Results of the first aerial survey of Moose Management Area 92 (February 12–24, 2019)

Technical Report · August 2019

DOI: 10.13140/RG.2.2.15234.02243

3 authors:

Meredith Purcell
NunatuKavut Community Council

Shawn Rivoire

Jamie Snook
Torngat Wildlife Plants and Fisheries Secretariat

Results of the first aerial survey of Moose Management Area 92 (February 12-24, 2019)

Purcell, M., Rivoire, S., and J. Snook

Torngat Wildlife, Plants and Fisheries Secretariat
217 Hamilton River Road, PO Box 2050 Stn. B
Happy Valley-Goose Bay, NL A0P1E0

2019

Torngat Wildlife and Plants Co-Management Board

Torngat Wildlife, Plants and Fisheries Secretariat

The primary responsibilities of the Torngat Wildlife and Plants Co-management Board and the Torngat Joint Fisheries Board are to establish total allowable harvests for non-migratory species of wildlife and for plants, recommend conservation and management measures for wildlife, plants, and habitat in the Labrador Inuit Settlement Area (LISA) and to make recommendations in relation to the conservation of species, stocks of fish, aquatic plants, fish habitat, and the management of fisheries in the Labrador Inuit Settlement Area.

The Secretariat is the implementation agent of the Torngat Joint Fisheries Board and the Torngat Wildlife and Plants Co-Management Board. The Secretariat is a team of professionals based in Happy Valley-Goose Bay that provide financial management, logistical, project management and analytical support to both boards.

Torngat Omajunik, Piguttunik Oganniaganillu Suliangit

Suliagigumajangit Torngat Omajunik, Piguttunillu AulatsiKatigengita AngajukKauKatigengit ammalu Torngat Ikajuttiget Oganniatuligijingita AngajukKauKatigengit sakKititsigiamut pijaugunnatunik katillugit aullaigatsatagiamut nokataKattangitunik omajunik ammalu piguttunik, uKautjigiajut asikKitailigiamut ammalu aulatsigiamut omajunik, piguttunik, ammalu inigiKattajanginnik Labradorimi Inuit Satusasimajanginni Nunani (LISA) ammalu uKautjigiagutinik ilingajunik asikKitailigiamut omajunik, oganniaganik, piguttunik, oganik, ammalu aulatsigiamut oganniaganik Labradorimi Inuit Satusasimajanginni Nunani.

SuliaKattet atuliaKititsigumajut kiggatuttinganik Torngat Ikajuttiget Oganniatuligijingita AngajukKauKatigenginnik ammalu Torngat Omajuligijinginnik Piguttunillu AulatsiKattajut AngajukKauKatigenginnik, sunatuinnanik, suliatsanik aulatsigiamut ammalu ikajutsitaullutik tamâginnut angajukKauKatigenut.

Torngat Wildlife, Plants & Fisheries Secretariat Series

2019

Results of the first aerial survey of Moose Management Area 92 (February 12-24, 2019)

Purcell, M., Rivoire, S., and Snook, J.

Torngat Wildlife Plants and Fisheries Secretariat
217 Hamilton River Road, PO Box 2050, Station B
Happy Valley-Goose Bay, NL
A0P1E0

Published by:
Torngat Wildlife, Plants and Fisheries Secretariat
217 Hamilton River Rd., P.O. Box 2050 Stn. B
Happy Valley-Goose Bay, NL
A0P 1E0

Correct citation for this publication:
Purcell, M., Rivoire, S., and Snook, J. (2019). Results of the first aerial survey of Moose Management Area 92 (February 12-24, 2019). *Torngat Wildlife, Plants and Fisheries Secretariat. Ser*. 2019/21 + 9 p.

Table of Contents

List of Figures

List of Tables

Acknowledgements

A great deal of gratitude is owed to Serge Couturier, who provided excellent guidance in choosing a suitable methodology for surveying moose in Nunatsiavut, as well as to Frank Phillips, who provided invaluable knowledge regarding the unique behaviors of moose in Labrador. I am thoroughly appreciative of the field crew: Colin Webb and Andrew Andersen, who brought along a great deal of knowledge of the land and tracking, and Devin Stetler, who navigated us safely around numerous canyons and mountains throughout the ever-windy survey area. This work would not have been possible without funding from the Torngat Wildlife and Plants Co-Management Board and the support of our partners at the Nunatsiavut Government and the Government of Newfoundland and Labrador. We would also like to thank all of the Inuit knowledge-holders who gave their time to share with us, and Katie Rosa for implementing the Board's first Inuit knowledge work in relation to moose.

Executive Summary

Moose are a relatively new resident to Labrador after expanding their range from adjacent Quebec beginning in the 1950's. Since this time, moose have been seen increasingly farther north, and Inuit Knowledge indicates that moose densities began to increase in Nunatsiavut, Labrador within the past few decades. With the precipitous decline and subsequent harvesting ban for the George River caribou herd, moose are becoming an important staple in northern diets, and are playing a significant role in increasing food security for Inuit in the region. Harvest, however, has remained conservative since the beginning of regulation in 2011 because little was known about the abundance or population dynamics of moose in the Nunatsiavut region. In order to address this knowledge gap, the Torngat Wildlife and Plants Co-Management Board initiated an Inuit Knowledge study and began a monitoring program for moose in Nunatsiavut, utilizing aerial surveys and harvest data to help inform total allowable harvest decisions.

In February 2019, a stratified random block survey of the northernmost Moose Management Area (MMA) was conducted. The entire MMA was stratified into high- and low-density or non-habitat using Inuit Knowledge combined with land cover data. 7.14% of the 4,789 km^2 survey area was flown and all observed moose were classified by age (adult, calf) and sex when possible. 21 moose were observed during the survey, 15 of which were on-transect. All moose were classified by age, and 20 were classified by sex. 19% of observed moose were calves, and calf-cow and bull-cow ratios were 31:100 and 23:100, respectively. During flight it was realized that the habitat stratification was not accurately reflecting density expectations, so counts from both strata were combined to obtain an abundance estimate of 210 moose (90% CI: 76-343). This assumes that moose densities are equal in the south and north, which is untrue, and is therefore an overestimation of population size. In light of this, the minimum population estimate of 76 moose should be used to inform total allowable harvest decisions.

AngajukKaunet Naillitisimajanga

Moose nutânguvut iniKaliaKitainnatunut Labradorimi angilligiakKâtillugit inigijanginnik atajumut Quebec-imi pigianniminit 1950-ni. Taimanganit, moose takujauKattaliaKisimajut Kaninginitsamut taggami, amma Inuit Kaujimausingit nalunaitsivuk taikkua moose ununnigijangit puttuvallialauttut Nunatsiavut, Labradorimi jârini unuttugalannik Kângisimalittuni. Pimmagittumik ikilliumilimmata amma pinasuattaugunnalugunnaimata kangitluasutjuak tuttuKutingit, moose ikKanattoliaKilittut niKigijaulluni taggamiut niKitsanginnut, amma angijummilu iniKalilluni niKitsaKatsiagiamut Inuit nunakKatigengituni. Katitsuinik, tâvatualli, nungotsitailigasuanginnatut taimanganit maligatsak sakKilaugaminik 2011-imi tamannauluasimajuk Kaujimatsiasimangimata pitjutigillugit ununnigijangit upvalu Kanuk moose-iKutigijausimajunut Nunatsiavut nunakKatigengituni. kamagigasuagiangit taikkuninga Kaujimajautsiangitunut, taikkua Omajunut amma Pigutsianut Ikajuttigejunut AngajukKauKatigengit pigiasititsilauttut Inuit Kaujimajaugettunut Kaujisannimik amma kamagiasilauttut kimiggutaunningit suliangujumik moose-inut Nunatsiavummi, tingijokkotlutik Kaujisannimik amma katitsutauKattajunut Kaujimajaugettunut ikajugiamut Katset tigujaugajammangâmmik kajusiutiliugiamut.

Februara 2019-ami, âkKisuttausimajut Kaujisattaulangajut tagganettoluak moose-inut aulatsigiamut iningata (MAI) suliagijaulauttuk. Ilonnanga MAI âkKisuttausimalauttuk puttujunut amma naittunut takutsausongutillugit upvalu inigijauKattasimangitutnut malitillugit Inuit Kaujimausinginnik katingatitautlutik nunanik Kaujisagiamut. 7.14% ininganit 4,789 km^2 Kaujisattaujumut Kulauttaulauttut amma ilonnatik moose nalunaittaulauttut jâringitigut (Pigullagisimajut, piagait) amma Kanuittoningit pigunnasinnapata. 21 moose takujaulauttut KaujisattuKaniammat, 15 taikkunangat sittungajulimmik Kulauttautlutik Kaujisalauttut. Ilonnatik moose nalunaittaulauttut jâringinnik atutlutik, amma 20 nalunaittaulauttut Kanuittoninginnik. 19% takujausimajut moose piagaulauttut , amma nuggalet amma angutialuit imailingasimajut 31:100 amma 23:100, isumagituinnalugit. Tingijokkoniammata malugijaulauttut inigijangita nalautsilulaungitut takunâjangita anginigijanginnik nigiugijaujunut, taimaimmat kititausimajut tamâgennut sittungajunit katittaulauttut tigusigunnagiamut ununnigijanginnik kititangita Kaninninga 210 moose-inik (90% CI: 76-343). Tamanna sakKititsijuk moose ununnigijangit atjigengujut siKinganimmi amma taggami, tamanna sulingituk, amma taimaimmat angiluamik kititausimajut ununnigijaujunut. Tamanna Kaujimajaulimmat moose-iKutet kititangit Kanitanganejut 76 moose atuttaugialet Kaujimagiamut Katsinik pijuKasongummangât kajusiutiliulippata.

