Re-evaluation of the Northern Kivalliq Muskoxen (Ovibos moschatus) Distribution, Abundance and Total Allowable Harvests in muskox management unit MX-10

Final Technical Report

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Introduction / Summary

Prior to the enactment of protection in 1917 (Burch, 1977), muskox subpopulations throughout the central Arctic were hunted to near extirpation. Muskox populations within Nunavut are currently re-colonizing much of their historical range (Fournier and Gunn, 1998; Campbell, 2017), but there remain gaps in information on the status of muskox subpopulations in the area collectively known as the Northeastern Mainland north of the Thelon River, Baker Lake, and Chesterfield Inlet where the Northern Kivalliq Muskox subpopulation (NKMX) resides, within the MX-10 muskox management unit (**Figure 1**). This subpopulation is part of a greater population in Kivalliq which also includes the subpopulation south of MX-10, the Central Kivalliq Muskox (CKMX) in management unit MX-13.

At its greatest extent, the distribution of muskox in the Kivalliq region of Nunavut occurred within an area extending south of 66° latitude, west to the Northwest Territories (NWT)/Thelon Game Sanctuary boundaries, east to the Hudson Bay coastline and south to the Manitoba border (Barr, 1991)**.** Survey work conducted within the last 20 years has indicated a range expansion of Kivalliq muskox subpopulations to the northeast, east, and south of their historical range (Campbell, 2017) **(Figure 2)**.

Prior to 2010, Kivalliq muskox subpopulations were estimated using fixed-width line transect surveys in July of 1985, July 1986, July 1991, July 1999 and July 2000 (Campbell and Setterington, 2006; Fournier and Gunn, 1998; Case and Graf 1986; Graff et al. 1989; Mulders and Bradley 1991). Surveys were generally flown in July when muskox are distributed more evenly across the landscape, as compared with the winter season when groups can often coalesce due to limited forage accessibility due to snow and ice (Banfield, 1974). The history and reasons behind fluctuations in muskox numbers for the NKMX subpopulation are poorly understood. The first abundance survey of this subpopulation was undertaken in July 1999 within the southern extents of the MX-10 management zone, formerly known as the MX-20 management zone. This July 1999 survey resulted in an estimated population size of 1,522 (95% CI = 679; CV = 0.22) adult and yearling muskox (Campbell and Setterington, 2006) for the NKMX in MX-10.

In the five years following the July 1999 survey estimates, local hunters from Arviat, Whale Cove, Rankin Inlet, Chesterfield Inlet and Baker Lake reported increased muskox abundance in MX-10 and a continued expansion of muskox into previously unoccupied range. Motivated by this local knowledge, the Government of Nunavut Department of Environment (GN DOE) met with the Kivalliq Wildlife Board (KWB) to discuss an increase in the Total Allowable Harvest (TAH), and the removal of the seasonal Non-Quota limitations (NQL), based on a new population assessment of both the CKMX and NKMX subpopulations.

By the fall of 2008, a new TAH was established for both the CKMX and NKMX subpopulations. All parties agreed to increase the TAH from 3% to 5% of the lower confidence intervals of the 1999 survey estimates, with the understanding that aerial surveys to confirm hunter observations of increased muskox numbers would be flown as soon as possible. Additionally, all NQLs were removed for both the CKMX and NKMX subpopulations.

A re-evaluation of Kivalliq muskox subpopulations was undertaken in July 2010, and again in 2016, for the CKMX subpopulation, and in July 2012 for the NKMX subpopulation. Using the Jolly (1969) method for unequal sample sizes to analyze survey observations, the 2010 CKMX survey suggested continued growth from the estimated 2,143 (95% CI = 396; CV = 0.09) adults and yearlings in MX-13 in July 1999 to an estimated 4,506 (95% CI = 948; CV = 0.11) adult and yearling muskox in MX-13 by July 2010. The most recent survey of the CKMX subpopulation flown in July 2016, resulted in an abundance estimate of 4,437 (95% CI = 1,054; CV = 0.12) adult and yearling muskox, suggesting that the muskox population had remained stable between survey periods.

The July 2012 NKMX subpopulation abundance survey estimated 2,341 (95% CI = 545; CV = 0.12) adult and yearling muskox, an increase from the July 1999 survey estimate of 1,522 (95% CI = 679; CV = 0.22) adult and yearling muskox (Campbell and Setterington, 2006). The results of this survey suggested strong growth within the NKMX subpopulation. Additionally, range expansion to the south and east for the CKMX subpopulation, and eastward for the NKMX subpopulation was evident (Campbell and Lee, 2013) **(Figure 2)**. The following report provides a re-assessment of the NKMX subpopulation and summer range.

To date, there are no indications of disease within the herd. Research into the distribution of the lungworm (*Omingmakstrongylus pallikuukensis)* amongst mainland muskox has included samples from the NKMX subpopulation, but no evidence of the disease had been found (Kutz et al., 2002; Gunn and Wobeser, 1993). Similarly, no evidence of Yersisiosis has been discovered in muskox within the Kivalliq region, though no screening has occurred for Kivalliq muskox in recent years (Blake et al., 1991). Despite the lack of evidence of prevalent disease within Kivalliq muskox subpopulations, continued screening of suspect samples provided by hunters is strongly recommended.

From the late 1980s to present, hunters have been reporting increased observations of muskox closer to their communities both south and east of previously known distributions (Mulders and Bradley, 1991; Rankin Inlet (HTO pers. comm.; Baker Lake HTO pers. comm.; Arviat HTO pers. comm.; Chesterfield Inlet HTO pers. comm.; Repulse Bay HTO pers. comm.; Coral Harbour HTO, pers. comm.; Whale Cove HTO, pers. comm. 2008). Ideally, communities in the Kivalliq region would like to have access to healthy muskox populations. Both population estimates and distribution observations discussed herein will provide information that will enable Regional Wildlife Organizations (RWOs), local Hunters and Trappers Organizations (HTOs), and biologists to determine the potential long-term effects of current harvest regimes on muskox populations in the Kivalliq, while also providing information on the continued expansion of muskox into their historical range.

At present, the Government of Nunavut continues to use aerial surveys and strip transect quantitative methods to estimate both CKMX and NKMX subpopulation numbers, and uses these estimates to re-assess the TAH for both management units (Heard, 1985; Heard, 1987; Jolly, 1969). The TAH for Kivalliq muskox subpopulations is currently based on 5% of the estimated lower 95% Confidence Interval (CI) of the mean population estimate. At present there is a TAH of 190 for MX-10 **(Figure 1)**. There are no NQLs established for either subpopulation.

In this report we provide the detailed analysis of the results of our 2017 abundance survey for the NKMX subpopulation. The abundance survey of MX-10 in July 2017 resulted in an estimated 3,239 adult and yearling muskox and significant range expansion within the management unit.

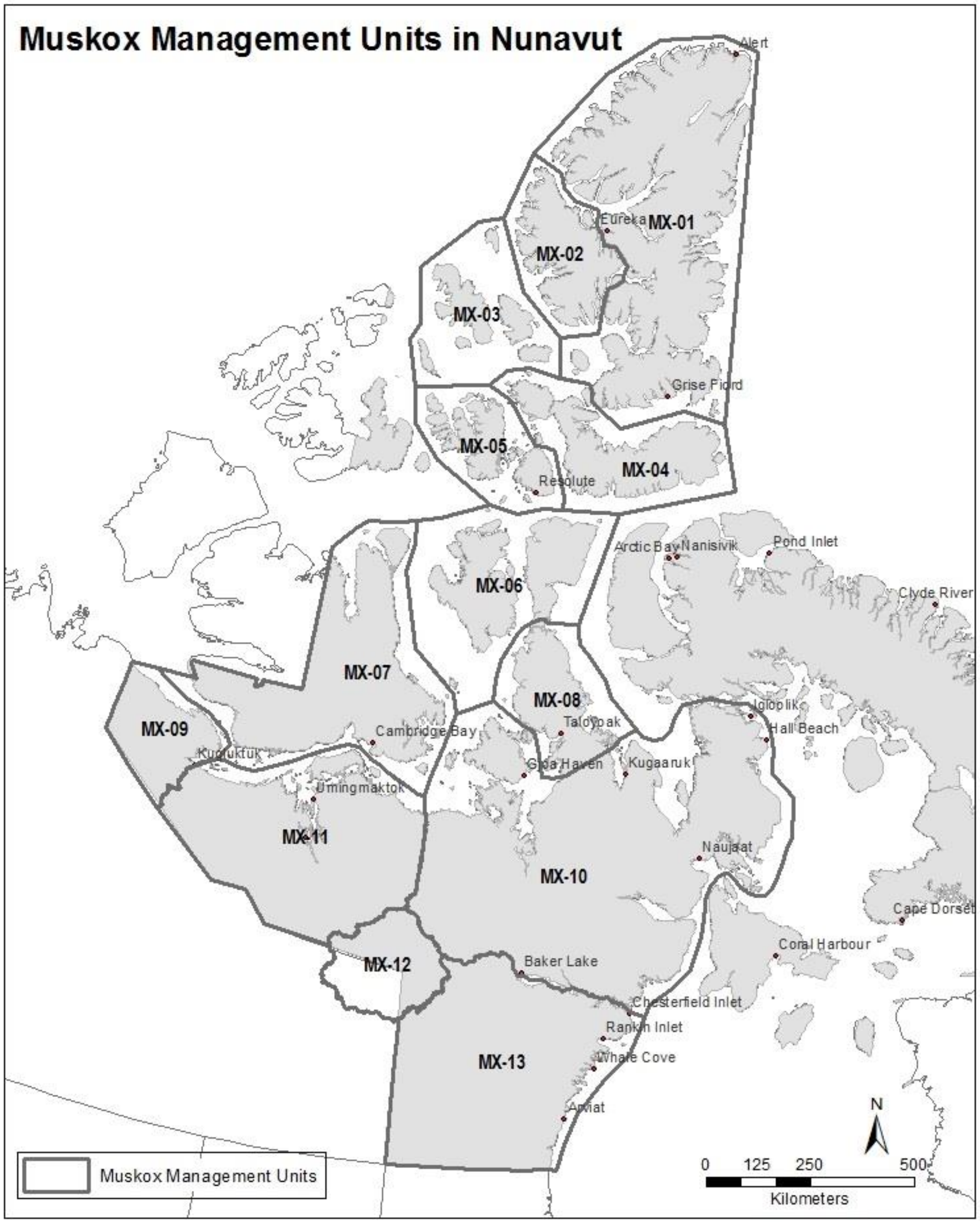

Figure 1. Nunavut's muskox management zones. The northern Kivalliq muskox subpopulation (NKMX) extents are represented by the southern extents of the northeastern mainland group (MX-10).

