DISTRIBUTION AND ABUNDANCE OF PEARY CARIBOU (*Rangifer tarandus pearyi*) AND MUSKOX (*Ovibos moschatus*) ON CENTRAL ELLESMERE ISLAND, MARCH 2017

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Summary

We flew a survey of central Ellesmere Island (Fosheim Peninsula, Raanes Peninsula, and Svendsen Peninsula), Nunavut, between March 8th and 20th, 2017 to update the regional abundance estimate for Peary caribou (*Rangifer tarandus pearyi*) and muskox (*Ovibos moschatus*). This survey was intended to be the second portion of three consecutive surveys that together would cover the entirety of Ellesmere Island. The southern portion was surveyed in 2015 and the northern portion was planned to be surveyed in 2018, however the survey did not occur due to logistical and financial constraints. Before 2017 the most recent survey of central Ellesmere Island was in May 2006 (which included northern Ellesmere Island).

Muskoxen were most abundant north of the Sawtooth Range on the Fosheim Peninsula with moderate densities of muskoxen found on the northern portion of Raanes Peninsula and the southern portion of Svendsen Peninsula. A total of 2,153 muskoxen were observed, and we estimated 6,902 ± SE 1,036 (95% confidence interval [CI] = 5,134-9,278, coefficient of variation [CV] = 15%) across central Ellesmere Island. The previous estimate for the area (from 2006) was 8,115 (95% CI 6,632 – 9,930) but also included northern Ellesmere Island. A separate population estimate for central Ellesmere Island was not calculated from the 2006 survey.

Fourteen Peary caribou were seen on transect during the survey, and we estimated a population of 32 ± SE 25 (95% CI = 8-127, CV = 79%). The few observations provided for a very imprecise estimate. Peary caribou were observed on the north portion of Raanes and Svendsen Peninsulas, and one group was seen at the south end of Fosheim Peninsula.

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ᖃᖓᑕᓚᐅᖅᑐᒍᑦ ᖃᐅᔨᓴᖅᓱᑕ ᕿᑎᖓᓂ ᐊᐅᓱᐃᑦᑑᑉ ᕿᑭᖅᑖᓗᐊ (Fosheim Peninsula, Raanes Peninsula, and Svendsen Peninsula), ᓄᓇᕗᑦ, ᐊᑯᓐᓂᖓᓂ ᒫᑦᓯ 8th ᐊᒻᒪ 20th, 2017 ᓄᑖᙳᕈᓇᐊᖅᑎᓪᓗᒍ ᓄᓇᓕᖓᓂ ᐊᕝᕕᒃᑐᖅᓯᒪᓂᐅᔪᓂ ᐱᑕᖃᑦᑎᐊᕐᓂᖓᑕ ᓇᓚᐅᑦᑖᖅᑕᑦ ᖁᑦᑎᒃᑑᑉ ᑐᑐᖏᑦ (*Rangifer tarandus pearyi*) ᐊᒻᒪ ᐅᒥᖕᒪᑦ (*Ovibos moschatus*). ᑖᓐᓇ ᖃᐅᔨᓴᕐᑎ ᑐᕋᖓᖃᓚᐅᖅᑐᖅ ᐱᖃᑎᒋᓗᓂᐅᒃ ᐃᓚᖓᑕ ᐱᖓᓲᔪᑦ ᖃᐅᔨᓴᕐᑎᓂᑦ ᑲᑎᙵᓗᑎᒃ ᑕᒪᒃᑭᖅᑎᑦᑎᓇᔭᖅᑐᖅ ᐊᐅᓱᐃᑦᑑᑉ ᕿᑭᖅᑖᓗᐊᓂᒃ. ᓂᕆᖅᐸᓯᐊᑕ ᐃᓚᖓ ᖃᐅᔨᓴᖅᑕᐅᓪᓗᓂ 2015-ᖑᑎᓪᓗᒍ ᐊᒻᒪ ᐅᐊᖕᓇᖅᐸᓯᐊᑕ ᐃᓚᖓ ᐱᕙᕇᔭᖅᑕᐅᓪᓗᓂ ᖃᐅᔨᓴᖅᑕᐅᓂᐊᕐᓂᕐᒧᑦ 2018-ᒥ, ᑭᓯᐊᓂ ᖃᐅᔨᓴᖅᑐᖃᓚᐅᙱᑦᑐᖅ ᐱᔾᔪᑎᒋᓪᓗᒍ ᐱᑕᕇᔾᔪᑎᑦ ᑮᓇᐅᔭᓄᓪᓗ ᓈᒻᒪᙱᑕᐅᕈᑎᓄᑦ. 2017−ᖑᓚᐅᙱᑎᓪᓗᒍ ᖃᓂᒑᖑᔪᒃᑯᑦ ᖃᐅᔨᓴᕐᑎᑦ ᕿᑎᖓᓂ ᐊᐅᓱᐃᑦᑑᑉ ᕿᑭᖅᑖᓗᐊᓂ ᐊᑐᖅᓱᓂ ᒪᐃ 2006 (ᐃᓚᐅᑎᑦᑎᓪᓗᓂ ᐅᐊᖕᓇᖅᐸᓯᐊᓂᒃ ᐊᐅᓱᐃᑦᑑᑉ ᕿᑭᖅᑖᓗᐊᓂᒃ).

ᐅᒥᖕᒪᑦ ᐱᑕᖃᓛᖑᓚᐅᖅᑐᑦ ᐅᐊᖕᓇᖓᓂ Sawtooth Range ᑕᐃᑲᓂ Fosheim Peninsula ᓈᒻᒪᒃᓱᑎᒃ ᖃᔅᓯᐅᓂᖏᑦ ᐅᒥᖕᒪᑦ ᓇᓂᔭᐅᔪᑦ ᐅᐊᖕᓇᖅᐸᓯᐊᑕ ᐃᓚᖓᓂᒃ Raanes Peninsula ᐊᒻᒪ ᓂᕆᖅᐸᓯᐊᑕ ᐃᓚᖓᓂ Svendsen Peninsula. ᑲᑎᕐᓗᒋᑦ 2,153 ᐅᒥᖕᒪᑦ ᑕᑯᔭᐅᓚᐅᖅᑐᑦ, ᓇᓚᐅᑦᑖᕐᓗᑎᒍᓪᓗ 6,902 ± SE 1,036 (95% ᓇᓗᓇᙱᕐᓗᑎᒃ ᐊᒡᒍᓂᓕᓈᑦ [CI] = 5,134-9,278, ᐊᒥᓱᕈᕐᑕᕐᓂᖏᑦ ᐊᔾᔨᒌᙱᕐᓗᑎᒃ [CV] = 15%) ᕿᑎᖓᓂ ᐊᐅᓱᐃᑦᑑᑉ ᕿᑭᖅᑖᓗᐊᓂ. ᓇᓚᐅᑦᑖᖅᑕᐅᓛᖅᓂᑯ ᐊᕙᑎᖓᓂᒃ (ᑕᐃᑲᙵᑦ 2006) ᐃᒪᓐᓇᐅᓚᐅᖅᑐᖅ 8,115 (95% ᓇᓗᓇᙱᕐᓗᑎᒃ ᐊᒡᒍᓂᓕᓈᑦ 6,632 – 9,930) ᑭᓯᐊᓂ ᐃᓚᐅᑎᑦᑎᖕᒥᓪᓗᑎᒃ ᐅᐊᖕᓇᖅᐸᓯᐊᓂ ᐊᐅᓱᐃᑦᑑᑉ ᕿᑭᖅᑖᓗᐊᓂᒃ. ᑲᑎᙵᙱᑕᖓ ᖃᔅᓯᐅᓂᖏᓐᓂᒃ ᓇᓚᐅᑦᑖᖅᑕᖅ ᕿᑎᖓᓂᒃ ᐊᐅᓱᐃᑦᑑᑉ ᕿᑭᖅᑖᓗᐊᓂ ᐃᓚᐅᑎᑕᐅᙱᕐᓗᓂ ᓈᓴᐅᓯᓇᔭᐅᓂᖓᓂᒃ ᑕᐃᑲᙵᑦ 2006 ᖃᐅᔨᓴᕐᑎᓂᒃ.

14 ᖁᑦᑎᒃᑑᑉ ᑐᒃᑐᖏᑦ ᑕᑯᔭᐅᓪᓗᑎᒃ ᐃᑳᖅᕕᖕᓂ ᖃᐅᔨᓴᖅᑎᓪᓗᒋᑦ, ᓇᓚᐅᑦᑖᕐᓗᑎᒍᓪᓗ ᖃᔅᓯᐅᓂᖏᓐᓂᒃ 32 ± SE 25 (95% ᓇᓗᓇᙱᕐᓗᑎᒃ ᐊᒡᒍᓂᓕᓈᑦ = 8-127, ᐊᒥᓱᕈᕐᑕᕐᓂᖏᑦ ᐊᔾᔨᒌᙱᕐᓗᑎᒃ = 79%). ᐅᓄᙱᑦᑐᑦ ᑕᑯᔭᕐᓂ ᐱᑎᑦᑎᓪᓗᑎᒃ ᑕᐃᒪᐃᓪᓕᑦᑖᓗᐊᙱᑦᑐᓂᒃ ᓇᓚᐅᑦᑖᕐᓂᕐᓂᒃ. ᖁᑦᑎᒃᑑᑉ ᑐᒃᑐᖏᑦ ᑕᑯᔭᐅᔪᑦ ᐅᐊᖕᓇᖓᑕ ᐃᓚᖓᓂᒃ Raanes ᐊᒻᒪ Svendsen Peninsulas, ᐊᒻᒪ ᐊᑕᐅᓯᕐᒥ ᑲᑎᙵᔪᓂ ᑕᑯᓪᓗᑎᒃ ᑲᓇᖕᓇᖓᑕ ᐃᓱᐊᓂ Fosheim Peninsula.

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Introduction

Caribou (*Rangifer tarandus*) and muskoxen (*Ovibos moschatus*) are the largest herbivores that inhabit the Canadian Arctic Archipelago. Peary caribou (*R. t. pearyi*) is the most northern subspecies of caribou and occurs almost entirely within the islands of the Canadian Arctic Archipelago, including the unglaciated portions of Ellesmere Island. They are smaller, lighter in colour, and have a shorter face then barren-ground caribou (*R. t. groenlandicus*). In February 2011, Peary caribou was listed as Endangered under the federal *Species at Risk Act* (SARA). In November 2015, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) re-assessed Peary caribou as Threatened (COSEWIC 2015). As mandated under SARA, a Recovery Strategy is currently under development, and the lack of up-to-date population information has been consistently identified as a knowledge gap, particularly for the northern part of Peary caribou range including Ellesmere Island. Since 2015, the Government of Nunavut has undertaken aerial surveys of Ellesmere Island to help address this knowledge gap and inform designation of critical habitat.

Surveys of Peary caribou on Ellesmere Island have been performed occasionally over the past 50 years. The first complete survey occurred from July 30 – August 11, 1961, and the survey estimated 200 animals on the island (Tener 1963). Even at the time, Tener (1963) considered this estimate a 'best guess' and an extrapolation based on relatively few observations and incomplete coverage of the survey area due to weather. A few other surveys have been conducted since then with varying degrees of coverage. During the period from May 8 – 15, and July 4 – 7 of 1973, Riewe flew an unsystematic survey primarily north of Sydkap Ice Cap, along Baumann and Vendom Fiords and on Svendsen, Raanes, and Bjorne peninsulas. This survey reported a minimum count of 150 Peary caribou (Riewe 1976). Following a request from the Iviq (Grise Fiord) Hunters and Trappers Association (HTA), the southern portion of Ellesmere Island (including the Svendsen Peninsula) was surveyed from July 17 – 23, 1989. This survey provided an estimate of 89 ± SE 31 caribou (Case and Ellsworth 1991). Unsystematic surveys of central Ellesmere in June 1995 returned a minimum count of 38 caribou (Gauthier 1996). Between May 4 – 30, 2005, the Government of Nunavut (GN) systematically surveyed southern Ellesmere Island and Graham Island, and estimated 219 caribou (95% CI=109-244) in the area. The GN survey continued the next year from April 6 to May 22, 2006, over the central and northern part of Ellesmere Island, providing an estimate of 803 caribou (95%CI = 531-2,107; Jenkins *et al.* 2011). From March 19 – 26, 2015 the GN again systematically surveyed the southern Ellesmere Island study area and estimated 183 ± SE 128 caribou (Anderson and Kingsley 2017).

