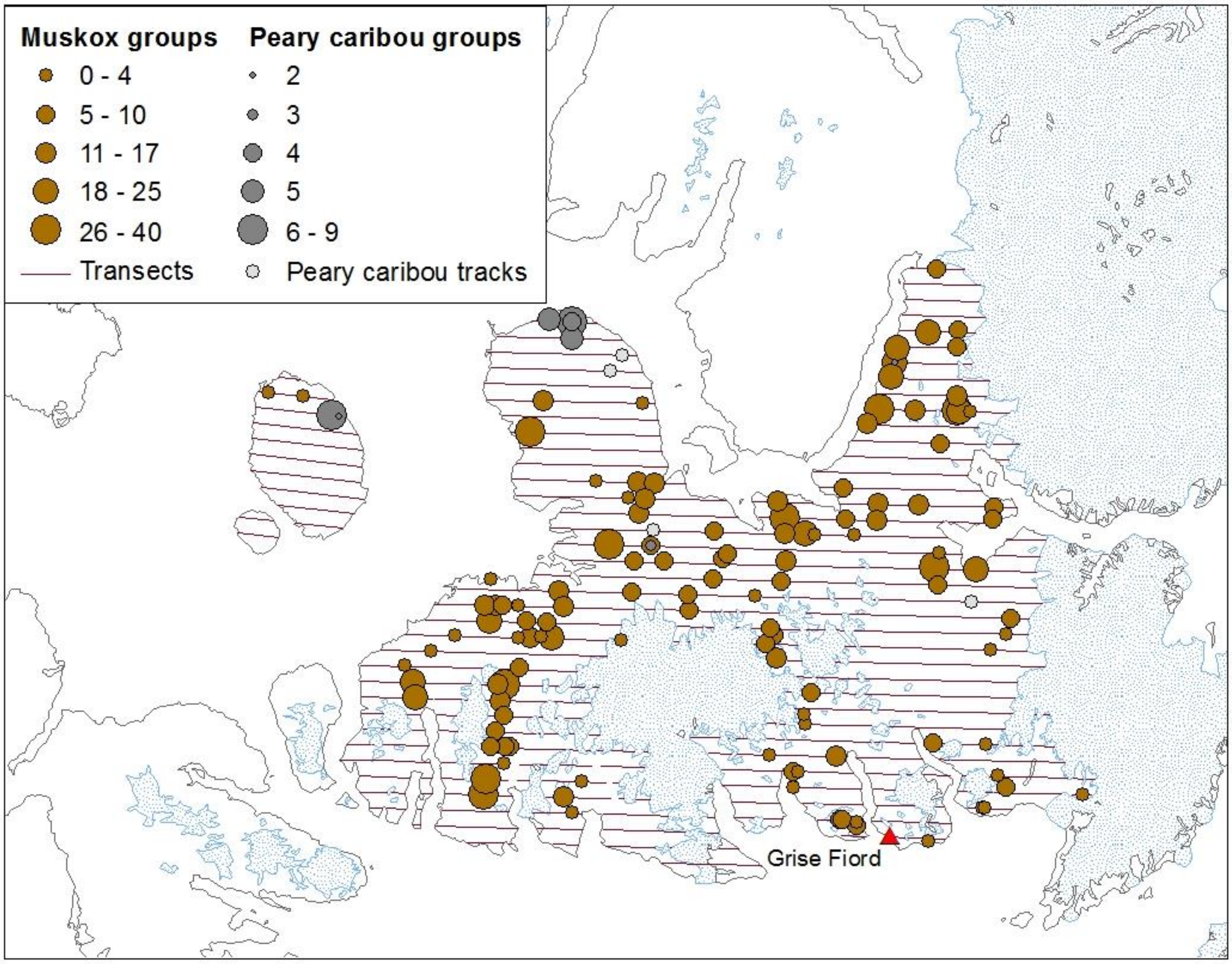

Figure 4. Observations of Peary caribou and muskoxen on southern Ellesmere, Graham, and Buckingham islands.

Abundance Estimates

Abundance estimates for muskoxen are given in Table 7 and population estimates for caribou are given in Table 8. The overall population estimates were 3200 ± SE 602 (CV=19%) and 183 ± SE 128 Peary caribou (CV=70%). The few observations used to calculate the caribou population estimate should be considered in interpreting the results.

Table 2. Calculations following Cochran (1977) for a systematic survey and ratio estimator for muskoxen on southern Ellesmere Island. Variance was calculated based on sample mean and based on nearest-neighbor to account for serial correlation in the data.

Stratum	Stratum area Z (km^2)	Surveyed area z (km^2)	Count, y	Estimate, $\hat{Y}$	Density, $\hat{R}$	Nearest Neighbor				Deviations from sample mean			
						Error Sum of Squares	Var ($\hat{Y}$)	SE	CV	Error Sum of Squares	Var ($\hat{Y}$)	SE	CV
All	21260	4225	636	**3200**	0.151	164.804	362230	602	0.188	194.057	426528	653	0.204
Low Elev	13921	2792	571	2847	0.205	180.633	257061	507	0.178	202.559	288263	537	0.189
High Elev	7339	1433	65	333	0.045	14.438	11488	107	0.322	15.726	12513	112	0.336
Total	21260	4225	636	**3180**	0.150		268549	518	0.163		300776	548	0.172
Main	18988	3768	623	3140	0.165	247.205	486171	697	0.222	340.405	669465	818	0.291
Bjorne	2272	457	13	65	0.028	3.069	3076	55	0.858	2.768	2775	53	0.815
Total	21260	4225	636	**3204**	0.151		489248	699	0.218		672240	820	0.256
I Southeast	10029	2658	222	838	0.084	48.545	43637	209	0.249	91.216	81994	286	0.342
III Vendom	2865	576	212	1054	0.368	209.096	140033	374	0.355	255.597	171175	414	0.392
IV Bjorne	3397	685	30	149	0.044	8.269	6949	83	0.560	7.128	5990	77	0.520
V Southwest	4969	977	172	875	0.176	36.869	41588	204	0.233	34.958	39433	199	0.227
Total	21260	4896	636	**2916**	0.137		232207	482	0.165		298592	546	0.187

Table 3. Calculations following Cochran (1977) for a systematic survey and ratio estimator for Peary caribou on southern Ellesmere Island. Variance was calculated based on sample mean and based on nearest-neighbor to account for serial correlation in the data.

Stratum	Stratum area Z (km^2)	Surveyed area z (km^2)	Count, y	Estimate, $\hat{Y}$	Density, $\hat{R}$	Nearest Neighbor				Deviations from sample mean			
						Error Sum of Squares	Var ($\hat{Y}$)	SE	CV	Error Sum of Squares	Var ($\hat{Y}$)	SE	CV
All	21260	4225	26	131	0.006	5.606	14405	120	0.618	7.247	18622	136	0.702
Graham	1531	296	10	52	0.034	3.513	2036	45	0.874	3.172	1838	43	0.830
Total	22791	4521	36	**183**	0.008		16441	128	0.702		20460	143	0.784
Low Elev	13921	2792	26	130	0.009	9.150	16458	128	1.103	9.193	16537	129	1.106
Graham	1531	296	10	52	0.034	3.513	2035	45	0.874	3.172	1838	43	0.830
Total	15452	3088	36	**181**	0.012		18493	136	0.750		18375	136	0.747
Main	18988	3768	3	15	0.001	0.072	168	13	0.793	0.067	156	12	0.845
Bjorne	2272	457	23	114	0.050	7.699	7717	88	0.768	14.800	14836	122	1.065
Graham	1531	296	10	52	0.034	3.513	2036	45	0.874	3.172	1838	42	0.830
Total	22791	4521	36	**181**	0.008		9921	100	0.550		16830	129	0.716
IV Bjorne	3397	685	26	129	0.038	8.027	6745	82	0.637	15.240	12806	113	0.878
Graham	1531	296	10	52	0.034	3.513	2036	45	0.874	3.172	1838	42	0.830
Total	4928	981	36	**181**	0.037		8781	94	0.519		14644	121	0.670

Population Trends

Muskoxen have clearly increased since the last survey in 2005. Based on a population estimate of 3200 in 2015 and 456 in 2005 (Jenkins et al, 2011), the instantaneous growth rate r would be 0.202, or a lambda of 1.224. The few caribou sightings and large variance in the 2015 estimate of 183 caribou make determination of a trend since the 2005 estimate of 219 difficult, and the growth rate r of -0.018 or lambda of 0.982 should be interpreted with that in mind. More sophisticated analyses incorporating uncertainty in the estimates have not been undertaken, but the large uncertainty in both estimates would likely still make trend determination tenuous.

Calf Recruitment

In April 2014, 33 muskox groups were classified, with 42 short yearlings to 311 adults, or 15.6% short yearlings. In August, the spring 2014 calves were easily identified in 20 groups of 23 calves and 88 adults, making the new calves 23.9% of the population. In March 2015, we classified 101 groups, with 64 short yearlings and 289 adults. Short yearlings made up 22.1% of the population in March, suggesting high overwinter survival if the August calf counts are reflective of the entire study area.

Only 4 caribou groups were classified, totaling 1 short yearling to 8 adults. The low sample size prevents drawing any conclusions on calf recruitment.

Group Size

Muskox group size was about the same in March 2015, averaging 8.9-12.1 muskoxen (95% CI, n=106, median=8; Figure 5), as in April 2014, averaging 6.8-12.0 muskoxen (95% CI, n=33, median=6). The spring groups were larger than the August 2014 groups, which averaged 2.6-6.2 muskoxen (95% CI, n=20, median=3).

Caribou groups were much smaller, 2.6-6.9 caribou (95% CI, n=8; Figure 6). No caribou were seen in April 2014, and only 2 groups, of 1 caribou and 8 caribou, were seen in August 2014.

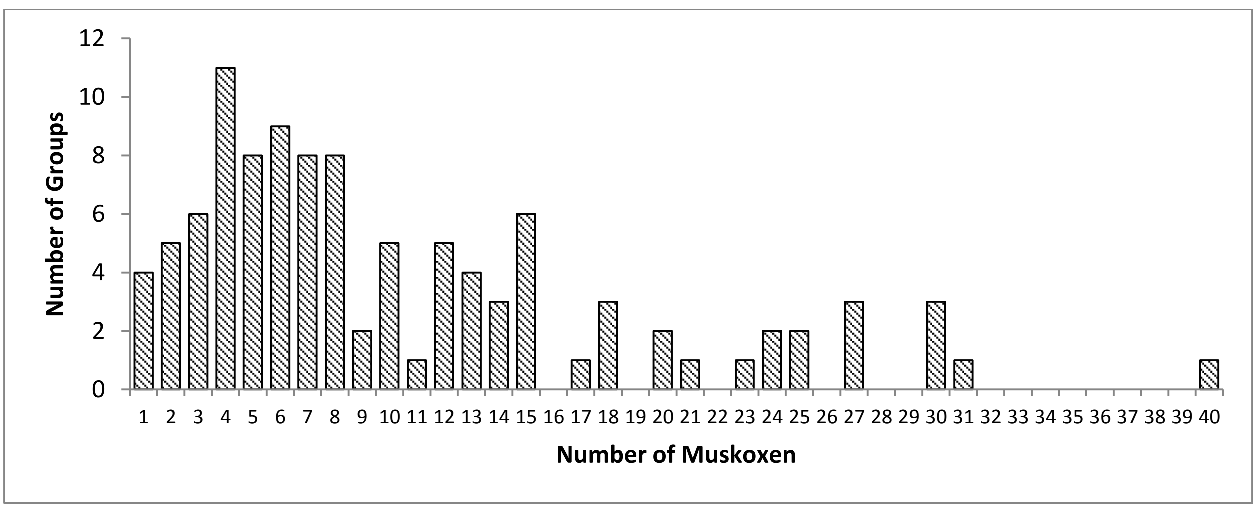

Figure 5. Histogram of group size for 106 muskox group size encountered March 19-26, 2015 on southern Ellesmere Island.

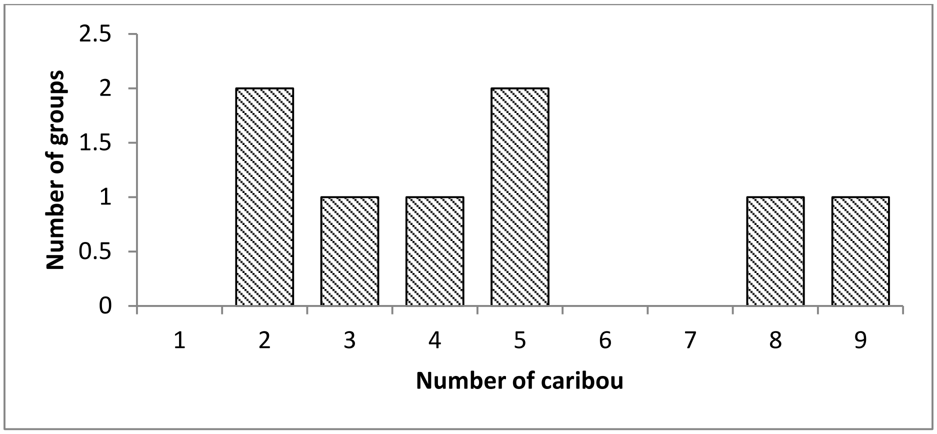

Figure 6. Histogram of group size for 8 Peary caribou groups encountered March 19-26, 2015 on southern Ellesmere Island.

Discussion

Population Trends

Previous surveys of southern Ellesmere Island have used different survey platforms (Piper Super Cub, Tener 1963; Bell 206, Case and Ellsworth 1991, Jenkins et al. 2011 and April 2014 survey attempt; Twin Otter, Riewe 1973, this survey; ground surveys, Freeman 1971), different methodologies (distance sampling, Jenkins et al. 2011 and April 2014 survey attempt; strip transect, this survey, Tener 1963, Case and Ellsworth 1991; unstratified random block sampling, Case and Ellsworth 1991; unsystematic, Freeman 1971, Riewe 1973), and different survey areas. Population estimates and minimum counts are presented in Figure 7, although perhaps the most useful interpretation of the figure is the substantial data gaps it presents. Drawing conclusions on population trends using the disparate data available is difficult.