1. Introduction

Moose (*Alces americanus*) have been expanding their range into Labrador since the 1950's through natural dispersal from adjacent Quebec, along river valleys on the north shore of the St. Lawrence (Chubbs and Schaefer 1997). To enhance this, 12 moose were also introduced to southern Labrador from the island of Newfoundland (Pimlott and Carberry 1958), though genetic evidence indicates that natural dispersion was the primary driver of range expansion (Broders et al. 1999). The northern limit of moose has been steadily increasing with sightings reported as far north as Nain (56°N) in the 1980's, Okak Bay (57°N) in the 1990's, and Hebron Fjord (58°N) in the 2000's (Phillips, F., pers. comm.). Along with this increased range came an increase in abundance, resulting in the first regulated moose harvest in southern Labrador in 1977 (Chubbs and Schaefer 1997).

There are four Moose Management Areas (MMA) within the Labrador Inuit Settlement Area (LISA), which falls under the jurisdiction of the Torngat Wildlife and Plants Co-Management Board (hereafter the Board) under the Labrador Inuit Lands Claim Agreement (2005). Through this accord, the Board was made responsible for making recommendations on total allowable harvest (TAH) levels for non-migratory wildlife within the LISA (Labrador Inuit Land Claims Agreement 2005). At the time, moose densities were still quite low within Nunatsiavut, and a regulated harvest did not begin until 2011, prompted by the decline of the George River caribou (*Rangifer tarandus*) herd and an increased need for food security through alternative means. TAH was initially set conservatively low at 35 moose shared between six communities and was only increased in 2017 to 39 tags, allowing one additional moose to be harvested from each MMA. At the time of this increase, the Board noted that further adjustments to TAH would not be warranted due to the lack of knowledge surrounding moose population status (Torngat Wildlife and Plants Co-Management Board 2015). They committed to initiate an Inuit Knowledge (IK) study, collect and analyze harvested jawbones, and collaborate with the Government of Newfoundland and Labrador and Nunatsiavut Government to conduct aerial surveys (Torngat Wildlife and Plants Co-Management Board 2015).

Until this survey, little was known regarding the status of moose in Nunatsiavut, aside from a small number of surveys which accounted for portions of southern MMAs prior to their modern delineation (Phillips 1983; Barney 2008a; Barney 2008b). This is the first strategic aerial survey done within MMA 92, the northernmost unit in Nunatsiavut, Labrador. The goal of this work was to develop scientific knowledge in the form of abundance and demographic indices that, when combined with IK, would be able to help inform management decisions that ensure a sustainable harvest for Nunatsiavummiut while still permitting the moose population to grow.

2. Methodology

2.1 Survey Area

MMA 92 lies in northern Labrador, extending from the southern border of Torngat Mountains National Park to approximately 56^0N latitude and spans 32,283 km^2 from the Labrador Sea to the Quebec border (Figure 1). The entirety of this MMA is made up of Arctic Cordillera and Taiga Shield ecozones, which are broadly characterized by rocky barren uplands and sparse black spruce (*Picea mariana*) and lichen forests. This vast area includes the southern portions of The Domes and Saglek ecodistricts, which are home to other large mammals like polar bears (*Ursus maritimus*) and historically were home to the Torngat Mountains caribou herd, but this area is well above the treeline. Suitable moose habitat is only found within the Nain Coast and Fraser River ecodistricts, where larger and older black spruce and lichen forests are most prominent, along with the occasional birch (*Betula sp.*), tamarack (*Larix laricina*), and willow (*Salix sp.*) stands. The Upper Kingurutik ecodistrict is characterized mostly by high-altitude plateaus, which are within the winter range of the George River caribou herd and also are not suitable for moose.

Nain is the sole community within these boundaries, with a population of 1,125 (Statistics Canada 2017), making it the largest settlement in Nunatsiavut. The area surrounding Nain has limited access, with the major forms of transportation being aircraft year-round or by snowmobile in the winter and boat in the summer. Moose harvest within this MMA is low, with eight tags available in 2019/20, which were allocated either to an individual or the community freezer. Other human activities occur at the Voisey's Bay Mine, which is an open pit nickel-copper-cobalt mine that is 35 km southwest of Nain. This mine is only accessible by aircraft and snowmobile, though small road networks exist in and around the mine. Natural disturbance in this area is most prevalent in the form of forest fires, rock slides, and avalanches, though regeneration of forested habitat is relatively slow in Labrador even in comparison to similar forest types found elsewhere (Foster 1985; Viglas et al. 2013).

To delineate a survey area that excluded unsuitable areas, IK (Rosa, K., *in prep*) was combined with ecodistrict boundaries, which differed in scale. Ecodistricts are quite coarse, and reflect habitat type within a large designated area, while IK provided GPS locations for moose sightings and harvest locations in the MMA. In this region, however, moose tend to move along river valleys (Kelsall 1972; Wald and Neilson 2014) that extend westwards from the coast, and therefore tend to inhabit the Nain Coast and Fraser River ecodistricts. By combining knowledge at these two scales, large expanses of unsuitable habitat found in The Domes, Saglek, and Upper Kingurutik ecodistricts could confidently be removed from the survey area. Due to the remoteness of the northern and western portions of the survey area and limitations on helicopter range and fuel capacity, only the suitable area within 120 km of Nain was included, although marginally suitable habitat may exist beyond this (Figure 1). The resulting survey area encompassed 4,789.5 km^2, or 14.8% of the entire MMA.

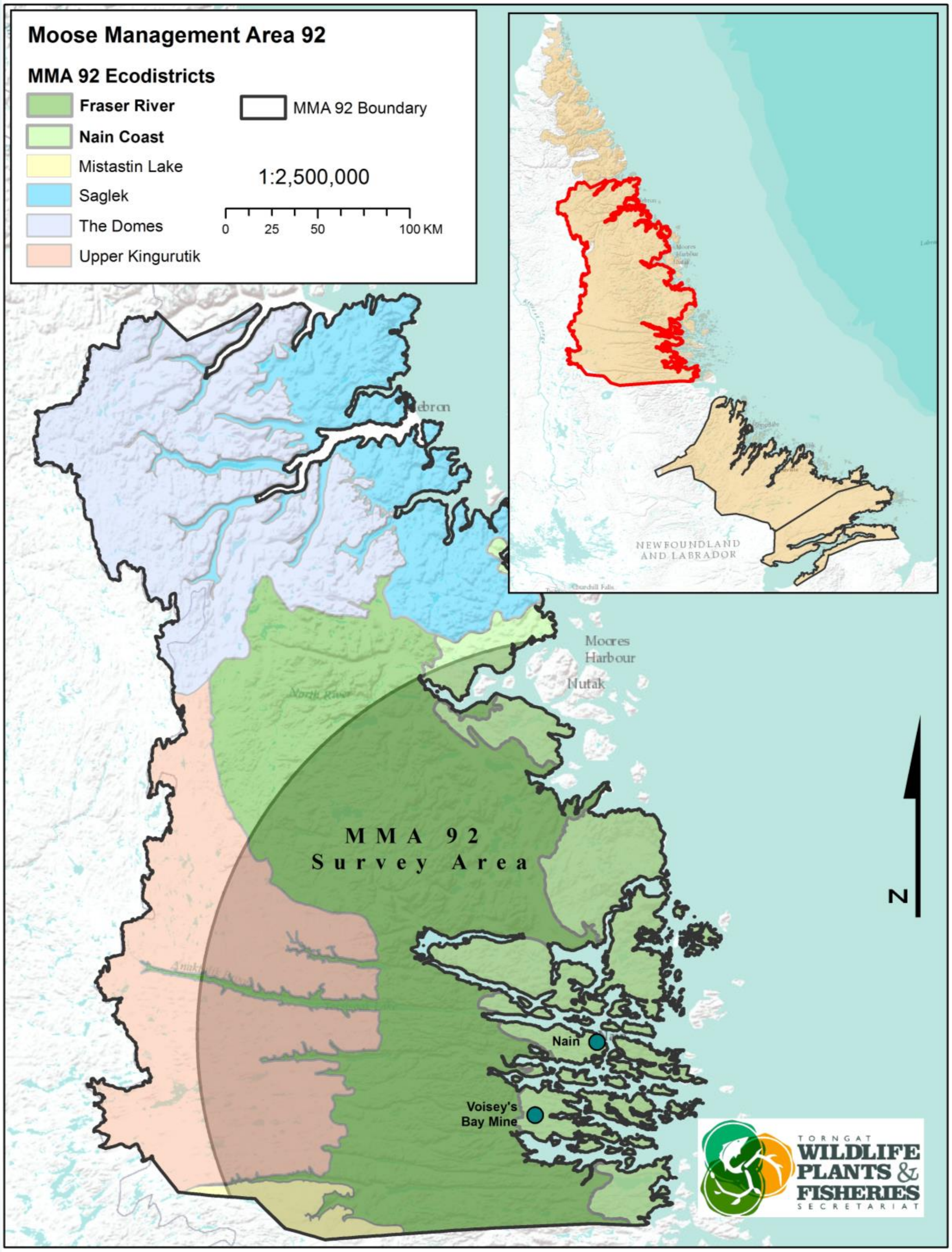

Figure 1. Ecodistricts found within Moose Management Area 92. The survey area is shaded in gray, and is made up of mostly the Nain Coast (light green) and Fraser River (dark green) ecodistricts.

