



**MUSKOX (*Ovibos moschatus*) DISTRIBUTION AND ABUNDANCE, MUSKOX MANAGEMENT UNITS
MX-07, VICTORIA ISLAND, SEPTEMBER 2013-2014.**

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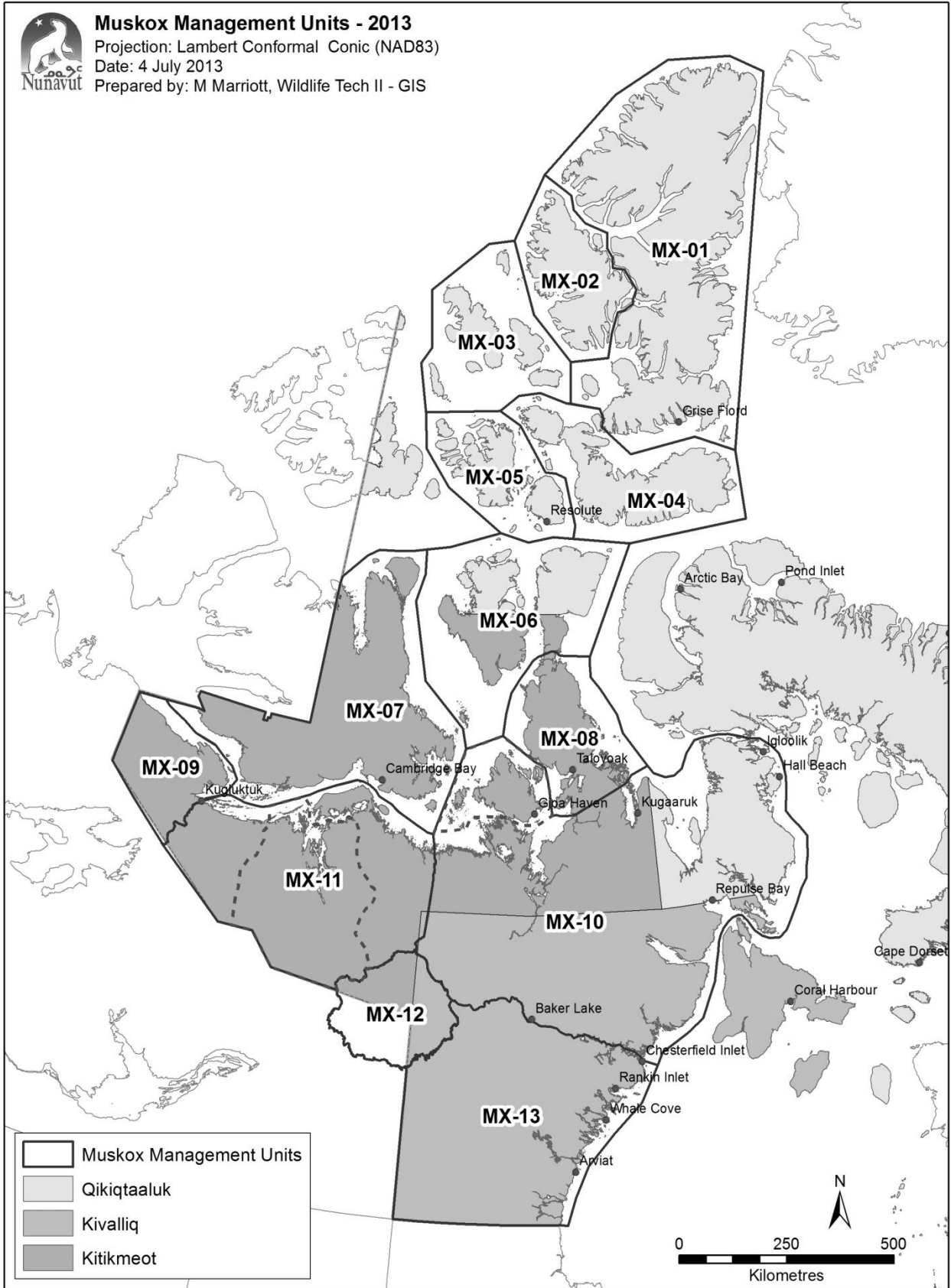


Muskox Management Units - 2013

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Executive Summary

Systematic strips transect surveys of the Nunavut portion of Victoria Island to determine the abundance and distribution of muskox were undertaken in fall 2013 and 2014. The first part of the survey, which consisted of stratum 1, 2 and 3, took place from August 26 to September 3, 2013 with the remaining of the Management Unit MX-07, stratum 4, 5 and 6, surveyed from August 2 to August 12, 2014. A total of 17,453.52 km² were flown, representing 13% coverage of the study area of 134,934 km². During the survey, 1,296 adult muskoxen were recorded on transect resulting in an estimated number of 10,026 ± 597 (S.E.) for the study area. This is a decline of muskox number in MX-07 from what have been estimated previously, but it is consistent with local observations. Muskoxen were mostly uniformly distributed thought the management units MX-07. Calves represented 8% of the adult muskox seen and the average adult per group was small, 5.7 ± 4.32 (S.D.). The lowest muskox density was encounter to the west south of the North West Territory boarder and north of Ferguson Lake, 0.0617 muskox / km² and 0.0618 muskox / km² respectively. It is east of Cambridge Bay that the density was found to be the highest with 0.1321 muskox / km². A recommended harvest rate of 4% is suggested to support an increase of the muskox on the Nunavut side of Victoria Island. Increase in monitoring, harvest reports and health monitoring program are recommended based on this survey results. The next survey of this area should be effectuated no later than 2019, so harvest rate could be review.

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Introduction

For thousands of years, Inuit survival was directly linked to the use of available animals, such as Muskox (*Ovibos moschatus*). Inuit developed traditional management strategies to assure their subsistence off the land was sustainable. However, in the wake of whalers, fur-traders, explorers and scientists, muskox were hunted for their meat and hides (Spencer 1976; Gunn 1984). This hunting pressure and others possible contributing factors, reduced muskox numbers to near extinction levels and considerably changed their natural distribution and range, as some Arctic islands saw virtual extirpation (Spencer 1976; Gunn 1984). A moratorium was then introduced in 1917.

Complete protection for close to 59 years allowed the muskox to recover. Muskoxen have been recolonizing their former habitats from small residual populations and are now more prone to respond to environmental factors. Muskox constitutes an important source of food for the Inuit communities of the Kitikmeot. Fluctuation in population numbers has management concerns especially when muskox is an important source of food for Inuit in the Kitikmeot Region.

To allow a sustainable hunt, management units were created so the boundaries of those units coincide with the remaining pockets of distinguished muskox populations or sub-populations. Resulting population oscillations bring different management strategies. Thus, conservative management harvest level were maintained and the harvesting rate and harvest zones have been adjusted in function of the number of muskox estimate in the harvest zone during aerial surveys (Gunn 1984).