Peary caribou and muskoxen are sympatric across most of their range and they are often surveyed together to maximize limited monitoring resources. When Tener (1963) surveyed Ellesmere Island in 1961, he estimated 4,000 muskoxen on the island, although again, this was considered a best guess and likely an underestimate. The unsystematic survey in 1973 conducted by Riewe (1973) estimated 1,060 muskoxen in the area north of Sydkap Ice Cap and on the Bjorne Peninsula, Raanes Peninsula, Svendsen Peninsula, Graham Island, and Buckingham Island. The July 1989 survey of southern Ellesmere, including Svendsen Peninsula, by Case and Ellsworth (1991) estimated 2,020 ± SE 285 muskoxen. During the May 2005 survey of southern Ellesmere Island, the GN estimated 456 muskoxen (95% CI = 312-670, Jenkins *et al.* 2011). Along with the low numbers, 40 muskox carcasses were also observed (Jenkins *et al.* 2011) and residents of Grise Fiord recalled freezing rain and ground-fast ice in the fall/winter of 2005 (Anderson and Kingsley 2017). In April and May 2006, the central and northern portions of Ellesmere Island were surveyed by the GN, and estimated 8,115 muskoxen (95%CI=6,632-9,930; Jenkins *et al.* 2011). The survey of southern Ellesmere Island in March 2015 by the GN estimated 3200 ± SE 602 (CV=19%) muskoxen (Anderson and Kingsley 2017), indicating strong recovery from the low numbers observed in 2005.

Peary caribou and muskoxen are very important to the community of Grise Fiord, the sole community that harvests on Ellesmere Island (Anderson 2015). Community members have relied on muskoxen and caribou on the island for sustenance and cultural persistence since the community was established in 1953. Monitoring caribou and muskox population trends (using both scientific approaches and Inuit Qaujimajatuqangit) around the community is therefore especially important (Anderson and Kingsley 2015).

Logistics and cost have prevented a survey of all of Ellesmere Island since 1961, and even in 1961 parts of the island could not be flown due to weather. Adverse weather still prevents survey completion some years - the 2015 GN survey of southern Ellesmere took three attempts before the survey was successfully completed (Anderson and Kingsley 2015). Costs and logistic constraints meant that rather than flying the entire 2006 study area in one year, central and northern Ellesmere Island were split into two study areas.

Study Area

The March 2017 aerial survey was flown to correspond with the west – east orientation of the transect lines from the 2006 survey of central and northern Ellesmere Island (Jenkins *et al.* 2011). The study area included the Raanes Peninsula, Svendsen Peninsula, Fosheim Peninsula, as well as the Bache and Knud Peninsulas (area north of Prince of Wales Mountains and south of the Agassiz Ice Cap). However, due to weather and logistic constraints, the Bache and Knud Peninsula transects were not able to be surveyed.

Central Ellesmere Island has a natural division with southern Ellesmere where Svendsen Peninsula and the head of Vendom Fiord meet the extensive ice fields of the Prince of Wales Mountains. Another constriction in unglaciated habitat lies along Canon Fiord at the Agassiz Ice Cap, which marked the northern boundary of our study area (Figure 1). Much of the area is very mountainous with valleys and a few plateaus. The Fosheim Peninsula is divided by the southwest-northeast trending Sawtooth Mountains, and the Raanes and Svendsen peninsulas are mostly rugged with some wide river valleys.

During March 2017 the average daily temperatures were between -37.1°C and -32.0°C with 5-7 cm of snow on the ground at Eureka. The historical (1981-2010) March daily average temperature is -36.8°C with 15 cm average snow depth at the Eureka Weather Station.

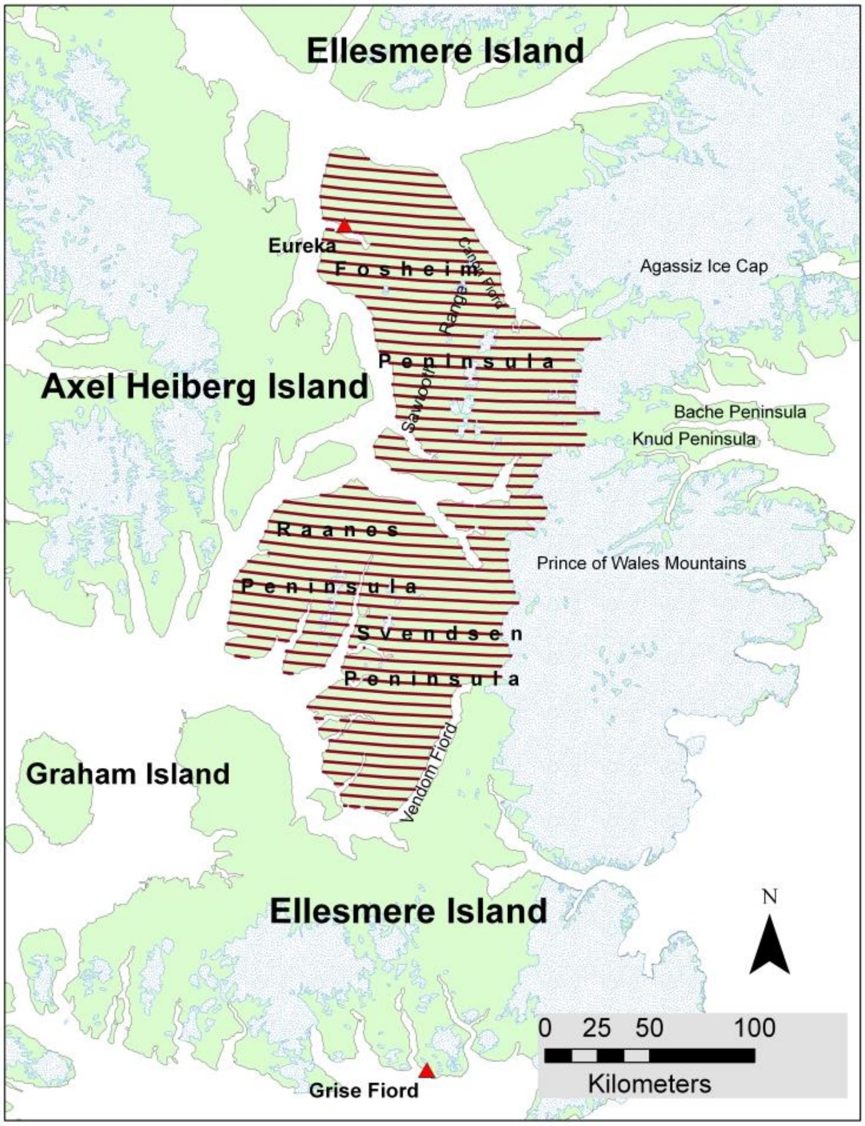

Figure 1. Central Ellesmere Island study area and survey transects.

Methods

Aerial Survey

Fixed-width transect aerial surveys are a standard way to monitor ungulate populations and have been used in the High Arctic since 1961. For this survey, we marked distance bins on the wing struts to allow for both distance sampling (Buckland *et al.* 2001, Thomas *et al.* 2009) as well as standard fixed-width strip transect sampling methods (Jolly 1969, Caughley 1977, Cochran 1977, Kingsley and Smith 1981). The central Ellesmere survey transects (n = 62) were flown using a fixed-wing de Havilland Twin Otter aircraft parallel to lines of latitude 5 km apart, at 180km/h. Surveys were flown at 400 feet above ground level, set with a radar altimeter. In rugged terrain this was adhered to as closely as crew safety and aircraft capabilities allowed. Surveys were flown only on days that provided good visibility and sufficient daylight due to the latitude and time of year of the survey.

The survey crew consisted of a pilot, co-pilot, navigator/recorder, and two observers on each side of the aircraft (four total) to enable a double dependent observer platform. Occasionally the recorder also functioned as an observer. The double observer platform has been effective on other caribou surveys in Nunavut and the Canadian Arctic Archipelago (e.g., Campbell *et al.* 2012, Anderson 2014). As with the most recent southern Ellesmere survey (Anderson and Kingsley 2015), all observers could communicate and the front and rear observations for each side were combined. Using this approach, a primary observer, seated in the first seat, called out all caribou or muskox groups observed to the secondary observer (seated in the back seat). The secondary observer then identified whether they observed those groups and any additional groups not sighted by the primary observer. Compared to a single observer, this method provides more accurate estimates of group size. Ideally, the observers switched seats over the course of the survey (Cook and Jacobsen 1979) and this method allows for the estimation of detection probabilities for observers.

Five distance bins were established on each side of the aircraft: 0-200 m, 201-400 m, 401-600 m, 601-1, 000 m, and 1,001-1,500 m. The bin intervals were derived from guidelines for bin intervals for aerial surveys (Buckland *et al.* 1993) which had been successfully implemented in similar survey conditions on the Baffin Island caribou survey (Campbell *et al.* 2015). The bins were marked on the struts of the aircraft following methods described by Norton-Griffiths (1978) and Buckland et al (1998). Strut markings were positioned using:

$$w = W(h/H)$$

where W is the strip width, H is the flight height, h is the observers eye level when the plane is on level ground and w is the measured distance on the ground to position the wing strut marks (Figure 2).

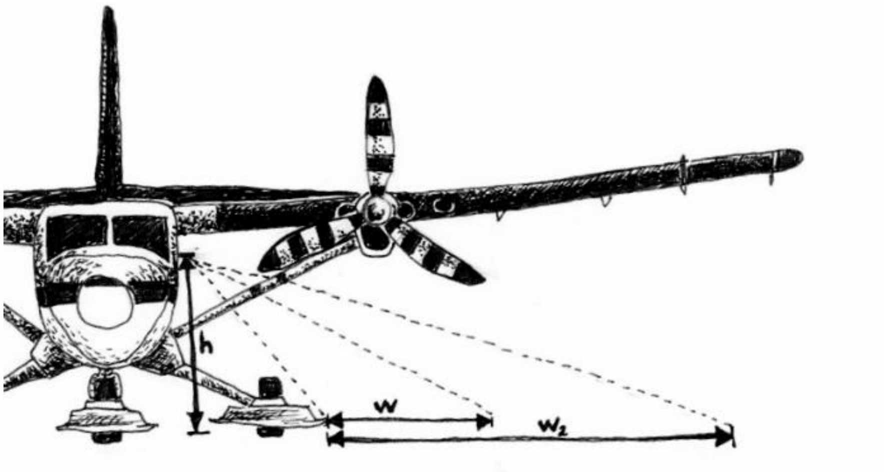

Figure 2: Derivation of wing strut marks for strip boundaries, where *w* and w_2 are calculated as described in the text, *h* is measured, and dotted lines indicate observer sightlines as modified from Norton-Griffiths (1978), drawing from Anderson (2016).

Observation of wildlife and tracks were recorded on a handheld Garmin global positioning system (GPS) (Garmin Montana 650) which also recorded the flight path. To reduce disturbance to animals we did not make multiple passes with the aircraft. During the single pass made it was not always possible to determine the sex and age of all animals in a group, and so we did not determine age or sex classes for Peary caribou, and only differentiated between adult and short-yearling (10-month old calves) muskoxen. If the group of muskoxen huddled quickly it was also difficult to determine group size and underestimates were likely in some cases. We downloaded GPS tracks and waypoints using DNR Garmin and saved them as ESRI shapefiles. Observation data were entered and manipulated in Microsoft Excel and ArcMAP (ESRI, Redlands, CA).