2.2 *Survey Method*

A stratified random block (SRB) survey methodology was utilized to obtain estimates of abundance and demographic indices. This allowed for more flight time to be allocated to those areas which are most likely to contain moose (Gasaway et al. 1986). The entire survey area was overlaid with a 4 km^2 fishnet of 2 km x 2 km cells in ArcMap (ESRI), with each cell constituting one subunit. When subunits were smaller than 4 km^2, usually due to the inclusion of large lakes or bays within them, they were merged with neighboring cells until the subunit was approximately 4 km^2. Within the survey area, moose habitat is nearly exclusive to river valleys amongst high-altitude plateaus, leaving large expanses of non-habitat between suitable habitats (Figure 2). To address this, habitat characteristics at recorded harvest locations were used to determine the habitat preferences of moose using land cover, digital elevation, waterbodies, and landform information collected by the Labrador Nature Atlas (NCC). Habitat values at each site were then used as a guide to stratify 4 km^2 subunits throughout the survey area into high-density, low-density, or non-habitat (Table 1). Each subunit was given a unique identifier, and 17% and 5% of subunits in high- and low-density strata were randomly selected to be flown using a random number table, with an overall coverage of 9.6% of the survey area (Figure 2).

Survey flights were conducted at approximately 100 m above ground and at a speed of 100 km/h in a Bell206 LongRanger with three observers plus the pilot who served as a fourth observer when able. Flight transects within each randomly selected subunit that were spaced 500 m apart from each other and 250 m from the edge to ensure complete coverage along 250 m of each side of the transect line (Oswald 1998). When necessary, flight lines were occasionally added to fly over any points missed due to terrain or removed when sightability was greater than 250 m on either side of the aircraft. All observations of moose tracks were verbally reported and followed until a moose was found or tracks got older. When tracks got older, they were followed in the reverse direction until a moose was found. On the rare occasion that moose were still not observed, circles were flown around the freshest tracks to try and observe additional track networks or a bedded moose that may have been missed.

All moose were classified by sex and age when possible based primarily on the presence or absence of a vulva patch for sex and body size for age. Occasionally, behavior was used to justify additional search time and classification, most notably with defensive cow behavior towards the helicopter indicating that there was a calf nearby. Locations of moose sightings, caribou sightings, and wolf (*Canis lupus*) tracks were recorded on the Collector for ArcGIS app (v.18.0.3; ESRI) installed on a Samsung S9 cellular device. Using Collector, time, date, species, group size, classification (for moose: adult cow, adult bull, calf, unknown adult, unknown), classification criteria (for moose: vulva patch, face color, behavior, size), behavior (standing, bedded), habitat (open coniferous, closed coniferous, mixed wood, hardwood, burn, bog, riparian shrub, barren uplands, river, lake), canopy cover (0-25%, 26-50%, 51-75%, 76-100%), snow cover (complete, partial, none), and a sightability rating (good, fair, poor) were recorded for each animal observation, whether on- or off-transect. Data was backed up each evening to ArcGIS Online (ESRI). Additional environmental data (*i.e.*, air temperature, cloud cover, wind speed and direction, visibility, snow cover, light type and intensity) was collected on a paper form for each

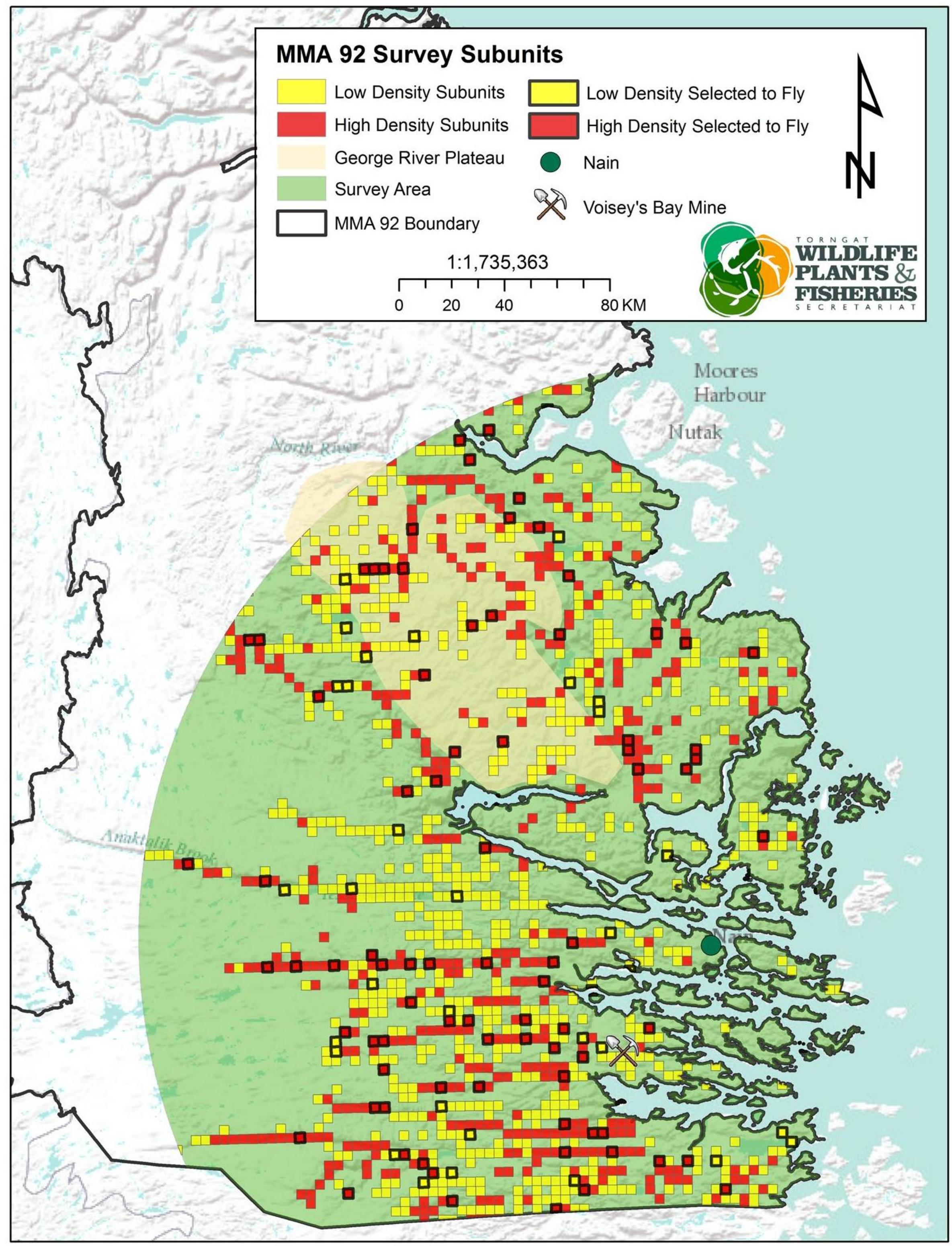

Figure 2. Stratified survey area within Moose Management Area 92 in Nunatsiavut, Labrador. High- (red) and low-density (yellow) subunits throughout the survey area (green) are shown, and those that were randomly selected to be surveyed are outlined in black.

Table 1. Habitat, elevation, and waterbody parameters gathered from Nature Conservancy Canada's Labrador Nature Atlas were used to classify subunits into low- and high-density strata. Preferred habitat was weighted based on site characteristics at moose sightings and harvesting locations recorded from an Inuit Knowledge study (Rosa, K., *in prep*).

	Stratum	
	Low-density	High-density
Ecodistricts	Fraser Nain Coast	Fraser Nain Coast
Elevation	500 m	500 m
Land Cover	Softwood Open (25-50%) Softwood Sparse (25-50%) Burn (≥ 50%) Cleared (≥ 50%)	Softwood Open (25-50%) Softwood Sparse (25-50%) Burn (≥ 75%) Cleared (≥ 75%)
Water	Wetlands (≥ 13%) Lakes/Intertidal (≥ 13%) River (≥ 3.8 km)	Wetlands (≥ 30%) Lakes/Intertidal (≥ 30%) River (≥ 3.8 km)

surveyed subunit. Flight tracks were recorded on 10 second intervals using a Garmin in-reach device.