The harvest zones in Nunavut have been expanded and reviewed to match the population expansion and increase in population size characteristic of the population dynamic (Gunn 1984). In July 2013, new muskox management units were established in Nunavut to better represent the population boundaries. Genetic studies were conducted to add information on the delineation of muskox population.

Based off this genetic study, recommended management zones were developed based on muskox distribution clusters and the fact that muskox generally stay within a 50 km radius which slows down re-colonization and exchange between populations or clusters (Dumond, 2011; Tener, 1965). Gunn et al. (1984) traced the muskox re-colonization of the Queen Maud Gulf and estimated that the average annual rate of spread to the east was 13 km/year. Therefore, the three old management unites; MX-07, MX-10, and MX-11 of Victoria Island were fused to one new muskox management unit, MX-07, to better represent the population boundaries.

Victoria Island constitutes a very important habitat for muskox. Jakimchuk and Carruthers (1980) surveyed Victoria Island and the number of muskox estimated then represented 27% of the estimated population of muskox in Canada. In 1979, commercial harvest was written into

regulation. With the population bloom on Victoria Island, commercial harvest was adopted in aim to “reduce the overpopulation” or at best control it and to foster economic development. Victoria Island commercial harvest was initiated with portable abattoirs handling up to 100 - 200 muskox to occasional large-scale harvest taking up to 1,800 muskoxen (Gunn *et al.* 1991; Nagy *et al.* 2001).

The low movement rate of the muskox and intensive hunting pressure around the community called for rigorous monitoring programs where commercial harvest took place. Muskox monitoring by systematic strip transects began in 1988, 1993 and 1999 on the southeastern Victoria Island, MX-11. This area includes the surrounding of Cambridge Bay where most harvests were undertaken. Despite the monitoring, between November 1993 and March 2000, the commercial harvest at Ekaluk River has resulted in the virtual absence of muskoxen within a 50-70 km radius of the abattoir on 10 occasions (Gunn and Patterson 2000). Either the harvest removes muskoxen at the rate they move into the area and or there is behavioral avoidance.

Current harvesting rates in Cambridge Bay are based on the last muskox numbers estimated in 1999. In consequence, management issues are emerging as seen in the past for this localized commercial harvest. Kitikmeot Foods, Ltd stopped their commercial harvest in two consecutive years, in 2013 and 2014, due to very few muskox being within their commercial harvesting zone (Kitikmeot Foods Ltd 2012). In recent years, the opening of a permanent abattoir in Cambridge Bay limited the commercial harvest zone to within a 60 km radius. As a consequence, local hunters have to travel longer distances to harvest muskox for subsistence, community harvest or during sport hunt.

The recent documentation of the muskox lungworm, *Umingmakstrongylus pallikuukensis*, in the central part of Victoria Island raised additional concerns about the spread of this parasite inland (Kutz, 2000; Kutz *et al.* *in press*). This parasite can affect muskox survival by making them more vulnerable to other diseases, and increasing the risk of predation where the numbers of predators have been reported by local community member to have increased (Hudson *et al.* 1992). All these factors may affect muskox population dynamics negatively and impact management plans and decision making related to harvest levels.

This study aims to provide essential inventory information required to review existing management strategies and promote the conservation of the muskox group, so that future generations of Inuit may continue to harvest this resource. To do so, relative muskox numbers, distribution, and calf crops will be assessed. Natural population oscillations may bring different management strategies, thus, conservative management harvest levels were maintained and the harvesting rate has been adjusted as a function of the number of muskox estimated in the management units (Gunn, 1984).

This is the first report on the muskox abundance and distribution of MX-07. Muskox population dynamics have an impact on management plan and decision making-related to harvest levels. The recommendations in this report are intended as short-term advice applying base on the 2013 and 2014 season surveys. From the scientific data, management recommendations

included in this scientific report will be used with the community consultation report as support documents to the West Kitikmeot muskox management plan.

Objectives

This project aims to address the concerns and requests of Inuit hunters, as well as to provide up to date scientific information. Therefore, the main objectives of this study are:

1. Determine the estimated number of muskox;
2. Determine muskox distribution and density;
3. Determine calf crop and group size.

By doing so, it will be possible to have better information on current muskox abundance and distribution on Victoria Island. Information on group structure, calf crop, group size and density, is essential to gain insight on the relation between these variables and population dynamic.

Materials and Methods

Study Area

Victoria Island is mainly characterized with undulating lowlands formed on flat-lying Palaeozoic and late Proterozoic carbonate rock that slope gently. The elevation rises up to 200 meters. However, the central part of the Shaler Mountains, at the north, reaches about 760 meters. The study area is part of the Northern Arctic Ecozone characterized with three ecoregions, the Wager Bay Plateau, Victoria Island Lowlands and the Shaler Mountains.

The southern coast of Victoria Island is part of the Wager Bay Plateau ecoregion. At some sites, taller dwarf birch, willow and alder occur, but the vegetation is mostly characterized with a discontinuous cover consisting of dwarf birch, willow, northern Labrador tea, *Dryas* spp., and *Vaccinium* spp. The rock outcroppings are covered with lichen. The Victoria Island Lowlands ecoregion, which constitutes two-thirds of Victoria Island, is mainly dominated by arctic willow, alpine foxtail, wood rush and other saxifrage species, such as the purple saxifrage. The land is covered with numerous ponds and small lakes. The lakes are surrounded with sedge, cottongrass, saxifrage and moss. The Shaler Mountains ecoregion overtakes the Natkusiak Peninsula in the north part of the Island. This ecoregion has a 40-60% vegetation cover mixed with exposed bedrock. The tundra is composed of purple saxifrage, arctic willow, along with alpine foxtail, and woodrush (Environment Canada, 1995).

Survey Area

No reconnaissance survey was undertaken prior to surveys to maximize the coverage area investigated. Instead, anticipated muskox distribution patterns were obtained from past ground

surveys, hunter observations, and Inuit Traditional Knowledge/*Inuit Qaujimajatuqangit* (IQ). Base on this information and the large space to cover, the management unit MX-07 was divided into six stratum that were surveyed in two consecutive summer seasons, 2013 and 2014. Consistent standard procedures used throughout the 2013 muskox surveys were also applied in summer 2014 (Figure 1).

Past studies had recommended surveying southeastern Victoria Island, specifically an area within 160 km of Cambridge Bay (JingFors 1984). Extensive coverage was then set for this area, stratum 1, 2 and 3, and was flown first in 2013 and then stratum 4, 5, 6 the following summer at a lower coverage. In addition, survey effort was allocated according to muskox sightings and importance of the area for harvesters. This contributed to optimizing the number of transects flown in each stratum and to cover a minimum of 10% in area where no harvest occurred up to 25% where muskox sightings and harvest pressures were higher.

The northern part of Victoria Island (stratum 6) and the stratum 5 were surveyed at 10%, as there is a very low muskox harvest rate and human impact (Figure 1). Few hunters from Kugluktuk traditionally cross the sea ice to go hunting on the south coast of Victoria Island. Therefore, southern-west stratum (4) was surveyed at 15% to increase the precision of the muskox number estimate at this location.