The Fosheim, Raanes, and Svendsen peninsulas of Ellesmere Island were surveyed from March 8 to March 20, 2017 with 62 transect lines (Figure 1). Although small ice caps in the middle of transects were flown, no tracks or animals were seen and the ice cap area was excluded from the analysis. We did not stratify the area based on predicted densities of caribou and muskoxen, but did divide the study area into discrete areas based on geographic features (i.e. large peninsulas) to identify differences in distribution and abundance for Peary caribou and muskoxen (Table 1).

Table 1. Survey strata used in central Ellesmere Island caribou survey

Location	Strata ID	Strata Area (km^2)	Base-line (km)	Mean Transect Length (km)	Total Transect Length (km)	Transect spacing (km)	Number of Transects
Fosheim Peninsula	CEI-1	11543	132	85	2624	5	31
Raanes and Svendsen Peninsulas	CEI-3	13244	319	74	2282	5	31

Abundance estimation

We used a combined distance sampling and mark-recapture approach to estimate abundance for survey strata on Ellesmere Island. The approach involved using mark-recapture to estimate the probability of detection of caribou at zero distance from the blindspot marker (the plane's wheel), and distance sampling methods to estimate the decrease in probability of detection at greater distances from the plane under the assumption of point independence (Buckland *et al.* 2010). This approach ensured a more robust estimate than using distance sampling methods alone, which assume that the probability of detection of groups at zero distance from the plane is 1 (Borchers *et al.* 1998, Buckland *et al.* 2004, Laake *et al.* 2008a, Laake *et al.* 2008b, Buckland *et al.* 2010, Laake *et al.* 2012).

We used the program *Distance* (Buckland *et al.* 1993, Buckland *et al.* 2004, Thomas *et al.* 2009) to format the data which was then ported into the MRDS package (Laake *et al.* 2012) in program *R* (R Development Core Team 2009). The mark-recapture/distance sampling analysis had two phases. In the first phase, we fit competing distance sampling models with mark-recapture covariates held constant. We used information-theoretic model selection methods to determine which model had the most support (Burnham and Anderson 1992). Once a distance sampling model was selected, we used it to compare removal double observer mark-recapture models under the point independence assumption. Using this approach provided a seamless way to model both sources of variation. We produced abundance estimates for the entire study area for each model formulation to assess the sensitivity of estimates to model specification.

The main covariates we used in the analysis are listed in Table 2. The observer covariate corresponds to each primary observer in the survey. The distance covariate was mainly used in the mark-recapture analysis given that it is explicitly considered in the distance analysis. Covariate predictions were assessed graphically to evaluate biological validity and model fit.

Table 2. Distance and mark-recapture model covariates

Covariate	Acronym	Type
Observer	ob1-3	binary
Distance bin from plane	distance	ordinal
Group size	size	continuous
Log(group size)	logsize	continuous
Snow cover	snow	ordinal
Cloud cover	cloud	continuous
Snow patchiness	patch	ordinal
Observer pairs	Ob1, Ob2	categorical

We compared estimates from the MRDS analysis to estimates from distance sampling and strip-transect methods only. Strip transect estimates were generated in program *Distance* using observations of 400 meters or less from the survey plane. We used a uniform detection function to emulate the strip transect assumption of perfect sightability within 400 meters of the survey plane. Variance was estimated in program MRDS which considered the distance sampling, mark-recapture, and encounter rate variation (Innes *et al.* 2002). We applied the “O2” approach in MRDS, which accounted for the systematic sampling design with sequential transect lines between strata and likely correlation of adjacent transects, to estimate encounter rate variance (Fewster *et al.* 2009).

Results

Muskox

Across the survey region we observed 254 groups of muskoxen and 2,153 muskoxen in total. Each group was assigned to a distance bin. The mean group size was 8.5 muskoxen (range = 1-38, standard deviation [SD] = 6.9). We used the total number of adults and 10-month-old calves for our analysis.

Muskoxen were most numerous on the central part of the Fosheim Peninsula north of the Sawtooth Range, and on northern Raanes Peninsula (Figure 3).

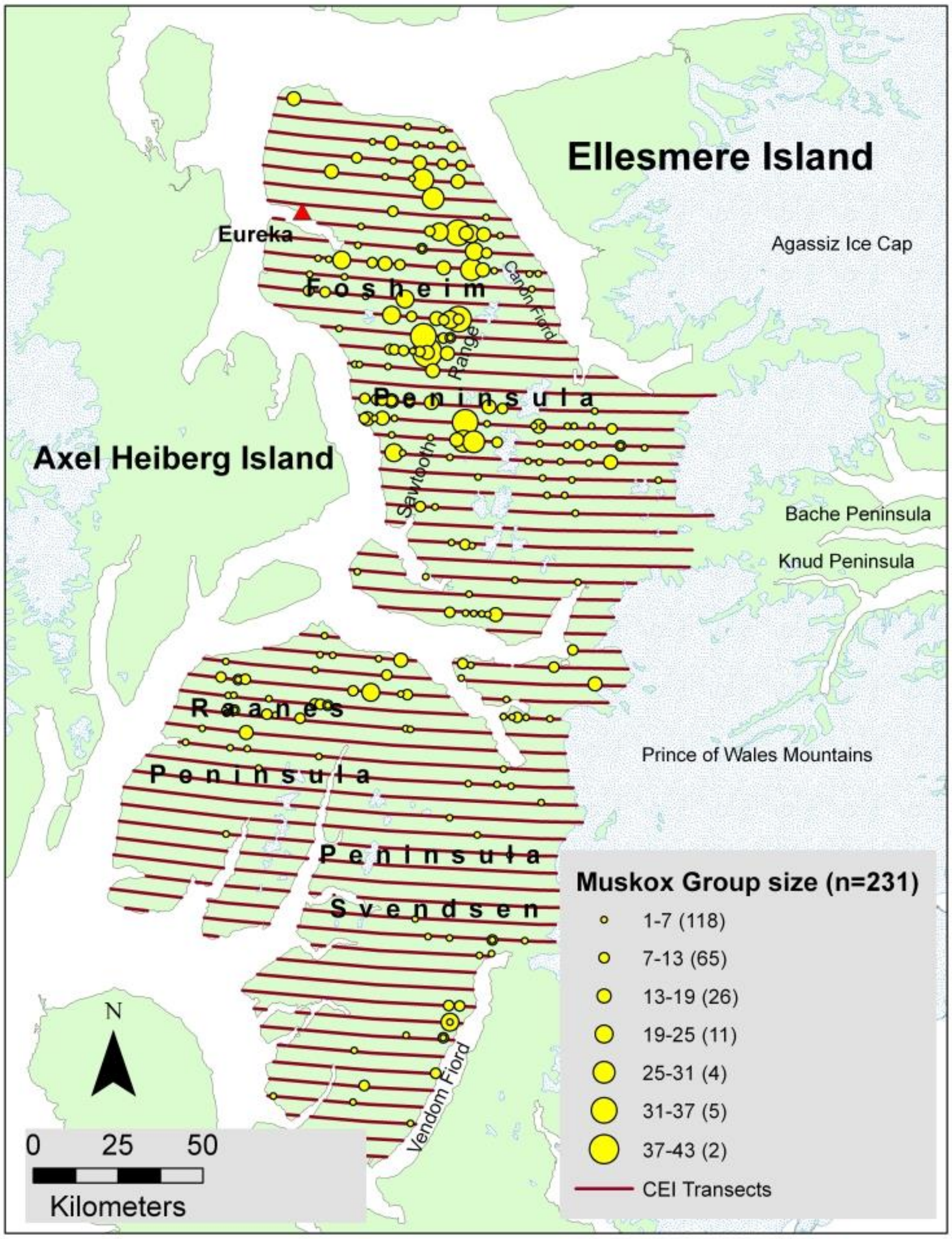

Figure 3. Distribution and group sizes of muskox observations during the 2017 Central Ellesmere Island survey. Frequencies of each group size are given next to each bin interval.

As expected, most groups were observed in the distance bins closest to the transect line. There were a similar number of observations in the first two distance bins (i.e. within 400 m of the aircraft), with fewer groups detected in distance bins further from the transect line, even after adjusting for unequal sized distance bins (200 m versus 500 m; Figure 4).

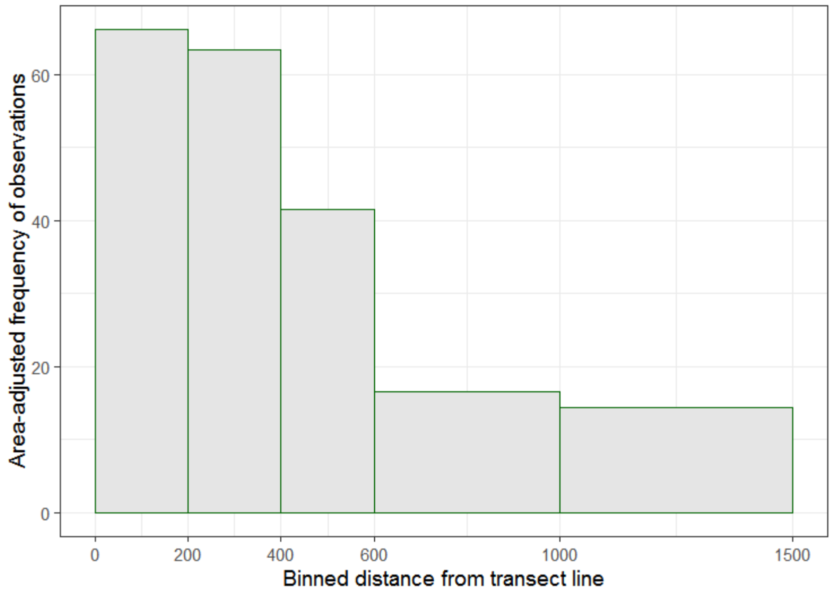

Figure 4. Bin-width adjusted frequencies of muskox observations on Central Ellesmere Island.

Muskoxen were usually seen in groups of ten or fewer, but we detected group sizes up to 38 muskoxen (Figure 5).

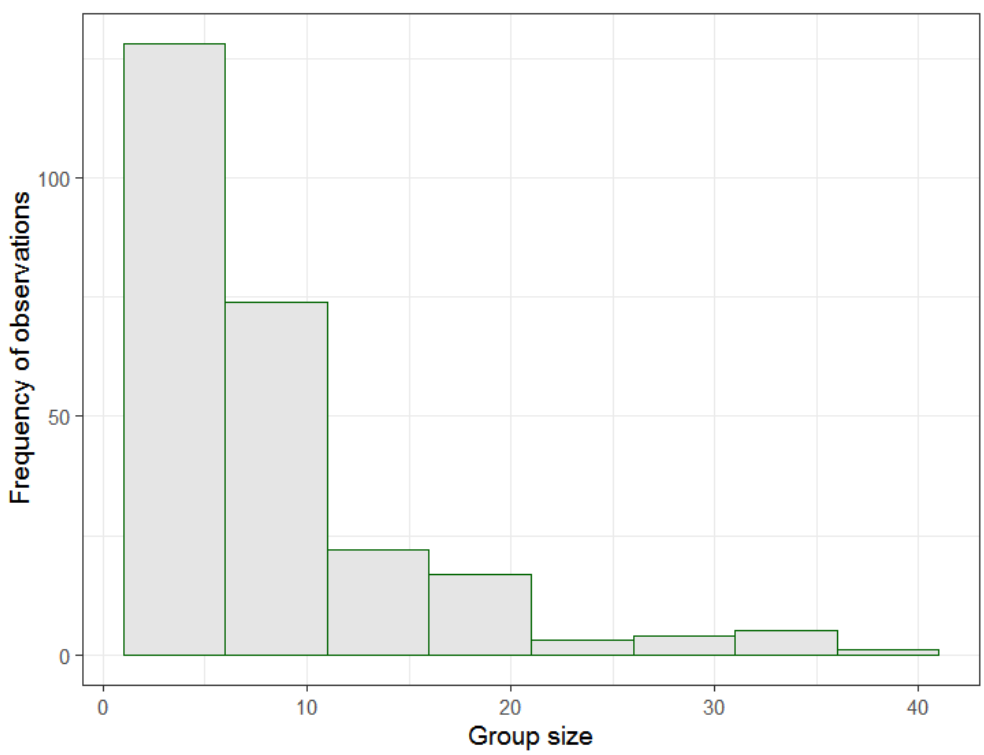

Figure 5. Frequency of muskox group sizes observed on Central Ellesmere Island, March 2017.