2.3 Data Analysis

Counts for each surveyed subunit were transferred into an excel spreadsheet prepared with formulas modified after Gasaway *et al.* 1986. A density estimate (moose per square kilometer) was obtained using all on-transect moose observations and the surveyed subunit area (km^2), which was then converted to a population estimate over the entire survey area with a 90% confidence interval (CI) (Gasaway et al. 1986). From raw counts, group size, bull-cow and calf-cow ratios, proportion of calves in the population, and the twinning rate were calculated.

3. Results

3.1 Survey Conditions and Search Effort

Following methodological recommendations in the Moose Action Plan for Nunatsiavut (Purcell et al. 2019), the survey was initiated on February 13, 2019 following fresh snowfall of approximately 20 cm on February 9 - 10, 2019. High winds gusting 80 - 100 km/h in the days that followed the snowfall cleared all old tracks. Additional snowfall occurred midway through the survey with approximately 15 cm of accumulation, which was enough to refresh tracks throughout the survey area. Skies were nearly always clear with bright, high-intensity light and good visibility. Winds in the first week were calm to 30 km/h, but increased in the second week, ranging from 40 - 80 km/h. Days since last snowfall did not seem to aid in sightability, as moose seen during the survey were confined to small areas, reusing old tracks to navigate, but it did allow for quicker observations and reduced tracking time because directionality could be more easily determined.

Helicopter issues tied to the cold and high winds resulted in partial flight days during the first week of the survey, but all survey plots were flown no earlier than 08:51 and no later than 15:49. 3,713 km were flown in the course of 34 flight hours from February 13-24, 2019. 14% of the high- and 3% of the low-density subunits were surveyed for an overall coverage of 7.14% of the survey area (Table 2). The reduction from the planned survey coverage is primarily due to removal of subunits within mainly unsuitable habitat over the George River Plateau in the northwestern portion of the survey area. Average search effort was 2.6 min / km^2, and ranged from 0.75 min / km^2 in open habitat due to fewer transects that were actually flown and 8.5 min / km^2 when moose were found and additional time was used to classify them by age and sex (Table 2).

Table 2. Search effort and population estimation using standard calculations (Gasaway et al. 2019) from counts obtained during a stratified random block survey of Moose Management Area 92 in Nunatsiavut, Labrador. The stratification did not accurately reflect moose density gradients, and both strata were analyzed together.

Number of subunits surveyed	86
Number of subunits in survey area (single stratum)	1203
Area of subunits surveyed (km^2)	342.4
Area of entire stratum (km^2)	4789.5
Average search effort (min/km^2)	2.6
Coverage of survey area	7.14%
Number of moose observed on transect	15
Density (moose/km^2)	0.044
Population estimate	210
Sampling Variance	*6429.5*
90% Confidence interval	63.5%
Minimum population estimate	76

During the survey, it was realized that the stratification did not accurately differentiate habitat quality, and therefore, did not represent moose densities within the survey area. Of the 21 moose observed, 15 occurred on-transect, all within the high-density stratum. Out of the remaining six observations, four were observed in subunits classified as non-habitat (Figure 3). No moose were observed within the low-density stratum either on- or off-transect. Specifically, the stratification failed in the northern part of the survey area. Subunits at higher altitudes and with poorer habitat were more likely to be included in the high-density stratum, despite high-quality habitat being in a lesser abundance. This was reflected in the observations, with the majority of moose being found in the southern portion of the survey area. Only 5 moose were observed north of Nain Bay and Fraser River, three of which were just north of Nain Bay (Figure 3).

3.2 Sightability

As this is the first moose aerial survey in Nunatsiavut, sightability information was also collected during the survey. Behavior (standing, bedded), habitat type, snow cover, canopy cover, and time of day were recorded at the location of each observed moose (Table 3). All moose that were observed were standing (95.2%), except one that was bedded (4.8%). Again, all but one moose were observed in black spruce forests (95.2%), though some were found in more sparse (26-50% canopy cover: 14%) as opposed to more dense (>50% canopy cover: 81%) forested areas. One moose was observed in habitat classified as bare (4.8%), which was likely an outlier and stirred from its bed in a spruce forest below the steep rocky slope it was found on. Snow cover was complete throughout the survey area, aside from the one outlier mentioned above, which was likely bedded down in complete snow cover below. In this case, snow cover was partial at the site of observation (4.8%) while all others were observed with complete snow cover on the ground (95.2%).

3.3 Demography

Due to the anticipated low density, moose both on- and off-transect were classified whenever possible to increase sample size. 20 out of 21 moose observed during the survey were classified by sex based on the presence or absence of a vulva patch, and all were classified by age (calf, adult) based on body size and behavior. Bull-cow and calf-cow ratios were 23:100 and 31:100, respectively (Table 4). One individual was classified as an unknown adult, so all 21 observations were used to calculate the proportion of calves in the population, which at 19% was the slightly higher than the average of values reported elsewhere in Labrador from 1980 - 2008 (Couturier et al. 2019) (Table 4). Average group size was low (1.4 moose / group), and no twins were observed during the survey (Table 4).

3.4 Abundance

Establishing a population estimate based on an inaccurate stratification can lead to over- or under-estimation of abundance. This was addressed by removing the stratification entirely from the calculation of the population estimate by combining all counts from both low- and high-density strata into one data set. Abundance calculations followed Gasaway *et al.* 1986, with counts in all surveyed subunits used to determine the average moose density across the surveyed subunits, which was then applied to the entire survey area to obtain a population estimate and

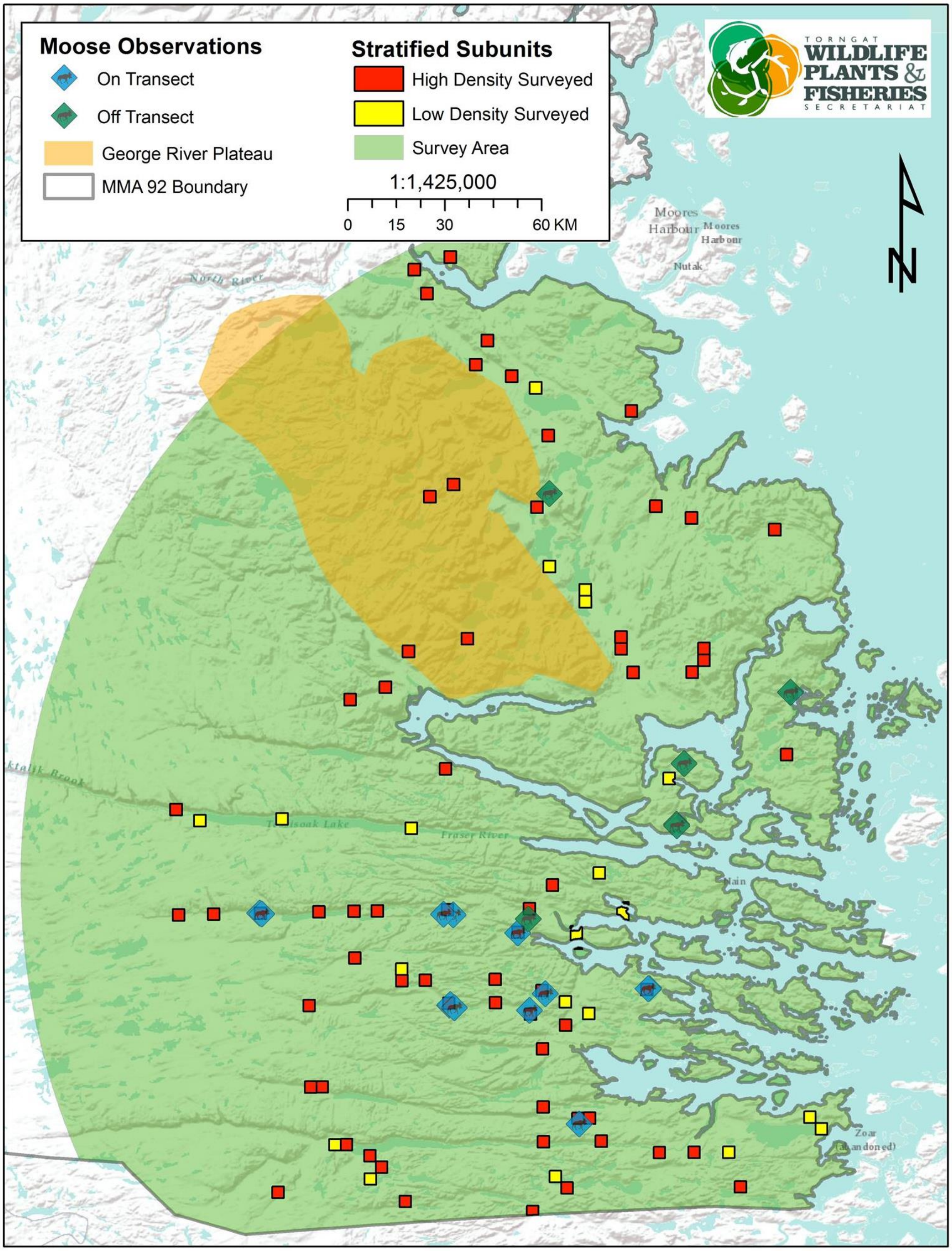

Figure 3. Moose observed in surveyed subunits from a stratified random block survey of Moose Management Area 92 in Nunatsiavut, Labrador. On-transect sightings that contributed to the population estimate are shown in blue. All observations on- and off-transect were used to calculate calf-cow ratio, bull-cow ratio, and the proportion of calves in the population.