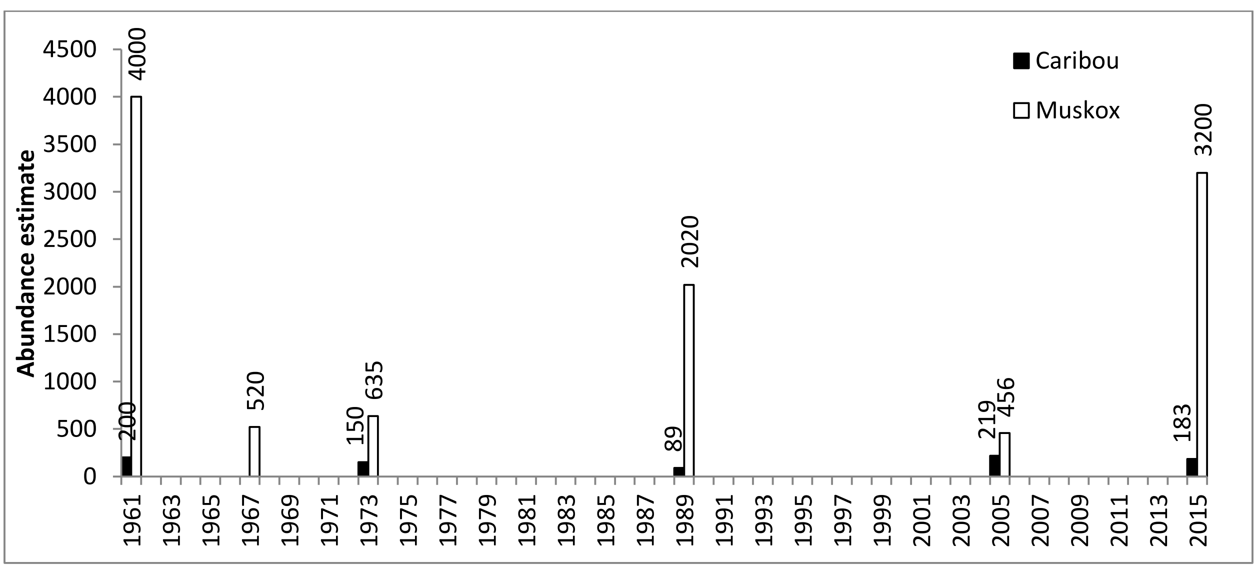

Figure 7. Summary of population estimates for muskoxen and Peary caribou on southern Ellesmere Island and Graham Island. The 1961 estimate is a guess for all of Ellesmere Island (Tener 1963), the 1989 estimate does not include Graham Island (Case and Ellsworth 1991), and 1967 and 1973 are based on minimum counts from unsystematic surveys (Freeman 1971, Riewe 1973). The 2005

and 2015 surveys covered the same study area as in 1989, but included Graham Island and excluded Hoved Island (Jenkins et al. 2011, this report).

In 1961, Tener (1963) observed 1165 muskoxen on Ellesmere Island, except parts of the south and east coasts and northwestern coasts that were inaccessible due to weather. He estimated about 4000 muskoxen on the island, and suggested about a quarter of the population was likely on the Fosheim Peninsula and Lake Hazen-Alert plateau, north of the southern Ellesmere study area (Tener 1963). Concentration areas on southern Ellesmere Island were identified at the head of Baumann Fiord and east of Vendom Fiord. Although he did not survey Vendom Fiord, Freeman (1971) counted 470 muskoxen on southern Ellesmere Island and 50 muskoxen on Graham Island during ground surveys in 1966 and 1967. In early May 1973, Riewe flew the Bjorne Penisula and saw 148 muskoxen, and an additional 60 between Sor and Stenkul Fiords – however, the transect spacing was 8 km and the flight height was 760 m AGL, too high to get more than a reconnaissance survey for muskox and too high to detect caribou at all (Riewe 1973). Later in May, they flew east of Vendom Fiord at 500 m AGL, and the July 1973 surveys were redesigned to be lower (152 m) and slower (176 kph) with more observers to more accurately survey wildlife. Overall, Riewe estimated 625 muskoxen on southern Ellesmere and another 10 on Graham Island (Riewe 1973). Case and Ellsworth (1991) estimated 2020 ± SE 285 muskoxen in July 1989 over approximately the same study area we flew in 2015 (minus Graham Island and including Hoved Island). They estimated a 56% increase in the muskox population from 1973 (Case and Ellsworth 1991). Approximating Case and Ellsworth's (1991) stratification for the 2015 survey, we calculated an average muskox density of 0.137 muskox/km^2, somewhat higher than the 1989 density estimate of 0.081 muskox/km^2 (Case and Ellsworth 1991).

In 2005, southern Ellesmere Island from Vendom Fiord south, the same area in this survey, was flown with an adaptive sampling technique, with east-west transects spaced 5 km apart, tightened to 2.5 km where caribou or caribou sign was detected (Jenkins et al. 2011). A ground survey was also conducted from Grise Fiord, primarily on the Bjorne Peninsula and north of the Sydkap Ice Cap – most other areas are not accessible by snowmobile. Ground crews observed 23 groups of 56 muskoxen and 6 dead muskoxen over 1662 km of survey (Jenkins et al. 2011). The aerial survey, May 4-30 2005, recorded 99 groups of muskoxen, totaling 277 1+ year-old animals and 2 newborns, on transect, and an additional 19 groups and 43 muskoxen off transect (Jenkins et al 2011, Government of Nunavut data unpubl.). In addition to the very low proportion of calves in the population (2%), observers reported 40 muskox carcasses during the survey and 2 adult muskoxen near death (Campbell and Hope 2006, Jenkins et al. 2011). Residents of Grise Fiord suggested freezing rain in winter 2002 (Taylor 2005), which may have reduced muskox condition, survival, and reproduction, and also recall ground-fast ice in winter 2005 (Iviq HTA, pers. comm.). The muskox population appears to have recovered from these climatic events, with rapid growth over the last 10 years.

It appears as though caribou have not been abundant on southern Ellesmere Island in recent times, which corroborates local knowledge of caribou distribution and abundance. The first survey of Ellesmere Island, in 1961, recorded 74 caribou (10.8% calves) and suggested 200 caribou present on the entire island (Tener 1963). Tener (1963) noted the low coverage and 'best guess' nature of this estimate, however. Of the observed caribou, most were seen north of the 2015 study area, and only 11 were seen at the head of Baumann Fiord (Tener 1963). The south coast from Grise Fiord to Simmons Peninsula was not surveyed due to weather (Tener 1963). In unsystematic surveys in May and July 1973, Riewe estimated 80 caribou on Bjorne Peninsula, along Sor and Stenkul Fiords, and along Vendom Fiord, and another 15 on Graham and Buckingham islands (Riewe

1973). Case and Ellsworth (1991) estimated 89 ± SE 31 caribou on southern Ellesmere Island, or an average density of 0.0036 caribou/km^2. If we include the entire 1989 study area, the caribou density would be slightly higher in 2015, at 0.006 caribou/km^2. The error around the estimate of 183 caribou for the 2015 survey is too broad to determine definitively whether the caribou population has increased, decreased, or remained stable since the 2005 survey, which estimated 109-442 caribou (95% CI). However, the pattern over several decades seems to suggest a persistent low density, so it is likely that the population is fairly stable at present.

Changes in Distribution

Muskox concentrations have been recorded along Baumann Fiord, Sor and Stenkul Fiords, the flat plain along Vendom Fiord, north of Muskox Fiord and along Norwegian Bay, and at Fram Fiord (Iviq HTA, pers. comm., Tener 1963, Riewe 1973, Case and Ellsworth 1991, Jenkins et al. 2011). Muskoxen were seen in all these areas during the 2015 survey, as well as the two survey attempts in April and August 2014, if the areas were flown.

Riewe (1973) noted some caribou on Graham Island, between Sor and Stenkul fiords, and on the Bjorne Peninsula. Case and Ellsworth (1991) described caribou observations as scattered across the study area, but in 2005 there were some clear concentration areas on Graham and Buckingham islands, northern Bjorne Peninsula, and southeast of Okse Bay. In 2014 and 2015, we saw caribou in the same areas, as well as a group on northern Vendom Fiord. We did not detect any caribou along the south coast, although they were formerly found in the area of Craig Harbor, Fram Fiord, and King Edward Point in the 1950s and 1960s, and occasionally seen there into the 1990s (IQ in Taylor 2005). We only saw one set of tracks south of Piliravijuk Bay, although caribou have been found there previously (IQ in Taylor 2005, Iviq HTA pers. comm.). Grise Fiord residents were also surprised that we did not see caribou at the head of Goose Fiord or Muskox Fiord, since they can usually be found there.

The most notable change in distribution compared to the 2005 survey is the relative lack of caribou and muskoxen on Graham and Buckingham Islands. During the 2005 survey, 50 caribou in 18 groups and 12 muskoxen in 3 groups were seen on Graham and Buckingham Islands. In 2015, we saw 10 caribou in 2 groups and 3 muskoxen in 2 groups. Part of this discrepancy is explained by the adaptive sampling protocol used in 2005; transects were flown 2.5 km apart in 2005 and 5 km apart in 2015. At the time of the 2015 survey, lack of snow had prevented hunters from Grise Fiord from accessing Graham Island, with the exception of one trip to retrieve a broken snowmobile during the survey, so additional information from hunters was not available for Graham Island. Caribou are known to move between islands in regular seasonal movements and when conditions force them (Miller 2002, Miller et al. 2005, IQ in Taylor 2005), and they do move between Graham Island and Bjorne Peninsula (IQ in Taylor 2005, Iviq HTA pers. comm.).

Calf Recruitment

The proportion of muskox calves in summer 2014 (24%) was higher than previous summer reports for the area. In 1961 Tener estimated 8% calves for the Bjorne Peninsula, not including solitary muskoxen (Tener 1963). Freeman (1971) suggested 12.5% calves for southern Ellesmere, Graham, and northern Devon islands based on 1965 and 1967 aerial surveys. Freeman (1970) developed a preliminary population model that suggested 10.5% calf production would be required to balance natural mortality for the region. Hubert (1972) surveyed northeast Devon Island in May 1972 and reported 16% calves. Riewe (1973) noted calf crops of 16% in July 1973 on the Bjorne Peninsula and surrounding area. In July 1989, Case and Ellsworth (1991) reported 17.3% calves, but only 7.3% yearlings. Only 2 newborn calves were seen on the 2005 survey (Campbell et al.

2006, Jenkins et al. 2011). The adult:calf ratios for August 2014 (24% calves) and March 2015 (22% calves) suggest high recruitment and good overwinter survival, and 16% short yearlings in April 2014 suggests good recruitment of the previous calf crop, in line with previously recorded recruitment rates for the area.

Lack of observations prevents any conclusions on calf recruitment for Peary caribou. In 1961, Tener (1963) observed 10.8% calves in the area. In July 1973, Riewe (1973) reported 5.5% calves. In July 1989, Case and Ellsworth (1991) reported 22.2% calves of 45 caribou observed, but no yearlings were present. The low yearling crop observed for muskoxen during the same survey suggests there may have been a severe winter that limited calf production and recruitment for both species in 1988. Observations by Grise Fiord hunters of caribou moving from Goose Point to Sherwood Head on Axel Heiberg and 2 dead muskoxen and 1 dead caribou on sea ice west of Bjorne Peninsula (IQ in Taylor 2005), also suggest there may have been an extreme weather event around this time. In 2005, there were no short yearlings seen and only 7% of the classified caribou were yearlings, following unusually snowy winters with icing events (Iviq HTA, pers. comm., Jenkins et al. 2011). Restricted forage access is expected to decrease calf production, since Peary caribou show a direct relationship between late winter fat and fertility (Thomas 1982). At least identifying one short yearling in the few groups we observed in 2015 is an improvement over 2005.

Group Sizes

Although there were fewer muskox groups encountered in August, the pattern of smaller group sizes reflects group sizes recorded by other researchers for summer. Muskox groups are largest early in the spring and smaller as summer progresses (Freeman 1971, Gray 1973), with winter (including April and May) groups about 1.7 times larger than summer groups (Heard 1992). Although Heard (1992) noted that group size is not generally related to muskox density, the group size in May 2005, 2.7 muskoxen on average (2.4-3.0 95% CI), was much smaller than the group sizes encountered in April 2014, August 2014, or March 2015. It is possible that the severe starvation conditions had fragmented groups and normal group structure was not observed during the 2005 survey. Group sizes encountered in March 2015 (8.9-12.1 muskoxen/group, 95%CI) were similar to the 10.0 muskoxen/group reported in 1966-1967 (Freeman 1971).

Ferguson (1991) suggested that caribou groups are largest in August and smaller in late winter. Fischer and Duncan (1976) noted that groups across the Arctic islands averaged 4.0 caribou in late winter, 2.8 caribou in early summer, and 8.8 caribou in mid-summer. The lack of observations during any of the 3 survey attempts means we are unable to evaluate any seasonal effect of group size for Peary caribou, but our average group size of 2.6-6.9 caribou (95% CI) is similar to the late winter group sizes encountered by Fischer and Duncan (1976).

The survey conducted by Case and Ellsworth (1991) in July 1989 was in response to observations by Grise Fiord residents of declining caribou populations and increasing muskox populations. It is interesting to note that after a crash in muskox populations in the early 2000s, a similar dynamic may be manifesting on southern Ellesmere again, with relatively few caribou and a muskox population that has increased rapidly over the last decade. The inverse relationship between caribou and muskox abundance has been noted by many communities where Peary caribou and muskoxen are sympatric, but the mechanism explaining this pattern remains unknown (Iviq HTA and Resolute Bay HTA, pers. comm., IQ in Taylor 2005). Furthermore, there appear to be some areas or conditions that permit both species to remain at high densities, as appears to currently be the case on Bathurst and Melville islands (Davison and Williams 2012, Anderson 2014).