The southeastern portion of Victoria Island is the location of intensive commercial harvest, sport hunts as well as subsistence harvest take place in the vicinity of Cambridge Bay. The percentage of area covered in stratum 1, 2, and 3 was determined in function of the land use but also based on the number and distribution of muskox previously encountered during the winter ground surveys in May 2013 and March 2014 (Leclerc per. comm). The south-east stratum (stratum 1) and the north-east (stratum 2) was surveyed at 20% coverage and the stratum to the west of Cambridge at 25% (stratum 3).



Figure 1 Transect lines and the six strata boundaries (1,2,3,4,5,and 6) of the muskox management units MX-07 during a muskox survey of the Nunavut portion of Victoria Island, August 2013 and 2014.

To increase the precision of the survey areas, ESRI'S ArcGIS software with an adapted tool was used to plot the transect lines. The tool allows the user to determine the precise number of transects and the distance between each transect line required to reach the predetermined percentage of cover in function of the transect strip width and the total area of each stratum within the management unit. Orientation of the transect lines within the stratum was determined in function to have the most homogeneous and shorter transect line length under the assumption that muskox are randomly and uniformly distributed on the landscape (Figure 1).

Table 1, below, summarize for each six stratum in management unit MX-07, the total area, the percentage of cover, the total number of km of transects of different length, the number of

lines, the resulting distance between each transect line and the orientation of the transect line. In sum, the management unit, MX-07, of 134,934 km² was surveyed with a total of 10,906 km of transect lines, which represented 125 transect lines of different length (Table 1).

Table 1 Characteristic of the study area and the transect lines per stratum in the Management Unit MX-07.

| Stratum | Total area (km ²) | Percentages (%) | Total transect lines (km) | Number of lines | Distance between transect line (km) | Orientation |
|---------|-------------------------------|-----------------|---------------------------|-----------------|-------------------------------------|-------------|
| 1 | 11,855 | 20 | 1,187 | 19 | 9.89 | North-South |
| 2 | 22,642 | 20 | 2,318 | 22 | 9.89 | North-South |
| 3 | 14,147 | 25 | 1,749 | 21 | 7.95 | East-West |
| 4 | 11,539 | 15 | 1,040 | 23 | 10.86 | North-South |
| 5 | 28,321 | 10 | 1,750 | 20 | 15.90 | North-South |
| 6 | 46,430 | 10 | 2,862 | 20 | 15,90 | East-West |
| MX-07 | 134,934 | ---- | 10,906 | 125 | ---- | ---- |

Aircraft configuration

A systematic transects line survey was flown with a fixed-wing single engine turbine aircraft, a Turbo Beaver. The transect lines were surveyed at a speed of 160 km/hr and at an altitude of about 150 meters which was consistently maintained due the flat relief of the study area. Pre-determined transect width of 800 meters was set on the window based on calculation using the formula of Norton-Griffiths (1978) and others (Gunn and Patterson 2000; Howard 2011).

$$w = W * h / H$$

Where, W= the required strip width; h= the height of the observer's eye from the tarmac; and H= the required flying height.

The strip transect was 800 meters on each side of the aircraft, for a total transect width of 1.6 kilometers. The strip width calculations were confirmed by flying perpendicular over a known distance marked at 800 meters. Two observers in the rear continuously searched for and counted muskox, either as on or off-transect; the number of calves (5-6 months old) were counted when they were conspicuous. No sex and age classification count were systematically attempted. Photographs were taken of large groups (> 20 muskoxen). The data keeper recorded the number of muskox, GPS location and their distance from the transect line. Even if this survey focused on muskox, additional sightings of other species were recorded, such as caribou, grizzly bear, polar bear and wolf.

Analyses

As this survey focused mainly on obtaining an estimated number, only unambiguous classification criteria were used to determine the number of calves and adults. The group was then broken down into adults (female/male) and calves (Howard 2011). The flying height and speed did not allow for accurately distinguishing male from female muskox in a group from horn size. Therefore, the proportion of calves per female cow was not determined, and no information on the recruitment or productivity was generated. The group structure was however described such as calf crop, mean group size and the number of single lone bulls encounter was also recorded.

To determine the number of muskox in the study area, only the adults muskox sightings recorded on transect were analyzed using Jolly's Method 2 for unequal sample sizes (Jolly 1969) using a coefficient limit of 95%. The count was automated by a script in ESRI'S ArcGIS software.

Density, the number of muskox per unit area (muskox/km²), was determined using the number of adult muskox seen on transect divided by the total area of the study area. Lakes and streams areas were not subtracted from the total area calculations used in muskox density.

The area occupied by the muskox during this specific season within the study area was determined. Thus, the distribution was illustrated by plotting each muskox sighting on transect based on their precise geospatial position captured with a Global Positioning System (GPS) during the survey. In addition, the number of animals composing each group was highlighted using an increasing size of symbol to represent group of 1-5, 6-12, 13-20, 21-30, 31-45 and 46 to 91 animals.

Given the importance of predators, Grizzly Bear (*Ursus arctos horribilis*) and Arctic Wolf (*Canis lupus arctos*) in affecting muskox numbers and the difficulty of estimating their predation rates, we collected standardized information of predator sightings in the management units using the predator index (Heard, 1992). The predator index reports all predator sighting per species against the reported total number hours of flying, in this case also including the ferry time. This gives a way of comparisons between study areas, as the number of predators observed is expressed per 100 hours.

Results

The first part of the survey, which consisted of stratum 1, 2 and 3, took place from August 26 to September 3, 2013. There were no flights on August 27 and September 1, due to a mechanical problem and a weather day. The three stratum were surveyed in 58 hours, including time on transect and ferry flight from the transect lines to Cambridge Bay.

The remaining of the Management Unit MX-07, stratum 4, 5 and 6, was surveyed from August 2 to August 12, 2014. Localized rain showers prohibited the departure to the fuel cache and

camps location. The survey resumed on August 3. This area was surveyed in 71 hours, including on transect and ferry flight from the Cambridge Bay airport to the transect lines. Note that due to the extensive area to cover, ferry flight time was reduced by setting fuel caches and camps at two strategic locations.

Group Characteristic

During the survey, 227 groups of muskox were recorded on transect, where 38 were single lone bulls. Whereas the lone bulls accounted for 3% of the total number of muskox observed, the calves represented 9% (120 calves and 1, 296 adult muskoxen). The average number of adults per group was 5.7 ± 4.32 (S.D.). The highest number of adults counted in one group was 25, which represented a too low percentage to be display in Figure 2. The majority of the groups (49%) were very small group of 2 to 5 animals follow closely from group of 6 to 12 animals (41%) (Figure 2). Groups with more than 13 adults were infrequent (20 groups, 8%).