Table 3. Sightability data collected at the site of moose observations during an aerial survey of Moose Management Area 92 in Nunatsiavut, Labrador.

Sightability Factors		Number of Moose Observed	Proportion of Total Observations
Behavior	Bedded	1	4.8%
	Standing	20	95.2%
Habitat	Open Coniferous	11	52.4%
	Closed Coniferous	9	42.9%
	Bare	1	4.8%
Snow Cover	Complete	20	95.2%
	Partial	1	4.8%
Relative Canopy Cover	<26%	1	4.8%
	26-50%	3	14.3%
	51-75%	8	38.1%
	>75%	9	42.9%
Time of Day	9-10*	1	4.2%
	10-11	4	19.0%
	11-12	5	23.8%
	12-13*	6	28.6%
	13-14*	0	0%
	14-15	3	14.3%
	15-16	2	9.5%

* often during ferrying time or refueling

Table 4. Demographic indices from 21 moose observed and classified by age and sex during an aerial survey of Moose Management Area 92.

Number of moose observed	21
Number of bulls	3
Number of cows	13
Number of calves	4
Number of adults of unknown sex*	1
Average group size	1.4
Bull-cow ratio	23:100
Calf-cow ratio	31:100
Proportion of calves in the population	19%
Twinning rate	0%

*only used for calculation of the proportion of calves in the population.

Table 4. Demographic indices from 21 moose observed and classified by age and sex during an aerial survey of MMA 92.

90% CI. Using the 15 individuals observed on-transect, the population was estimated at 210 moose (90% CI: 76 – 343 moose) (Table 2). This value, however, assumes that the densities found within the south would be equal to those in the north, which is untrue. When moose observations found primarily in the south are applied to the entire survey area, the resulting abundance is a gross overestimation. In light of this, and in congruency with informing a sustainable harvest, the lower confidence limit of 76 moose should be used for management purposes as the minimum population estimate, as done in Quebec, when inadequate sampling resulted in an overestimate of population size (Couturier et al. 2004).

4. Discussion

4.1 Survey Method

The habitat stratification did not appear to accurately reflect density gradients within the survey area. Broadly, the locations of moose observed during the survey corresponded well to the sightings reported by Inuit Knowledge-holders, which were used to inform the stratification. This indicates that the mismatch in success laid primarily within our interpretation of this data. This was likely due to a combination of factors, including inaccurate or large scale habitat data not being indicative of actual habitat present and a mismatch between the size of subunits and the scale at which habitat varies in this region.

4.1.1 Habitat Stratification

Moose observations were nearly exclusive to the high-density stratum. Four off-transect observations occurred within subunits classified as non-habitat, and no moose were observed in the low-density stratum. In this way, the habitat stratification did not accurately reflect actual moose densities. To address this in future surveys, there are two options: use an aerial stratification to differentiate strata or modify the habitat stratification in an attempt to more accurately classify subunits. The former option, aerial stratification, uses pre-survey flights and track density to assign subunits to high- and low-density strata (Gasaway et al. 1986). The remoteness of the survey area and low-densities of moose in the area preclude this, as it would be a significant expenditure and would reduce the ability to fly the survey area at a reasonable level of coverage. For this reason, a habitat stratification is the preferred method for distinguishing moose density expectations (Purcell et al. 2019), and with some modifications, it may still be a feasible option. First, the Labrador Nature Atlas (NCC) data utilized was merged from multiple sources at varying spatial and temporal scales, resulting in false assignment of subunits to either stratum. This could be improved by using a more detailed land cover classification such as the Global Ecological Land Unit Classification (USGS) that has spatial resolution ranging from 30 m - 250 m, much closer to the scale needed to inform stratification of 4 km^2 subunits. Reviewing the assignment of subunits to strata using satellite imagery would also be a useful step, because presence or absence of older spruce forest is an easy criteria to distinguish potential habitat. Low elevation and slope should also be given a higher weighting in order to eliminate steep slopes and high-altitude habitat, which are unsuitable for moose. Open and burned habitats were included in both strata, though both were found to not contain moose. This was likely influenced by the at-site features at harvesting locations, which should be taken into account. Although these locations show areas where moose exist, they are usually the recorded site where the moose was killed, which may have been impacted by giving chase once the animal was observed, or pushing the moose outside of its favored habitat and into more open areas where they are easier to shoot. Additionally, follow-up consultations within communities prior to conducting a survey in a particular MMA would allow for updating and fine-tuning of the IK sightings that have previously been documented to ensure accuracy and include recent sightings and harvesting locations.

The above modifications should all make differentiating non-habitat from potential moose habitat much more accurate, but distinguishing low- and high-density subunits will be more difficult. No moose were observed within the low density stratum. However, lack of potential habitat was not always the cause. Additionally, the majority of moose were seen by observing tracks on or near treelines along ponds and rivers, especially oxbow lakes. It may be wise to focus on distance from these features, with high-density cells most proximal and low-density neighboring and farther away from rivers and lakes or in sub-optimal habitat to reflect a potential density gradient. If future surveys fail to distinguish high- from low-density, it would be recommended that they be combined once again, as done here and elsewhere (Maltais et al. 1993; Leblanc et al. 1993). This should result in a more biologically reasonable estimate, especially if non-habitat is accurately removed from the survey area in the primary stratification.

A large portion of the survey area was unsuitable habitat found within the George River Plateau. After surveying a few subunits there, it was decided that the remainder would be removed from the survey area, which accounted for the majority of the difference between expected and actual survey coverage. In future surveys, it would be beneficial to remove this area prior to habitat stratification, as well as those subunits in the Kiglapait Mountains and on other high-altitude plateaus that border rivers. This would reduce the overall survey area by approximately 35%, allowing for greater coverage of the area which has the potential to sustain moose by removing non-habitat.

4.1.2 Subunit Size

The heterogeneity of habitat within MMA 92 is quite drastic. Sea level river valleys bisect high-altitude plateaus ranging from 870 m to over 1000 m high, and even in areas with lower altitude peaks, steep slopes prevent moose from traveling outside of river valleys during winter. Suitable habitat is therefore present at a relatively small scale, even in relation to the small (4 km^2) subunits utilized here. Frequently, an individual subunit would encompass portions of large lakes or rivers, small amounts of suitable habitat, and steep slope leading up to high altitude plateaus (Figure 4). This not only was difficult to survey for the observers, but also required that significant time be spent gaining altitude and surveying extremely unsuitable habitat alongside good habitat that would be characteristic of the high-density stratum. A creative strategy may be able to address this limitation by ensuring that subunits in the high- and low-density strata are as uniform as possible. 4 km^2 is an ideal size for surveying. Subunits of this size required an average of 6 minutes to survey in their entirety, resulting in very low probability of observer fatigue. It is also the standard size utilized in Newfoundland and Labrador (O'Donoghue and McLaren 2000), making it a useful size for comparison. Therefore, we suggest that the overall subunit area remain as 4 km^2, but rather that a fishnet of 1 km x 1 km cells be overlaid across the survey area, followed by stratification of each cell. These cells may be randomly selected in the same manner as done here, but an additional step would be required. To obtain an average subunit size of 4 km^2, three neighboring cells would be combined with the randomly selected cell. Selected cells would need to be stratified equally (i.e., high-density cells should only be combined with high-density selected cells), and in the case that there are several neighboring cells that could be combined, three could be randomly selected. This technique would require more work in the

Figure 4. Examples of the highly heterogeneous landscape found within subunits that make surveying difficult for both pilots and observers. Spruce forests comprise the best possible habitat, and are therefore expected to contain relatively high densities of moose, but are often bordered by open water and steep slopes that lead up to high-altitude mountains (top) or plateaus (bottom).

planning stage of the survey, but would still ensure randomization while matching cell size and configuration to the scale at which habitat changes.