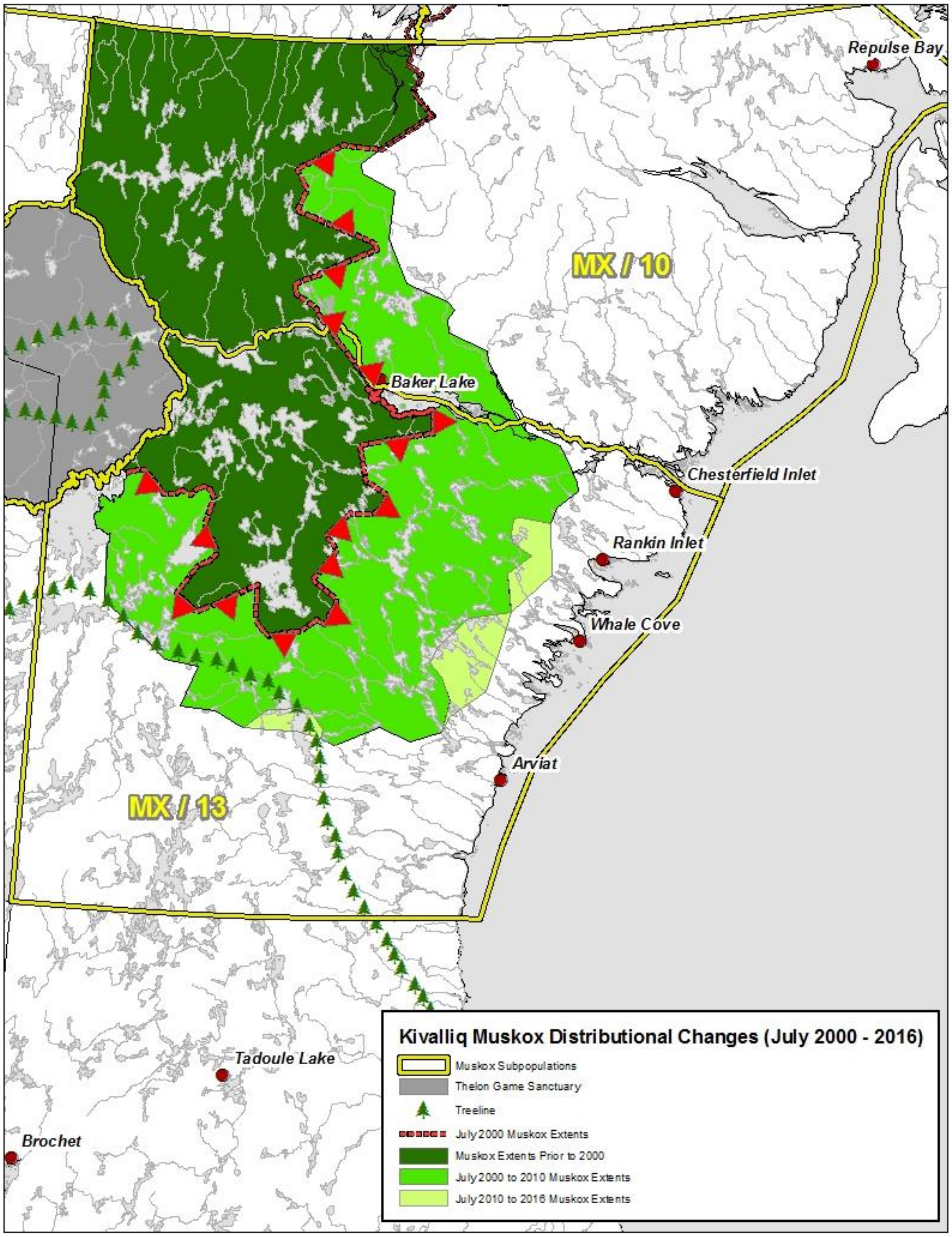

Figure 2. Indicated central and northern Kivalliq muskox range expansion from pre-2000 extents to July 2010, and to July 2016 extents (Campbell, 2017).

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Study Area:

The survey study area was based on the July 1999 and 2012 survey observations and extents, as well as observations from local hunters and other reported sightings, collected during consultations with local HTOs. Local HTO representatives taking part in the survey also indicated areas where muskox range expansion had likely occurred in recent years. Efforts were also made to survey outside of known distributions to ensure questions regarding range expansion were addressed, and to ensure overlap between survey years was achieved, for distributional and density-related comparisons. The July 2017 survey area is an estimated 60,576 km^2 and encompassed the lower half of the MX-10 muskox management zone **(Figure 3)**. The study area included portions of the Back River Plain, the Garry Lake Lowland ecoregions of the Southern Arctic ecozone, and the Wager Bay Plateau ecoregion of the Northern Arctic ecozone (Wiken, 1986; Ecological Stratification Working Group, 1996) **(**Error! Reference source not found.**, Figure 3)**.

Table 1. Ecoregions of the northern Kivalliq muskox survey study areas in the Kivalliq region of Nunavut.

Study Area	**Ecozone**	**Ecoregion**
NKMX	Southern Arctic	Back River Plain Garry Lake Lowland
	Northern Arctic	Wager Bay Plateau

Northern Arctic Ecozone:

The Northern Arctic Ecozone covers an estimated 1.5 million square kilometres, or about one seventh of Canada, and extends over most of the non-mountainous areas of the Arctic islands and parts of northeastern Kivalliq, western Baffin Island, and northern Quebec. This ecozone covers the eastern half of the survey area and is one of the largest arctic ecosystems in the world (**Figure 3**). Winters in this ecozone pass in near darkness. Snow may fall any month of the year and usually remains on the ground from September to June. Extremely low temperatures and an average precipitation of about 200 mm per year characterize the climate. When not covered in snow, much of the landscape is typified by barren plains covered in frost-patterned soils and the occasional rock outcrop (Wiken, 1986; Ecological Stratification Working Group, 1996).

The Wager Bay Plateau ecoregion, a part of the Northern Arctic Ecozone, covers the eastern half of the survey area (**Figure 4**). This ecoregion is classified as having a low arctic ecoclimate with a mean annual temperature of approximately -11°C. Seasonal mean temperatures are 4.5°C in summer and -26.5°C in winter. The mean annual precipitation ranges between 200 and 300 mm. Vegetation of the ecoregion includes a discontinuous cover of tundra plant communities dominated by dwarf birch (*Betula glandulosa*), willow (*Salix spp*.), northern Labrador tea (*Ledum decumbens*), Mountain Avens (*Dryas integrifolia)*, and *Vaccinium* spp. Taller dwarf birch, willow, and alder (*Alnus spp*) occur on warm sites while wet sites are dominated by willow and sedge (*Carex spp*). Lichen-covered rock outcroppings are prominent throughout the ecoregion. Massive Archean rocks of the Canadian Shield form broad, sloping uplands, plains, and valleys within this ecoregion, rising gradually westward from Chesterfield Inlet to 600 m asl elevation, where it is deeply dissected. Turbic and Static Cryosols developed on discontinuous, thin, sandy moraine and alluvial deposits are the dominant soils in the ecoregion, while large areas of Regosolic Static Cryosols are associated with marine deposits along the coast. Permafrost is continuous with low ice content (Wiken, 1986; Ecological Stratification Working Group, 1996).

Southern Arctic Ecozone:

The Southern Arctic Ecozone forms an extensive ecosystem covering close to a million square kilometres of sprawling shrub lands, wet sedge meadows, and cold, clear lakes. This ecozone covers the western half of the survey area (**Figure 3**). Habitats within this ecozone are characterized by intense frost action and the resultant formation of frost-patterned soils. The two ecoregions covering the western half of the survey area and include the Garry Lake Lowland, covering the central quarter of the survey area, and the Back River plain, covering the western quarter (**Figure 4**).

The Garry Lake Lowland extends across a vast area of massive granitic Archean rocks, forming a broad, level to gently sloping plain that reaches about 300 m asl in elevation. This ecoregion is classified as having a low arctic ecoclimate with a mean annual temperature of -10.5°C. Summer and winter mean temperatures are 5.5°C and -26.5°C, respectively. The mean annual precipitation ranges from 200 to 275 mm. Dominant plant communities include shrub tundra composed predominantly of dwarf birch, willow, and alder on warm, dry sites. Poorly drained sites are dominated by willow, sedge, and moss. Soils within this ecoregion are composed of Turbic and Static Cryosols developed on discontinuous, thin, sandy moraine with Organic Cryosolic soils on level high-centre peat polygons. Permafrost is continuous with low ice content throughout the ecoregion (Wiken, 1986; Ecological Stratification Working Group, 1996).