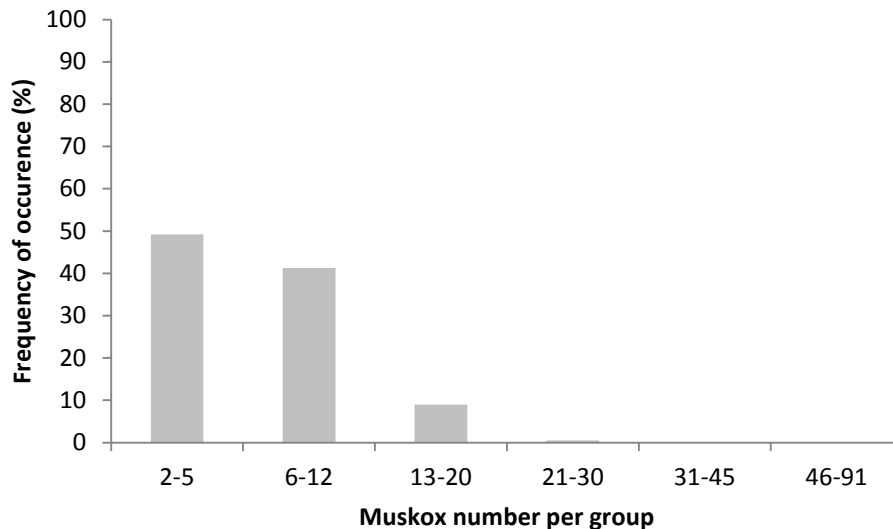


Figure 2 Frequency of occurrence (%) of the different muskox number per group, grouped as follow 2-5, 6-12, 13-20, 21-30, 31-45, and 46-91, during the survey of the management unit MX-07.

Estimate

The percentage of each stratum varied from 10% to 25%, the overall cover of the management unit surveyed with $17,453.52 \text{ km}^2$ represented 13% of the total study area ($134,933.72 \text{ km}^2$). During the survey, 1,296 adults muskoxen on transect were recorded. The estimated number of muskox in the management unit 07, totalized $10,026 \pm 596.90$ (S.E.) ($p < 0.005$, $t = 1.984$, $N = 732$ and $n = 125$). For this estimate, the total number of transect at 100% coverage was 732 (N) and 125 (n) transect lines were surveyed (Table 2).

Within the six stratum, the number of adult muskox on transect varied from 112 to 299 giving an estimate from 777 ± 143.21 (S.E.) to $3,032 \pm 437.21$ (S.E.) respectively. The stratum with the lowest number of sightings was on the south cost of Victoria Island (4) whereas most of the muskox appears to be north of Victoria Island (6) (Table 2).

Table 2 Muskox estimate in the Muskox management Unit MX-07

| Stratum | Area Survey (km ²) | Total area (km ²) | Muskox on Transect | Estimate | Standard error (S.E.) | 95% CL (±) | CV |
|---------|--------------------------------|-------------------------------|--------------------|----------|-----------------------|------------|-------|
| 1 | 1,899.94 | 11,854.85 | 251 | 1,566 | 140.88 | 295.99 | 0.090 |
| 2 | 3,711.14 | 22,642.23 | 229 | 1,397 | 180.26 | 374.94 | 0.129 |
| 3 | 2,798.61 | 14,147.27 | 232 | 1,173 | 186.81 | 389.70 | 0.159 |
| 4 | 1,663.63 | 11,538.85 | 112 | 777 | 143.21 | 297.02 | 0.184 |
| 5 | 2,800.80 | 28,320.87 | 173 | 1,750 | 239.57 | 501.42 | 0.137 |
| 6 | 4,579.40 | 46,429.65 | 299 | 3,032 | 437.21 | 915.07 | 0.144 |
| MX-07 | 17,453.52 | 134,933.72 | 1,296 | 10,026 | 596.90 | 1,184.26 | 0.060 |

* $p < 0.005$, $t = 2.101$, $N = 90$ and $n = 19$

** $p < 0.005$, $t = 2.080$, $N = 109$ and $n = 22$

*** $p < 0.005$, $t = 2.086$, $N = 86$ and $n = 21$

**** $p < 0.005$, $t = 2.074$, $N = 125$ and $n = 23$

***** $p < 0.005$, $t = 2.093$, $N = 162$ and $n = 20$

***** $p < 0.005$, $t = 2.093$, $N = 160$ and $n = 20$

***** $p < 0.005$, $t = 1.984$, $N = 732$ and $n = 125$

Distribution

The distribution and the abundance of muskox for the two surveys, August 26 to September 3, 2013 (stratum 1, 2 and 3) and from August 2 to August 12, 2014 (stratum 4,5, and 6) was combined in the figure below (Figure 3). Muskoxen were mostly uniformly distributed through the study area. Most of the groups were small, with a number of muskox around 6 to 12 animals. Unfortunately, the fuel capacity of the plane and the distance from the airport to the eastern satellite islands, prohibited surveying of Admiralty Island, Jenny Island, and Gateshead Island. No muskox were seen 25 km around Cambridge Bay as local observations reported. In addition no muskox was found 10 km north-west of Washburn Lake in the central desert, East of Mount Bumpus, on the east coast, the Northern part of the Storkerson Peninsula and Stefansson Island as well.