Management Recommendations

Peary caribou and muskoxen on southern Ellesmere and Graham islands are an important source of country food and cultural persistence for the Inuit of Grise Fiord. Consistent with the Nunavut Land Claim Agreement, and the Management Plan for High Arctic Muskoxen of the Qikiqtaaluk Region, 2012-2017 (DOE 2014), these management recommendations emphasize the importance of maintaining healthy populations of caribou and muskox that support sustainable harvest. The current abundance and good calf recruitment suggests that the muskox population is healthy, and although relatively few caribou were seen, this appears to be fairly normal for the area.

Under the Management Plan (DOE 2014), Ellesmere Island is considered a single management unit, MX-01, with no quota. It is highly recommended that a harvest reporting system be maintained even without a quota in place. This allows biologists, community members, and decision makers to track harvest patterns and changes in wildlife populations over time and to determine whether changes to management zones or harvest restrictions have the desired effect.

Harvest trends for muskoxen over the last decade suggest that Grise Fiord harvests fewer muskoxen than in the 1990s, averaging fewer than 10 tags per year from 2005-2014 (Government of Nunavut Harvest Database, unpubl. data). An unusually high harvest in 2012-13 due to several problem muskoxen in town resulted in the use of 13 tags in what is now MX-01 - less than 0.5% harvest if the population was similar in 2013 to the current 2015 population and if only southern Ellesmere Island and Graham Island are considered (which does not take into account the high muskox populations elsewhere in MX-01, notably the Fosheim Peninsula and Lake Hazen). Hunters can also access the Svendsen and Raanes peninsulas, north of the study area, which are also included in MX-01, and were not surveyed in 2015. As local knowledge and previous surveys have demonstrated, population changes can be rapid and unexpected if severe weather causes localized or widespread starvation or movement, so continuous monitoring and adaptive management is necessary.

Although we saw only 38 caribou during the survey, the results of previous surveys over the same areas suggest that caribou have persisted at relatively low densities on southern Ellesmere Island for at least as long as they have been regularly hunted from Grise Fiord. There may or may not have been a decline from the 2005 survey, the variation around the estimates is too wide to tell. It is unlikely that harvest restrictions on Peary caribou will result in any marked increase in the population, as harvest is restricted to a small human population with limited access to the caribou range. Increased monitoring of sightings and reporting caribou harvest would provide a more complete picture of where caribou are on the landscape, and could inform population metrics like calf recruitment.

This survey also contributes additional data to the pattern observed by community members, of the inverse relationship between muskox and caribou densities. Although there is general consensus that when some muskox populations are high, sympatric caribou populations are low, the mechanism remains a subject of some debate – the strong smell of the muskoxen is repulsive to caribou, or the muskoxen trample foraging areas and compact the snow, or wolves that hunt the muskoxen have a disproportionate effect on the caribou, or some other factors. Additional research by biologists and IQ holders into this mechanism would be beneficial for informing caribou and muskox management in the High Arctic.

ᐊᐅᓚᑦ ᑎᓂᕐ ᒧᑦ ᐊᑐᓕᖁᔭᐅᔪᑦ

ᑐᒃ ᑐᐃᑦ ᐅᒥᖕᒪᐃᓪᓗ ᐅᒥᖕᒪᑦ ᓄᓈᑦᑕ ᓂᒋᐊᓂ ᒍᓅᕼᐊᒻ ᕿᑭᖅᑖᖓᓂ ᐱᒻᒪᕆᐅᕗᑦ ᓂᕿᑉ ᓴᕆᔭᐅᕙᒃ ᓘᑎᒃ ᐃᓕᖅᑯᓯᕐ ᒧᓪᓗ ᐸᐸᑦᑎᑦ ᔪᑕᐅᓪᓗᓂ ᐃᓄᖕᓄ ᐊᐅᓯᐃᑦᑐᒥ. ᒪᓕᒃ ᓘᒍᑦ ᓄᓇᕗᒻᒥ ᓄᓇᑖᕐ ᓂᕐ ᒧᑦ ᐊᖏᕈᑎ, ᐊᐅᓚᑦ ᑎᓂᕐ ᒧᓪᓗ ᐸᕐ ᓇᐅᑎ ᐅᑭᐅᖅᑕᖅᑑᑉ ᐅᒥᖕᒪᖏᓐᓄ ᕿᑭᖅᑖᕈᖕᒥ, 2012-2017 (ᐊᕙᑎᓕᕆᔨᒃᑯᑦ 2014), ᑕᒪᒃᑯᐊ ᐊᐅᓚᑦ ᑎᓂᕐ ᒧᑦ ᐊᑐᓕᖁᔭᐅᔪᑦ ᓴᖅᑭᔮᖅᑎᑦ ᑎᕗᑦ ᐱᒻᒪᕆᐅᓂᖓᓂ ᐊᒥᓲᑎᑦ ᑏᓐ ᓇᕋᓯ ᐊᕐ ᓂᖅ ᑐᒃ ᑐᓂᑦ ᐅᒥᖕᒪᖕ ᓂᓪᓗ ᐊᖑᓇᓯᒃ ᑕᐅᖃᑦ ᑕᐃᓐ ᓇᒍᓐ ᓇᖁᓪ ᓗᒋᑦ. ᒫᓐ ᓇᐅᔭᖅ ᐊᒥᓲᑎᒋ ᓂᖏᑦ ᓄᕐ ᕋᖃᐅᑦ ᑎᐊᕐ ᓂᖏᓗ ᓇᓗᓇᐃᖅᐳᖅ ᐅᒥᖕᒪᑦ ᐅᓄᖅᑎᒋ ᓂᖏᑦ ᖃᓄᐃᙱᑎᐊᕐ ᓂᖓᓐ, ᑭᓯᐊᓂᑦ ᑕᐅᖅ ᐊᒥᓲᖏᑐᓂᒃ ᑐᒃ ᑐᓂᑦ ᑕᑯᓚᐅᕋᓗᐊᖅᑎᓪ ᓗᒋᑦ, ᑕᒪᓐ ᓇ ᖃᐅᔨᓴᕐ ᕿᐅᔭᖅ ᑕᐃᒪ ᐃᓚᔭᒃ ᑐᖅ.

ᐊᐅᓚᑦ ᑎᓂᕐ ᒥᑦ ᐸᕐ ᓇᐅᑎᑎᒍᑦ (ᐊᕙᑎᓕᕆᔨᒃᑯᑦ 2014), ᐅᒥᖕᒪᑦ ᓄᓈ ᑕᐅᑐᒃ ᑕᐅᕗᖅ ᐊᑕᐅᓯᖅᑐᑦ ᐊᐅᓚᑕᐅᔾᔪ ᓇᐊᓕᒃ ᑐᑦ, MX-01, ᓂᕈᕐᕕᒃ ᑯᑕᒃ ᑰᕐᕿᑐᖅ. ᐊᑐᖁᔨᒪᓇᒃ ᐳᑦ ᐊᖑᓇᓯᒃ ᑕᐅᕙᒃ ᑐᓄᑦ ᐅᓂᒃ ᑳᑯᑎᒥᒃ ᓂᕈᕐᕕᒃ ᑯᑕᒃ ᑰᕐᕿᑲ ᓗᐊᖅᑎᓪ ᓗᒋᑦ. ᑕᐃᒪ ᐃᑎᓪ ᓗᒍᑦ ᓂᕐ ᔪᑎᓂᒃ ᖃᐅᔨᓴᖅᑏᑦ, ᓄᓇᓕᖕ ᓂᕐ ᒥᐅᑦ, ᐃᓯᒪᓕᐅᕆᔩᓪ ᓗ ᓇᐅᑦ ᑎᖅᓯᕆᓐ ᓇᕐ ᓂᐊᖅ ᑐᑦ ᐊᖑᓇᓯᓪ ᕕᐅᕙᒃ ᑐᓂᑦ ᐊᓯᔾ ᔨᖅ ᐸᓪ ᓕᐊᔭ ᓂᓪ ᓗ ᐊᒥᓲᑎᒋ ᓂᖏᓐ ᓂ ᖃᑯᒧᙳᖅ ᐸᓪ ᓕᐊᑎᓪ ᓗᒍᑦ ᓇᓗᓇᐃᕐ ᓗᑎᓪ ᓗ ᐊᓯᔾ ᔨᖅ ᑐᑦ ᐊᐅᓚᑦ ᑎᑦ ᔭᐅᔪᓄᑦ ᐊᖑᓇᓯᒃ ᑕᐅᕙᒃ ᑐᓂ ᑑᓐ ᓃᑦ ᑭᓪ ᓕᖅᑲᓕᖅ ᑎᑦ ᑎᓂᕐ ᒧᑦ ᐊᑑᑎᓂᖃᕐ ᒪᖔᑦ.

ᐊᖑᓇᓯᖕ ᓂᐅᕙᒃ ᑐᑦ ᐅᒥᖕᒪᖕ ᓂᑦ ᐊᕐ ᕌᒍᑦ ᖁᓕᐅᓵᖅ ᑐᓄᑦ ᓇᓗᓇᐃᖅᐳᖅ ᐊᐅᓯᐃᑦ ᑐᕐ ᒥᐅᑦ ᐅᒥᖕᒪᒃ ᐸᕐᕿᓂᐊᖅ ᓴᓕᕐ ᓂᖕᒋ ᓂᒃ ᑕᐃᒪᙵ 1990-ᖕᒋ ᓂᑦ, ᖁᓕᑦ ᑐᖕᒌᓂ ᓂᕈᕐᕕᒃ ᑯᑕᓂᒃ ᐊᑐᖅ ᑐᖅᑲᖅ ᐸᒃ ᔪᓂ 2005-ᒥᑦ 2014-ᒧᑦ (ᓄᓇᕗᑦ ᒎᕙᒪᒃ ᑯᑦ ᐊᖑᓇᓯᒃ ᑕᐅᕙᒃ ᑐᓄᑦ ᑎᑎᖅᑲ ᖁᑎᖕᒋ, ᓴᖅᑭᑕᐅᓯᒪᕐ ᕿᑐᑦ ᑎᑎᖅᑲᑦ). ᐅᓄᕐ ᔩᒥᓪ ᓗᑎᒃ ᐊᖑᓇᓯᒃ ᑕᐅᔪᑦ 2012-13-ᒥᑦ ᐱᓪ ᓗᒋᑦ ᐊᒥᓱᑦ ᐊᑲ ᐅᕐᕈᐅᕈᑏᑦ ᐅᒥᖕᒪᑦ ᓄᓇᓕᖕ ᓄᐊᖅᑕᕐ ᓂᖕᒋ ᓄᑦ ᐊᑐᕈᑕᐅᓕᓚᐅᖅᐳᖅ 13-ᓂᒃ ᓂᕈᕐᕕᒃ ᑯᑕᓂᑦ ᑕᐃᔭ ᐅᓕᖅ ᑐᒥᑦ MX-01 - 0.5% ᑐᖕᒌᓂ ᐊᖑᔭ ᐅᓇᔭᖅ ᑐᑦ ᐅᓄᖅ ᑎᒋ ᓂᖕᒋ ᐊᔾ ᔨᖅᑲᓚᐅᕈᑎᒃ 2013-ᒥᑦ ᒫᓐ ᓇᐅᔭᖅ 2015-ᒥᑦ ᐅᓄᖅ ᑎᒋ ᓂᖕᒋ ᐊᓪ ᓚᑐ ᐅᒥᖕᒪᑦ ᓄᓈᑦᑕ ᓂᒋᐊᓂᕐ ᒥᐅᑦ ᒍᓅᕼᐊᓪ ᓗ ᕿᑭᖅᑕᖕᒍᓂ ᐃᓯᒪᑭᔭᐅᒍᑎᒃ (ᐃᓚᓕᐅᔾ ᔨᓯᒪᕐ ᕿᑐᖅ ᐅᒥᖕᒪᑲᓪ ᓚᖕ ᓂᑦ MX-01-ᒥᕈᔭᒃ, ᐱᓗᐊᙳᐊᖅᑐᒥᑦ ᔫᓴ ᐃᓪᒥ ᕼᐋᓯᓐ ᓗ ᑕᓯᐊᓂ). ᐊᖑᓇᓯᒃ ᐲᑦ ᕝᕙᓐ ᓴᓐ ᑰᕈᓐ ᓇᕐ ᒥᔪᑦ ᕋᓐ ᒃ ᑯᓪ ᓗ, ᖃᐅᔨᓴᕐ ᕕᐅᔫᑉ ᐅᐊᖕ ᓇᖕᒥᓂ, ᐱᖃᓯ ᐅᔾ ᔭ ᐅᓯᒪᔪᑦ MX-01-ᒥᑦ, ᖃᐅᔨᓴᖅ ᑕᐅᓚᐅᕋᑎᓪ ᓗ 2015-ᒥᑦ. ᓄᓇᓕᖕ ᓂ ᖃᐅᔨᒪᔭᐅᔪᑦ ᐊᓪ ᓚ ᑭᖑᓂᑦ ᑎᓐ ᓂ ᖃᐅᔨᓴᖅ ᑕᐅᓂᑯᑦ ᑕᒃᑯᒃ ᓴᐅᑎᑦ ᑎᓯᒪᕗᑦ, ᐅᓄᖅ ᑎᒋ ᓂᖕᒋ ᐊᓯᔾ ᔨᖅ ᑳᓚᒍᓐ ᓇᖅ ᑐᑦ ᓂᕆᐅᓐ ᓇᕐ ᑐᒃ ᑯᓪ ᓗ ᓯᓚᕈᔭᒃ ᖃᓂᖕᒋᔭᖕᒋ ᓇᓂᑯ ᔪᔭᕐ ᔫᓐ ᓅᑦ ᐱᕐ ᓕᕆᕈᑕᐅᔭᓐ ᓇᖅ ᑐᖅ ᓅᔾ ᔭᑕᐅᔭᓐ ᓇᖅ ᑐᕐ ᔫᓐ ᓅᑦ, ᑕᐃᒪ ᐃᓪ ᒪᑦ ᓇᐅᑦ ᑎᖅᓯᐃᓐ ᓇᕐ ᓂᖅ ᐊᓯᔾ ᔩᖅ ᑲᑎᑕᕐ ᓂᕐ ᓗ ᐊᐅᓚᑦ ᑎᔾ ᔭᑎᓂᒃ ᐱᒻᒪᕆᐅᕗᑦ.