Influence of covariates on detection

Group size can influence detection, so the potential effect of group size on the distribution of detections was also examined (Figure 6). Proportionally more large groups were observed further from the transect line. Densities were used to compare among distance bins to account for bins covering different distance intervals (200-m or 500-m).

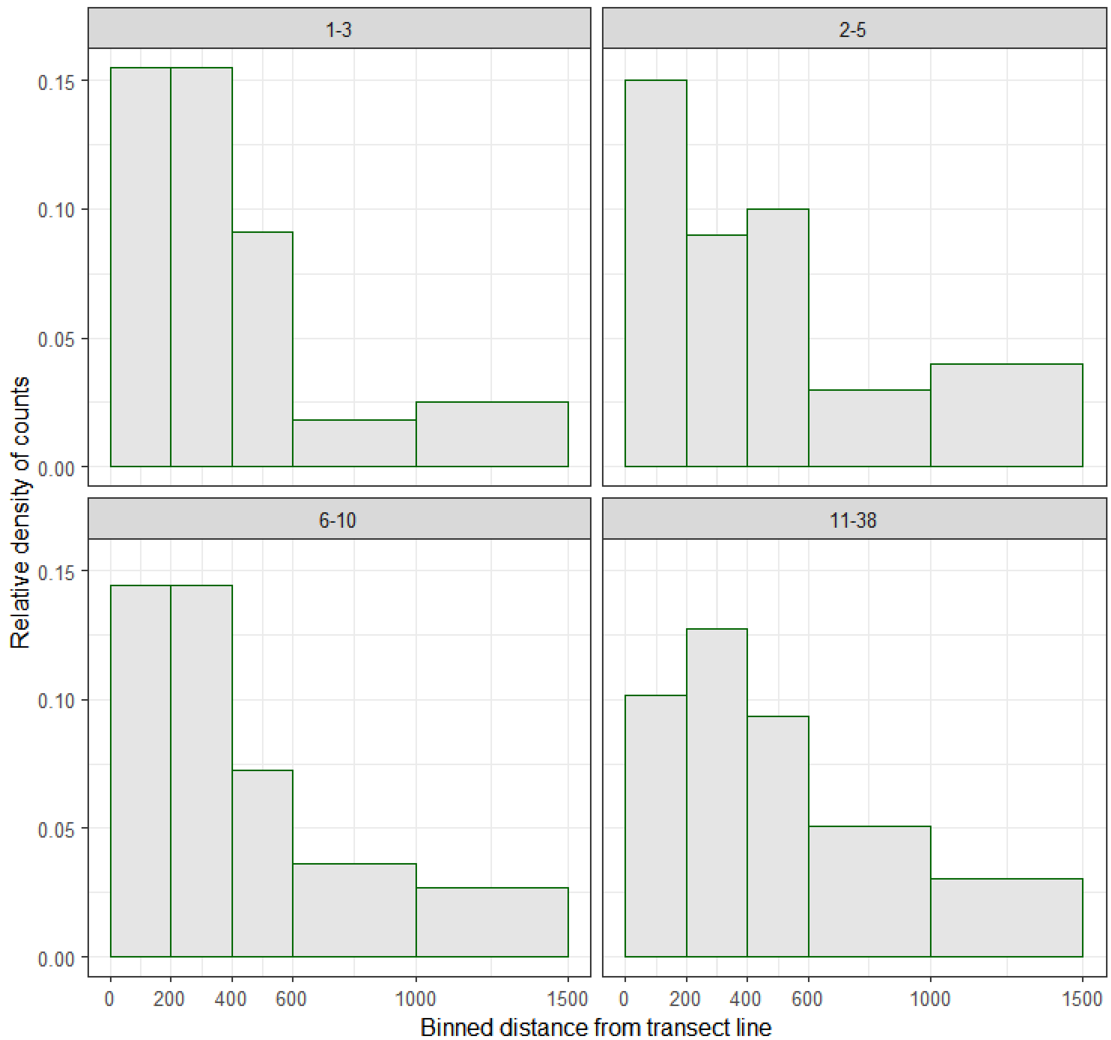

Figure 6. Density of muskox observations in each distance bin for group sizes of 1-3, 2-5, 6-10, and 11-38 muskoxen.

The observer pairings on either side of the aircraft might also have influenced the detection of groups and the shape of the detection function. There were two main observer pairings during the survey (Pair 1 and Pair 2) with a third pairing (Pair 3) accounting for relatively few observations (Table 3). The Pair 1 observers were in the same order for the majority of observations, whereas Pair 2 observers had similar observation frequencies in both positions. The overall pooled detection probabilities were similar for Pair 1 and Pair 2 based on naïve detection probabilities (Table 3). Our analysis largely uses observations from Pair 1 and Pair 2 given the low sample sizes for Pair 3.

Table 3. Frequencies of muskox observations by observer pairing and order. Observations are binned by whether front (F), rear (R), or both (B) observers reported a muskox group. The naïve probability of the front observer seeing a group, P(F), is estimated as 1 minus the proportion of observations only observed by the rear observer for any given pairing.

	Observer		Obs. Order 1-2				Obs. Order 2-1				Pooled			
Pair	**Observer 1**	**Observer 2**	**F**	**R**	**B**	**P(F)**	**F**	**R**	**B**	**P(F)**	**F**	**R**	**B**	**P(F)**
1	F. Noah	J. Pijamini	5	15	45	0.77	3	3	24	0.90	8	18	69	0.81
2	J. Kiguktak	M. Fredlund	1	8	60	0.88	0	1	54	0.98	1	9	114	0.93
3	M. Campbell	J. Pijamini	3	2	6	0.82	0	0	1	1.00	3	2	7	0.83

The distribution of sightings was slightly different by observer pairings with Pair 1 having relatively greater observations closer to the plane in comparison to Pair 2 (Figure 7).

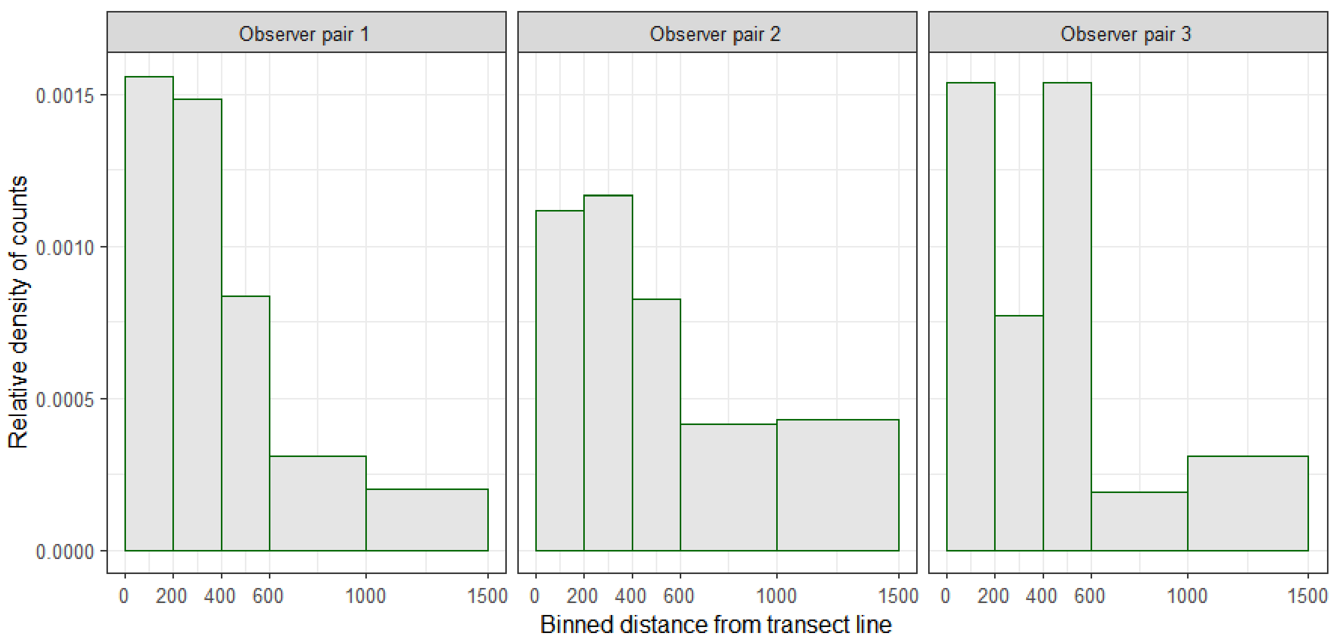

Figure 7. Muskox observation densities in each distance bin by observer pairing.

Abundance estimation

Our two-phase abundance estimate incorporated both mark-recapture and distance sampling analysis. In the first phase, distance models were fit while mark-recapture covariates were held constant. Once a distance sampling model was fit, mark-recapture models were considered under the point independence assumption. For the distance phase (Table 4, models 10-20) a model with log of group size and observer Pair 1 influencing a hazard rate detection function had the lowest AIC_c score (model

10), although models 11 and 12 were tied for support with model 10 ($\Delta AIC_c < 2$). Due to the similar support for models 10-12, further analyses with mark-recapture covariates used model 10 as a base model. Models with covariates stratum and cloud cover had less support than the null model (model 16). Snow cover and snow patchiness covariates showed minimal variation and therefore were not considered in any models.

Using model 10 as a base model, we compared additional models that included mark-recapture covariates (models 1-10). Of these, model 1, with covariates log of group size and observer pair 1, had the lowest AIC value, although models 2 and 3 received equivalent support ($\Delta AIC_c < 2$). Estimates of abundance from these three models were very close (within 2 animals), suggesting minimal influence of the covariates on the final abundance estimate. Abundance estimates were similar for most models, ranging from 6,900-7,194. Model 16, the null model, produced the highest abundance estimate. Most models used a hazard rate detection function, although in two cases a half normal function was used, with poor results.

Table 4. Mark-recapture/distance sampling model selection results. Models are defined by distance detection function (DF: HR = Hazard rate, HN = half normal), distance sampling and mark-recapture covariates (as defined in Table 2). A “1” indicates that the parameter was held constant. Akaike Information Criteria corrected for small sample sizes (AIC_c), the difference in AIC_c values between the *i*th model and the model with the lowest AIC_c value (ΔAIC_c), Akaike weights (w_i), number of parameters (*K*), and log-likelihood of the model are presented. Baseline models are shaded for reference.