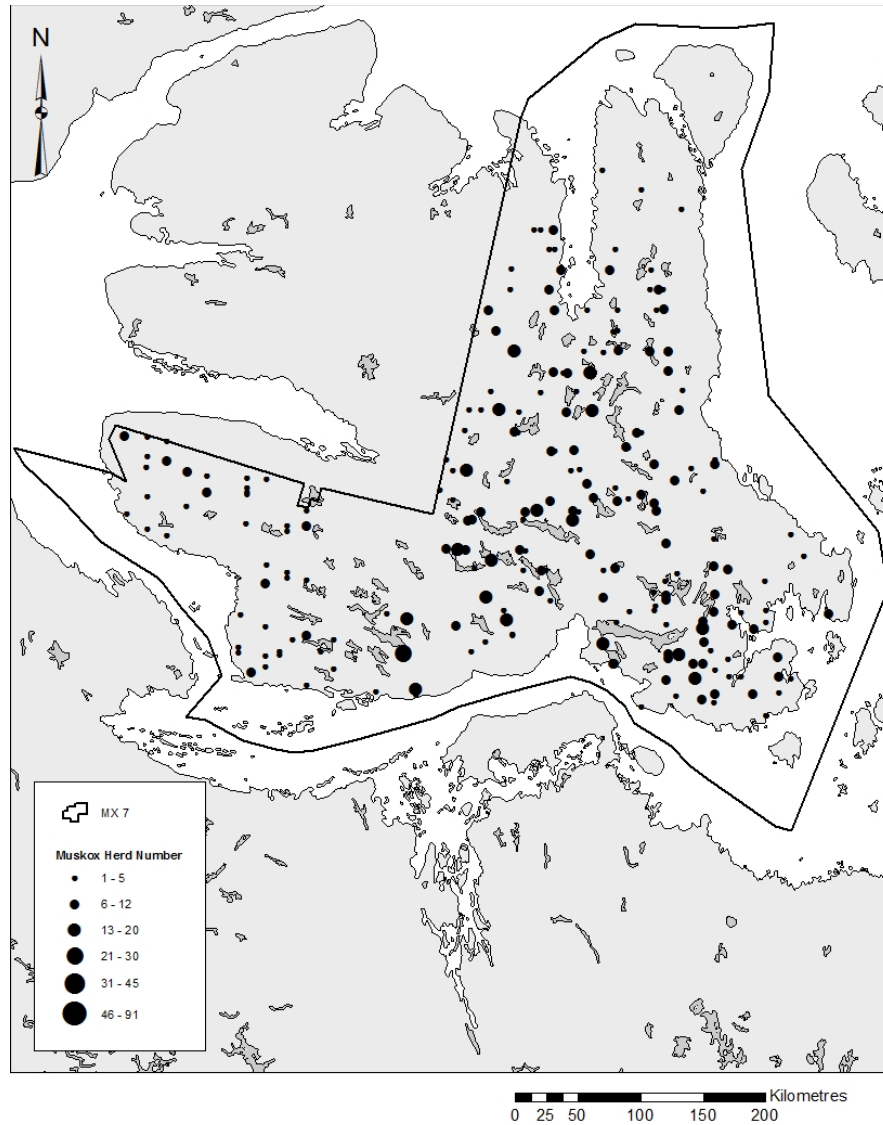


Figure 3 Muskox distribution and abundance recorded in the management unit MX-07 during the survey taking place August 26 to September 3, 2013 (stratum 1, 2 and 3) and from August 2 to August 12, 2014 (stratum 4,5, and 6), where the number of animal per group was grouped as 1-5, 6-12, 13-20, 21-30, 31-45, and 46-91.

Density

The stratum 2, localized north of Cambridge Bay, and the stratum 5, along the North West Territory boarder to the west, have the lowest muskox density with 0.0617 muskox / km² and 0.0618 muskox / km² respectively. It is around Cambridge Bay (stratum 1) that the density was found to be the highest with 0.1321 muskox / km² (Table 3). Overall, the muskox density of the entire management unit (134,933.72 km²) was 0.0743 muskox / km².

Table 3 Muskox density with each of the six stratum and within the management unit, MX-07.

| Stratum | Estimate number | Total area (km ²) | Density (muskox/km ²) |
|---------|-----------------|-------------------------------|-----------------------------------|
| 1 | 1,566 | 11,854.85 | 0.1321 |
| 2 | 1,397 | 22,642.23 | 0.0617 |
| 3 | 1,173 | 14,147.27 | 0.0829 |
| 4 | 777 | 11,538.85 | 0.0673 |
| 5 | 1,750 | 28,320.87 | 0.0618 |
| 6 | 3,032 | 46,429.65 | 0.0653 |
| MX-07 | 10,026 | 134,933.72 | 0.0743 |

Predator sighting (wolves, polar bear and grizzly Bear)

In 2013, during the 58 hours of flying within the stratum 1, 2, and 3, 2 wolves, 4 polar bear and 1 grizzly bear sightings were recorded. The wolves were two individuals traveling alone on the south coast of Victoria Island and the other one was spotted on the north side of Surrey Lake. Two single individuals and two females and cubs (4 adults and 2 cubs) were encounter around the same location, on the north shore of Collinson Peninsula by the M'Clintock Channel. Only one single grizzly bear was found during the survey. Predator sightings, using the predator index, (Heard, 1992) reveled 2 wolves / 100 hours, 10 polar bears / 100 hours and 2 grizzly bears / 100 hours.

In 2014, during the 71 hours of flying, no predators were observed on the north part of Victoria Island. The observation were then concentrated on the west coast of Victoria Island. One female grizzly with two cubs and 2 packs of two woves were seen (4 animals). Predator sightings, using the predator index, (Heard, 1992) revealed 4 wolfs / 100 hours and 7 grizzly bears / 100 hours.

Discussion

Group Characteristic

The calf crop represented 8% of the total number of adult muskox observed on transect, which is rather low. As it has been establish that 10.5% of calf crops is necessary to keep the muskox population stable (Freeman, 1971). Low percentage of calf crop presumably reflects variation in the severity of the winter (Ferns, 1977). It was established that an average snow cover deeper than 50 cm may be responsible for low calf productivity (Patterson, 1984). However, in this study, another factor may be at play then since snow depth, as winter ground surveys found, a snow depth varying from 10 to 30 cm at different location on the island and snow accumulation

is prohibited as snow is carry away by strong winds (Leclerc pers. comm). This low calf crop might have been a punctual event. Long term data series of calf crops is needed in order to see a trend in the population, as high variance in the rate of population increase and decreases in calf production have been found (Reynolds, 1998).

The small average of adults per group, 5.7 ± 4.32 (S.D.) where group size varied between 2 and 25, are characteristic of Victoria Island. In fact, similar observations were done on Victoria Island between 6 and 13 August 1998. At this time, the group size on Victoria Island was smaller than on the Canadian mainland (Queen Maud Gulf) with a group size mean of $10.23 \pm .4.44$ (S.D.) (Gunn, 1991).

In 2013 and 2014 smaller herds, but many single bulls were observed, The percentage of lone bulls, 3%, were encountered which does not support the assumption that a greater number of smaller herds offered more adult bulls the chance to be the herd bulls (Gunn, 1991). As this survey was done during the rut, it is expected that the single bulls will expend more energy to fight and be more competitive with the other herd bulls or invest energy in dispersal and searching for less contested breeding opportunities. Therefore the number of lonely bull accounted for a large proportion of the group encounter, as observed in Scoresby and Jameson Land, Greenland in 1974 (Ferns, 1977).

Abundance Estimate

Since the extirpation of the muskox at the beginning of the century, only a small residual population was found in the south west of Wynniatt Bay in the Shaler Mountain (Anderson, 1930). The numbers of muskox left at this location was estimated to be between 20 to 670 muskoxen (Anderson, 1974; Tener, 1958). In 1982, the muskox distribution re-colonized Victoria Island (Urquhart, 1982). At this time the population of muskox on the island was found to be abundant (Jakimchuk and Carruthers, 1980).

Due to the large size of Victoria Island ($218, 129 \text{ km}^2$), attempts to determine the population muskox on that island have been done in multiple successive surveys done within one or two years apart. The sedentary nature of the muskox, justify determining the muskox number in consecutive years as the likelihood of movement is minimal. The winter and summer range of muskox may be up to 50 miles apart, adjacent to each other or even overlap and muskox were recolonizing their former range at 13 km per year (Tener, 1965; Gunn and Case, 1984). Thus, muskox marked fidelity to seasonal range result in a minimal displacement between strata or survey year.