The Back River Plain ecoregion occurs in the central Kivalliq from the Back River south to Aberdeen Lake. The ecoregion is characterized by relatively level terrain, differing from adjacent ecoregions which tend to have greater relief. The Back River Plain has a low arctic ecoclimate and an estimated mean annual temperature of -10.5°C with a summer mean of 5.5°C and a winter mean of -26.5°C. Mean annual precipitation ranges from 200 to 300 mm. Plant communities within the ecoregion are characterized by shrub tundra consisting of dwarf birch, willow, Labrador tea, Mountain avens, and the genus *Vaccinium*. Tall dwarf birch, willow, and alder occur on warm sites with well-drained upper slopes tending to have a discontinuous vegetative cover. Wet sites are dominated by willow, moss, and sedge hummocks and tussocks. The ecoregion includes areas of nearly flat-lying sandstones and volcanic rocks that are commonly expressed on the surface by sandy flats covered with sparse vegetation. Soils of the ecoregion are typified by Turbic Cryosols developed on level to undulating, discontinuous veneers of sandy morainal and fluvioglacial material. Within wetlands, Organic Cryosols with associated frost-formed patterned ground are typical. Permafrost is continuous with low ice content throughout the ecoregion (Wiken, 1986; Ecological Stratification Working Group, 1996).

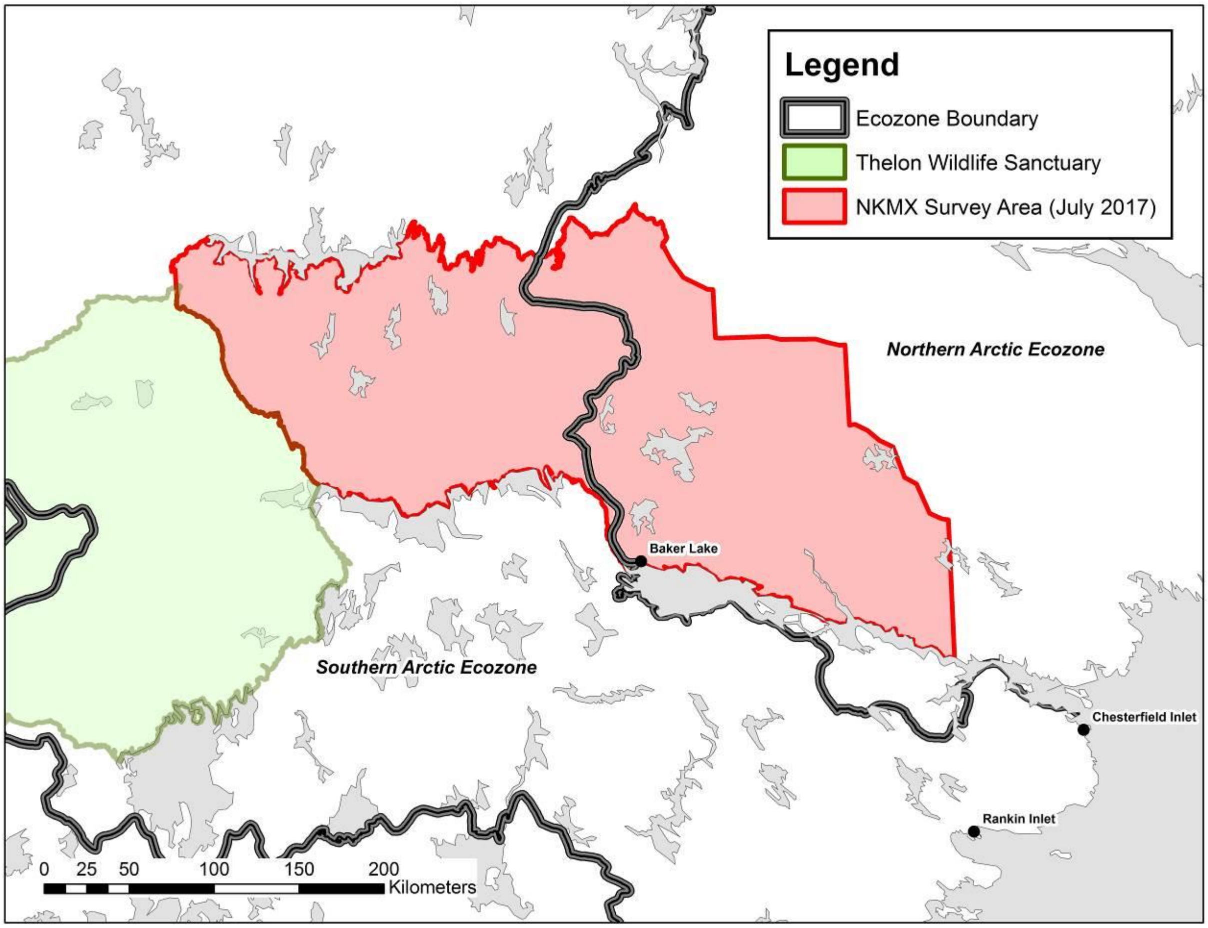


Figure 3. Ecozones of the northern Kivalliq muskox subpopulation (After Wiken, 1986; Ecological Stratification Working Group, 1996).

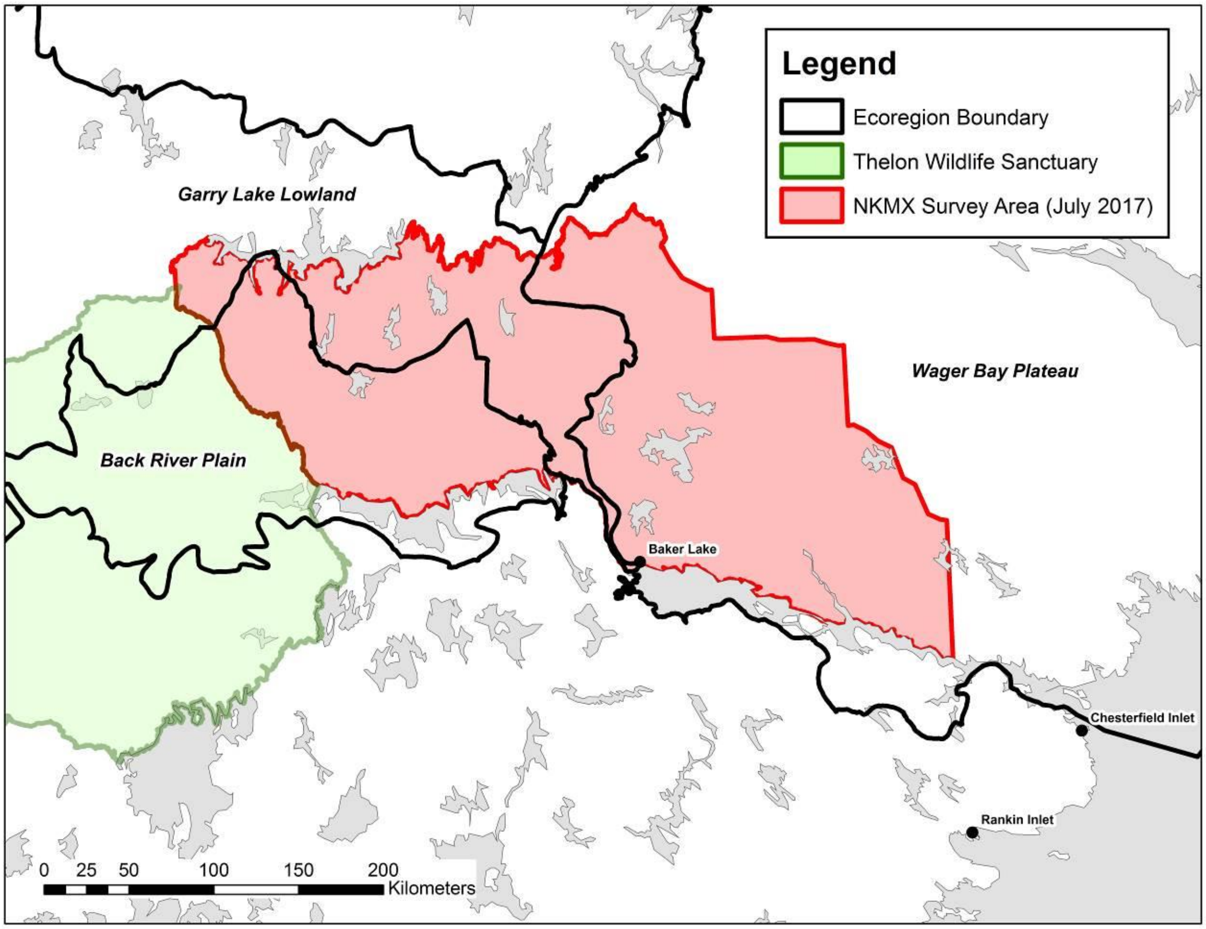


Figure 4. Ecoregions of the northern Kivalliq muskox subpopulation and survey area (After Wiken, 1986; Ecological Stratification Working Group, 1996).

Methods:

Two methods were used to determine the geographical extent of the July 2017 abundance survey: the first being the collection of *Inuit Qaujimajatuqangit* (IQ) and local knowledge to determine contemporary distributions of the NKMX subpopulation, and the second: an examination of past survey extents and estimates based on muskox observation data. IQ and local knowledge were collected and compiled during annual consultation visits with the communities of Rankin Inlet, Baker Lake, Chesterfield Inlet and Naujaat. The whole of the information collected was then used to help determine subpopulation boundaries and survey study area extents. Once the survey study area was designated, systematic transects were drawn every 7.0 kilometers, with a random starting point. Survey transect placement was the same as that used in July 2012, with some necessary additions and/or extensions to accommodate hypothesized range expansion (Campbell and Lee, 2013). All transects were placed perpendicular to the longitudinal axis of the survey area (Campbell and Lee, 2013). Transects were numbered west to east and oriented north-south across major riparian habitat as in previous Kivalliq based muskox surveys (Fournier and Gunn, 1998; Campbell, 2017; Campbell and Setterington, 2006; Case and Graf 1986; Graff et al. 1989; Mulders and Bradley 1991). Transects were flown at an altitude of 152 meters (500 ft.) above ground level (agl) which, when configured on the survey planes wing struts, provided a cumulative left side and right-side observer strip width of 2,000 meters (1,000 meters per side). The 2,000-meter strip width yielded 29.2% coverage of the entire survey area (**Figure 5**). Due to the size of the study area, the relatively limited data on muskox densities within much of the study area, and time and other logistic limitations, we decided to allocate all the survey effort into one systematic random transect survey. We also used this same allocation of effort during the previous July 2012 survey of the NKMX population.