38-ᖕᒋ ᓇᕐ ᓂᑦ ᑕᒃᑯᓚᐅᕋᓗᐊᖅᑎᓪ ᓗᑕ ᑐᒃ ᑐᓂᒃ ᖃᐅᔨᓴᖅᑎᓪ ᓗᑕ, ᖃᐅᔨᓴᔭᐅᓯᒪᔪᑦ ᑭᖑᓂᑦ ᑎᓐ ᓂᒃ ᖃᐅᔨᓴᕈᑕᐅᓯᒪᔪᓂᒃ ᑕᐃᑲᓂ ᓴᐃᓐ ᓇᖅ ᓇᓗᓇᐃᖅᐳᖅ ᑐᒃ ᑐᐃᑦ ᐊᒥᓲᖅᑦ ᑖᕿ ᓂᖕᒋ ᓂᒃ ᐅᒥᖕᒪᑦ ᓄᓈᑦᑕ ᓂᒋᐊᓂ ᑕᐃᒪᙵᐊᖑᓇᓯᒃ ᑕᐅᖅᑦ ᑕᕐ ᒪᑕ ᐊᐅᓯᐃᑦᑐᕐ ᒥ. ᐅᓄᕈᓐ ᓃᕙᓕ ᓕᑐᐃᓐ ᓇᓇᐊᖅᑲᓚᐅᖅᑐᑦ 2005-ᒥᑦ ᖃᐅᔨᓴᕐ ᓂᐅᔪᒥᑦ, ᐊᔾ ᔨᒌᖕᒋ ᓂᖕᒋ ᓇᓚᐅᑦ ᑖᖅ ᑕᐅᔪᒥᑦ ᐊᔾ ᔨᒌᙶᐊᖅᐳᑦ ᓇᓗᓇᐃᓇᐊᒃ ᓴᓴᖅ. ᐊᖑᓇᓯᖕ ᓂᕐ ᒧᑦ ᑭᓪ ᓕᖅᑎᑦ ᑎᓂᖅ ᑐᑦ ᐅᓄᕈᓐ ᓃᕙᓕ ᓕᖅᑎᓪ ᓗᑎᒃ ᓇᓗᓇᐃᖅᑐᓂᑦ ᖃᐅᔨᓴᖅᑎᓪ ᓗᑎᒃ ᐃᒡᓗᕐ ᑕᐅᓯᒃ ᑕᐅᕙᒃ ᑐᒃ ᑎᑦ ᑎᓇᔭᖅᑯᒫᕐ ᑲᓪ ᓗᐊᖅᓄᓂ, ᐊᖑᓇᓯᖕ ᓂᖅ ᑭᓪ ᓕᖅᑎᑕᐅᕙᓂᒃ ᑲᒥᑦ ᐃᓄᑭᖅ ᓂᐅᔪᒧᑦ ᐱᕕᑭᓯᐊᓂᒃ ᑐᒃ ᑐᓕᖕ ᓄ. ᓇᐅᑦ ᑎᖅᓯᕐ ᔩᒥᓕᕐ ᓂᖅ ᑕᑯᔭ ᐅᕙᒃ ᑐᓂᑦ ᐅᓂᒃ ᑲᐅᓯᖅᑲᑦ ᑕᕐ ᓂᕐ ᓗ ᑐᒃ ᑐᑕᐅᕙᒃ ᑐᓂᑦ ᓇᓗᓇᐃᕈᑕᐅᔾ ᔩᒥᓇᔭᖅᐳᖅ ᑐᒃ ᑐᑦ ᓇᓃᓪ ᒪᖔᑦ ᓄᓇᒥᑦ, ᑐᑭᓯᓇᕈᑕᐅᔭᓐ ᓇᑎᓪ ᓗᓂ ᓲᕐ ᓗ ᖃᓄᖅ ᓄᕐ ᕋᖅᑎᕐ ᒪᖔᑦ.

ᑖᓐ ᓇ ᖃᐅᔨᓴᕐ ᓂᖅ ᐃᓚᓕᐅᔾ ᔭᐅᑎᑦ ᑎᕐ ᕗᖅ ᑎᑎᖅᑲᓂᒃ ᖃᓄᐃᑉ ᐸᓕᐊᓂᕆᔭ ᐅᕙᒃ ᑐᓂᒃ ᑕᐅᑐᒃ ᑕᐅᕙᒃ ᑐᑦ ᓄᓇᓕᖕ ᓂᕐ ᒥᐅᓂ, ᖃᓄᐃᖅᑎᑦ ᑎᑉ ᐸᖕ ᒪᖔᑦ ᐅᒥᖕᒪᑦ ᑐᒃ ᑐᐃᓪ ᓗ. ᑐᑭᓯ ᓇᕐ ᓂᖕᒐ ᐊᖏᕈᑕᐅᓯᒪᒐ ᓗᐊᖅ ᓱᓂ ᐅᒥᖕᒪᒃ ᑕᐅᖅᑲᐅᕚᖕᒐ, ᑐᒃ ᑐᐃᑦ ᐊᒥᓲᕙᖕᒋ ᓂᖕᒋ ᓂ, ᐊᐅᓚᓂᕆᔭᖕᒐ ᓯᓕ ᐅᖅᑲᐅᓯᐅᖅᑲᑦ ᑕᖅᐳᖅ – ᐅᒥᖕᒪᒃ ᓯᓈ ᓂᓗᐊᕐ ᓂᖅ ᒪᒪᕆᔭᐅᙲᖅ ᑐᒃ ᑐᓂᑦ, ᐅᒥᖕᒪᐃᑦ ᑐᖕᒪᖅ ᑕᖕᒋ ᓂᕿᖅᑲᕐ ᕕᐅᕙᒃ ᑐᓂᑦ ᑎᓯᒃ ᓴᐅᑕᐅᓂᖕᒎ ᐊᐅᓪ ᒥ, ᐊᒪᖅ ᑯᓪ ᓗ ᔫᓐ ᓅᑦ ᐅᒥᖕᒪᒐ ᓯᒃ ᐸᒃ ᑐᑦ ᐊᔾ ᔨᖕᒋ ᑐᓂᒃ ᐊᒃ ᑑᑎᕗᑦ ᑐᒃ ᑐᓄᑦ, ᐊᓯᖕᒋ ᔫᓐ ᓅᑦ ᖃᓄᐃᔾ ᔭᑕᐅᔪᑦ. ᖃᐅᔨᓴᕈᑕᐅᒃ ᑲᓐ ᓂᖅ ᑐᑦ ᐆᒪᔾ ᔨᓂᒃ

ᖃᐅᔨ ᓴ ᖅ ᑎᓂᑦ ᐊᒻ ᒪ ᐃᓄᐃᑦ ᖃᐅᔨ ᒪ ᔭ ᑐᖃᖕᒋ ᓂ ᐱᖃᖅ ᑎᐅᖃᑕᐅᔪ ᓂᑦ ᑕᒪ ᑐᒧ ᖕᒐ ᐊᐅᓚᓂᕆᔭ ᖕᓄ ᐊᑑᑎᓇᔭ ᖅᑐᖅ ᑐᑭ ᓯ ᕆ ᐊᕈ ᑕᐅᓗᑎᒃ ᑐᒃ ᑐᓂᑦ ᐅᒥ ᖕ ᒪ ᖕ ᓂᓪ ᓗ ᐊᐅᓚᑦ ᑎᑦ ᔪ ᑎᒃ ᓴ ᓂᑦ ᖁᑦ ᑎᒃ ᑐᖅ ᐅᑭ ᐅᖅ ᑕᖅ ᑐᒥ ᑦ.

Acknowledgements

Thank you to everyone involved in attempting this survey three times in one fiscal year, probably an ill-fated record of some sort. Thanks to the survey observers, without whom we could not have run the survey: Eepa Ootoovak, Adrian Kakkee, Josh Kilabuk, Mark Akeeagok, Jaypetee Akeeagok, Etuangat Akeeagok, Frankie Noah, Olaf Killiktee, Simon Singoorie, Imooshie Nutaraqjuk, Aksakjuk Ningiuk, Jopee Kiguktak, Frank Holland, and Jon Neely. Engineers Garland Pope, Tim Hall, and Scott Darroch were also drafted into spotting wildlife beyond their maintenance duties. Universal Helicopter pilot Darryl Hefler and Kenn Borek Air pilots Terry Welsh, Sebastien Trudel, Rob Bergeron, and John Sidwell also helped spot wildlife while flying transects. Thanks to the Iviq Hunters and Trappers Association and Hamlet of Grise Fiord for their guidance, support, and for organizing observers, particularly Mark Akeeagok, Jaypetee Akeeagok, Larry Idlout, Marty Kuluguqtuq, Imooshie Nutaraqjuk, Aksajuk Ningiuk, Liza Ningiuk, and Amun Akeeagok. Wildlife Officer Jon Neely also provided guidance, logistical support. Mike Kristjanson, Tim McCaugherty, Glenn Parsons, Jodi MacGregor, and the rest of the team at Polar Continental Shelf Program provided logistical support for all 3 survey attempts. Melanie Wilson, David Lee, and Lisa-Marie Leclerc provided comments on the report.

Funding for this work was provided by the Nunavut Department of Environment Wildlife Research Section and the Nunavut Wildlife Research Trust (Project 2-14-02). The Polar Continental Shelf Program provided in-kind logistical support (Project 314-14 and 321-15). The work was completed under Government of Nunavut Wildlife Research Section permit 2014-014.

Literature Cited

Anderson, M. 2014. Distribution and abundance of Peary caribou (*Rangifer tarandus pearyii*) and muskoxen (*Ovibos moschatus*) on the Bathurst Island Group, May 2013. Nunavut Department of Environment, Wildlife Research Section, Status Report, Igloolik, NU. 39 pp.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers and L. Thomas. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press. 432 pp.

Campbell, M., J. Boulanger, D. S. Lee, M. Dumond, and J. McPherson. 2012. Calving ground abundance estimates of the Beverly and Ahiak subpopulations of barren-ground caribou (*Rangifer tarandus groenlandicus*) – June 2011. Nunavut Department of Environment, Technical Summary, Arviat NU. 111 pp.

Case, R. and T. Ellsworth 1991 Distribution and abundance of muskoxen and Peary caribou on southern Ellesmere Island, NWT, July 1989. Department of Renewable Resources, Government of the Northwest Territories, Manuscript Report 41, Yellowknife, NT. 23 pp.

Caughley, G. 1977. Sampling in aerial survey. Journal of Wildlife Management 41(4): 605-615.

Cochran, W. G. 1977. Sampling techniques. 3rd ed. Wiley, New York, NY. 428 pp.

Department of Environment (DOE), in collaboration with Nunavut Tunngavik Inc. (NTI) Wildlife, Resolute Bay Hunters and Trappers Association, Ikajutit Hunters and Trappers Organization (Arctic Bay), Iviq Hunters and Trappers Association (Grise Fiord) and the Qikiqtaaluk Wildlife Board. 2013. Management Plan for the High Arctic Muskoxen of the Qikiqtaaluk Region, 2012-2017. Nunavut Department of Environment, Iqaluit, NU. 20 pp.

Ferguson, M. A. D. 1991. Peary caribou and muskoxen on Bathurst Island, Northwest Territories, from 1961-1981. Government of Northwest Territories, Pond Inlet. File report 88. 54 pp.

Fischer, C. A. and E. A. Duncan. 1976. Ecological studies of caribou and muskoxen in the Arctic Archipelago and northern Keewatin. Renewable Resources Consulting Services. Report to Polar Gas Project. 194 pp.

Freeman, M. M. R. 1970. Productivity studies of high arctic muskoxen. Arctic Circular 20:58-65.

Freeman, M. M. R. 1971. Population characteristics of musk-oxen in the Jones Sound region of the Northwest Territories. Journal of Wildlife Management 35(1): 103-108.

Gould, W. A., M. Raynolds, and D. A. Walker. 2003. Vegetation, plant biomass, and net primary productivity patterns in the Canadian Arctic. Journal of Geophysical Research 108 (D2): 8167, doi:10.1029/2001JD000948.

Gray, D. R. 1973. Social organization and behavior of muskoxen (*Ovibos moschatus*) on Bathurst Island, NWT. PhD Thesis. University of Alberta, Edmonton, AB. 212 pp.

Heard, D. 1992. The effects of wolf predation and snow cover on muskox group size. The American Naturalist 139(1): 190-204.

Hubert, B. 1972. Productivity of muskox. In: Bliss, L. C., ed. Devon Island International Biological Programme Project, High Arctic Ecosystem. Project Report 1970 and 1971, Edmonton, AB. Pp 272-280.

Jenkins, D., M. Campbell, G. Hope, J. Goorts, and P. McLoughlin. 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, Wildlife Report No. 1, Pond Inlet, Nunavut. 184 pp.

Johnson, D. H. 1996. Population analysis. In: T. A. Bookhout, ed. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesday, MD: 419-444.

Jolly, G. M. 1969. Sampling methods for aerial censuses of wildlife populations. East African Agricultural and Forestry Journal 34 (special issue):46-49.

Kingsley, M. C. S., and G. E. J. Smith. 1981. Analysis of data arising from systematic transect surveys. Pp 40-48 in F. L. Miller and A. Gunn, eds. Proceedings, Symposium on Census and Inventory Methods for Populations and Habitats, Banff, AB, April 1980.

Kingsley, M. C. S., I. Stirling, and W. Calvert. 1985. The distribution and abundance of seals in the Canadian high arctic, 1980-82. Canadian Journal of Fisheries and Aquatic Sciences 42 (6): 1189-1210.

Miller, F. L. 2002. Multi-island seasonal home range use by two Peary caribou, Canadian High Arctic, 1993-94. Arctic 55:133-142.

Miller, F. L. and S. J. Barry. 2009. Long-term control of Peary caribou numbers by unpredictable, exceptionally severe snow or ice conditions in a non-equilibrium grazing system. Arctic 62(2): 175-189.