No.	DF	Model covariates		Model fit					Abundance	
		Distance	Mark-recapture	AIC	ΔAIC_c	w_i	K	LL	N	CV
1	HR	logsize + ob1	ob1 + logsize	981.10	0.00	0.39	7	-483.6	6,902	15.0%
2	HR	logsize + ob1	ob2 + logsize	981.38	0.28	0.33	7	-483.7	6,903	15.0%
3	HR	logsize + ob1	ob1+ob2 + logsize	982.45	1.35	0.20	8	-483.2	6,904	15.0%
4	HR	logsize + ob1	ob1	986.10	5.00	0.03	6	-487.1	6,938	15.1%
5	HR	logsize + ob1	ob2	987.00	5.90	0.02	6	-487.5	6,941	15.1%
6	HR	logsize + ob1	cloud	987.65	6.55	0.01	6	-487.8	6,927	15.0%
7	HR	logsize + ob1	ob1 + ob2	987.93	6.83	0.01	7	-487.0	6,941	15.1%
8	HR	logsize + ob1	logsize	991.85	10.75	0.00	6	-489.9	6,889	15.0%
9	HR	logsize + ob1	size	993.26	12.16	0.00	6	-490.6	6,894	15.0%
10	HR	logsize + ob1	1	993.99	12.89	0.00	5	-492.0	6,916	15.0%
11	HR	logsize + ob2	1	994.14	13.04	0.00	5	-492.1	6,875	14.9%
12	HR	logsize + ob1 + ob2	1	995.66	14.56	0.00	6	-491.8	6,871	14.9%
13	HR	size + ob1 + ob2	1	997.38	16.28	0.00	6	-492.7	7,010	14.9%
14	HR	logsize	1	997.66	16.55	0.00	4	-494.8	7,107	15.7%
15	HR	size	1	999.57	18.46	0.00	4	-495.8	7,194	15.6%
16	HR	1	1	1000.96	19.86	0.00	3	-497.5	8,026	15.7%
17	HR	stratumcov	1	1001.71	20.61	0.00	4	-496.9	7,642	14.8%
18	HR	cloud	1	1001.74	20.64	0.00	4	-496.9	7,736	14.7%
19	HN	logsize	1	1009.47	28.37	0.00	3	-501.7	6,299	12.5%
20	HN	1	1	1012.59	31.49	0.00	2	-504.3	6,881	12.8%

Goodness of fit tests suggested adequate fit for the mark-recapture part of the model ($\chi^2 = 5.0$, df = 7, p = 0.65) but marginal fit to the 600-1,000-m bin for the distance sampling component, which caused the overall fit of the model to be marginal ($\chi^2 = 12.6$, df = 2, p = 0.001). Inspection of the individual fit of each bin suggested the only area of low fit was the 600-1,000-m bin ($\chi^2 = 6.9$), with other component χ^2 scores being less than 1. It is likely that lack of fit of this bin, which is far from the shoulder of the detection function, did not greatly influence abundance estimates. Inspection of detection probabilities relative to densities of observations (Figure 8) also suggested reasonable fit for detections by the primary observer only and pooled detections from both observers. Group size and observer pairings also influenced the predicted detection of model1 (Figure 9).

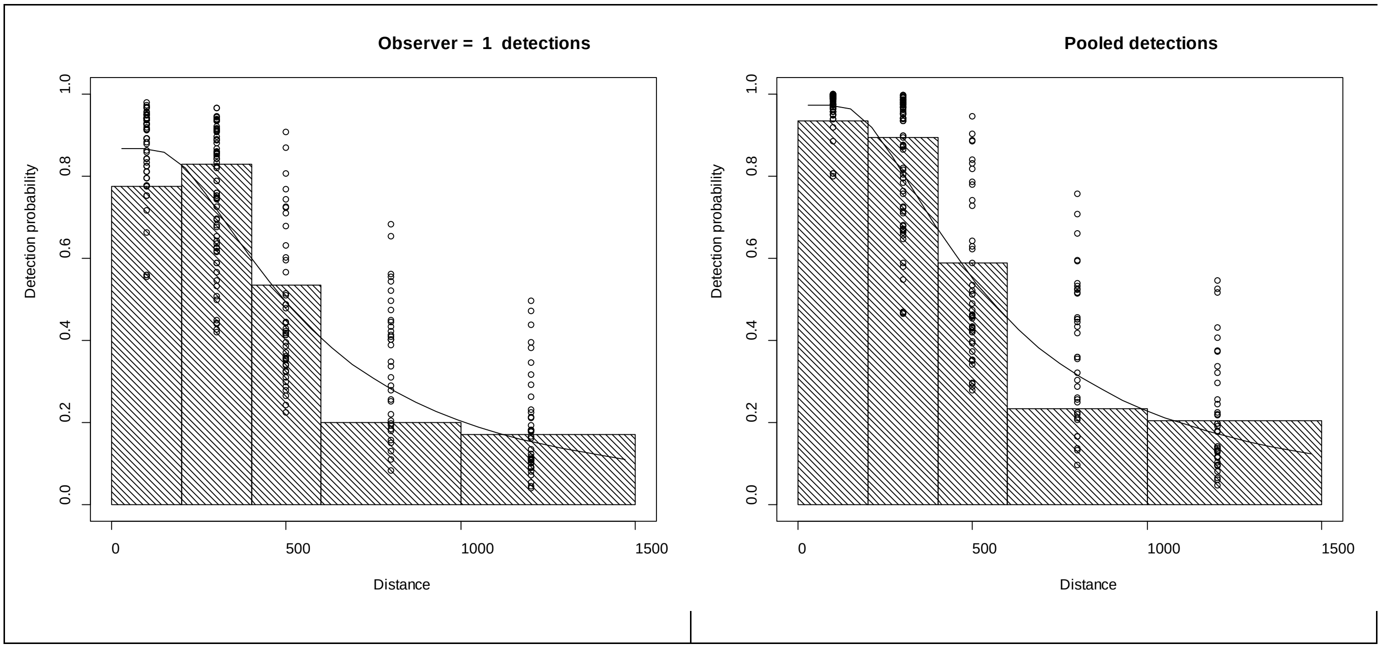

Figure 8. Predicted and observed detection probabilities for the primary observer (left) and pooled observers (right) from model 1 (Table 4). The histograms denote the relative frequency of observations whereas the points and line display the predicted detection probabilities and fitted detection function.

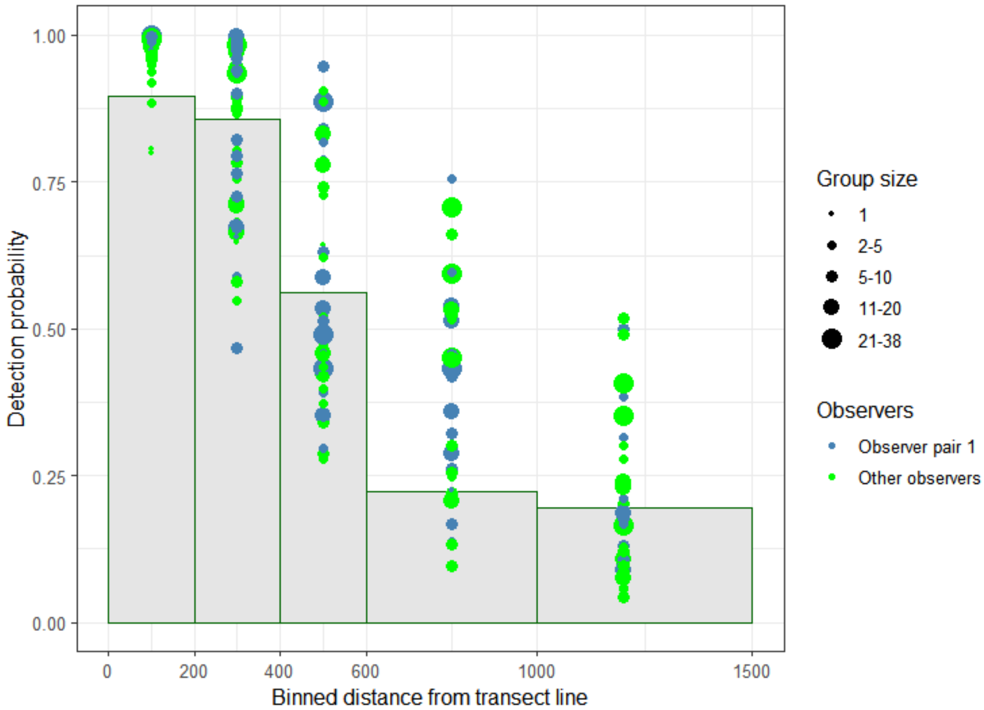

Figure 9. Predicted and observed detection probabilities for pooled detections of muskox groups as a function of observer pairs and muskox group size from model 1 (Table 4). The histograms denote the relative frequency of observations whereas the points and line display the predicted detection probabilities and fitted detection function. Covariate values associated with points (group size and observer) are also indicated by size and color of each point.

Muskox abundance was estimated for the study area using the most supported MRDS model, model 1 (Table 4). To investigate the sensitivity of our abundance estimate to different analysis methods, we also estimated muskox abundance using mark-recapture strip transect, distance sampling without mark recapture, and strip-transect only methods (Table 5). The highest estimate was from the MRDS model, which accounts for heterogeneity in detections. Precision was reasonably similar between approaches (Table 5). Estimates from MRDS model 1 were also computed for individual stratum (Table 6).

Table 5. Estimates of muskox abundance for Ellesmere Island derived by mark-recapture distance sampling (MRDS), mark-recapture strip transect (MR), distance sampling without mark recapture (DS), and strip transect methods.

Method	Muskoxen observed	Muskoxen estimated	SE	Confindence Limits (95%)		CV (%)
MRDS (Model 1, Table 4)	2,153	6,902	1,036	5,134	9,278	15.0
MR only (400 m strip)	1,067	6,857	887	5,286	8,896	12.9
DS only	2,153	6,807	1,001	5,092	9,098	14.7
Strip (400m)	1,067	6,741	998	5,029	9,037	14.8

Table 6. Estimates of muskox abundance by survey stratum on central Ellesmere Island March 2017 using mark-recapture distance sampling model 1.

Stratum	Muskoxen observed	Muskoxen estimated	SE	Confindence Limits (95%)		CV (%)
Raanes and Svendsen Peninsulas	562	1,948	280	1,467	2,585	14.4
Fosheim Peninsula	1591	4,954	897	3,461	7,091	18.1
Total	2153	6,902	1,036	5,134	9,278	15.0

Peary caribou

The Peary caribou analysis was constrained by a very small number of observations, with only nine individuals in five groups seen by the dedicated observers. Five additional individuals were seen by a recorder only. Peary caribou were seen on the northern Raanes and Svendsen peninsulas, and on the Fosheim Peninsula east of Bay Fiord (Figure 10).