4.2 Sightability

One of the biggest considerations in the development of the Moose Action Plan and its associated aerial survey methodology was the timing and how that might affect sightability (Purcell et al. 2019). Mid-February provided a good amount of daylight, and prime weather conditions were present for a good majority of survey days. Snow cover was complete throughout the survey area, and bright, high intensity light provided good contrast for tracking. IK also indicated that moose should be surveyed during late winter, as their presence or absence becomes more predictable (Rosa, K., *in prep*). In other areas, deep snow confines moose to closed-canopy coniferous forests where less accumulation occurs (Telfer 1970; Bubenik 2007). However, in regions where this is true, food sources are also available within or near these habitats. In Nunatsiavut, food sources are almost exclusively found in and along rivers and lakes, and black spruce canopies are usually open, providing little reprieve from deep snow. This results in a behavior unique to moose in Labrador, where deep snow brings them closer to water edges (Phillips, F., pers. comm.). This was clearly the case in MMA 92, as nearly all observations occurred on or in close proximity to lakes and rivers. Snowfall in this MMA is typically hard-packed and windblown, but snow accumulation was much greater than average in 2018 - 19. Moose were often observed in snow depths of 1 m to 1.5 m in some parts of the survey area. To adapt to this, they appeared to be utilizing the same paths to make moving between shelter in the trees and food in the open areas easier. Tree wells were usually the only area with shallow snow, and moose often stood in them during classification. This could have resulted in missing some calves or other moose, but in almost all cases where tracks were found, moose were also identified, so there is confidence in the number of groups that were recorded. Based on this, there should be no hesitation to initiate the survey no more than 2 weeks earlier if favorable snow conditions exist, which may allow for classifying moose after snowfall is deep enough to make their locations predictable, but not so deep as to promote the utilization of tree wells.

Sightability data that was collected indicates that moose are most likely to be observed when standing. Bedded moose are extremely difficult to distinguish from the thick, shadowed bases of black spruce foliage and without observing their slight movements, would likely be missed. Our tracking technique allowed for thorough investigation of all tracks, and only rarely did this not result in a moose observation. Aside from one outlier, all moose were observed in open canopy black spruce habitat, usually with more dense coverage produced by larger, older trees. This is a common observation throughout Labrador. Observer experience can also play a large role in sightability (Gasaway et al. 1986; Oswald 1998). The entire crew for this survey was ‘green’, which could have reduced sightability significantly. However, nearly every time tracks were observed, a moose was also found. Additionally, two of the three observers were very familiar with the region and had significant experience with tracking from the ground, which was an asset to the survey, and all crew members had participated in aerial work in the past. Moving forward, it is recommended that the now experienced crew continue to participate in subsequent years, and that no more than one observer should be new to moose surveys if at all possible.

4.3 Demography

Demographic indices are an important metric that can be used to coarsely guide TAH decisions and gauge the potential for moose populations to increase, decrease, or remain stable. The Collector app (ESRI) allowed for accurate recording of location, even when not directly on-top of the moose, which was useful when attempting to classify multiple moose at the same site. It was, however, difficult to record all information on a small screen. It would be beneficial, if using this app again, to install it and its associated maps on an iPad or similar tablet.

The bull-cow ratio observed was lower than expected, with 23 bulls per 100 cows, though this ratio is higher elsewhere in Labrador (Couturier et al. 2019) (Figure 5). A minimum of 30-40 bulls per 100 cows may be needed to maintain low-density populations (Craig and Stout 2014). With fewer than 30 bulls per 100 cows, reproductive success may be impacted (Aitken and Child 1992; Timmermann 1992; Environment Yukon 2016). Skewed sex-ratios are often caused by preferential selection for males, but little evidence for this exists in Nunatsiavut. It may also be tied to sightability, in that bulls may be more difficult to stir in deep snow, and therefore less likely to be observed, but others have reported the opposite to be true (Gasaway et al. 1986). Harvest is low in MMA 92, with no more than eight tags filled each year. Although licenses are issued for either sex, IK does not indicate a preference for males over females, with most reporting that they harvest whatever moose they see first on their hunt (Rosa, K., *in prep*). In the past three years, fourteen out of twenty moose harvested from MMA 92 were bulls. Therefore, preferences aside, bulls were more commonly harvested in recent years. It is also a possibility that the low bull-cow ratio observed here may be due to chance and the variation associated with low, unrepresentative sample sizes.

Late-winter calf-cow ratios are more representative of true recruitment than in early-winter, because at this time calves are 9-10 months of age and less susceptible to predation (Gasaway et al. 1986). Therefore, 31 calves per 100 cows is likely sufficient for the maintenance of the population, which should be at least 20-30 calves per 100 cows (Environment Yukon 2016). With this ratio in late February, there is also small potential for population growth based on sufficient inferred recruitment. In Labrador more widely, this is just below the past average of 44 calves per 100 cows (Figure 5). The proportion of calves in the population (19%) is slightly higher than the Labrador average of 18% (Figure 5). However, no twins were observed during the survey. Twinning is often an indicator of habitat quality (Couturier et al. 2019), with more twins produced in better quality habitat. This may indicate that habitat is a limiting factor in the further growth of the moose population in MMA 92, with the caution that drawing conclusions based on low sample sizes can be problematic.

Demographic estimates can be highly variable year-to-year, and only present half of the picture when investigating population dynamics. Birth and death rates are important factors that aren't explicitly addressed here. Although late-winter calf-cow ratios are a good indication of recruitment, mortality rates are unknown, which is an important piece in interpreting the demographic indices obtained during aerial classifications. Radio-collaring adult moose would be an important aspect of future monitoring, and would allow for the quantification of mortality

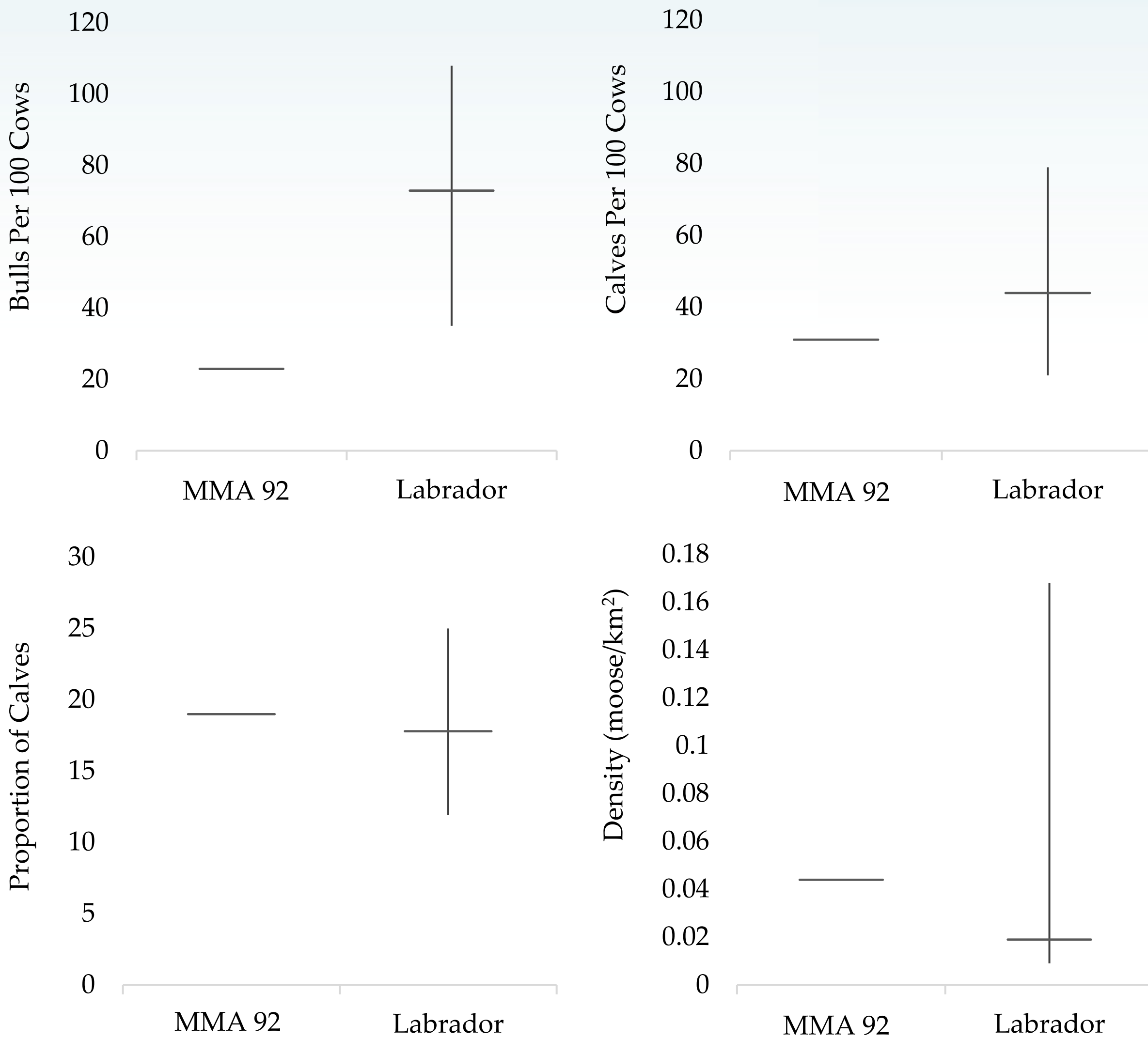

Figure 5. Comparisons of demographic indices and moose density in Moose Management Area (MMA) 92 to other surveys done in Labrador (Couturier et al. 2019). Horizontal lines indicate mean of reported values in Labrador, and the observed value found in MMA 92 in February 2019. Vertical lines indicate the range of values found within Labrador.

rates and identification of their causes. During the survey, tracks of 2-3 wolves were observed, which indicates that wolf density is low, and predation on moose by wolves is likely not significant in the area. Black bear (*Ursus americanus*) are also present, and both predators likely play some role in moose calf mortality, though this has never been quantified in Nunatsiavut.