Miller, F. L, S. J. Barry, and W. A. Calvert. 2005. Sea-ice crossings by caribou in the south-central Canadian Arctic Archipelago and their ecological importance. Rangifer Special Issue 16:77-88.

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

Miller, F. L., R. H. Russell and A. Gunn. 1975. The decline of caribou on the western Queen Elizabeth Islands. Polarforschung 45: 17-22.

Norton-Griffiths, M. 1978. Counting animals. In: J. J. R. Grimsdell, ed. Handbooks on techniques currently used in African wildlife ecology. No 1. AWLF, Nairobi, Kenya.

Riewe, R. R. 1976. Final report on a survey of ungulate populations on the Bjorne Peninsula, Ellesmere Island: determination of numbers and distribution and assessment of the effects of seismic activities on the behaviour of these populations. Report fulfilling contract YK-73/74-020, University of Manitoba, Winnipeg, MB. 58 pp.

Stirling, I., M. C. S. Kingsley and W. Calvert. 1982. The distribution and abundance of seals in the Beaufort Sea, 1974-1979. Canadian Wildlife Service Occasional Paper 47.

Taylor, A. D. M. 2005. Inuit Qaujimajatuqangit about population changes and ecology of Peary caribou and muskoxen on the High Arctic Islands of Nunavut. MA Thesis. Queen's University, Kingston ON. 123 pp.

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

Thomas, D. C. and P. Everson. 1982. Geographic variation in caribou on the Canadian arctic islands. Canadian Journal of Zoology 60(10): 2442-2454.

Thomas, L., S. T. Buckland, E. A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R. B. Bishop, T. A. Marques, and K. P. Burnham. 2009. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology doi: 10.1111/j.1365-2664.2009.01737.x

Walker, D. A., M. K. Raynolds, F. J. A. Daniëls, E. Einarsson, A. Elvebakk, W. A. Gould, A. E. Katenin, S. S. Kholod, C. J. Markon, E. S. Melnikov, N. G. Moskalenko, S. S.Talbot, B. A. Yurtsev, and the other members of the CAVM Team. 2005. The Circumpolar Arctic vegetation map. Journal of Vegetation Science 16: 267-282.

Appendix 1. Summary of partial survey conducted by helicopter in April 2014.

Methods – April Helicopter Survey

Survey transects approximately followed transects established for the 2005 distance sampling helicopter survey parallel to lines of latitude at 5-km spacing. The April survey was designed to follow the same methodology as the 2005 survey (helicopter distance-sampling, Buckland et al. 2001, Jenkins et al. 2011). Transects were flown at 150 km/hr (81 kts) with a Bell 206 helicopter. Surveys were only conducted on days with good visibility and high contrast to facilitate detection of animals, tracks, and feeding craters, as well as for operational reasons to ensure crew safety. Flight height was set at 400' (122 m). The April survey was flown with one pilot, 1 front observer/navigator, and 2 rear observers.

All observations of wildlife and fresh tracks were marked on a handheld Garmin Montana 650 GPS unit, which also recorded the flight path with positions taken every 30 seconds. During the helicopter survey, we circled groups and marked their exact locations, but the Twin Otter did not approach groups. Sex and age classification was limited to adult/short yearling/newborn calf. Only one newborn muskox was seen in April, on April 24. In April, because the survey was prior to caribou calving, smaller body size and shorter faces on caribou were the primary distinguishing features of young of the year (10-month-old calves/short yearlings). In August, calves were obvious by small body size and we did not attempt to distinguish yearlings. GPS tracks and waypoints were downloaded through DNR Garmin and saved in Garmin GPS eXchange Format, Google Keyhole Markup Language, and as ESRI shapefiles. Data was entered and manipulated in Microsoft Excel spreadsheets.

Small ferry flights (flights linking consecutive transects) were removed for population analysis, although survey speed and height were maintained and all observations recorded as if on survey. Similarly, sections of transect crossing inlets and between islands were removed since density calculations are based on land area only.

Since the survey was not completed, nor did it cover a reasonable unit for which a population estimate could be calculated, no population estimate was derived. The survey was structured to have data analyzed in Distance 6.0 (Thomas et al. 2009, available from http://distancesampling.org/), with distance to transects calculated for each observation using the Euclidean Distance function in ArcMap 10 (ESRI, Redlands, CA). Conventional distance sampling for line transect data would have been used, with detection function curves, following Buckland et al. (2001). The detection function $\hat{g}(x)$ is the probability of detecting a cluster of animals given its perpendicular distance from the transect line, and $\hat{P}_\alpha$ is the probability that a cluster is detected:

$$\hat{P}_\alpha = \frac{\int_0^w \hat{g}(x)dx}{w}$$

The effective strip width (ESW) is the distance at which as many clusters are detected beyond it as are missed within it (Buckland et al. 2001). The ESW can be substituted for $w\hat{P}_\alpha$ to calculate density, where *n* is the number of clusters observed and *L* is the transect length:

$$\hat{D} = \frac{n}{(2wL\hat{P}_\alpha)}$$

Since each cluster represents one or several animals, $\widehat{D}$ is multiplied by the average cluster size to obtain the density, *D*. The cluster size likely influenced detection function as well – where size bias was present, it can be incorporated into the regression; where size bias was not present, the average cluster size can be used.

Results – April Helicopter Survey

We attempted the survey from April 1-25, but the helicopter was delayed in Pond Inlet until April 9. We flew transects by helicopter on April 12, 13, 16, 20, and 24, 2014 for a total of 3,340 km (1,899 km on transect). Visibility was excellent for all survey flights with clear skies (visual estimates of <10% cloud) and high contrast. We observed 311 muskoxen in 33 groups (Figure 8), including 42 short yearlings (11 months old), making up 15.6% of the population. The only newborn calf was observed on April 24, 2014. Of the 33 groups seen, group size averaged 9.4 including short yearlings (6.8-12.0 95% CI), or 8.2 adults (5.8-10.5 95% CI) (Figure 9).

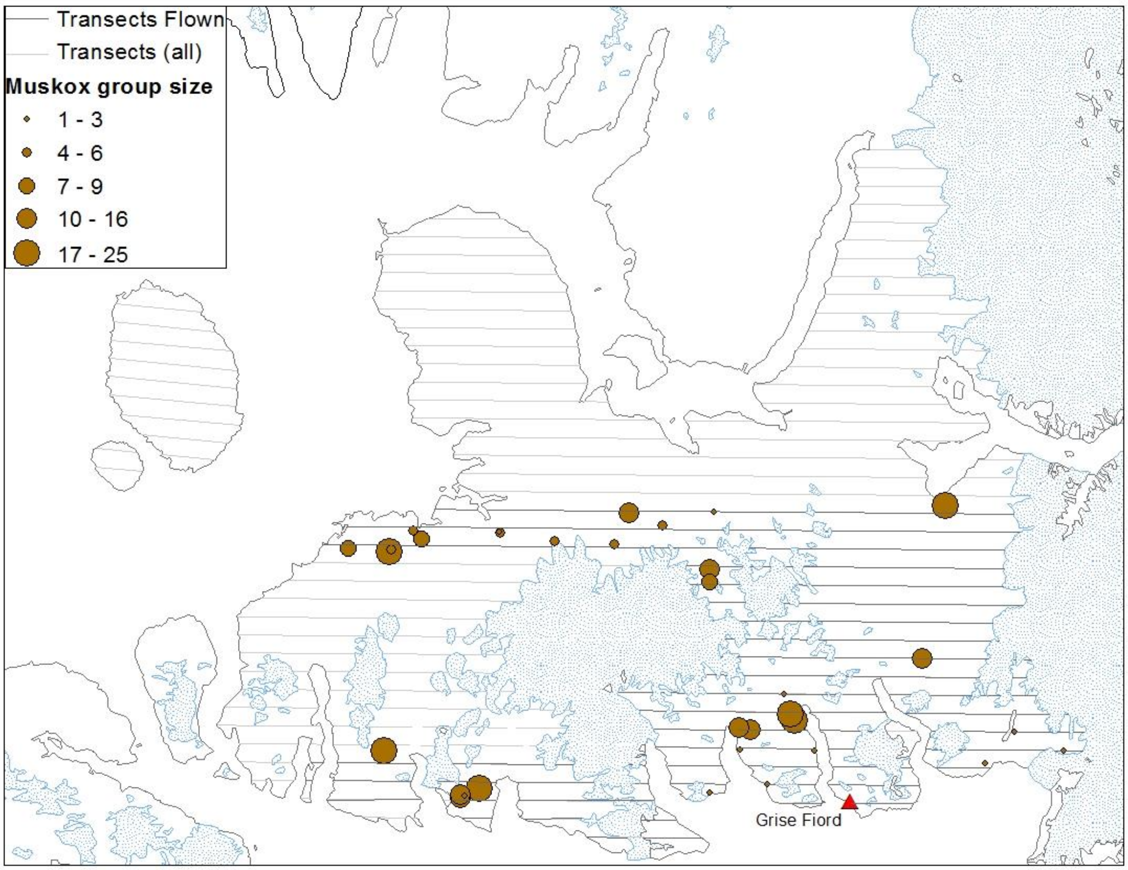

Figure 8. Observations of muskox April 12-24, 2014, totaling 311 muskoxen in 33 groups, on helicopter distance-sampling survey of southern Ellesmere Island. No caribou were observed.

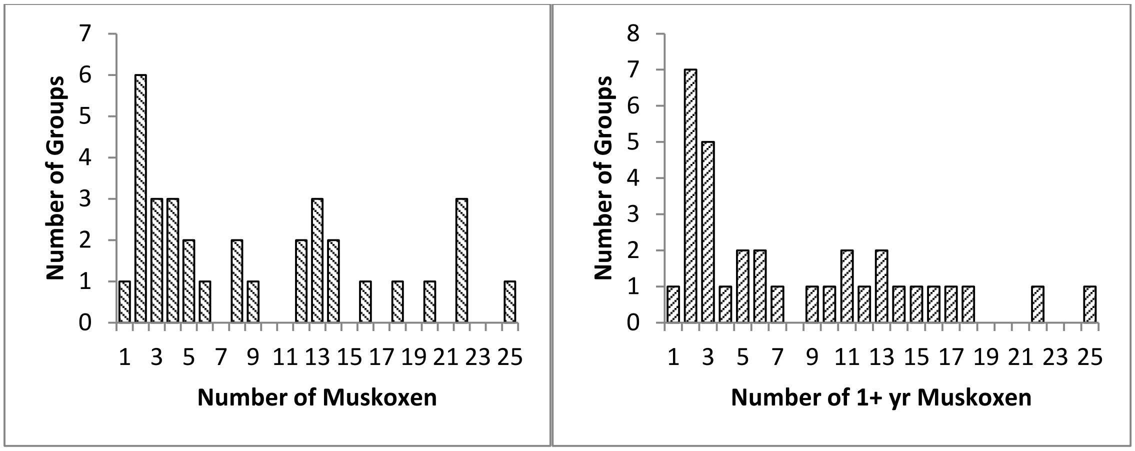

Figure 9. Histograms showing group size including short yearlings and including 1+ year-old animals only for 33 muskoxen groups observed on southern Ellesmere Island in April 2014.

Daily Flight Summaries

12 APRIL 2014
Grise Fiord, South Ellesmere
Transects 48, 49, 50, 57 (part), 58, 59, 60, 61
Track file: 12Apr2014.shp/kml/gpx
Waypoint file: SEllemsere_12Apr2014.shp/kml/gpx

Aircraft: Bell 206LR F-PHO
Pilot: Darryl Hefler
Navigator/Recorder: Morgan Anderson
Observers: Adrian Kakkee, Eepa Ootoovak

Weather mostly calm and clear with light breeze (strong at ground level off the ice cap). Saw 1 polar bear, 75 muskox – several large groups. 1 set of wolf tracks up a valley. Fog west towards Hell Gate and wind off ice caps in the east.

Flight times: 09:20-11:42; 12:00-14:28; 15:15-16:36. Refuel in Grise Fiord.

13 APRIL 2014
Sydkap Ice Cap, South Ellesmere
Transects 51, 52, 53, 54, 55, 56, 57 (part); 35, 36, 51 between ice caps
Track file: 13Apr2014.shp/kml/gpx
Waypoint file: SEllemsere_13Apr2014.shp/kml/gpx

Aircraft: Bell 206LR F-PHO
Pilot: Darryl Hefler
Navigator/Recorder: Morgan Anderson
Observers: Adrian Kakkee, Eepa Ootoovak

Weather mostly calm and clear with ice crystals over the fiords. Polar bear track in valley up onto ridge, 1 set of caribou tracks seen. 35 muskox seen.

Flight times: 13:27-16:02; 16:18-18:39. Refuel at Sydkap cache.

16 APRIL 2014
Sydkap Ice Cap, South Ellesmere
Transects East part of 51, 36, 35, 34
Track file: 16Apr2014.shp/kml/gpx
Waypoint file: SEllemsere_16Apr2014.shp/kml/gpx

Aircraft: Bell 206LR F-PHO
Pilot: Darryl Hefler
Navigator/Recorder: Morgan Anderson
Observers: Josh Kilabuk, Jaypetee Akeeagok

Morning cloudy clearing in afternoon, still hazy to north and west. Turned back early due to wind. Saw no wildlife.

Flight times: 15:04-16:34; 16:55-18:16. Refuel at Sydkap cache.

20 APRIL 2014
North of Sydkap Ice Cap, South Ellesmere
Transects 34, 33, part 32
Track file: 20Apr2014.shp/kml/gpx
Waypoint file: SEllemsere_20Apr2014.shp/kml/gpx

Aircraft: Bell 206LR F-PHO
Pilot: Darryl Hefler
Navigator/Recorder: Morgan Anderson
Observers: Morgan Anderson, Garland Pope

Weather clear and calm, -15°C. Saw 82 muskox.
Flight times: 15:55-18:20; 18:35-19:31; 19:47-20:11. Refuel at Sydkap cache.