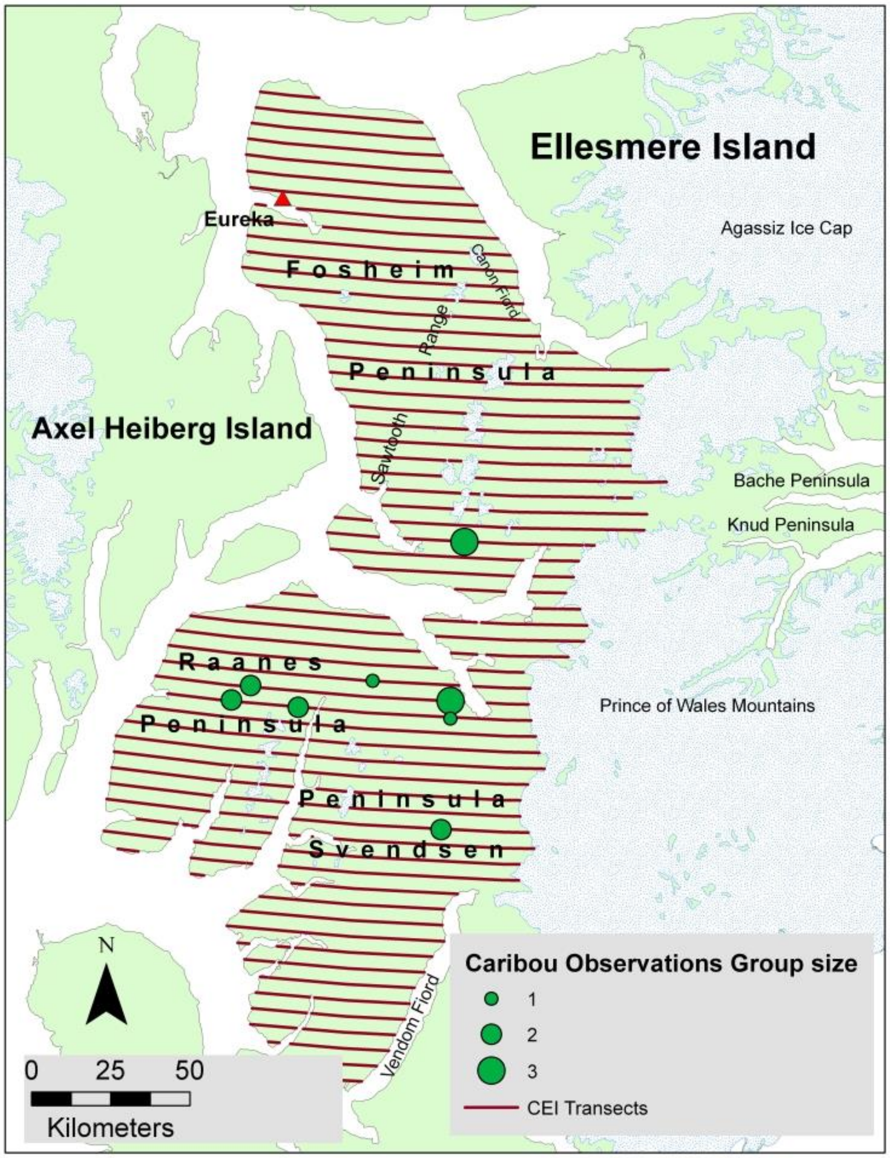

Figure 10. Observation locations and group sizes of Peary caribou during the 2017 Central Ellesmere Island survey.

The dedicated observer pairs saw Peary caribou up to the 600-1,000 m distance bin, and two groups totaling five individuals were seen by the recorder in the 600-1000-m bin. No individuals were observed in the 1,000-1,500-m distance bin (Figure 11). Statistical analysis was run with and without the recorder observations.

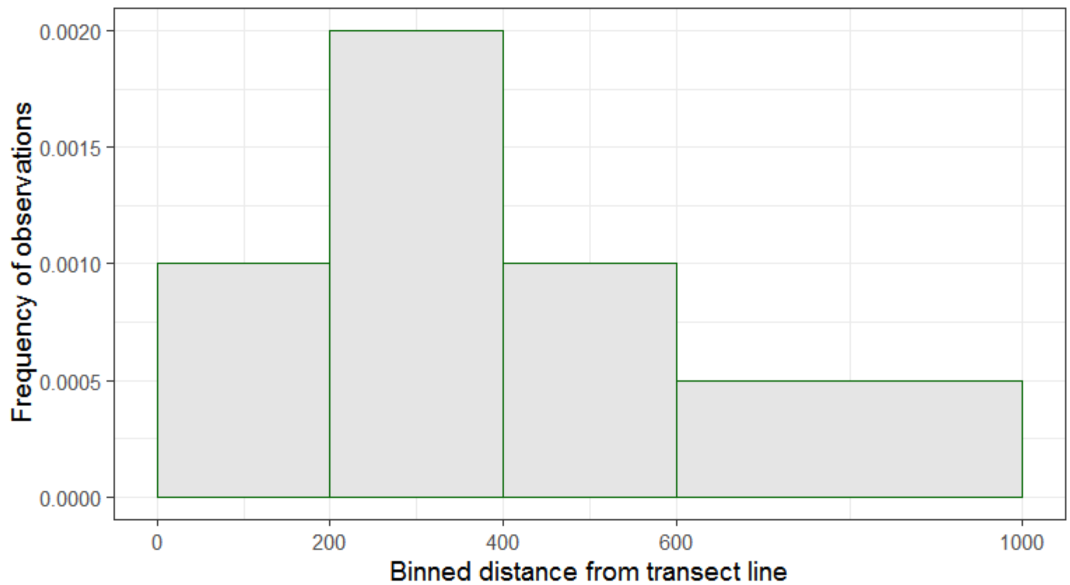

Figure 11. Bin-width adjusted frequencies of Peary caribou observations during the survey by the two dedicated observer pairs (recorder observations not included).

The low number of observations precluded more advanced modelling methods such as mark-recapture distance sampling. Half normal and hazard rate detection functions were fitted to the data on an exploratory basis. Of these, a half-normal detection function was most supported (Figure 12) with goodness of fit tests suggesting adequate fit ($\chi^2 = 0.51$, df = 2, p = 0.77). However, the reliability of this test is compromised by the small sample size. The resulting abundance estimate from this model was 32 ± SE 25 caribou (95% CI = 8 - 127, CV = 78.8%). A model with group size as a covariate was also considered, and was equally as likely as the half-normal model without group size. The estimate from this model was 36 ± SE 29 caribou (95% CI = 8-163, CV = 80.5%). A strip transect estimate assuming a 400-m strip width was also run, with an estimate of 25 ± SE 19 caribou (CI = 6 - 101, CV = 76.6%).

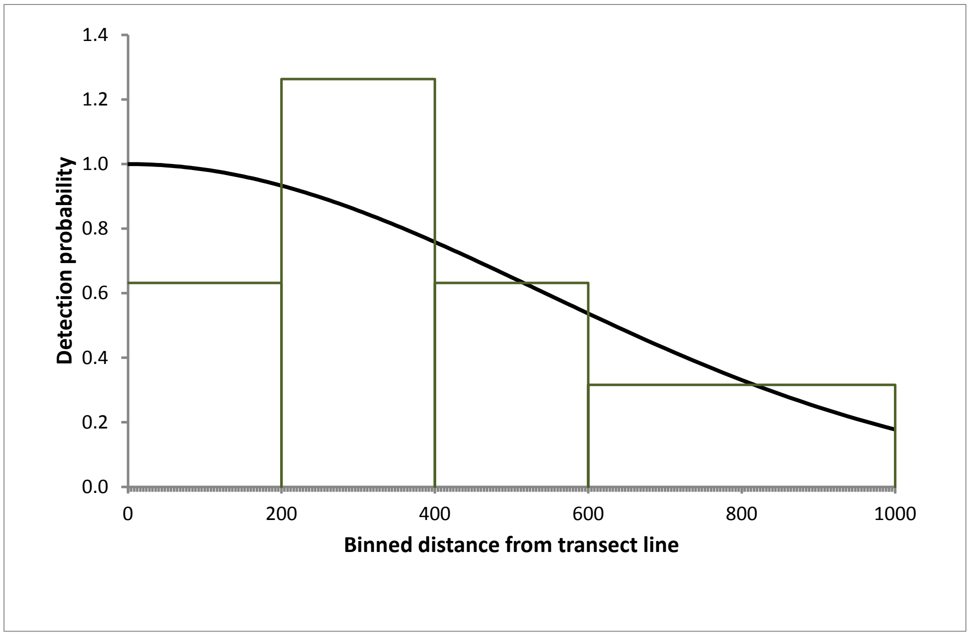

Figure 12. Fit of the half-normal detection function to the Peary caribou observation data.

Inclusion of recorder observations could be justified when the recorder was scanning the same area as observers and acting as a third observer with a similar detection function. The two additional recorder observations occurred in the 600-1000-m bin, and inclusion of these observations increased the detection function in this bin (Figure 13). Models using recorder observations that included group size as a covariate were more supported than models without group size. The half-normal detection function without group size was essentially flat, suggesting similar sightability in all distance bins. When group size was included, the detection function declined sharply up to 400 metres from the transect line, and then became uniform at 0.4 for distances up to 1000 meters (Figure 13). This detection function may be an artifact of the distribution of a small number of observations, as sightability should decline as distance increases. We estimated 49 ± SE 30 caribou (95% CI = 16-154, CV = 60.7%) using the model that included recorder observations and a group size covariate. If group size was not included, the estimate was 35 ± SE 24 caribou (95% CI = 10-127, CV = 67.8%).

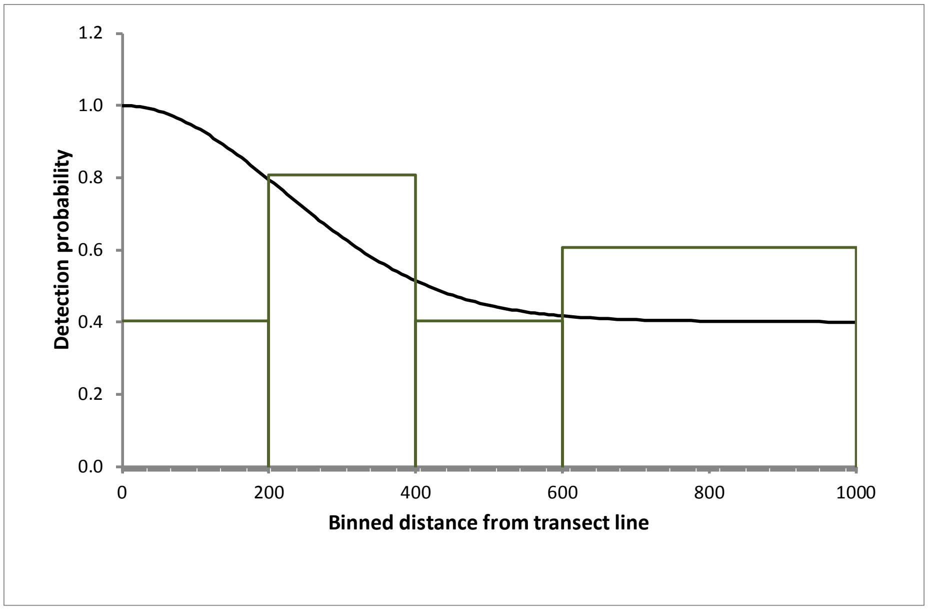

Figure 13. Fit of the half-normal detection function to the Peary caribou data including recorder observations and group size as a covariate.

Discussion

With the lack of consistency in both the frequency and method of surveys of Ellesmere Island it is challenging to confidently provide trends for either the muskoxen or Peary caribou populations (Anderson and Kingsley, 2015).

Muskoxen

In 1961, Tener (1963) flew a survey of Ellesmere Island and estimated 4,000 muskoxen on the entire island, admitting that this was a 'best guess' and more intensive surveys would be required for an accurate population estimate. Of the 605 muskoxen that he observed, 38% were on the Fosheim Peninsula, and he estimated a quarter of the island's muskox population was distributed between the Fosheim Peninsula and the Tanquary Fiord-Lake Hazen-Alert plateau (Tener 1963). In 1973, Riewe flew a series of surveys centered on the Bjorne Peninsula to investigate the distribution of wildlife during a seismic program conducted by PanArctic Oil (Riewe 1976). He estimated 425 muskoxen on the Svendsen Peninsula and 200 muskoxen on the Raanes Peninsula (Riewe 1973). In 1989, Case and Ellsworth (1991) covered southern Ellesmere Island, including the Svendsen Peninsula, and estimated 350 ± SE 90 muskoxen (Case and Ellsworth 1991). In 1995, Gauthier flew unsystematic surveys of Ellesmere Island an observed 1196 muskoxen (Gauthier 1996). The most recent survey of central Ellesmere Island occurred in 2006 when it was part of a systematic survey of central and northern Ellesmere Island (Campbell 2006, Jenkins *et al.* 2011).The 2006 survey estimated 8,115 muskoxen (95% CI = 6,632-9,930) on northern and central Ellesmere Island, based on 4,999 muskoxen seen on transect (Jenkins *et al.* 2011). Most of the muskoxen in 2006 were seen on the Fosheim Peninsula (n = 3286), with other concentrations on the Lake Hazen Plateau (n = 1428) between Tanquary Fiord and Alert. The number groups seen in 2006 for the Fosheim Peninsula Strata was greater than in 2017 as shown in Figure 14. However, there were more groups observed in 2017 on the Raanes and Svendsen Peninsulas.