The three consecutive surveys from 1983 to 1984 surveying different parts of the Island, suggested that the entire muskox population of the Island was 11,000 to 12,000 animals (Jingfors, 1984; Jingfors, 1985; Poole, 1984), where the southeastern parts numbers were estimated at 3300 ± 345 (S.D.) in 1983. Two other successive surveys happened in the northwest and southeast portion of Victoria Island in July 1998 and March 1999 respectively.

An estimate of $18,290 \pm 1,100$ (S.D.) muskoxen in the northwest portion and an estimate of $18,795 \pm 2,869$ (95% CI) muskox was established, leading to a minimal rough estimate of 37,085 muskoxen on Victoria Island (Nagy et al. 2009; Gunn and Patterson, unpublished). It is important to note that due to the concentrated harvest around the community of Holman and Cambridge Bay, more intensive monitoring was done at these locations, leaving the southwest and the northeast part of the Island infrequently surveyed.

Based on genetic study, recommended management zones were developed based on muskox distribution clusters and the fact that muskox generally stay within a 50 km radius which slows down exchange between population or clusters (Dumond, 2011; Tener, 1965). Therefore, the three old management units; MX-07, MX-10, and MX-11 of Victoria Island were fused to one new muskox management unit, MX-07, to better represent the population boundaries.

The creation of the new management unit, MX-07, has permitted the surveying of the entire Nunavut side of Victoria Island in August 2013 and 2014. For this study area ($134,933.72 \text{ km}^2$), the number of muskox estimate was $10,026 \pm 1,184$ (95% CI). In April-May 2015, the northwest part of Victoria Island was surveyed and the estimated number of muskox at this location was $14,547 \pm 2,593$ (95% CI) ($49,811.3 \text{ km}^2$) (Davison pers. comm 2015). These consecutive surveys combined, give a minimal number of 24,000 muskoxen on the island where $184,744 \text{ km}^2$ of the $218,129 \text{ km}^2$ was surveyed (85% of the Island).

Comparison between the three series of consecutive surveys, 1980s, 2000, and 2010s, and between areas is difficult, making it very difficult to accurately get a population trend. This is due to the change in management areas, non-standardization of the survey methodology and the gaps in temporal monitoring prevents making any conclusions on the status of the population.

The lush vegetation as well as the low number of predators allowed the muskox population to fully recover from its previously historic lows. Compared with 16 years ago, the population of muskox on the island has declined, but not reaching the lows encountered in the 1980s. Whereas the number of muskox on the northwest part of the Island seems stable, the decline of muskox on the Nunavut portion is consistent with local knowledge. The rapidity of this decline is unknown, but local observations reveal that the muskoxen were still abundant until 2010, after which carcasses of dead muskox were reported on the land. Post mortem investigation of some of the dead muskox in 2011 and 2010 tested positive for *Erysipelothrix rhusiopathiae*. Thus, this bacterium was associated with the recent widespread death of muskox on Victoria Island (Kutz per.comm). From post re-colonization and population boom, environmental factors such as plant availability, the presence of predators, severe winters resulting in malnutrition, and presence of disease are potentially affecting the population dynamics and playing a role in a density-dependent population declining phase.

Distribution

Within the two surveys years in 2013 and 2014, the muskox distribution appears uniformly dispersed in small herds; muskox were found mostly evenly dispersed in the study area. The predominantly low lying areas of Victoria Island and the uniform Wager Bay Plateau and the Victoria Island Lowlands ecoregion provide muskox with extensive forage areas and shallow snow cover allows muskox to use the vegetation in this habitat year-round and not form aggregation. No muskox were seen 25 km around Cambridge Bay as local observations reported due to the local extirpation of muskoxen due to the commercial harvest.

In addition, no muskox was found between Namaycush and Washburn lakes (the extensive sandy areas), the Northern part of the Storkerson Peninsula and Stefansson Island. These locations were characterized with poorly vegetated ground with frequent rock outcrops. However, during the first systematic survey in 1990, one muskox was counted on transect and 19 were seen off the southern tip of Stefansson Island (Gunn and Lee, 2000). In addition, aggregation of muskox herds around the lake and water-course edge and feeding on a thin cover of grasses and semi-aquatic sedges was observed in the sandy areas. In 2014, the non-existing vegetation around the lake could have triggered a change in the distribution of the muskox at at this location.

Density

Direct comparison with previous densities is difficult due to the inconsistency of the time of the year the survey was performed as well as the different survey area, leaving us to qualitatively compare the densities encountered in this study with previous years and locations.

According to Thomas et al. (1981) the muskox habitat below 200 m in Canadian Arctic could support 1-2 muskox/ km². Muskox density varied from 0.0617 to 0.1321 muskoxen / km² where the entire density of the management unit, MX-07, was 0.0743 muskox / km². Considering the relatively low altitude of Victoria Island, these densities are lower to what would have been expected or what was encounter in East Greenland were the land elevation was also below 200 m and the density varied from 0.3 to up to 1.0 muskox / km² (Fern, 1977). This density however is similar to the northwest part of Victoria Island in 2015 with a muskox density reaching 0.31 muskoxen / km² (Davison per. comm).

When compared to the previous surveys of the 80s and the 2000s, there is consistent variation of density per different location on the Island. The mean density between the northeast and the southeast of Victoria island is different where the densities in the north (0.12 muskoxen / km² in 1990 and 0,0653 in 2014) was lower than the south (0,2 muskoxen / km² in 1988 and 0,1321 in 2013).

Consistently over the years, the density of muskox in the northwest part of the island has been higher. In 1983 the southeastern part had a density of 0.08 muskoxen/ km² and the northwest

part of the island represented the highest density with 0.10 muskoxen / km² (Jingfors, 1985). Similarly the density in 2015 in the northwest part (0.31 muskoxen / km²) was higher than the density encounter around Cambridge Bay in 2013 (0.1321 muskoxen / km²). Consistently low densities were found on the southwestern part with 0.02 muskoxen / km² in the 80s and 0.0618 and 0.0673 muskoxen / km² in 2014 (Poole, 1984).

At the same location over the years there is however variation in muskox densities. For examples the density of the southeastern part of the island varied from 0.08 muskoxen / km², 0.2 muskoxen / km², 0.3 muskoxen / km², 0.5 muskoxen / km² and 0.1321 muskoxen / km² in 1983, 1988, 1993, 1999 and 2013 respectively. Such change in density could either be attributable to change in muskox numbers at this location following population cycles or the difference in methodology used; although from 1988 to 1999 the same methodology was applied.

The mechanism driving muskox density is still not fully understood. Heard (1992) noted that group size is not generally related to muskox density. Summer temperature and plant growth decreased from south to north of Victoria Island which suggests, in addition to be poorly vegetated ground in the north, that Stefansson Island and the Storkeson Peninsula might have a lower carrying capacity and it is reflected in the lower density characterized these areas. These qualitative comparisons, between years and areas, highlight that density might fluctuate spatially and temporally.