Due largely to the exceptional sightability of muskox in July, visual transect survey methods are widely accepted as being the most cost-effective means of estimating muskox populations, while also still providing an acceptable level of precision (Case and Graf, 1986; Graf and Case, 1989; Graf *et al*, 1989; Gunn, 1995; Mulders and Bradley, 1991). The July 2017 visual survey was flown using a Cessna 206 Grand Caravan high wing single engine turbine aircraft, based out of Rankin Inlet and Baker Lake. To facilitate distance sampling techniques, strip widths of 0 to 250 meters, 250 to 500 meters, 500 to 750 meters and 750 to 1,000 meters were established on the wing struts on both sides of the aircraft using streamers to mark off the 0 meter, 500 meter and 1,000 meter markers and tape to delineate the remaining 250 and 750 meter segments (Buckland et al., 1996; Buckland et al., 2004; Buckland et al., 2010). Strip width (w) was calculated using the formula of Norton-Griffiths (1978, **Figure 6**). The strip width area for density calculations was 1,000 meters out each side of the aircraft, for a total of 2,000 m strip width along each transect. To investigate the accuracy of distance bins, each observed group of muskoxen was overflown at survey altitude and a waypoint of the exact location of the group recorded. Following any deviations from the transect to mark the position of groups, the aircraft would backtrack, parallel to the transect, and then rejoin the transect 1 to 2 kilometers behind the point of departure thus ensuring continuous observations along each transect. Survey altitude was maintained as close as possible to 152 m above ground level (agl,) using a radar altimeter. Ground speed was maintained between 175 and 195 kilometers per hour. The July 2017 abundance survey was initiated on July 21 and completed July 29, 2017.

The survey was flown using an independent double observer pair, sight-re-sight method (Borchers et al., 1998; Buckland et al. 2010; Laake, et al., 2008). To configure the double observer pair and distance sampling methods, we employed a survey crew of 7; two (2) data recorders/navigators (one in the front right seat and the second in the rear left seat), two left side observers, two right side observers and the pilot in the front left seat (**Figure 7**). We installed visual barriers between each of the left and right-side front (primary) and rear (secondary) observers to ensure no visual cues to muskox presence could be passed between same side observers. Additionally, we isolated all intercom systems between the front observers, data recorder and pilot, and the rear observers and data recorder. We also installed a quick intercom link between the front and rear in case of emergency. As part of the double observer pair sampling method, front and rear observers on both the left and right side switched between the front and rear positions halfway through the day though remained on their designated sides. This switching between front and rear positions was important to determine potential sightability, issues either with aircraft related limitations to viewing, and/or differences between observer ability.

Observations from all survey crew members were recorded along with the observer’s role and position. Where a dedicated observer was indisposed, the data recorder would move to the appropriate side to temporarily cover that position. In the case, this was to happen to the front left observer, and then the pilot, when feasible, would temporarily cover that side. For survey estimates, only observations from the four dedicated observers were used. Two of the selected observers, one for each side of the aircraft, had experience surveying wildlife visually from aircraft while the two remaining observers were selected by the local HTOs and were both Nunavut Inuit who had hunting grounds located within the survey area (Rankin Inlet, Baker Lake, Chesterfield Inlet, and Naujaat). The observers were further divided into front and rear teams, each isolated from the other using visual barriers between the seats as well as isolated through the use of two independent, intercom systems monitored by each of a front data recorder/navigator and a rear data recorder/navigator. The pilot’s responsibilities were to monitor air speed and altitude while following transects pre-programmed on a Garmin Montana 650 T geographic positioning system device (GPS). The data recorder/navigators were responsible for monitoring a second and third identically programmed GPS unit for the purposes of double-checking the position, as well as to record the waypoints and numbers of observed muskox groups, composed of adults and calves, on data sheets. The responsibilities of the observers were to, constantly and thoroughly, search their 1,000-meter strips and call out numbers of muskox within each of the delineated bins marked out on the wing struts. All observations were separated into adults and calves within each designated 250-meter-wide sub-strip. In addition to binning observations, actual group locations were also recorded by flying off transect to each observation to record position. The rear right and front left observers, the pilot and the two data collector/navigators remained consistent throughout the 2017 survey. Though calves were recorded, only counts of adults and yearlings were used in the final population estimate.

Statistical Analyses:

Survey data collected within the strata were analyzed using the Jolly method (1969). This method has been used effectively for several decades to estimate the abundance of numerous wildlife populations including muskox (Campbell and Setterington, 2006; Jolly, 1969; Mulders and Bradley, 1991). Only counts of adults and yearlings (> 1 year old) were used for the final population estimates and lake areas were not subtracted from the total area calculations used in density calculations.

Trend Analyses:

For the purposes of determining the significance of any change detected, we first conducted a z-test to compare the most recent population estimate (2017) and the previous population estimate (2012) to assess any significant difference in the population estimates. Specifically, we compared the 2017 population estimate to the 2012 population estimate using equation 5.3 of Thompson *et al*. (1998):

$$z = \frac{Y_{2017} - Y_{2012}}{\sqrt{Var(Y_{2017}) + Var(Y_{2012})}}$$

Where:

Y = Muskox Population Estimate
z = z Statistic;
Yx = Population Estimate for Year
$Var(Yx)$ = Variance of the Population Estimate

We then compared the 2017 population estimate to the 1999 population estimate. We used the two-tailed probability of the z statistic because there was no *a priori* prediction about whether there would be an increase or decrease in the population size. Hence the research hypothesis stipulated that there is a significant difference between 2012 and 2017, and the null hypothesis stated that there is no significant difference. To further explore potential differences between the 2017 and 2012 population estimates, we used Monte Carlo computer simulation methods. We assumed a log-normal distribution and built a probability distribution for each survey through random draws (n = 1,000,000) that were based upon the population estimate and standard error of each aerial survey. Several levels of difference between the two surveys were then assessed. We plotted the three survey estimates and applied a simple linear model, Poisson (log) model, and binomial (logit) model to further assess the observed changes in abundance.

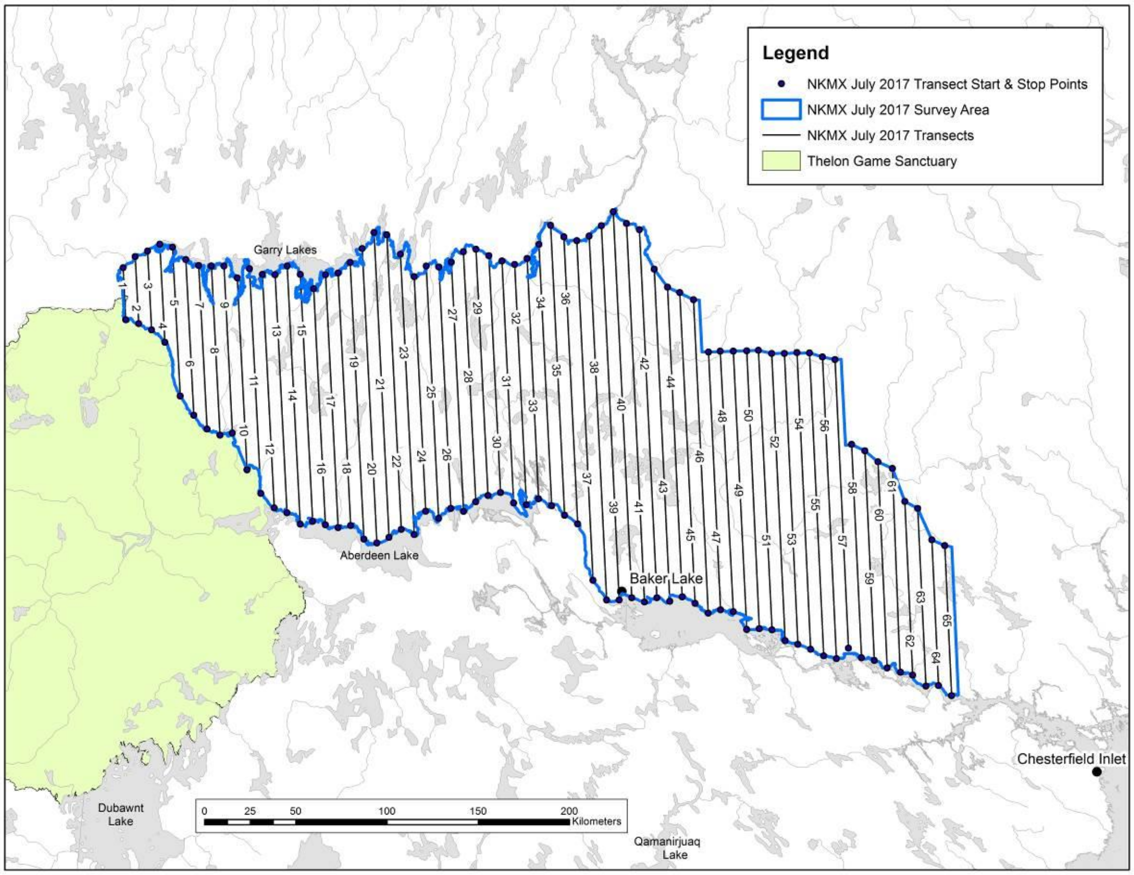


Figure 5. Study area and transects of the July 2017 northern Kivalliq muskox survey. The study area delineated based on estimated densities from IQ studies and past survey results.