4.4 Abundance

Stratification is a useful tool, but can fail particularly when surveying an area for the first time (Oswald 1998). In this case, the habitat stratification did not accurately reflect the actual moose density gradient, and therefore both strata were combined. The overall density of moose within the survey area is 0.044 moose / km^2, which is on the higher end of reported values in and near Nunatsiavut (Phillips 1983; Dalton 1986; Chubbs and Schaefer 1997; Barney 2008a; Barney 2008b), and slightly higher than the average of past surveys in Labrador (Figure 5). The population estimate of 210 moose (90% CI: 76 – 343) is an overestimation because without any stratification, the densities are assumed to be consistent across the entire survey area, which is untrue. Only four out of 15 groups were observed north of Fraser River, meaning that 73% of groups were observed in only 57% of the survey area. These groups were also larger south of the Fraser River.

Although the population estimate is likely within the lower bounds of the 90% CI, it is impossible to know how accurate the estimate is. Low precision overall means that there will be little power to detect change in subsequent years or monitoring (Gasaway et al. 1986), but the lower confidence limit can be used as a rough guide until more precise estimates can be obtained. Because the purpose of this work is to inform management, the lower confidence limit of 76 moose should be used as the minimum population estimate to ensure that harvest decisions remain conservative. In this way, TAH would be based on a conservative estimate of population size, which would prevent affecting the population in a way that we will not be readily able to detect in the near future.

In SRB surveys, a sightability correction factor (SCF) is often used to determine the proportion of moose that are missed in a standard search by comparing counts during an intensive search (Gasaway et al. 1986). With such a low-density population and small sample size, it was not feasible to obtain an SCF, but this may be a possibility in the southern MMAs. Radio-collared moose can also be used to establish an SCF (Gasaway et al. 1986). By flying cells which are known to have collared moose and dividing the number observed by the true number of moose in the unit, the proportion missed can be calculated. No matter how this is calculated, it is an important parameter that should be attempted when possible. In any case, the SCF could be retroactively applied to quantify the moose that may have been missed during past standard searches across Nunatsiavut and update this population estimate. Therefore, it is recommended that consideration be given to a separate radio-collaring project, to not only understand more about moose survival, but also to improve survey precision in future years.

5. Conclusion and Recommendations

Surveying along the northern range periphery of moose brings certain difficulties. Surveys of low-density populations often result in wide confidence intervals around population estimates that can limit their usefulness for making management decisions using solely abundance information. However, no matter the abundance, in a low-density population, harvest must remain relatively conservative. In line with this, the lower confidence limit of 76 moose should serve as the minimum population estimate for moose abundance in MMA 92. Using this value, changes to total allowable harvest will still be conservative, allowing the population to continue to grow while still providing harvesting opportunities for Nunatsiavummiut. However, any changes to total allowable harvest should be followed up on by completing additional monitoring to ensure that the actions had the desired effect.

Although the late-winter calf-cow ratio indicates a stable or slightly increasing population size, mortality factors are not yet quantified, so assuming that recruitment is indicative of population growth would be presumptive. The recruitment rate, however, does indicate that the population has the potential to increase in MMA 92. Radio-collaring at least 10-15 adult females would allow for adult mortality to be quantified, and would provide additional insight into factors that drive population dynamics. Also, low bull-cow ratios can result in reduced reproductive rates, and this ratio should be monitored on more frequent intervals through aerial classification surveys every two to three years. To follow up on these baseline estimates, we present the following recommendations for future monitoring:

- Estimate population size of each MMA every four to five years using a stratified random block survey informed by Inuit Knowledge and lessons learned in prior surveys;
- Measure recruitment and sex ratios every two to three years;
- Continue to collect jawbones to develop an understanding of age structure of harvested animals; and
- Aim to better understand drivers of adult mortality and its impact on survival and future trends in abundance.

Prior to this survey, the only inferences about abundance were related to the observations of more moose in Nunatsiavut. As the interest in moose harvesting increased in the region, it became evident that more information was needed in order to inform management decisions and ensure that TAH remains sustainable. Gaining a better understanding of abundance, distribution, and demographics using SRB surveys is an effective way to assess each of these aspects, but more modifications are needed to make commonly used methodologies to be useful in Nunatsiavut. Utilizing 4 km^2 subunits made by combining randomly selected 1 km^2 cells and more appropriate habitat data will allow for accurate stratification and subunit delineation at the proper scale. To verify stratification, satellite imagery should be utilized and local harvesters should be consulted. It is our expectation that methods developed in this monitoring program would be applicable to other low-density moose populations, and provide a unique framework with which standard aerial survey techniques may be modified to suit populations at the northern range periphery.

References

Aitken, D.A. and Child, K.N. 1992. Relationship between in utero productivity of moose and population sex-ratios: an exploratory analysis. Alces 28: 175-187.

Barney, W. 2008a. Moose population density estimate survey MMA 54- Double Mer, Labrador. Wildlife Division, Government of Newfoundland and Labrador.

Barney, W. 2008b. Moose population density estimate survey MMA 55- Double Mer, Labrador. Wildlife Division, Government of Newfoundland and Labrador.

Broders, H. G., Mahoney, S. P., Montevecchi, W. A. and Davidson, W. S. 1999. Population genetic structure and the effect of founder events on the genetic variability of moose, *Alces alces*, in Canada. Molecular Ecology 8: 1309-1315.

Bubenik, A.B. 2007. *In* Ecology and Management of the North American Moose. A.W. Franzmann and C.C. Schwartz. Ed., University Press of Colorado. Boulder, CO. pp. 173-221.

Chubbs, T. & Schaefer, J. 1997. Population growth of moose, *Alces alces*, in Labrador. The Canadian Field-Naturalist 111: 238-242.

Couturier, S., Jean, D., Otto, R., and Rivard, S. 2004. Demography of the migratory tundra caribou (*Rangifer tarandus*) of the Nord-du-Québec region and Labrador. Ministère des Ressources naturelles, de la Faune et des Parcs, Direction de l'aménagement de la faune du Nord-du-Québec and Direction de la recherche sur la faune. Québec: 68 p

Couturier, S., Purcell, M., Dale, A., and Snook. J. 2019. Monitoring options for moose in Nunatsiavut. Torngat Wildlife, Plants and Fisheries Secretariat Series 2019 : 25p.

Craig, T. and Stout, G.W. 2014. Aerial moose survey on and around Kanuti National Wildlife Refuge November 2013. Alaska Department of Fish and Game: 8p.

Dalton, W.J. 1986. Moose census in Labrador on management areas 51, 52, 53, and 54: February 27- March 25 1986. Wildlife Division, Department of Culture, Recreation, and Youth, Government of Newfoundland and Labrador. Project No. 4403. 56pp.

Environment Yukon. 2016. Science-based guidelines for management of moose in Yukon. Yukon Fish and Wildlife Branch Report MR-16-02. Whitehorse, Yukon, Canada.

Foster, D.R. 1985. Vegetation development following fire in *Picea mariana* (black spruce) forests of south-eastern Labrador, Canada. Journal of Ecology 73: 517-534.

Gasaway, W.C., Dubois, S.D., Reed, D.J., and Harbo, S.J. 1986. Estimating moose population parameters from aerial surveys. Biological Papers of the University of Alaska: 125p.

Kelsall, J.P. 1972. The northern limits of moose (*Alces alces*) in western Canada. Journal of Mammalogy 53: 129-138.

Labrador Inuit Land Claims Agreement *2005* (NL) part 12.3-9 (Canada).

Leblanc, Y., Laurin, G., Couturier, S. and Maltais, J. (1993). Inventaire aérien de l'orignal dans la zone de chasse 17 en janvier et février 1991. Ministère du Loisir, de la Chasse et de la Pêche, Direction régionale du Nouveau-Québec., Quebec. 36 p + 2 Appendices.

Maltais, J., Leblanc, Y. and Couturier, S. (1993). Inventaire aérien de l'orignal dans la zone de chasse 22 en février et mars 1991. Ministère du Loisir, de la Chasse et de la Pêche, Direction régionale du Nouveau-Québec, Quebec. 32 p + 2 Appendices

O'Donoghue, M., and McLaren, B. 2000. Manual for aerial surveys of caribou and moose in Newfoundland and Labrador and calculations of population size for these species. Ecosystem Research and Inventory Section, Wildlife Division, Government of Newfoundland and Labrador : 23p.

Oswald, K. 1998. Moose aerial observation manual. Ontario Ministry of Natural Resources, Northeast Science and Technology, 95p.