Predator sighting (wolves, polar bear and grizzly Bear)

The number of wolf and grizzly bear observed were higher during the second year of the survey on the north and the southwest part of the Island according to the predator index. At these locations, the predator index were 2 wolves / 100 hours, and 2 grizzly bears / 100 hours during in 2013 versus 4 wolves / 100 hours and 7 grizzly bears / 100 hours for the location flew in 2014. This difference might be explained by the fact that the survey area of 2013 (stratum 1, 2, and 3) represents a well-travelled area where hunting of predator, disturbance and harvest occurs.

Concerns were raised at a group workshop about the increase of wolf and also grizzly bear populations in on Victoria Island. Wolf predation on muskoxen is common, with packs or single wolves observed following and killing muskox. Grizzly bears have extended their range to Victoria Island and increase in number over the past few decades. While traveling on the land, a hunter followed a grizzly bear over a 16 to 24 kilometre distance, where he discovered that the grizzly bear had killed seven muskoxen spread over 1 to 2 kilometres (Cambridge Bay HTO pers. comm). The eruption phase of muskox in 2000 has allowed and supported the increase of predators on the island and support range expansion by grizzly bears. It would be important to establish predator monitoring to better understand this predator-prey relationship in shaping muskox population cycles as well as determine the percentage that muskox account in their diet.

Management Recommendation

In the late 1970s, the increases of muskox sightings from local harvesters lead to the end of the 1917 moratorium. In 1976, the first quota was established in the Kitikmeot Region, on Victoria Island (Urquhart, 1982). The quota was shared by Holman and Cambridge Bay, comprising 8 males and 4 females and 9 males and 7 females, respectively (Dumond 2006).

Victoria Island constitutes a very important habitat for the muskox. Jakimchuk and Carruthers (1980) surveyed Victoria Island and the number of muskox estimated then represented 27% of the estimated population of muskox in Canada. In 1984, two management zones were established in the southern part having a combined quota of 13 animals, and additional three management areas on northwestern were created with a total quota of 118 (110 muskoxen allotted to Holman and 8 to Natkusiak Peninsula) (Jingfors 1984; Jingfors 1985). The harvest rate was set to a very conservative level, 2-3% base on the low information available on the population dynamics of the Island and to promote the recovery to a historical high.

The harvest zones were established to reflect traditional hunting patterns by local residents and known muskox distribution (Gunn, 1984). These boundaries were not representing population range as it is unlikely that the south eastern part constituted a discrete population. Thus, the sedentary nature of the muskox justifies an area management approach over a wider geographical area.

The second set of extensive surveys, 1988, 1993 and 1999 on the southern part of the Island monitored a significant increase (32%) between 1993 and 1999 (Gunn and Patterson, unpublished). With this population increase and fear of a following population crash, commercial harvest was adopted and a less conservative harvest rate was implemented. These management actions aimed to “reduce the overpopulation” or at best control it and to foster economic development.

During the commercial harvest, portable abattoirs handling up to 100 - 200 muskox to rare large-scale harvest taking up to 1,800 muskoxen took place on Victoria Island (Gun *et al.* 1991; Nagy *et al.* 2001). Consistent commercial harvest in Ekaluk river resulted in the virtual extirpation of muskox within 50-70 km radius between 1993-2000, but closure of the abattoir provides evidence that the muskox was able to recolonize intensively the harvested areas (Gunn and Patterson, unpublished).

The Nunavut side of Victoria Island was divided into three management units around 2000. Based on an estimate count of 18,290 muskox on the southeast quarter of Victoria Island a TAH of 1,300 was established in 2000 on the southeastern part of the Island (Gunn and Patterson, unpublished) and the northwest was assigned 100 in 1992 (Gunn and Lee 2000). The quota on the southwest has been consistent with 100 since 1994 (Dumond 2006). The intensive harvest around the community of Cambridge Bay represented a harvest rate of 7.6% which according to

Tener (1965) a harvest rate higher than 7% will lead to a slow decline when factored over years of variable environment conditions.

Change from a portable abattoir to a sedentary one located in Cambridge also resulted in the virtual extirpation of muskox with 60 km radius of the harvesting zones as has been previously observed. The closure of the muskox harvest in addition to the difficulty in finding muskox 160 km around Cambridge Bay was a trigger to address concerns on the status of the population island wide.

Recent estimates indicate that the population has now declined to $10,026 \pm 596.90$ (S.D..) muskoxen on the Nunavut portion of the island. This decline was not only limited to the commercial harvest area, but was observed over a larger area. Consistent management regimes over 15 years and the lack of monitoring might have contributed to the inability to revise the management strategy leading to a drastic decline of muskox number. The harvest rate alone was not the main contributing factor of this decline. Less than 50% of the annual quota of 1,300 for the southern part of the island has been use over the year and this including the commercial harvest (100 to 300 muskoxen/ year) as well as substance and sport harvest (150 to 200 muskoxen/year). Other environmental factors such as disease, overgrazing, increase in numbers of predator and severe winters are contributing factors to muskox decline.

To mitigate taking into consideration also the environment conditions, a more conservative harvest rate should have been implemented. The TAH for each muskox population is based on the best practices for sustainable harvest of muskox and based on the input from the impacted communities on their management goal. During the West Kitikmeot Muskox workshop, the Cambridge Bay HTO mentioned that they would like to have a slight increase in the muskox population, but not let the population erupt again (Leclerc, 2015). The result of this study and the management goal recommend a harvest of 4%, which represent a decrease of Total Allowable Harvest from 1,500 to 400. Such harvest rates will promote slower growth (Tener 1965). It will also be prudent to invest more effort in explaining that fluctuating populations are natural and stable yields are unlikely, so consistent monitoring is required for sound management.

In addition, to continue the muskox commercial harvest and provide sustainable economic development, there is a need to develop better commercial harvesting strategies. Reducing the amount of muskox taken at a single location or a return to the portable abattoir where harvest rotate yearly between three to five locations should avoid local extirpation of muskox around the abattoir.

Following the near extirpation of the species, there is no long-term monitoring data available to visualize muskox population cycles similar to caribou. In the absence of fully understanding muskox ecology, interactions between muskoxen, their forage, plant growth and understanding of how carnivores limit muskox numbers a conservation approach should be maintained as muskox seems to respond to various undefined environmental factors independent of the harvest level.

Environmental factors may negatively affect muskox population dynamics and directly impact management planning and decision-making related to harvest levels. Increase in efforts to collect harvest information on which sex and age classes are harvested and where they are taken will be needed. Additional efforts on muskox sampling programs to monitor the spread of diseases, such as the lungworm (*Umingmakstrongylus pallikuukensis*), and muskox health should also be implemented at this location as such programs are currently non-existent.

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References:

Anderson, R.M. 1947. Catalogue of Canadian Recent Mammals. Bull. Nat. Mus. Canada. No 102. Biol. Ser. No. 3 vi: 238 pp.