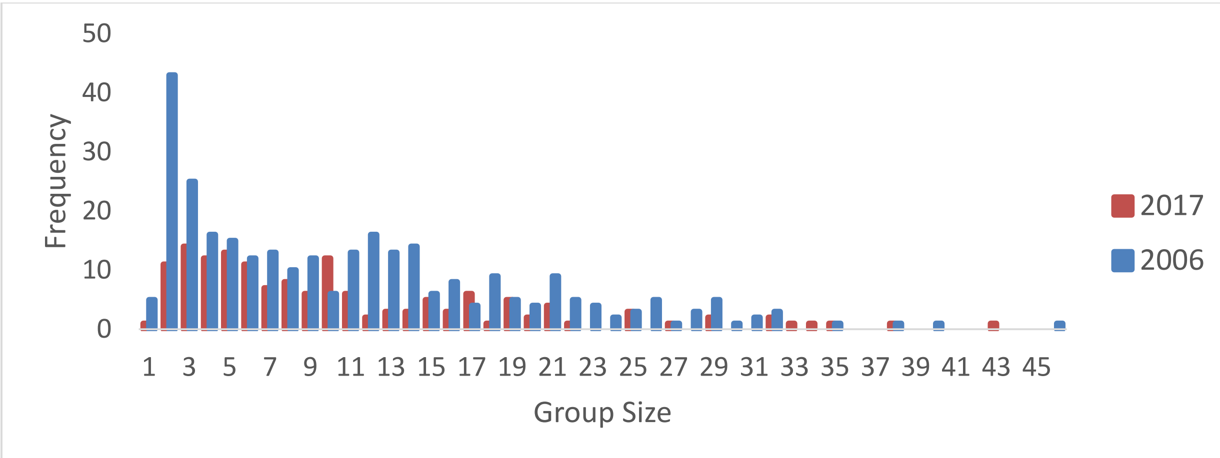

Figure 14. Frequency of observed group sizes during the 2006 and 2017 surveys for the Fosheim Peninsula stratum.

For muskox, the current analysis demonstrates the utility of the joint MRDS approach to account for multiple sources of variation in aerial survey data. The mark-recapture analysis suggested that detection was less than one near the plane, which would violate one of the assumptions of the distance sampling methodology. Use of the mark-recapture component accounted for this source of bias. The distance sampling component allowed all of the data to be used for analysis rather than only observations detected within a fixed-width strip transect.

Although the mark-recapture strip-transect estimate was the most precise (Table 5) of the methods examined, our data indicated that this estimate violates the method's assumption of equal sightability within the survey strip (i.e. detection was less than one in the 0- 400 m distance bin). However, the difference in precision between the most precise method and the MRDS estimate was small. The main loss of detection occurred for smaller groups which contributed less to the overall estimate, and the realized difference between mark-recapture strip transect and the slightly less precise MRDS abundance estimates was minimal (Table 5).

Peary caribou

Our Peary caribou analysis was compromised by the low number of observations, which limited our ability to model a distance detection function. Distance sampling data from similar studies might be able to assist in estimation of detection functions by allowing the pooling of data to estimate detection functions and associated detection probabilities. Approaches such as density surface modelling (Miller *et al.* 2013, Miller *et al.* 2016) that provide further inference on the distribution of patchy populations might improve estimates, especially if Peary caribou are associated with unique habitat characteristics within the study area.

Small sample sizes have been an issue for Peary caribou surveys on Ellesmere Island since Tener observed 74 Peary caribou (37 on transect) on the island in summer 1961 (Tener 1963). He guessed that about 200 caribou inhabited the island (Tener 1963). Riewe estimated 65 caribou on the Svendsen Peninsula and 300 caribou on the Raanes Peninsula in 1973, with a concentration of caribou at the head of Blind Fiord (Riewe 1976). In 1989, Case and Ellsworth (1991) estimated 31 ± SE 23 Peary caribou on the Svendsen Peninsula. In 2006, there were an estimated 802 Peary caribou (95% CI 531-1,207 caribou) on northern Ellesmere Island, including the central part of the island covered during this survey (Jenkins *et al.* 2011). Most caribou on that survey were seen on northern Ellesmere Island, on the Hvitland, Svartfjeld, and Marvin peninsulas and in the Blue and Blackwelder Mountains (Jenkins *et al.* 2011).

The small sample sizes and resulting low precision of abundance estimates make it difficult to interpret population trends, but the survey data that exist suggest that Peary caribou persist at low densities on central Ellesmere Island.

Management Recommendations

Over the past five years, muskox harvest has been managed through the Management Plan for High Arctic Muskoxen of the Qikiqtaaluk Region 2013-2018 (DOE *et al.* 2013). Ellesmere Island is encompassed completely within the Muskox Management Unit MX-01. Based on the results of the 2015 survey of southern Ellesmere Island, which found high densities of muskoxen in the most accessible part of MX-01, the total allowable harvest for muskox in MX-01 was lifted, although maintenance of a reliable reporting system for harvest was recommended to continue to collect and monitor harvest data. The results of this survey support those management actions.

Although only 14 caribou were seen on transect and a reliable population estimate was not attainable, the area surveyed is not within typical harvesting range of Grise Fiord and Peary caribou abundance on central Ellesmere Island is not limited by harvest activities. A management plan for Peary caribou in Nunavut is currently in development and regular monitoring (based on scientific methods and Inuit Qaujimajatuqangit) is expected to be an important part of the plan.

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Running a project in the High Arctic is an expensive endeavour and without financial support from the Government of Nunavut, Environment and Climate Change Canada's Habitat Stewardship Fund, and Nunavut General Monitoring Program this survey would never have occurred. This research was also conducted in accordance to permitting regulations under Government of Nunavut Wildlife Research permit WL 2017-003.

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Appendix 1. Previous surveys conducted on Ellesmere Island. Some of the surveys that have taken place within all or parts of the area surveyed and analysed in this report. Total Obs = Total muskoxen or caribou observed, Est = Abundance estimate, and '-' = no records taken.

Table 7. Past Muskoxen surveys that included central Ellesmere Island

<table>
<tr><th></th><th colspan="2">1961</th><th colspan="2">1973</th><th colspan="2">1989</th><th colspan="2">1995</th><th colspan="2">2006</th><th colspan="2">2017</th></tr>
<tr><th>Study Area</th><th>Total Obs</th><th>Est</th><th>Total Obs</th><th>Est</th><th>Total Obs</th><th>Est</th><th>Total Obs</th><th>Est</th><th>Total Obs</th><th>Est</th><th>Total Obs</th><th>Est</th></tr>
<tr><td>Fosheim Peninsula</td><td>227</td><td>1000</td><td>-</td><td>-</td><td>-</td><td>-</td><td>790</td><td>-</td><td rowspan="6">3745</td><td rowspan="7">8115
(95% CI
6,632-
9,930)</td><td rowspan="2">1591</td><td rowspan="2">4954
±897</td></tr>
<tr><td>Sverdrup Pass</td><td>47</td><td rowspan="7">3000</td><td>-</td><td>-</td><td>-</td><td>-</td><td>42</td><td>-</td></tr>
<tr><td>Raanes Peninsula</td><td>54</td><td>161</td><td>200</td><td>-</td><td>-</td><td>47</td><td>-</td><td rowspan="4">562</td><td rowspan="4">1948
±280</td></tr>
<tr><td>Svendsen Peninsula</td><td>20</td><td>362</td><td>425</td><td>89</td><td>350
±90</td><td rowspan="2">142</td><td>-</td></tr>
<tr><td>Vendom Fiord</td><td>-</td><td>100</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Strathcona Bay Fiords</td><td>-</td><td>32</td><td>-</td><td>-</td><td>-</td><td>91</td><td>-</td></tr>
<tr><td>Northern Ellesmere Island</td><td>182</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>1254</td><td>-</td><td>-</td></tr>
<tr><td>Southern Ellesmere Island</td><td>75</td><td>591</td><td>625</td><td>567</td><td>2020
±285</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Survey Date</td><td colspan="2">July 30 - Aug 11</td><td colspan="2">May 8, 15,
July 4, 7</td><td colspan="2">July 17 - 23</td><td colspan="2">June 12 - 21</td><td colspan="2">April 6 - May 22</td><td colspan="2">March 8 - 20</td></tr>
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</table>

[1]The surveys of 1961 and 1973 were not extensive enough to have any scale of accuracy for the estimates provided.
[2] The survey by Case and Ellsworth in 1989 had five strata, one of which was part of Svendsen Peninsula, and was able to be pulled out as a separate estimate. However, the full estimate for Southern Ellesmere also includes Svendsen peninsula.

Table 8. Past Peary Caribou Surveys that included central Ellesmere Island

<table>
<tr><th></th><th colspan="2">1961</th><th colspan="2">1973</th><th colspan="2">1989</th><th colspan="2">1995</th><th colspan="2">2006</th><th colspan="2">2017</th></tr>
<tr><th>Study Area</th><th>Total Obs</th><th>Est</th><th>Total Obs</th><th>Est</th><th>Total Obs</th><th>Est</th><th>Total Obs</th><th>Est</th><th>Total Obs</th><th>Est</th><th>Total Obs</th><th>Est</th></tr>
<tr><td>Fosheim Peninsula</td><td>1</td><td rowspan="8">200</td><td>-</td><td>-</td><td>-</td><td>-</td><td>11</td><td>-</td><td rowspan="6">36</td><td rowspan="7">802 (95% CI 531-1,207)</td><td rowspan="2">3</td><td rowspan="2">-</td></tr>
<tr><td>Sverdrup Pass</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>0</td><td>-</td></tr>
<tr><td>Raanes Peninsula</td><td>5</td><td>219</td><td>300</td><td>-</td><td>-</td><td>11</td><td>-</td><td rowspan="4">11</td><td rowspan="4">-</td></tr>
<tr><td>Svendsen Peninsula</td><td>-</td><td>23</td><td>65</td><td>25</td><td>31 ±23</td><td rowspan="2">12</td><td rowspan="2">-</td></tr>
<tr><td>Vendom Fiord</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Strathcona Bay Fiords</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>3</td><td>-</td></tr>
<tr><td>Northern Ellesmere Island</td><td>45</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>298</td><td>-</td><td>-</td></tr>
<tr><td>Southern Ellesmere Island</td><td>15</td><td>58</td><td>80</td><td>25</td><td>89 ±31</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Survey Date</td><td colspan="2">July 30 - Aug 11</td><td colspan="2">May 8, 15, July 4, 7</td><td colspan="2">July 17 - 23</td><td colspan="2">June 12 - 21</td><td colspan="2">April 6 - May 22</td><td colspan="2">March 8 - 20</td></tr>
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[1]The surveys of 1961 and 1973 were not extensive enough to have any scale of accuracy for the estimates provided.
[2] The survey by Case and Ellsworth in 1989 had five strata, one of which was part of Svendsen Peninsula, and was able to be pulled out as a separate estimate. However, the full estimate for Southern Ellesmere also includes Svendsen peninsula.