24 APRIL 2014
Okse Bay, South Ellesmere
Transects 32, 46, 47
Track file: 24Apr2014.shp/kml/gpx
Waypoint file: SEllemsere_24Apr2014.shp/kml/gpx

Aircraft: Bell 206LR F-PHO
Pilot: Darryl Hefler
Navigator/Recorder: Morgan Anderson
Observers: Josh Kilabuk, Jaypetee Akeeagok, Mark Akeeagok

Wind 2 kts, -13°C, clear. Fuel pump issues at Okse Bay cache so returned to refuel in Grise Fiord. Engineer couldn’t find anything wrong with fuel pump when checking drums at the airport – must have been vapor lock. Swapped observers and did a short trip along Jones Sound before wind picked up (some muskox groups seen previously from other survey lines).

Flight times: 11:10-12:28; 12:52-13:58; 14:50-16:51 Opened 1 drum at Okse cache but unable to pump it.

Appendix 2. Summary of partial survey conducted August 2014.

Methods – August Fixed-wing Survey

Survey methodology for the August fixed-wing survey was the same as that described for the March 2015 fixed-wing survey. However, we stratified the survey area to fly every second transect in the area north of Grise Fiord and east of the Sydkap Ice Cap (10-km transect spacing) since no caribou and few muskoxen had been observed there in April. We may have reflown that area if there was a marked seasonal distribution of muskoxen - unfortunately the limited seasons in which residents of Grise Fiord can access many of their hunting areas also meant local knowledge was not always available.

Results – August Fixed-wing Survey

We attempted to fly the survey area August 2-9, but were delayed due to weather and flew August 11-21. However, fog and wind continued to be an issue, and besides a brief flight on August 13 (593 km, 73 km on transect), we only flew 1 full day, August 15 (1865 km, 1259 km on transect). We saw 88 muskoxen in 20 groups, including 23 calves – 23.9% of the population (Figure 10). Group size was also significantly smaller than in April (t-test for unequal variances based on adult muskoxen only, p=0.001, df=48), with an average of the 20 groups observed being 4.4 muskoxen (2.6-6.2 95% CI) or 3.6 adult muskoxen (2.2-4.9 95% CI) (Figure 11).

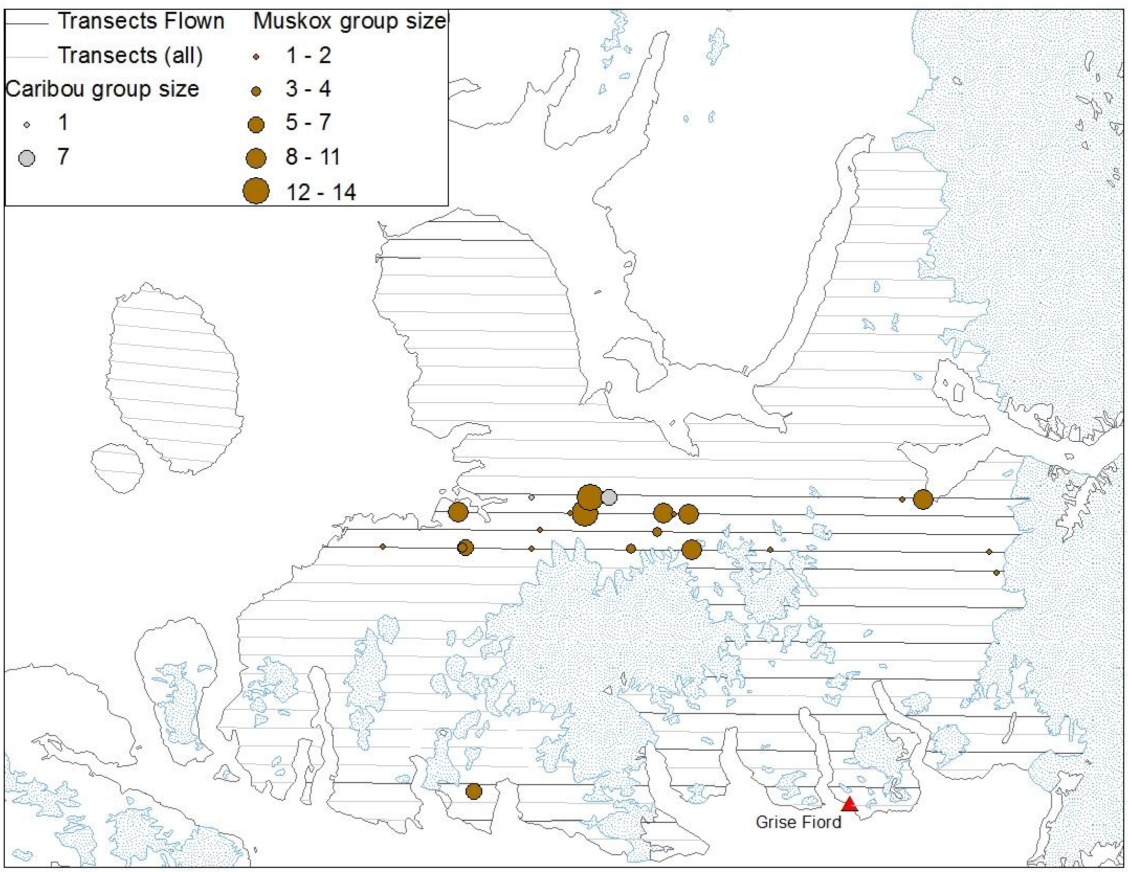

Figure 10. Observations of muskox August 15, 2014, totaling 88 muskoxen in 20 groups and 8 caribou in 2 groups, on Twin Otter fixed-width strip survey of southern Ellesmere Island.

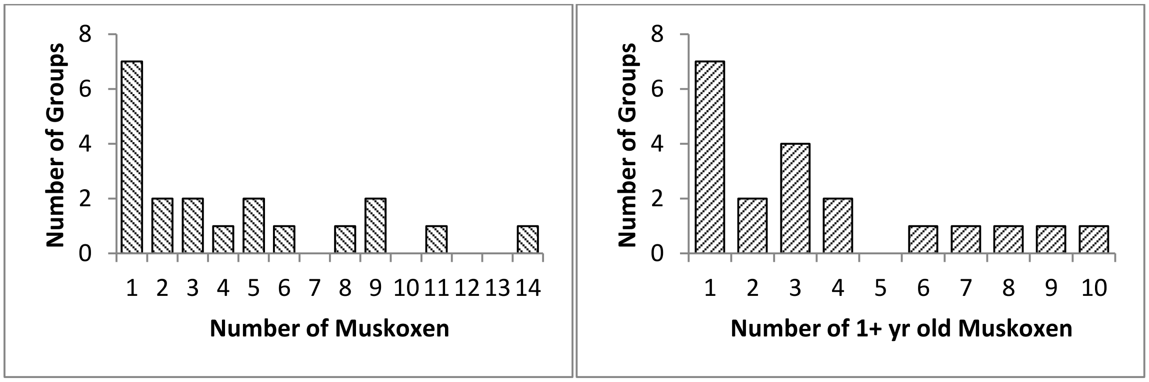

Figure 11. Histograms showing group size including short yearlings and including 1+ year-old animals only for 20 muskoxen groups observed on southern Ellesmere Island in August 2014.

Daily Flight Summaries

13 AUGUST 2014

Graham Island, Bjorne Peninsula
Transects 1, 2, 3
Track file: track_13aug14.shp/kml/gpx
Waypoint file: wpts_13aug14.shp/kml/gpx

Aircraft: Twin Otter F-KBG
Pilots: Terry Welch, Sebastien Trudel
Navigator/Recorder: Morgan Anderson
Observers: Etuangat Akeeagok, Eepa Ootoovak

Overcast at Grise Fiord with light wind from south. Ceiling dropping as day went on from 500' at Okse Bay down to 200' at Bjorne Peninsula until we were flying at 20' and had to turn back. 1 polar bear on Graham Island and a herd of 263 arctic hares on Bjorne Peninsula.
Flight times: 13:25-16:00.

15 AUGUST 2014

Grise Fiord, South Ellesmere
Transects 49, 47, 61, 59, 57, 55, 53, 51, 35, 34, 33, 32, 31
Track file: track_15aug14.shp/kml/gpx
Waypoint file: wpts_15aug14.shp/kml/gpx

Aircraft: Twin Otter F-KBG
Pilots: Terry Welch, Sebastien Trudel
Navigator/Recorder: Morgan Anderson
Observers: Etuangat Akeeagok, Tim Hall

Sunny and clear with some cloud in the east moving in, ceiling about 4000'. Saw 88 muskoxen, 8 caribou.
Flight times: 09:07-13:25; 14:00-19:50; 20:30-21:00. Refuel and pack out drums from Makinson Inlet cache.

Appendix 3. South Ellesmere Island survey transects, 2014-2015.

Table 4. Transect end points and general locations on southern Ellesmere Island, Graham Island, Buckingham Island, and North Kent Island for a Peary caribou and muskox survey in April 2014, August 2014, and March 2015.

Transect	Location	Longitude West End	Latitude West End	Longitude East End	Latitude East End	Flown Apr?	Flown Aug?	Flown Mar?
1	Bjorne Peninsula	-87.63447	77.86272	-86.73525	77.86813		Y	Y
2	Bjorne Peninsula	-88.10144	77.81358	-86.38718	77.82430		Y	Y
3	Bjorne Peninsula	-88.21828	77.76728	-86.17769	77.77975		Y	Y
4	Bjorne Peninsula	-88.15352	77.72272	-86.09019	77.73481			Y
5	Bjorne Peninsula	-88.20685	77.67702	-85.97389	77.68989			Y
6	Bjorne Peninsula	-88.16799	77.63222	-85.91615	77.64484			Y
7	Bjorne Peninsula	-87.95133	77.58906	-85.87106	77.59977			Y
8	Bjorne Peninsula	-87.81693	77.54505	-85.83368	77.55468			Y
9	Bjorne Peninsula	-87.67639	77.50104	-85.80916	77.50957			Y
10	Bjorne Peninsula	-87.71097	77.45559	-85.72368	77.46451			Y
11	Bjorne Peninsula	-87.76401	77.40998	-85.47639	77.41946			Y
12	Sor Fiord	-87.70839	77.36527	-81.15694	77.33925			Y
13	Vendom Fiord	-83.73859	77.41373	-81.58975	77.39114			Y
14	Vendom Fiord	-83.82041	77.45940	-81.78288	77.43910			Y
15	Vendom Fiord	-83.42168	77.50181	-81.23609	77.47629			Y
16	Vendom Fiord	-83.30973	77.54610	-81.08733	77.51917			Y
17	Vendom Fiord	-83.18055	77.59020	-81.61272	77.57242			Y
18	Vendom Fiord	-83.08156	77.63453	-81.19908	77.61148			Y
19	Vendom Fiord	-82.97330	77.67873	-81.49649	77.66122			Y
20	Vendom Fiord	-82.89174	77.72315	-81.44469	77.70571			Y
21	Vendom Fiord	-82.82779	77.76773	-81.67575	77.75424			Y
22	Vendom Fiord	-82.75438	77.81220	-81.72205	77.80010			Y
23	Vendom Fiord	-82.64875	77.85633	-81.60740	77.84376			Y
24	Vendom Fiord	-82.61015	77.90112	-81.46311	77.88695			Y
25	Vendom Fiord	-82.54402	77.94563	-81.54255	77.93333			Y
26	Vendom Fiord	-82.55925	77.99098	-81.47106	77.97755			Y
27	Vendom Fiord	-82.41491	78.03464	-81.72545	78.02630			Y
28	Sor Fiord	-87.10957	77.32436	-81.45119	77.29861			Y
29	Sor Fiord	-87.22732	77.27847	-80.80488	77.24276			Y
30	Okse Bay	-87.14461	77.23384	-80.88482	77.19888			Y
31	Okse Bay	-86.95900	77.18976	-80.91725	77.15417		Y	Y
32	Okse Bay	-87.41053	77.14174	-80.95440	77.10954	Y	Y	Y
33	Okse Bay	-88.41144	77.08742	-80.88911	77.06313	Y	Y	Y
34	Okse Bay	-88.64246	77.03956	-81.07619	77.02108	Y	Y	Y
35	Okse Bay	-88.76076	76.99291	-81.09787	76.97618	Y	Y	Y

Transect	Location	Longitude West End	Latitude West End	Longitude East End	Latitude East End	Flown Apr?	Flown Aug?	Flown Mar?
36	Okse Bay	-88.99815	76.94463	-81.12122	76.93131	Y		Y
37	Okse Bay	-89.28209	76.89543	-86.41150	76.92134			Y
38	Hell Gate	-89.52179	76.84659	-86.78557	76.87461			Y
39	Hell Gate	-89.50189	76.80165	-86.50905	76.83068			Y
40	Hell Gate	-89.46363	76.75700	-86.60392	76.78515			Y
41	Hell Gate	-89.44504	76.71205	-86.70739	76.73954			Y
42	Hell Gate	-89.41607	76.66726	-86.46522	76.69541			Y
43	Hell Gate	-89.58928	76.61929	-85.86393	76.65183			Y
44	Hell Gate	-89.65093	76.57305	-85.89644	76.60664			Y
45	Hell Gate	-89.39647	76.53185	-86.22186	76.56078			Y
46	Hell Gate	-89.37060	76.48701	-85.82347	76.51646	Y		Y
47	Hell Gate	-89.23670	76.44380	-85.59824	76.47151	Y		Y
48	South Cape	-88.69421	76.40607	-84.97882	76.42585	Y		Y
49	South Cape	-88.03612	76.36841	-84.72207	76.38004	Y	Y	Y
50	South Cape	-85.66961	76.33605	-84.45351	76.33392	Y		Y
51	Sydkap Ice Cap East	-84.35379	76.92041	-80.91082	76.88241	Y	Y	Y
52	Sydkap Ice Cap East	-84.03205	76.87364	-81.25458	76.84301	Y		Y
53	Sydkap Ice Cap East	-84.16772	76.82922	-81.29792	76.79847	Y	Y	Y
54	Sydkap Ice Cap East	-84.05603	76.76347	-81.33347	76.75379	Y		Y
55	Sydkap Ice Cap East	-84.40423	76.74004	-81.44148	76.71028	Y	Y	Y
56	Sydkap Ice Cap East	-85.35577	76.69719	-80.83927	76.65471	Y		Y
57	Sydkap Ice Cap East	-85.12552	76.65182	-80.71679	76.60719	Y	Y	Y
58	Sydkap Ice Cap East	-84.96454	76.60639	-80.36300	76.55497	Y		Y
59	Grise Fiord	-84.94742	76.56121	-80.38464	76.51010	Y	Y	Y
60	Grise Fiord	-84.82892	76.51578	-81.38498	76.48313	Y		Y
61	Grise Fiord	-84.79307	76.47054	-82.14173	76.44914	Y	Y	Y
62	Grise Fiord	-83.64674	76.41956	-82.21794	76.40494	Y		Y
63	King Edward Point	-80.32850	76.28240	-80.08014	76.27710			
64	King Edward Point	-80.70348	76.24464	-80.10151	76.23224			
65	King Edward Point	-81.08990	76.20656	-80.44681	76.19423			
66	King Edward Point	-81.06136	76.16078	-80.90309	76.15787			