$$w = W * h/H$$

where:

W = *the required strip width;*

h = *the height of the observer's eye from the tarmac; and*

H = *the required flying height*

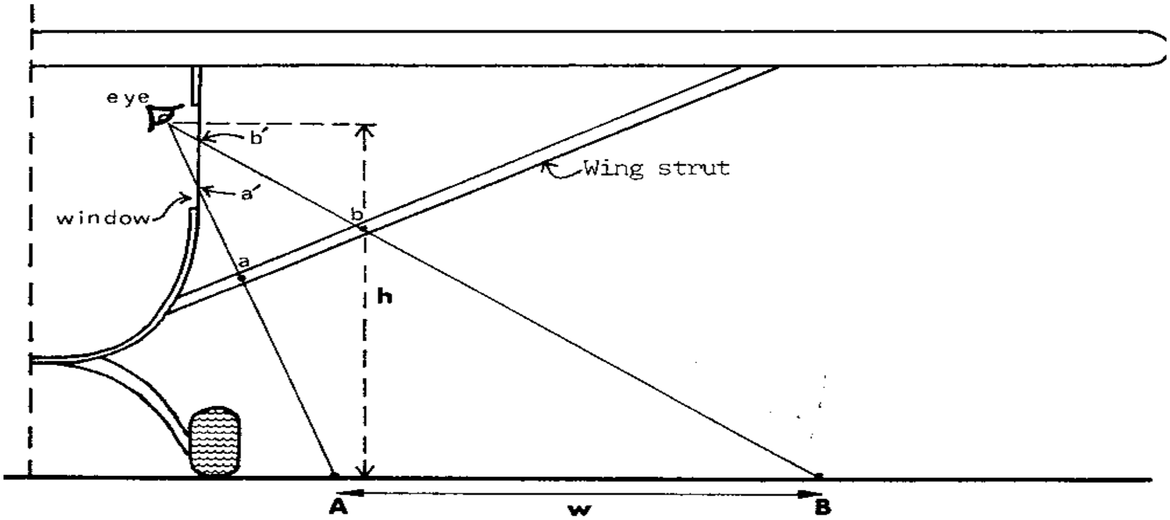


Figure 6. Schematic diagram of aircraft configuration for strip width sampling (Norton-Griffiths, 1978). W is marked out on the tarmac, and the two lines of sight a' – *a* – A and b' – *b* – B established. The streamers are attached to the struts at *a* and *b*. a' and b' are the window marks.

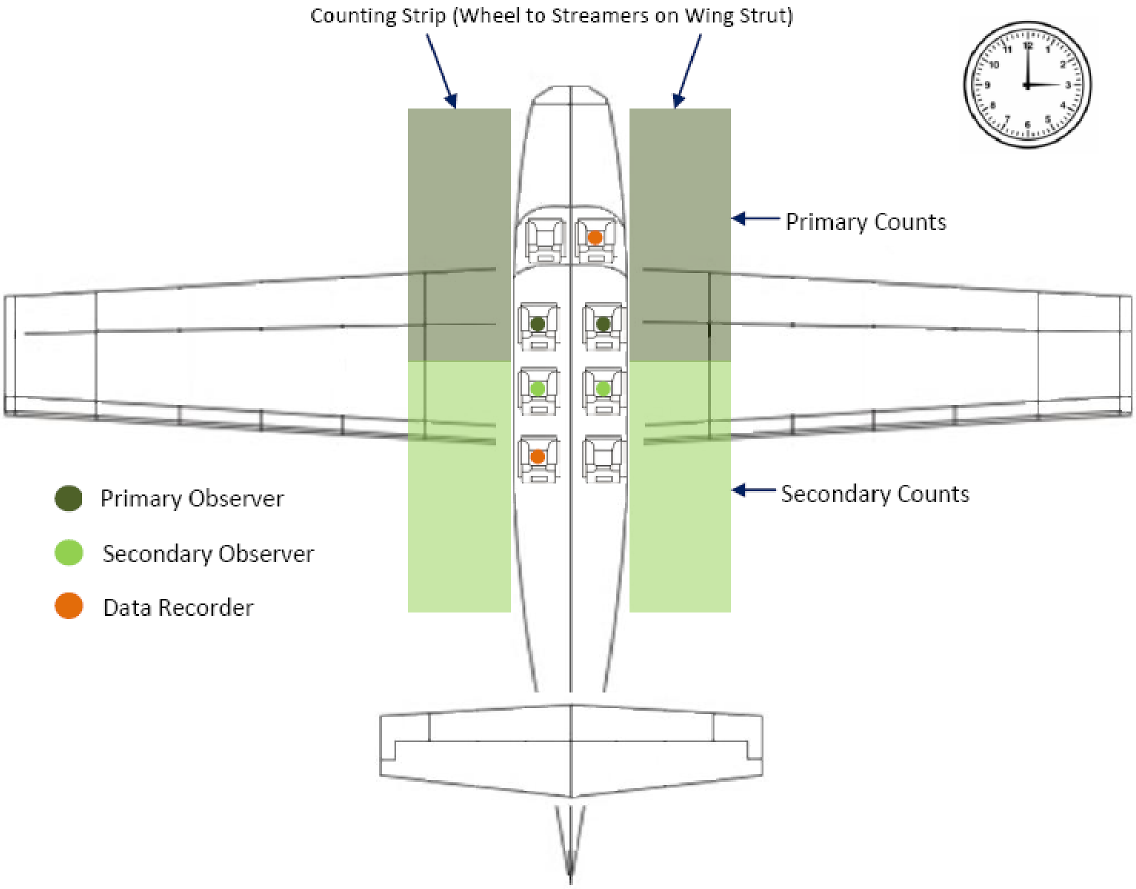


Figure 7. Observer position for the double observer sight-re-sight and distance sampling methods deployed on this survey. The secondary (rear) observer calls out muskox not seen by the primary (front) observer after the muskox have passed the main field of vision of the primary observer to their 9 (left side) or 3 (right side) o'clock. The small hand on a clock is used to reference relative locations of muskox groups (e.g. "muskox group at 3 o'clock" would suggest a muskox group 90^o to the right of the aircrafts longitudinal axis.).

Results and Discussion:

Initial results of the July 2017 muskox survey using Jolly (1969) indicate a continued increase in abundance from July 1999 through July 2017 (**Figure 8**). Current estimates show the northern Kivalliq muskox subpopulation to have increased from an estimated 1,522 (95% CI = 396; CV = 0.09) adult and yearling muskox in July 1999 to 2,341 (95% CI = 545; CV = 0.12) in July 2012, and 3,239 (95% CI = 1,050; CV = 0.16) by July 2017 (Campbell and Setterington, 2006; Campbell and Lee, 2013).

There was not a significant statistical difference between the 2012 and 2017 population estimates (z = 1.55, p =0.12) using the z-test. However, there was a significant statistical difference (z =2.83, p= 0.0047) between the 1999 mean estimate of 1,522 (CI = 843—2201, CV=0.22) and the 2017 mean estimate of 3,239 (CI = 2221—4257, CV=0.16) using the z-test, which is consistent with information gathered through local hunters that the numbers of muskox observed in the area have increased over the past two decades. In the Monto Carlo simulations, 92.4% of the runs demonstrated an increase of 100 animals from 2012 to 2017 (**Figure 8**). See **Table 2** for levels of increase ranging from 100 to 500.

Table 2 – Percentage of Runs that resulted in an increase, for each level of difference value explored.

Level of Difference between 2012 and 2017 (absolute numbers)	Percentage of Runs demonstrating an increase by the Value indicated
+100	92.4%
+200	89.2%
+300	85.3%
+400	80.5%
+500	74.9%

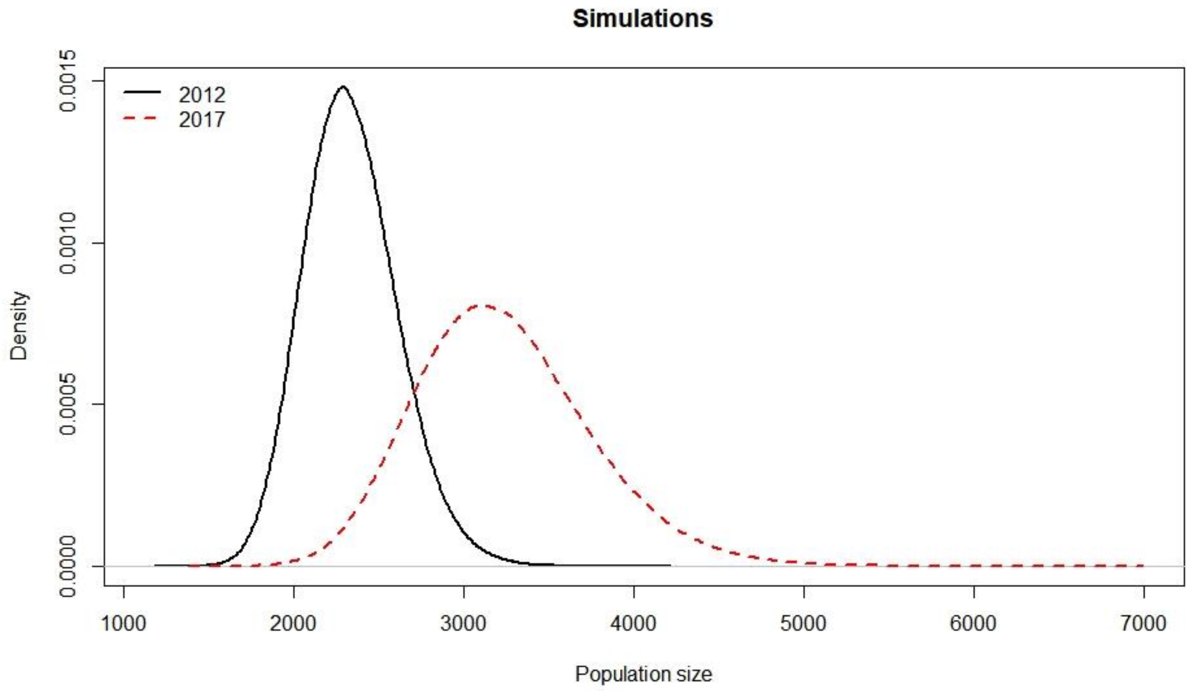


Figure 8. Distributions that were generated and used in the Monte Carlo simulation exercise to explore differences between the northern Kivalliq muskox 2012 and 2017 aerial surveys.