Appendix 2. Central Ellesmere Island survey transects

Table 9. Transect end points and strata on central Ellesmere Island flown during fixed-wing survey, March 2017

Transect	Stratum	Longitude (West terminus)	Latitude (West terminus)	Longitude (East terminus)	Latitude (East terminus)	Length (km)
1	CEI-1	-84.7780	77.5237	-83.7354	77.5228	19.1608
2	CEI-1	-84.8575	77.5690	-83.5489	77.5685	31.3538
3	CEI-1	-84.9946	77.6144	-83.4041	77.6141	34.1408
4	CEI-1	-85.2482	77.6596	-83.3364	77.6595	43.1923
5	CEI-1	-85.2462	77.7049	-83.2142	77.7050	46.2413
6	CEI-1	-85.2157	77.7503	-83.1664	77.7503	47.2176
7	CEI-1	-85.1769	77.7956	-83.1118	77.7957	49.0093
8	CEI-1	-85.4075	77.8407	-82.9872	77.8410	53.5812
9	CEI-1	-85.5188	77.8859	-82.8956	77.8863	51.6996
10	CEI-1	-85.6861	77.9308	-82.7443	77.9315	69.2458
11	CEI-1	-85.5166	77.9765	-82.7791	77.9769	63.3201
12	CEI-1	-85.2807	78.0222	-82.7615	78.0222	58.6650
13	CEI-1	-86.2412	78.0666	-82.5873	78.0673	61.5315
14	CEI-1	-87.2819	78.1128	-81.7566	78.1120	109.7099
15	CEI-1	-87.5011	78.1578	-81.7604	78.1573	116.6300
16	CEI-1	-87.0684	78.2036	-81.5613	78.2031	103.4846
17	CEI-1	-87.5185	78.2485	-81.6448	78.2482	126.1597
18	CEI-1	-87.5025	78.2938	-81.7677	78.2932	118.6898
19	CEI-1	-87.5044	78.3391	-81.7738	78.3385	119.8666
20	CEI-1	-87.4991	78.3845	-81.6719	78.3841	128.2379
21	CEI-1	-87.5032	78.4298	-81.4449	78.4299	131.8484
22	CEI-1	-87.4005	78.4753	-81.5262	78.4751	124.2423
23	CEI-1	-87.2582	78.5208	-81.5811	78.5203	123.5258
24	CEI-1	-86.8502	78.5662	-81.6516	78.5655	113.7587
25	CEI-1	-87.0480	78.6115	-81.6987	78.6107	112.5940
26	CEI-1	-86.9671	78.6568	-81.6786	78.6561	112.2479
27	CEI-1	-86.9129	78.7022	-81.7828	78.7011	103.4227
28	CEI-1	-86.8285	78.7474	-81.1386	78.7475	113.4587
29	CEI-1	-86.6517	78.7926	-80.9160	78.7928	114.6534
30	CEI-1	-85.8505	78.8369	-74.7333	78.8155	97.9495
31	CEI-1	-85.3706	78.8832	-75.0124	78.8610	25.6303
32	CEI-3	-82.8210	78.9287	-76.2201	78.9053	28.2383
33	CEI-3	-84.3314	78.9734	-75.7296	78.9508	63.4596
34	CEI-3	-84.6993	79.0193	-75.9464	78.9955	73.0550
35	CEI-3	-84.7698	79.0647	-74.4280	79.0642	75.6296
36	CEI-3	-84.6728	79.1099	-74.5175	79.1097	93.9799
37	CEI-3	-83.9752	79.1539	-80.0000	79.1538	82.7325

Transect	Stratum	Longitude (West terminus)	Latitude (West terminus)	Longitude (East terminus)	Latitude (East terminus)	Length (km)
38	CEI-3	-84.3200	79.2000	-80.0000	79.1991	89.1923
39	CEI-3	-84.3265	79.2453	-79.7043	79.2453	85.5274
40	CEI-3	-84.4059	79.2908	-80.2521	79.2905	78.1989
41	CEI-3	-84.4612	79.3362	-80.2482	79.3358	82.4700
42	CEI-3	-84.4570	79.3816	-80.2171	79.3811	83.8034
43	CEI-3	-84.5731	79.4271	-80.1208	79.4261	83.7156
44	CEI-3	-84.8181	79.4726	-80.2790	79.4719	92.3412
45	CEI-3	-84.9285	79.5180	-80.0719	79.5166	97.2458
46	CEI-3	-84.9813	79.5633	-79.6621	79.5626	105.2471
47	CEI-3	-85.0397	79.6086	-81.1001	79.6086	79.5353
48	CEI-3	-85.1830	79.6539	-81.6891	79.6532	71.0937
49	CEI-3	-85.4867	79.6989	-81.8610	79.6981	72.8418
50	CEI-3	-86.2028	79.7436	-81.9680	79.7432	76.6579
51	CEI-3	-86.4671	79.7895	-82.0603	79.7886	69.4444
52	CEI-3	-86.4077	79.8347	-82.0781	79.8340	86.0609
53	CEI-3	-86.4385	79.8801	-82.2032	79.8796	79.1084
54	CEI-3	-86.4361	79.9254	-82.4099	79.9254	73.9772
55	CEI-3	-86.3668	79.9706	-82.6389	79.9710	62.4448
56	CEI-3	-86.4800	80.0161	-82.7677	80.0165	72.2597
57	CEI-3	-86.5574	80.0616	-83.0152	80.0619	69.0022
58	CEI-3	-86.6099	80.1070	-83.2220	80.1071	64.8551
59	CEI-3	-86.6034	80.1523	-83.3805	80.1523	61.6405
60	CEI-3	-86.5741	80.1976	-83.5321	80.1974	57.5415
61	CEI-3	-86.5367	80.2429	-83.7497	80.2423	52.4790
62	CEI-3	-86.4941	80.2881	-85.5070	80.2881	18.3872

Appendix 3. Daily flight summaries

Table 10. Daily flight summaries for central Ellesmere Island survey, with recorder and observer locations on aircraft

Date	Time Up	Time Down	Data Recorder	Left Front Observer	Left Rear Observer	Right Front Observer	Right Rear Observer
Mar-08-2017			Mitch Campbell	Matthew Fredlund	Jopee Kiguktak	Frankie Noah	Jason Pijamini
Mar-09-2017			Mitch Campbell	Jopee Kiguktak	Matthew Fredlund	Jason Pijamini	Frankie Noah
Mar-10-2017	10:05	14:10	Mitch Campbell	Matthew Fredlund	Jopee Kiguktak	Frankie Noah	Jason Pijamini
Mar-11-2017	9:55	13:12	Mitch Campbell	Jopee Kiguktak	Matthew Fredlund	Jason Pijamini	Frankie Noah
Mar-12-2017	Weather Day - Did not survey						
Mar-13-2017	9:38	13:08	Mitch Campbell	Matthew Fredlund	Jopee Kiguktak	Frankie Noah	Jason Pijamini
Mar-14-2018	Weather Day - Did not survey						
Mar-15-2019	Weather Day - Did not survey						
Mar-16-2020	Weather Day - Did not survey						
Mar-17-2017	8:50	12:30	Mitch Campbell	Jopee Kiguktak	Matthew Fredlund	Frankie Noah	Jason Pijamini
Mar-18-2017	8:50	11:00	Mitch Campbell	Jopee Kiguktak	Matthew Fredlund	Frankie Noah[1]	Jason Pijamini
						Mitch Campbell[1]	Jason Pijamini
	11:30	15:27	Mitch Campbell	Matthew Fredlund	Jopee Kiguktak	Jason Pijamini	Frankie Noah
Mar-19-2017	8:40	12:35	Mitch Campbell	Jopee Kiguktak	Matthew Fredlund	Mitch Campbell	Jason Pijamini
	13:28	16:30	Mitch Campbell	Matthew Fredlund	Jopee Kiguktak	Jason Pijamini	Frankie Noah[2]
							Mitch Campbell[2]
Mar-20-2017	8:53	11:07	Mitch Campbell	Jopee Kiguktak	Matthew Fredlund	Frankie Noah	Jason Pijamini

[1] Right front observer replaced with right data recorder/observer during flight

[2] Right rear observer replaced with right data recorder/observer during flight

Appendix 4. Incidental wildlife observations

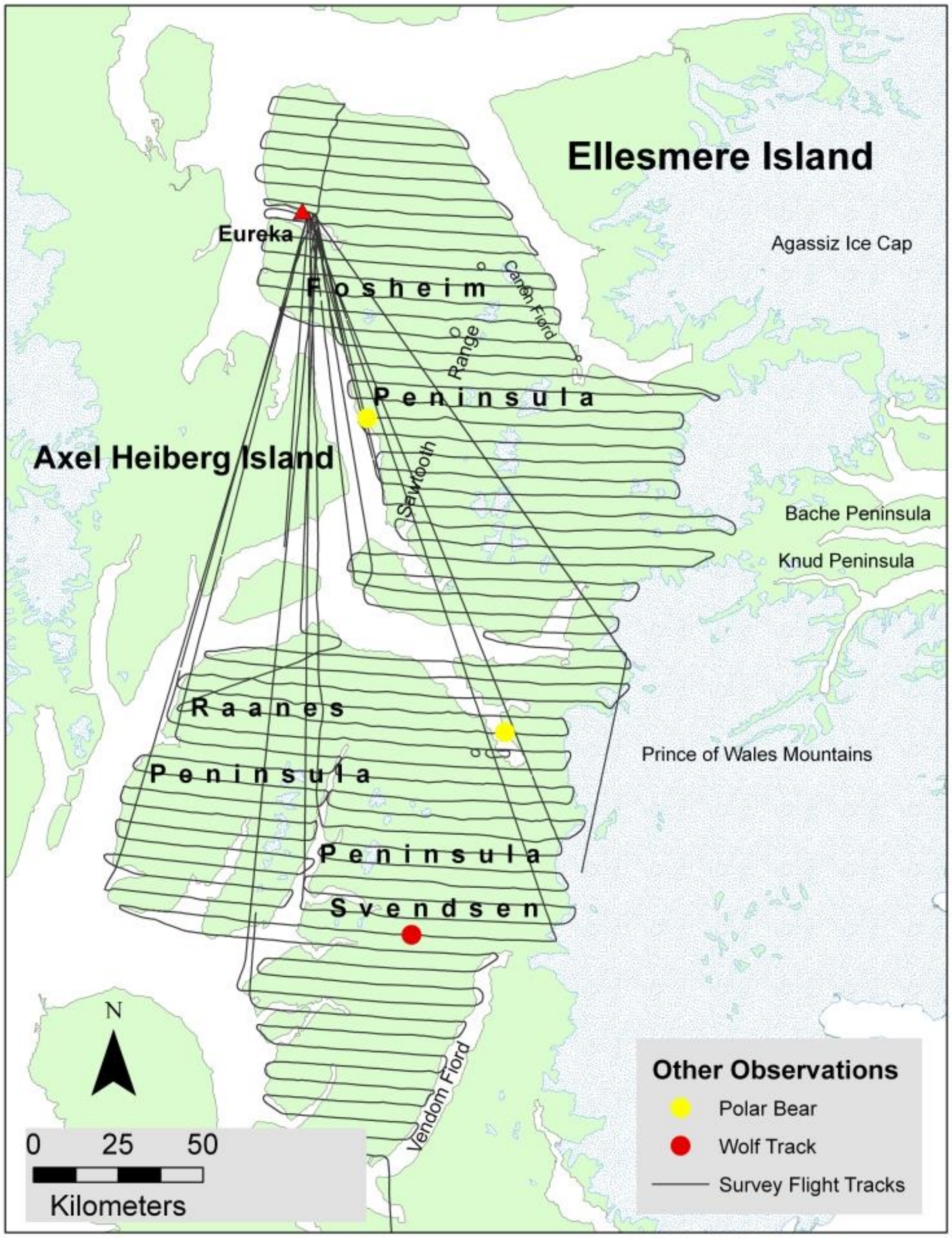

Figure 15. Incidental observations and flight lines from central Ellesmere Island aerial survey, March 8-20, 2017. A total of two polar bears were seen. Although no wolves were seen a track that appeared to be from a wolf was seen. Communication with staff from the Eureka Weather Station informed us that wolves had been seen around the station a few weeks earlier. Arctic hares were also seen but locations were not recorded.