Transect	Location	Longitude West End	Latitude West End	Longitude East End	Latitude East End	Flown Apr?	Flown Aug?	Flown Mar?
67	Graham Island	-90.94404	77.63906	-90.65056	77.63938			Y
68	Graham Island	-91.20496	77.59320	-90.19494	77.59394			Y
69	Graham Island	-91.20271	77.54789	-90.01941	77.54837			Y
70	Graham Island	-91.21067	77.50254	-89.81838	77.50261			Y
71	Graham Island	-91.20102	77.45724	-89.72927	77.45705			Y
72	Graham Island	-91.18842	77.41196	-89.72520	77.41172			Y
73	Graham Island	-91.15933	77.36670	-89.72157	77.36638			Y
74	Graham Island	-90.99896	77.32173	-89.65881	77.32087			Y
75	Graham Island	-90.75374	77.27676	-89.76529	77.27587			Y
76	Graham Island	-91.23614	77.23054	-89.89893	77.23087			Y
77	Buckingham Island	-91.22981	77.18523	-90.70254	77.18616			Y
78	North Kent Island	-90.51898	76.78474	-89.82273	76.79647			
79	North Kent Island	-90.59282	76.73708	-89.72872	76.75239			
80	North Kent Island	-90.52884	76.69304	-89.71216	76.70780			
81	North Kent Island	-90.44490	76.64939	-90.14237	76.65386			
82	North Kent Island	-90.24349	76.56265	-89.84342	76.57127			
83	North Kent Island	-90.18308	76.51749	-89.74876	76.52355			

Table 5. Transects matched up by latitude from north to south to make lines for analysis.

Transect(s)	Length (below 400 m), km	Length (above 400m), km	Total Length, km
27	16.41		16.41
26	16.85	7.84	24.69
25	17.57	5.84	23.41
24	20.11	6.81	26.92
23-01	34.91	10.73	45.64
22-02	55.20	9.61	64.81
21-03	55.83	18.21	74.04
20-04	68.60	14.85	83.44
19-05	76.34	12.16	88.49
18-06	78.34	19.66	98.00
17-07	69.88	17.75	87.64
16-08	81.20	18.62	99.82
15-09	84.52	6.19	90.70
14-10	90.48	7.22	97.70
13-11	106.85	0.04	106.89
12	140.97	2.80	143.77
28	127.76	2.75	130.51
29	130.09	9.40	139.49
30	107.16	37.68	144.84
31	92.73	52.71	145.45
32	77.24	78.52	155.76
33	79.65	99.91	179.57
34	68.04	102.41	170.45
35	58.64	97.44	156.08
36	52.77	86.78	139.55
37-51	50.80	96.00	146.80
38-52	55.98	76.14	132.12
39-53	54.89	72.83	127.73
40-54	64.19	69.54	133.73
41-55	49.61	55.67	105.27
42-56	53.12	75.92	129.04
43-57	90.89	78.03	168.92
44-58	106.59	65.52	172.12
45-59	104.67	43.03	147.70
46-60	98.19	30.73	128.92
47-61	95.77	26.04	121.82
48-62	86.83	11.98	98.81
49	41.85	4.00	45.85
50	30.00	2.08	32.08

Appendix 4. Alternate population calculations.

Jolly Method II Calculations

In this report, we used a systematic sampling approach to analysis, since we were estimating abundance of a patch population rather than estimating density in a habitat (which varied across the study area). Other systematic aerial surveys have frequently used Jolly's Method II, and estimates derived from both analyses were similar. Population estimates for fixed-width strip sampling using Jolly's Method 2 for uneven sample sizes (Jolly 1969; summarized in Caughley 1977) are derived as follows:

$$\hat{Y} = RZ = Z\frac{\sum_i y_i}{\sum_i z_i}$$

Where $\hat{Y}$ is the estimated number of animals in the population, R is the observed density of animals (sum of animals seen on all transects $\sum_i y_i$ divided by the total area surveyed $\sum_i z_i$), and Z is the total study area. The variance is given by:

$$Var(\hat{Y}) = \frac{N(N-n)}{n}\left(s_y^2 - 2Rs_{zy} + R^2 s_z^2\right)$$

Where N is the total number of transects required to completely cover study area Z, and n is the number of transects sampled in the survey. s_y^2 is the variance in counts, s_z^2 is the variance in areas surveyed on transects, and s_{zy} is the covariance. The estimate $\hat{Y}$ and variance $Var(\hat{Y})$ are calculated for each stratum and summed. The Coefficient of Variation (CV = σ/$\hat{Y}$) was calculated as a measure of precision.

To determine possible stratification regimes for future surveys on southern Ellesmere, we broke the study area into several strata (Table 6) and used Jolly's Method II to calculate population estimates (Table 7, Table 8).

Table 6. Survey strata for southern Ellesmere Island, March 2015.

Stratification	Block ID	Location	Strata Area (km^2)	Base-line[1] (km)	Transect Spacing (km)	Transects Surveyed	Survey Area (km^2)	Percent Covered
Islands	A	South Ellesmere	21260	257	5	62	4896.0	19.9
	C	Graham, Buckingham	1531	59	5	11	296.5	19.3
Elevation	A	South Ellesmere Low (<400 m)	13921	257	5	62	3322.5	20.1
	B	South Ellesmere High (>400 m)	7339	217	5	54	1573.6	19.5
	C	Graham, Buckingham	1531	59	5	11	296.5	19.3
Bjorne	A	South Ellesmere	18988	257	5	52	4439.1	19.8
	B	Bjorne Peninsula	2272	51	5	10	456.9	20.1
	C	Graham, Buckingham	1531	59	5	11	296.5	19.3
Case and Ellsworth	I	South Ellesmere	10029	124	5	31	2657.9	26.5
	III	East Vendom	2865	88	5	17	576.0	20.1
	IV	Bjorne	3397	82	5	16	685.2	20.2
	V	Southwest Ellesmere	4969	94	5	18	977.0	19.7
	C[2]	Graham, Buckingham	1531	59	5	11	296.5	19.3

[1] Baseline was the number of possible transects at 1-km wide and parallel to lines of longitude, to cover the entire strata.

[2] For caribou estimates, Graham/Buckingham islands were both included and excluded, but no muskoxen were seen on transect there.

Table 7. Abundance estimates (Jolly 1969 Method II) for muskoxen on southern Ellesmere Island, March 2015, based on several stratification regimes. N is the total number of transects required to completely cover study area Z, n is the number of transects sampled in the survey covering area z, y is the observed caribou/muskoxen, Y is the estimated caribou/muskoxen with variance Var(Y). The coefficient of variation (CV) is also included.

	Stratum	**Y**	**Var(Y)**	**n**	**Z (km^2)**	**z (km^2)**	**N**	**y**	**Density (per km^2)**
Islands CV=0.255	A	2604	441085	62	21260	5192.5	257	636	0.122
	C	0	0	11	1531	296.5	59	0	0
	Total	2604	441085	73	22791		316	636	0.122
Elevation CV=0.171	A	2392	219697	62	13921	3322.5	257	571	0.172
	B	303	8174	54	7339	1573.5	217	65	0.041
	C	0	0	11	1531	296.5	59	0	0
	Total	2696	227871	127	22791	5192.5	533	636	0.122
Bjorne CV=0.337	A	2665	594526	52	18988	4439.1	257	623	0.140
	B	19	3498	10	22712	1573.5	51	13	0.008
	C	0	0	11	1531	296.5	59	0	0
	Total	2684	598025	73	22791	6309.1	367	636	0.101
Case and Ellsworth CV=0.229	I	838	99075	31	10029	2657.9	124	222	0.084
	III	1055	241963	17	2865	576.0	88	212	0.368
	IV	149	8523	16	3397	685.2	82	30	0.044
	V	875	51843	18	4969	977.0	94	172	0.176
	Total	2916	401403	82	21260	4896.0	388	636	0.130

Table 8. Peary caribou population estimates for caribou on southern Ellesmere Island, March 2015, based on several stratification regimes. N is the total number of transects required to completely cover study area Z, n is the number of transects sampled in the survey covering area z, y is the observed caribou/muskoxen, Y is the estimated caribou/muskoxen with variance Var(Y). The coefficient of variation (CV) is also provided.

	Stratum	**Y**	**Var(Y)**	**n**	**Z (km^2)**	**z (km^2)**	**N**	**y**	**Density (per km^2)**
Islands CV=0.536	A	113	4822	62	21260	4896.0	257	26	0.005
	C	52	2343	11	1531	296.5	59	10	0.034
	Total	165	7164	73	22791	5192.5	316	36	0.007
Elevation CV=0.505	A	109	4681	62	13921	3322.5	257	26	0.008
	B	0	0	54	7339	1573.5	217	0	0
	C	57	2327	11	1531	296.5	59	10	0.037
	Total	166	7009	127	22791	5192.5	533	36	0.007
Bjorne CV=0.659	A	13	173	52	18988	4439.1	257	23	0.001
	B	33	7170	10	22712	1573.5	51	3	0.015
	C	57	0	11	1531	296.5	59	10	0.037
	Total	103	7343	73	22791	6309.1	367	36	0.006
Case and Ellsworth CV=0.786	I	0	0	31	10029	2657.9	124	0	0
	III	0	0	17	2865	576.0	88	0	0
	IV	129	7883	16	3397	685.2	82	26	0.038
	V	0	0	18	4969	977.0	94	0	0
	Total	129	7883	82	21260	4896.0	388	26	0.005
Case and Ellsworth (+Graham) CV=0.640	I	0	0	31	10029	2657.9	124	0	0
	III	0	0	17	2865	576.0	88	0	0
	IV	129	7883	16	3397	685.2	82	26	0.038
	V	0	0	18	4969	977.0	94	0	0
	C	52	2343	11	1531	296.5	59	10	0.034
	Total	181	10225	93	22791	5192.5	447	36	0.007

Stratified Systematic Survey Calculations

Following Cochran (1977), the abundance estimate for a systematic survey is given by:

$$\hat{Y} = \frac{S}{w} \times \sum n_i$$

Where $\hat{Y}$ is the population estimate, *S* is the transect spacing (5 km), *w* is the transect width (1 km), and n_i is the total number of animals observed on transect *i*, the sum of which is all animals observed on *I* transects in the survey. The configuration of the study area may mean that the actual sampling fraction (proportion of the study area that is surveyed) varies, which was partly why Cochran's ratio estimator was used instead, and why the estimate varied from 3180 muskoxen and 180 caribou between methods and stratification regimes. The variance is based on the sum of squared differences in counts between consecutive transects:

$$Var(\hat{Y}) = \frac{\frac{S}{w} \times \left(\frac{S}{w} - 1\right) \times I}{2 \times (I - 1)} \times \sum (n_i - n_{i-1})^2$$

Table 9. Abundance estimates for a stratified systematic survey (Cochran 1977) of muskoxen on southern Ellesmere Island, March 2015. *I* is the number of transects sampled.

	Strata	Estimated Abundance Y	Var(Y)	I	Transect Spacing S (km)	Transect Width w (km)	Observed Individuals y	Density (per km^2)
All CV=0.223		3180	331785	73	5	1	636	0.150
Elevation CV=0.172	A	2855	282070	62	5	1	571	0.205
	B	325	17321	54	5	1	65	0.044
	Total	3180	299390	136			636	0.150
Bjorne CV=0.181	A	3115	327264	52	5	1	623	0.164
	B	65	3756	10	5	1	13	0.029
	Total	3180	331019	62			636	0.150
Case and Ellsworth CV=0.184	I	1110	83886	31	5	1	222	0.111
	III	1060	199166	17	5	1	212	0.370
	IV	150	9771	16	5	1	30	0.044
	V	860	50781	18	5	1	172	0.173
	Total	3180	343603	82			636	0.150

Table 10. Abundance estimates for a stratified systematic survey (Cochran 1977) for Peary caribou on southern Ellesmere Island, March 2015. *I* is the number of transects sampled.

	Strata	Estimated Abundance Y	Var(Y)	I	Transect Spacing S (km)	Transect Width w (km)	Observed Individuals y	Density (per km^2)
All CV=0.359		180	4177	73	5	1	36	0.008
Elevation CV=0.367	A	130	2155	62	5	1	26	0.009
	B	0	0	54	5	1	0	0
	C	50	2200	11	5	1	10	0.033
	Total	180	4355				36	0.008
Bjorne CV=0.374	A	15	184	52	5	1	3	0.001
	B	115	2156	10	5	1	23	0.051
	C	50	2200	11	5	1	10	0.033
	Total	180	4539	73			36	0.008
Case and Ellsworth CV=0.366	I	0	0	31	5	1	0	0
	III	0	0	17	5	1	0	0
	IV	130	2261	16	5	1	26	0.038
	V	0	0	18	5	1	0	0
	Total	130	2261	82			26	0.006
Case and Ellsworth (+Graham) CV=0.371	I	0	0	31	5	1	0	0
	III	0	0	17	5	1	0	0
	IV	130	2261	16	5	1	26	0.038
	V	0	0	18	5	1	0	0
	C	50	2200	11	5	1	10	0.033
	Total	180	4461	93			36	0.008

Appendix 5. Daily flight summaries for south Ellesmere survey flown by Twin Otter, March 2015.