Generalized Linear Models:

We also fit a simple linear model, Poisson (log) model, and binomial (logit) model to the three years of survey data. The observations and models suggest population growth occurred between 1999 and 2017 in NKMX. Based on the simple linear regression model (R2= 0.92, p= 0.18), the population was increasing at an average rate of 4.3% per year from 1999 to 2012 and 6.5% from 2012 to 2017 (**Figure 9**). Carrying capacity for the population is unknown.

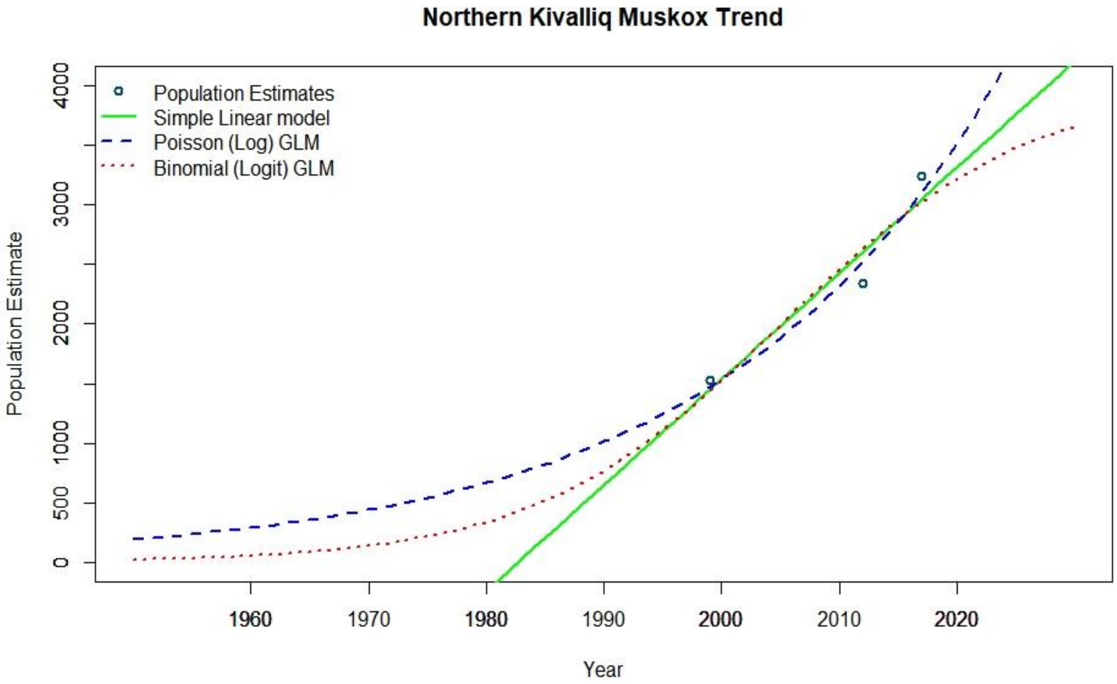


Figure 9. Plots of northern Kivalliq muskox population estimates with generalized Linear Models.

As with the CKMX subpopulation (MX-13), survey observations also suggest an expansion of the NKMX subpopulation's geographic distribution, eastwards (**Figure 10**). Survey areas, based on the extents of previous survey observations and IQ, have increased from 35,378 Km^2 in July 1999 to 49,302 Km^2 in July 2012 and to 60,576 Km^2 by July 2017, yielding an estimated increase in NKMX range area, between 1999 and 2017, of 41% (**Table 3**). A comparison using survey observations of muskox to construct a minimum convex polygon show continued expansion of the NKMX primarily to the east and southeast between July 1999 and July 2017 (Campbell et al. 2012) (**Figure 11**). Although our survey was not designed to estimate predator densities, in total we observed five wolves and no grizzly bears in July 2017. This provides no indication of quantitative changes in predator numbers from July 2012, when we observed 8 wolves and single grizzly bear (**Figure 12**).

Table 3. A summary of northern Kivalliq muskox survey results north of Chesterfield Inlet/Thelon River and west to the NWT/Thelon Game Sanctuary boundaries (1999–2017).

Year	*Total stratum area (km^2)*	*Population estimate*	*Standard error*	*CV*	*Lower 95% CI*	*Upper 95% CI*	*% calves*	*Authors*
1999 (July)	35,378	**1,522**	331	0.22	843	2,365	12.5	Campbell & Setterington, 2006
2012 (July)	49,302	**2,341**	275	0.12	1,796	2,886	13.2	Campbell & Lee, 2013.
2017 (July)	60,576	**3,239**	510	0.16	2,228	4,249	17.0	This Study

In addition to range expansion, the relative densities of the NKMX subpopulation have also increased when compared to the July 1999 abundance survey (**Table 4**). Relative densities of adult muskox within survey areas have increased from 0.043 muskox/km^2 in July 1999, to 0.048 muskox/km^2 in July 2012, and most recently, to 0.054 muskox/km^2, in July 2017. Relative densities within the 2017 survey extents are consistent with muskox densities of adjacent subpopulations, outside the survey area, and suggest that population stability and/or growth had occurred, compared with earlier findings of density in NKMX. A survey flown in July 1998 in the vicinity of the Thelon Game Sanctuary found between 0.021 and 0.063 adult muskox/km^2 (Bradley et al., 2001). Surveys flown to the north of the NKMK survey area in the vicinity of the Queen Maud Gulf (1996) found between 0.030 and 0.090 adult muskox/km^2, while a survey flown over the Adelaide Peninsula in June 1992 recorded 0.78 adult muskox/km^2 (Gunn et al., 1996; Nishi, 2001). Further north on the Boothia Peninsula, a survey flown in late July-early August of 2017 and recorded 0.084 adult muskox/km^2. There was an assessment of abundance and relative densities north of the survey area from the July 2000 Northeast Kitikmeot muskox survey (**Figure 13**). This July 2000 survey led to estimates which suggested stability in muskox abundance in Northeast Kitikmeot since the late 1990s, with reported relative densities within the southern extents of the survey area extending to the north shores of Garry Lakes of 0.056 adult muskox/km^2. Northern extents of the 2000 survey, extending to the northern shores of Adelaide Peninsula, reported adult muskox densities of 0.030/km^2, which was well below the June 1992 findings of 0.78/km^2 (Campbell and Setterington, 2006; Gunn et al., 1996). The most recent survey north of MX-10 was completed in 2017 for the MX-08 management unit. The results from this survey showed the population estimate increased significantly from 554 in 1995 and 1058 in 2006 to 3649 muskoxen in 2017. The increasing population in MX-08 may be an indication that the same trend could be occurring in the northern portion of MX-10 that was not included in this survey.

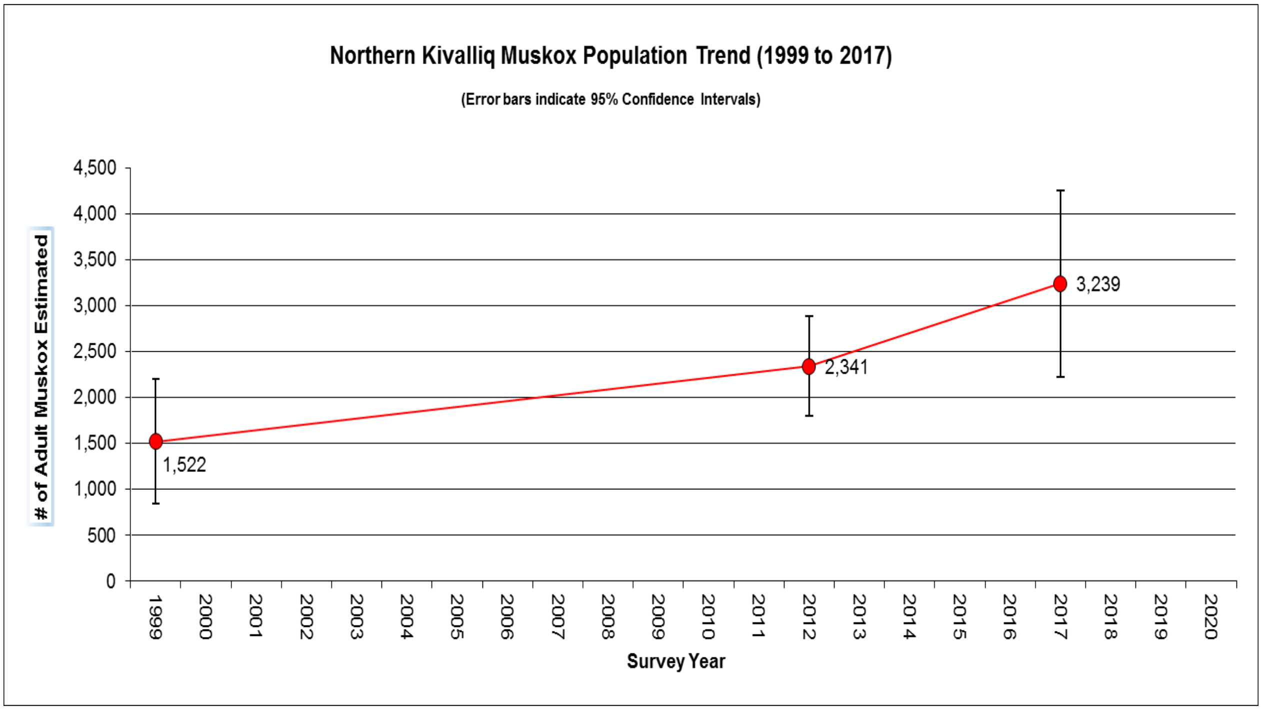
Calf proportions within the NKMX subpopulation have increased between survey years: from 12.5% in July 1999, to 13.2% in July 2012 and to 17.0% in July 2017. The 2017 calf proportions are consistent with the estimated productivity that would be related with a stable to increasing abundance. An examination of muskox abundance on the Adelaide Peninsula across three abundance survey years including July 1986, June 1992, and July 2000, suggested a period of strong growth between July 1986 and June 1992, which was reflected in an estimated increase in abundance from 213 (Coefficient of Variation, CV = 0.59) in July 1986 to 1,165 (CV = 0.33) adult muskox in July 1992. However, the high CVs for both surveys make it difficult to determine the confidence of this increase, although actual observations support the likelihood of an increase.