Caughley, G., 1977. Analysis of Vertebrate Populations. John Wiley and Sons. London.
Norton-Griffiths, M. 1978. Counting Animals. Serengeti Ecological Monitoring Program Handbook No.1. Afropress Ltd., Nairobi Kenya. 139 pp.

Dumond, M. 2006. Review of Muskox Populations Status in the Kitikmeot Region of Nunavut. Government of Nunavut, Working DRAFT- May 2006. 29 pp.

Dumond, M. 2007. Muskoxen Distribution and Abundance in the Area Between Bathurst Inlet, and the Coppermine River, Kitikmeot Region, Nunavut (MX19 and West MX14). Gov. of Nunavut, Unpubl. Rep., 27 pp.

Dumond, M. 2011. Muskox Management Consultation 2010-2011, Supporting information on Muskox population in the West-Kitikmeot. Consultation report, Government of Nunavut. 10 pp.

Environment Canada 1995. Ecological Framework of Canada. <http://ecozones.ca/english/>. Accessed September 1 2014.

Ferns, P.N. 1977. Muskox abundance in the southern part of the range in East Greenland. Arctic 30(1): 52-60.

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

Gunn, A., 1984. Aspects of the Management of Muskoxen in the Northwest Territories. Biol. Pap. Univ. Alaska Spec. Rep. No. 4, 33-40.

Gunn, A.R. Decher and T. W. Barry. 1984. Possible causes and consequences of an expanding muskox population, Queen Maud Gulf area, Northwest Territories. Bio. Pap. Univ. Alaska. Spec. Rep. 4: 41-61.

Gunn, A. and Case R. 1984. Numbers and distribution of muskoxen in the Queen Maud Gulf area, July 1982. File Report 39. Northwest Territories, Department of Renewable Resource, Yellowknife, Canada.

Gunn, A. 1991. Differences in the sex and age composition of two muskox populations and implications for male breeding strategies. Rangifer 12(1): 17-19.

- Gunn, A., Lambert, K. and Morrison R., 1996. Distribution and Abundance of Muskoxen on Adelaide Peninsula, NWT. Gov. of N.W.T., File Report No. 117, 19 pp.
- Gunn, A., and Patterson, B.R. 2000. Distribution and Abundance of Muskoxen on Southeastern Victoria Island, Nunavut. Gov. of the N.W.T., Unpubl. Rep.
- Heard, D.C. 1992. The effect of wolf predation and snow cover on musk-ox group size. *American Naturalist* 139: 190-204.
- Herbert, B., 1974. Estimated Productivity of Musk-oxen on Northeastern Devon Island, N.W.T. M.Sc.
- Howard, F., 2011. Aerial Wildlife Survey Manual. Aerial Procedure Manual v. 0.9 (Uganda). Wildlife Conservation Society. 81 pp.
- Hudson P.J., Dobson A. P., and Newborn D. 1992. Do parasites make prey vulnerable to predation? Red grouse and parasites. *Journal of Animal Ecology* 61(3): 681-692.
- Jakimchuk, R.d. and D.R. Carruthers. 1980. Caribou and muskoxen on Victoria Island, N.W.T. R.D. Jakimchuk Mgmt Assoc. Ltd. Rep. prepared for Polar Gas Environmental Program. 93 pp.
- Jingfors, K. 1984. Abundance, composition and distribution of muskoxen on southeastern Victoria Island. N.W.T. Wildlife Service. File Report No. 36. 24pp.
- Jingfors, K. 1985. Abundance and distribution of muskoxen on northwestern Victoria Island. N.W.T. Wildlife Service. File Report No. 47. 22pp.
- Jolly, G.M. 1969. Sampling methods for aerial census of wildlife populations. *East. Afr. Agric. For. J.* 34:46-49.
- Kitikmeot Foods Ltd, 2012. Cancellation of the 2013 Commercial Muskox Harvest. Letter to the Board of Directors, Ekaluktutiak Hunters and Trappers Organization. December 10, 2012.
- Kutz, S.J. 2000. The biology of *Umingmakstrongylus pallikuukensis*, a lung nematode of muskoxen in the Canadian Arctic: field and laboratory studies. Saskatoon: University of Saskatchewan.
- Kutz, S.J., Checkley S. Verocai G.G., Dumond M., Hoberg E., Peacock R., Wu J., Orsel K., Seegers K., Warren A., et al. In Revision. Invasion, establishment, and range expansion of two protostrongylid nematodes in the Canadian Arctic. *Global Change Biology*.
- Leclerc, L.-M..2015. West Kitikmeot Muskox Workshop Report. Cambridge Bay, October 14-15, 2014. Government of Nunavut, Department of Environment.

Leslie, P.H., 1965. Theoretical Consideration of the Intrinsic Rate of Natural Increase. In J.S. Tener, Musk-oxen in Canada, Can. Wilf. Ser. Mono. (2), 166 pp.

Patterson, E.A. 1984. Sightings of muskoxen in Northern Scoresby Land, Greenland. Arctic 37(1): 61-63

Poole, K.G. 1984. Muskox survey on southwestern Victoria Island, March 1983. NWT. Wildl. Serv. Rep. Ser. 14 pp.

Miller, F. and Russell, R.H. 1975. Aerial surveys of Peary caribou and muskoxen on Bathurst Island, Northwest Territories, 1973 and 1974. Canadian Wildlife Service. Progress Notes n 44.8 pp.

Ministry of Sustainable Resource Management, 2002. Aerial-based Inventory Methods for Selected Ungulates: Bison, Mountain Goat, Mountain Sheep, Moose, Elk, Deer, and Caribou. Standard for Components of British Columbia's Biodiversity No 32. Resources Inventory Committee, British Columbia. 91 pp.

Nagy, J.A., Larter N., Wright W.H. 2009. Population estimates for Peary caribou (Minto Inlet herd), Dolphin and Union caribou and muskox on Northwest Victoria Island, NT, July 1998.

Norton-Griffiths, M. 1978. Counting Animals. Serengeti Ecological Monitoring Programme Handbook No.1. Afropress Ltd., Nairobi Kenya. 139 pp.

Reynolds, P.E. 1998. Dynamics and range expansion of a re-established muskox population- J. Wildlife. Manage. 62:734-744.

Spencer, W., 1976. Muskox (*Ovibos moschatus*) surveys, central western Arctic. N.W.T. Wildl. Serv. Unpubl. Rep., 11pp.

Tener, J.S. 1965. Muskoxen in Canada; a biological and taxonomic review. Canadian Wildlife Service. Queens Printer and Controller of Stationary. Ottawa.

Thomas, D.C., Miller, F.L., Russell R.H. and Parker G.H. 1981. The Bailey Point region and other muskox refugia in the Canadian Arctic: a short review. Arctic 34: 34-36

Urquhart, D.R. 1982. Muskox; life history and current status of muskox in the NWT. GWNT Dept. of Ren. Res. 40 pp.

White. D., 2002. Muskoxen Density and Distribution on King William Island, Nunavut. Gov. of Nunavut, Unpubl. Rep., 22pp.