Table 11. Summary by day of survey flights and weather conditions for March 2015 Peary caribou and muskox survey, southern Ellesmere Island.

Date	Time Up	Time Down	Time Up 2	Time Down 2	Flying Time	Transect Time	Area	Comment
18-Mar-15	12:30	14:20			1.83	0	Bjorne Peninsula	-27°C, clear, some wind to east around Vendom Fd, otherwise calm
19-Mar-15	9:20	14:35	15:10	19:34	9.65	6.13	Graham and Buckingham Islands	-20°C, clear, almost no wind
20-Mar-15	12:10	16:30			4.33	3.78	Hell Gate and Grise Fiord	-28°C, some wind by Hell Gate and east, 15 kph +catabatics at ice sheets
21-Mar-15	11:30	15:40			4.17	3.63	Hell Gate to Skaare Fiord	-28°C, clouds around Hell Gate, wind about 15 kph
22-Mar-15					0	0	Grounded	Low cloud prevented flying
23-Mar-15	9:50	15:32	16:12	20:00	9.5	8.28	West of Sydkap Ice Cap and north of Grise Fiord	-25°C, 50% cloud around Grise Fiord to 100% cloud in east and fog over Hell Gate, fairly calm with more wind from east later in the day at east/west ends of study area
24-Mar-15	9:40	15:05	15:40	20:30	10.25	8.15	Sydkap ice cap north to Sor Fiord	-29°C, clear, some wind on east side of study area
25-Mar-15	9:18	13:15			3.95	2.58	Vendom Fiord	-28°C, sunny clear with scattered low cloud/fog around Makinson Inlet and along east coast (also wind/mechanical turbulence)
26-Mar-15	9:38	13:00	15:08	17:38	5.87	3.05	Sor Fiord to Makinson Inlet; Hell Gate	-30°C, clear with scattered cloud wind up to 15 kph but mostly calm, some fog around Hell Gate

Pilots - Rob Bergeron, John Sidwell; Navigator - Morgan Anderson

Observers:
Mar 19 – Morgan Anderson, Eepa Ootoovak, Scott Darroch
Mar 20 – Morgan Anderson, Aksakjuk Ningiuk
Mar 21 – Morgan Anderson, Olaf Killiktee, Imooshie Nutuqajuk, Mark Akeeagok
Mar 23 – Morgan Anderson, Simon Singoorie, Olaf Killiktee, Frankie Noah
Mar 24 – Morgan Anderson, Aksakjuk Ningiuk, Eepa Ootoovak, Simon Singoorie, Olaf Killiktee
Mar 25 – Morgan Anderson, Frankie Noah, Jon Neely, Frank Holland
Mar 26 – Morgan Anderson, Jopee Kiguktak, Scott Darroch

Appendix 6. Incidental wildlife observations.

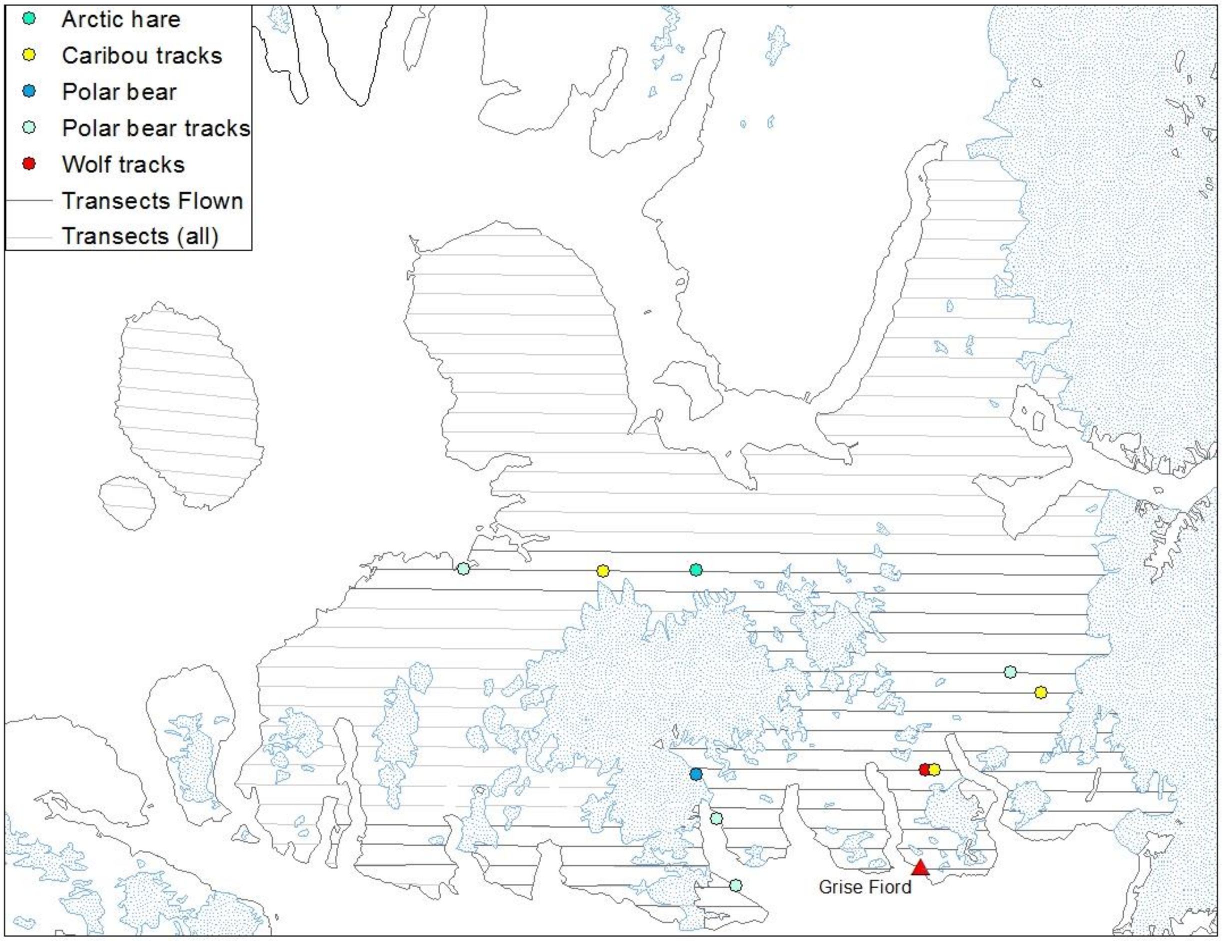

Figure 12. Incidental observations April 12-24, 2014 during a caribou/muskox survey of southern Ellesmere Island by Twin Otter.

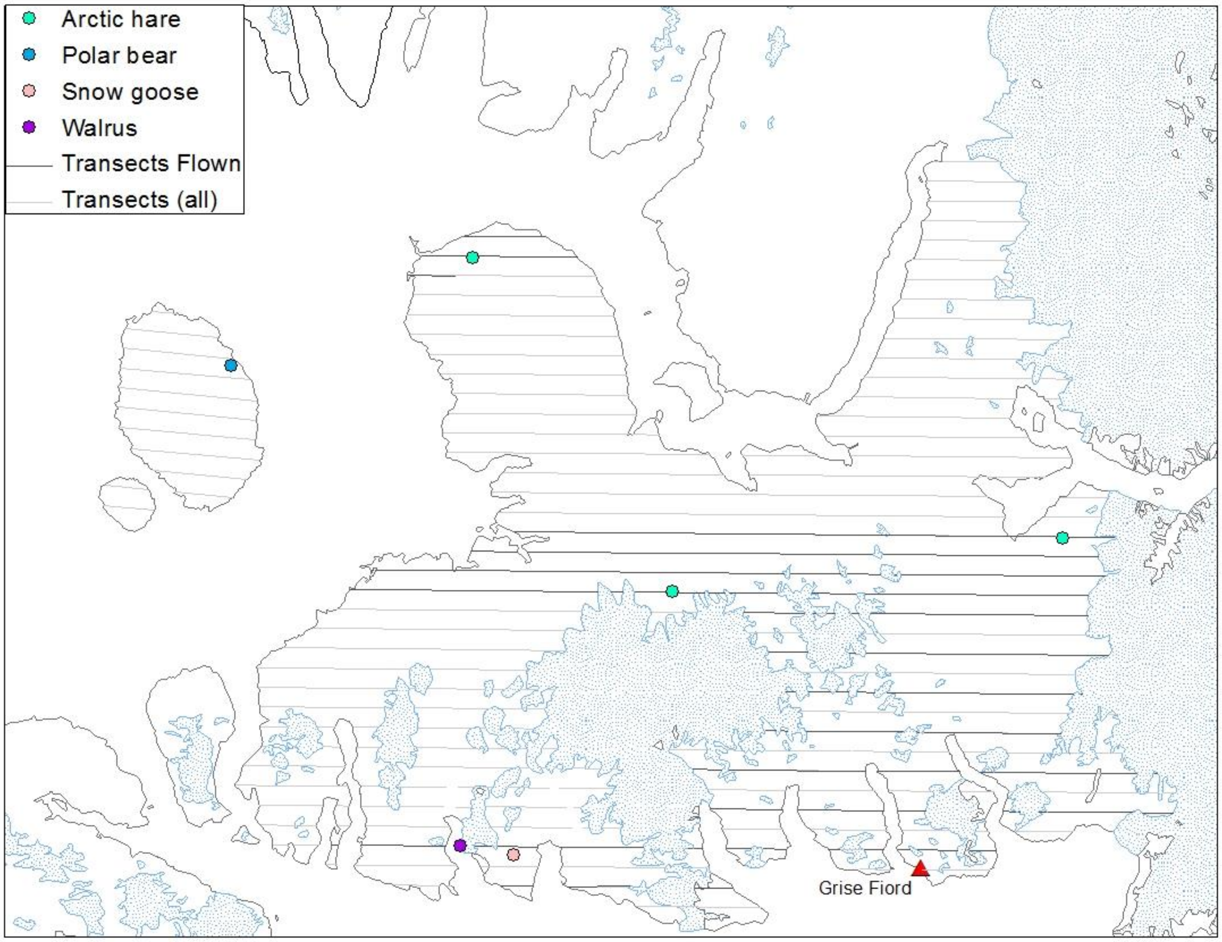

Figure 13. Incidental observations August 13 and 15, 2014 during a caribou/muskox survey of southern Ellesmere Island by Twin Otter.

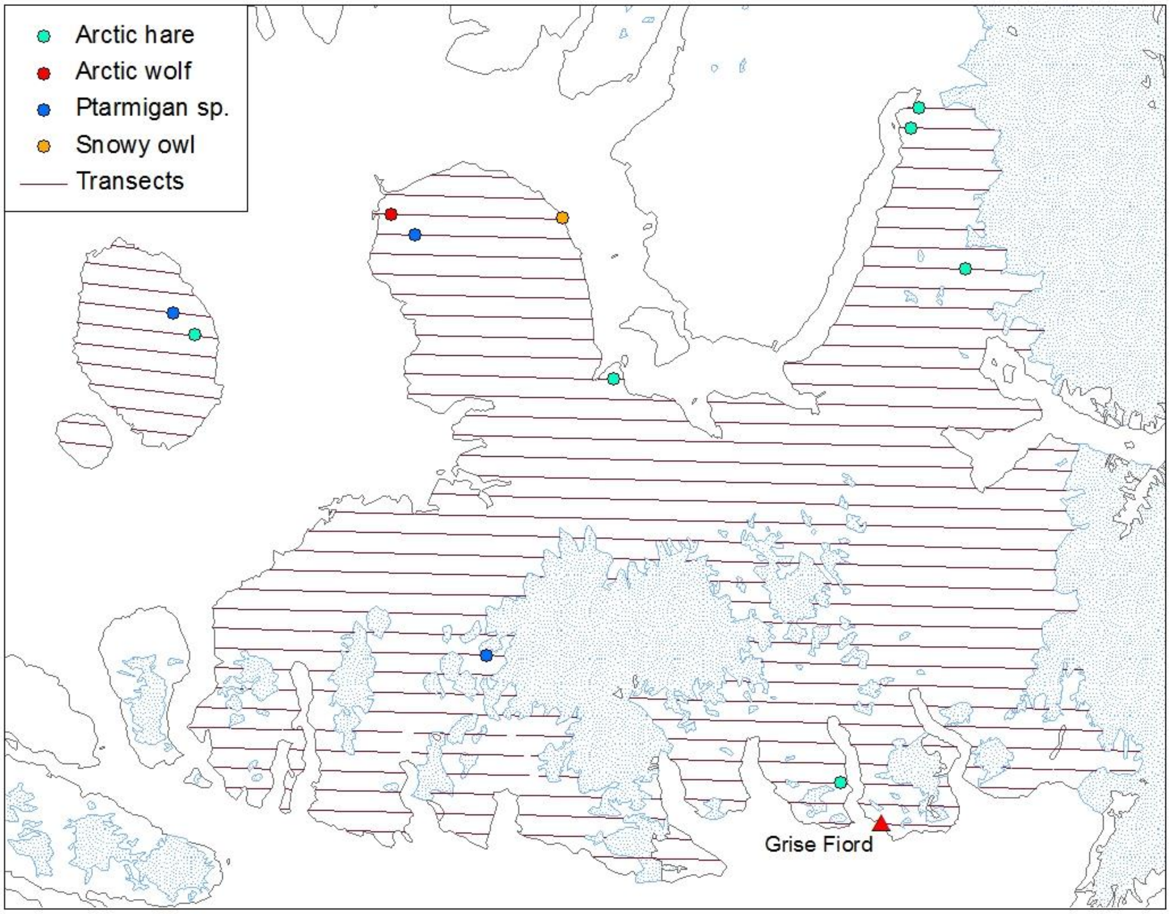

Figure 14. Incidental observations March 19-26, 2015 during a caribou/muskox survey of southern Ellesmere Island by Twin Otter. The hare observations at Baumann Fiord and north of Makinson Inlet were large herds. Two adult wolves were seen on Bjorne Peninsula.