On-transect observations of animals increased from 44 adult muskox in 1986 to 233 adult muskox in 1992. Over the same survey periods calf proportions were reported as 17.1% in 1986 and 6.6% in 1992 (Gunn et al., 1996). While a survey flown in July 2000 over the Adelaide Peninsula did not subsample nor estimate the population of the Adelaide Peninsula due to low abundance, an examination of the July 2000 observations over the same survey area covered by Gunn et al. (1996) revealed a total count of 142 adult muskoxen and calf proportions of 14.8%. Examining these past trends suggest that caution must be exercised when extrapolating calf proportions as an indication of longer-term trends. Additionally, calf proportions can vary widely from year to year. With this caution in mind, a comparison between calf proportions recorded in 1986, just prior to a reported increase in muskox relative densities within an area close to the July 2017 survey area, though qualitative, does corroborate the likelihood of the observed calf proportions in July 2017 as being consistent with increasing muskox abundance between July 2012 and 2017, when compared to a similar muskox subpopulation with a similar relative distribution and shared Ecozone.

Overall, the July 2017 NKMX surveys CV exceeded ten percent of the mean estimate, suggesting the need for stratification into two to three strata in future. The more clumped distributions of muskox encountered in 2017 were the main cause of the increased CVs. Because of the relatively high variance within the current analysis, these results should be used with caution.

Table 4. Data summary for the July northern Kivalliq muskox abundance survey, Nunavut.

Statistic		**July 1999**	**July 2012**	**July 2017**
Maximum number of transects	**N**	136	205	227
Number of transects surveyed	**n**	28	60	65
Total stratum area (km^2)	**Z**	35,378	49,302	60,576
Transect area (km^2)	**z**	7,276	14,405	17,600
Number of adult muskoxen counted	**y**	313	684	941
Number of Calves Counted		39	90	160
Muskox density (muskox/km^2)	**R**	0.043	0.048	0.054
Proportion Calves Observed		12.5 %	13.2 %	17.0 %
Population estimate (Adult Muskox)	**Y**	1,522	2,341	3,239
Population variance	**Var (Y)**	109569	75543	259659
Standard error	**SE (Y)**	331	275	510
95% confidence limits	**(±)**	679	566	1,050
Coefficient of variation	**CV**	0.22	0.12	0.16


Northern Kivalliq Muskox Population Trend (1999 to 2017)
(Error bars indicate 95% Confidence Intervals)
# of Adult Muskox Estimated
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1,522
2,341
3,239
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
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2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Survey Year

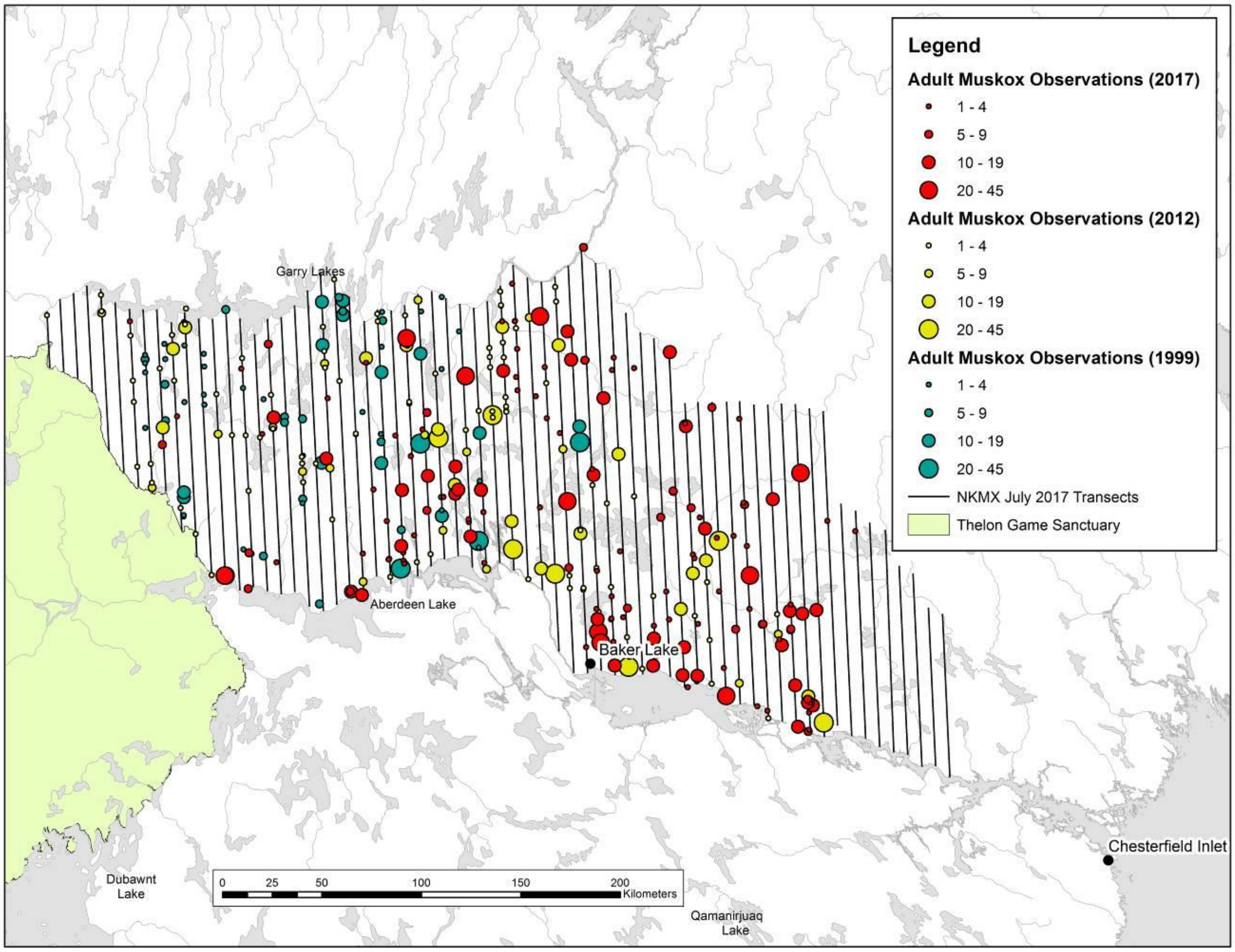

Figure 10. Northern Kivalliq muskox aerial survey observations of muskox from July 1999 (blue), to July 2012 (yellow), and July 2017 (red).

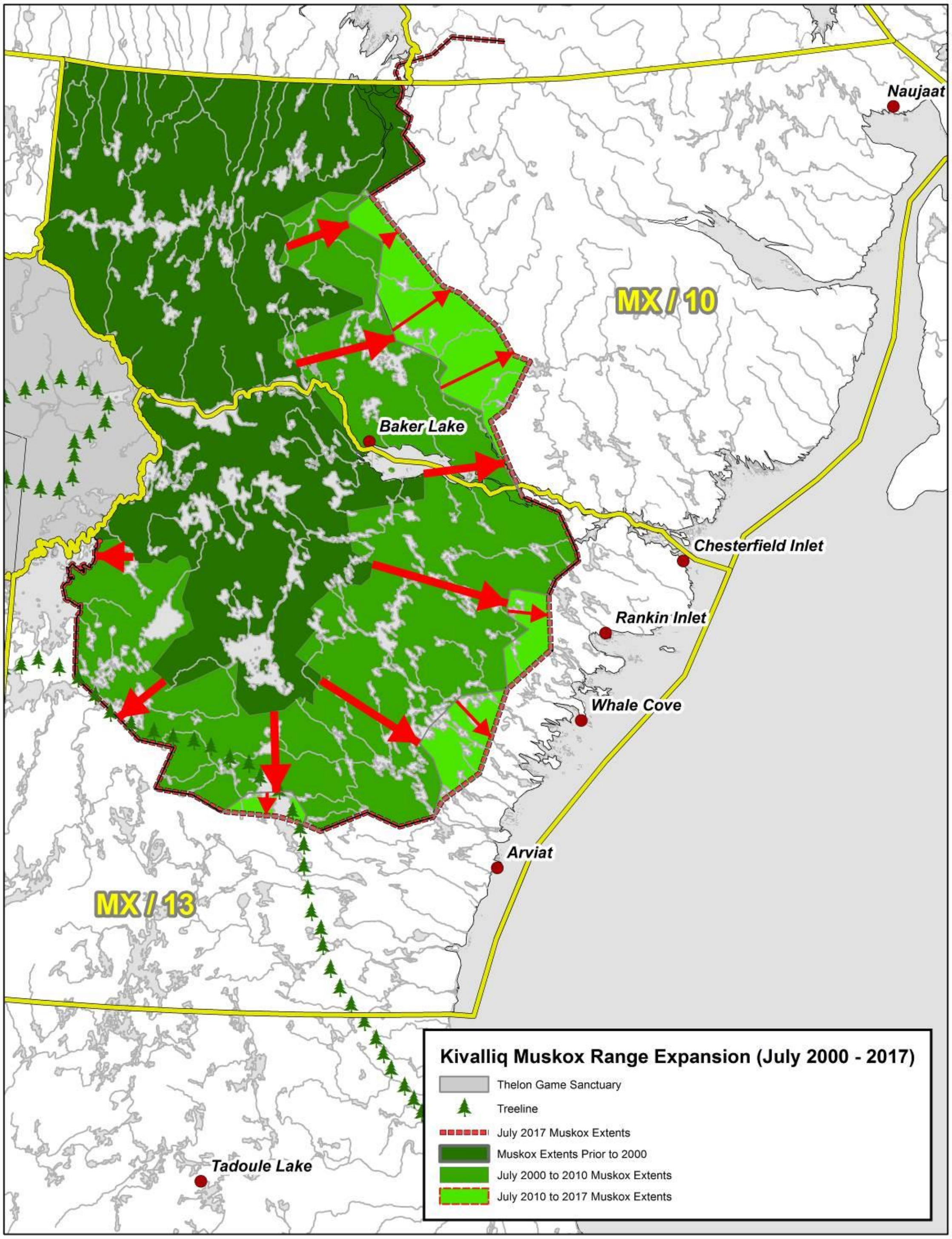

Figure 11. Indicated central and northern Kivalliq muskox range expansion between July 1999 and July 2016 (Central Kivalliq) and July 2017 (Northern Kivalliq).

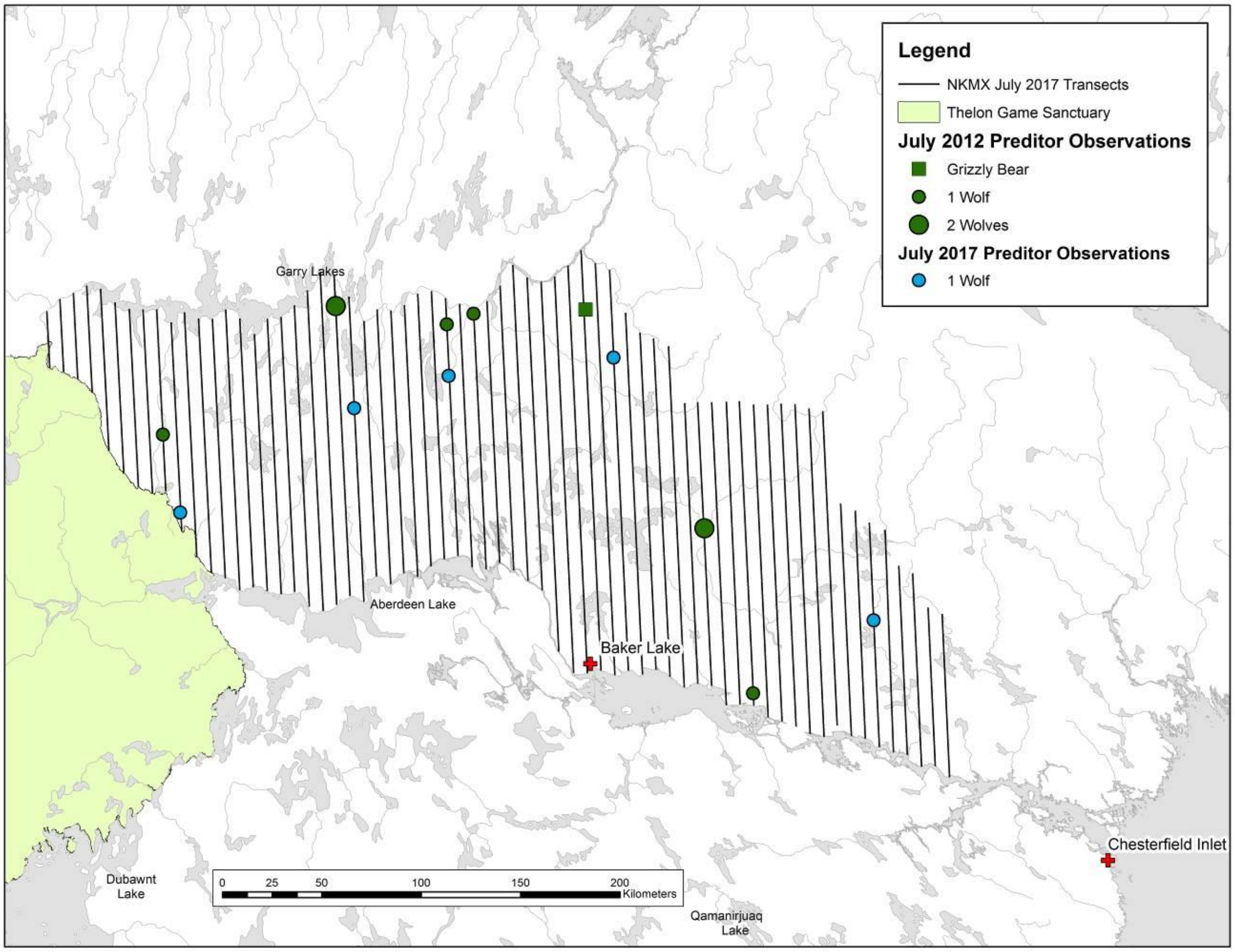

Figure 12. Predator observations during the July 2012 and 2017 northern Kivalliq muskox aerial surveys.

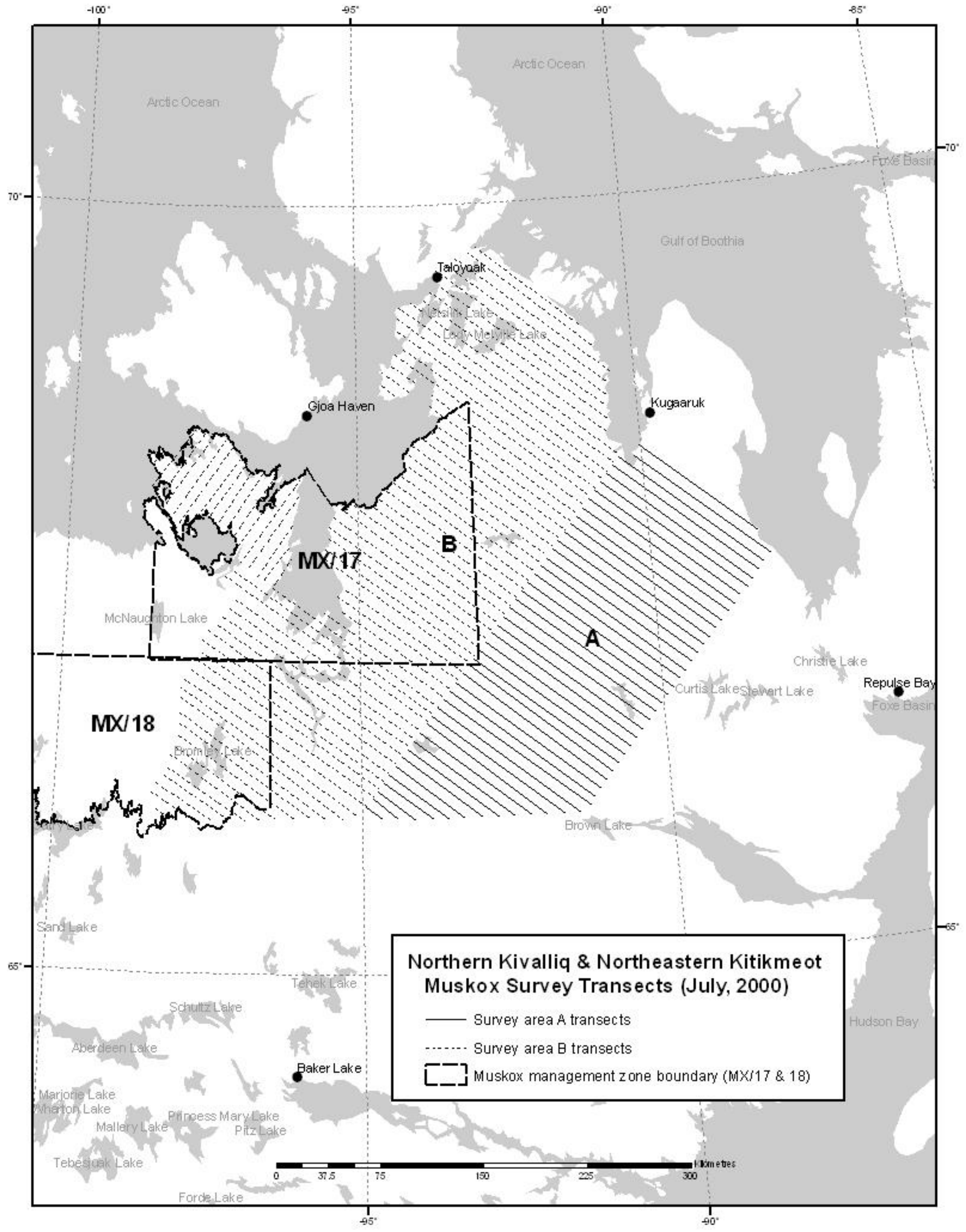

Figure 13. Survey areas and the transects flown over the northeastern Kitikmeot survey area in July 2000 (Campbell and Setterington, 2006).

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