Phillips, F. 1983. Aerial moose census in selected areas of Labrador, 7 April – 2 May 1980. Wildlife Division, Goose Bay, NL. Project No. 4402.

Pimlott, D. H., and Carberry, W. J. 1958. North American moose transplantations and handling techniques. Journal of Wildlife Management 22: 51–62.

Purcell, M.C., Couturier, S., and Snook, J. 2019. An action plan to inform the sustainable management of moose in Nunatsiavut. Torngat Wildlife, Plants and Fisheries Secretariat Series 2019 : 25p.

Statistics Canada. 2017. Census Profile. 2016 Census. Statistics Canada Catalogue no. 98-316-X2016001. Ottawa. Released November 29, 2017. http://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E

Telfer, E.S. 1970. Winter habitat selection by moose and white-tailed deer. Journal of Wildlife Management 34: 553-559.

Timmermann, H.R. 1992. Moose socio-biology and implications for harvest. Alces 28: 59-77.

Torngat Wildlife and Plants Co-management Board 2015. Moose total allowable harvest in the Labrador Inuit Settlement Area, 2016-17. Retrieved from https://www.torngatsecretariat.ca/home/files/cat12/2016-moose_tah_decision.pdf

Viglas, J.N., Brown, C.D., and Johnstone, J.F. 2013. Age and size effects on seed productivity of northern black spruce. Canadian Journal of Forest Research 43(6): 534-543.

Wald, E.J. & Nielson, R.M. 2014. Estimating moose abundance in linear subarctic habitats in low snow conditions with distance sampling and a kernel estimator. Alces 50: 133-158.

Appendix A

Timeline of the aerial survey of Moose Management Area 92 from February 12-24, 2019.

Date	Route/Area Flown	Flight Time (hours)	Number of Moose Observed	Number of Groups Observed
February 12, 2019	Departed Goose Bay for Nain	3.0	-	-
February 13, 2019	Mechanical Issues in AM; Surveyed northeast of Nain around the Kiglapait Mountains and south of Okak Bay in PM	4.1	3	2
February 14, 2019	Okak Bay in AM; Mechanical issues in PM	3.0	1	1
February 15, 2019	Mechanical Issue fixed by noon; southwestern George River Plateau and south of Okak Bay in PM	3.0	1	1
February 16, 2019	Snow storm moved in overnight- no flying done	0.0	-	-
February 17, 2019	Windy and poor visibility in AM; Coastal areas south of Nain in PM	2.6	0	0
February 18, 2019	High winds and additional snow overnight and throughout the day- no flying done	0.0	-	-
February 19, 2019	Flying attempted, but winds were much higher than reported/forecasted and no subunits were surveyed.	1.3	-	-
February 20, 2019	Coastal areas south and east around Voisey's Bay in AM; and further north and west of Voisey's Bay in PM	6.8	6	4
February 21, 2019	Area south of Anaktalik Brook and west of Nain in AM; southwest portion of survey area towards Head Brook in PM	6.5	5	3
February 22, 2019	Strong winds forecasted in Fraser Canyon- no flying done.	0.0	-	-
February 23, 2019	Fraser Canyon and west end of Anaktalik Brook in AM; remainder of Anaktalik Brook and Akadlivik Brook in PM	5.6	5	4
February 24, 2019	Tikkoatokak Bay in AM; Returned to Goose Bay	3.4	0	0

Appendix B

Environmental factors and search effort information for each subunit (SU) surveyed during an aerial survey of Moose Management Area 92 from February 12-24, 2019.

SU	Date	Stratum	Start/ end time	Search effort (min/km^2)	Visibility rating	Temp (^{0}c)	Cloud cover	Wind speed (km/h) and direction	Days since snow	Light type/ intensity	Snow cover	Comments
3535	2/13/19	High	11:37 11:45	2	Good	-22	Clear	10-20 NW	2	Bright High	Comp	
9260	2/13/19	High	12:07 12:14	1.75	Good	-22	Clear	30 NW	2	Bright High	Comp	
9151	2/13/19	High	12:21 12:27	1.5	Good	-22	Clear	30 NW	2	Bright High	Comp	
8582	2/13/19	High	12:30 12:39	2.25	Good	-22	Clear	30 NW	2	Bright High	Comp	
2598	2/13/19	High	12:45 12:54	2.25	Good	-20	Clear	30 NW	2	Bright High	Comp	
7645	2/13/19	High	13:12 13:18	1.5	Good	-20	Clear	30 NW	2	Bright High	Comp	
4938	2/13/19	High	13:18 13:25	1.75	Good	-20	Clear	30 NW	2	Bright High	Comp	
9662	2/13/19	High	13:26 13:33	1.75	Good	-20	Clear	30 NW	2	Bright High	Comp	
1255	2/13/19	Low	13:40 13:53	3.25	Good	-20	Clear	15 NW	2	Bright High	Comp	
5428	2/13/19	High	15:04 15:11	1.75	Good	-20	Clear	Calm	2	Bright High	Comp	female and calf towards transect
1172	2/13/19	High	15:14 15:22	2	Good	-20	Clear	Calm	2	Bright Medium	Comp	
1412	2/13/19	High	15:22 15:30	2	Good	-20	Clear	Calm	2	Bright Medium	Comp	
4372	2/13/19	Low	15:34 15:42	2	Good	-20	Clear	25 NW	2	Bright High	Comp	
9525	2/13/19	Low	15:42 15:49	1.75	Good	-20	Clear	25 NW	2	Bright High	Comp	
3818	2/14/19	High	10:48 11:04	4	Good	-22	Clear	8 E	3	Bright High	Comp	

415	2/14/19	High	11:06 11:15	2.25	Good	-22	Clear	8 E	3	Bright High	Comp	
6565	2/14/19	High	11:17 11:26	2.25	Good	-22	Clear	8 E	3	Bright High	Comp	
9577	2/14/19	High	11:34 11:41	1.75	Good	-22	Clear	8 E	3	Bright High	Comp	
3625	2/14/19	High	11:43 11:51	2	Good	-22	Clear	8 E	3	Bright High	Comp	
1022	2/15/19	High	13:19 13:29	2.5	Good	-20	Clear	Calm	4	Bright High	Partial	
5195	2/15/19	High	13:41 13:47	1.5	Good	-22	Clear	Calm	4	Bright High	Partial	
673	2/15/19	High	13:50 13:58	2	Good	-22	Clear	Calm	4	Bright High	Partial	
2810	2/15/19	High	14:08 14:17	2.25	Good	-21	Clear	5 NW	4	Bright High	Comp	
4879	2/15/19	Low	14:19 14:26	1.75	Good	-20	Clear	5 NW	4	Bright High	Comp	
10271	2/15/19	High	14:29 14:37	2	Good	-20	Clear	5 E	4	Bright High	Comp	moose tracks, unable to find amongst trees (first went to on Feb 14th, but ran out of time, no moose was spotted the following day (15th)
399	2/15/19	High	14:44 14:52	2	Good	-18	Clear	Calm	4	Bright High	Comp	
7866	2/15/19	Low	14:56 15:05	2.25	Good	-18	Clear	Calm	4	Bright High	Comp	
6247	2/17/19	Low	09:19 09:27	2	Fair	-13	Overcast	15 W	.5	Flat Medium	Comp	Colin noted he'd seen moose on this hill before
8731	2/17/19	High	09:30 09:39	2.25	Good	-13	Overcast	15 W	.5	Flat Medium	Comp	
2100	2/17/19	High	09:42 09:52	2.5	Good	-12	Overcast	15 W	.5	Flat Medium	Comp	
1809	2/17/19	Low	10:58 11:15	4.25	Fair	-12	Overcast	15 W	.5	Flat Medium	Comp	

686	2/17/19	Low	11:17 11:29	3	Fair	-12	Overcast	15 W	.5	Flat Medium	Comp	
10253	2/20/19	Low	08:51 09:00	2.25	Good	-31	Clear	40-55 NW	1	Bright High	Comp	
5601	2/20/19	Low	09:01 09:12	2.75	Good	-31	Clear	50 NW	1	Bright High	Comp	
4162	2/20/19	High	09:19 09:26	1.75	Good	-31	Clear	65 W	1	Bright High	Comp	
10291	2/20/19	Low	09:31 09:37	1.5	Good	-31	Clear	65 W	1	Bright High	Comp	bad stratification
349	2/20/19	High	09:39 09:47	2	Good	-31	Clear	65 W	1	Bright High	Comp	
4401	2/20/19	High	09:52 10:00	2	Good	-31	Clear	65 W	1	Bright High	Comp	
8542	2/20/19	High	10:06 10:24	4.5	Good	-30	Clear	65 W	1	Bright High	Comp	
8409	2/20/19	Low	10:30 10:36	1.5	Good	-32	Clear	65 W	1	Bright High	Comp	
11204	2/20/19	High	10:37 10:46	2.25	Good	-32	Clear	65 W	1	Bright High	Comp	
172	2/20/19	High	10:49 10:57	2	Good	-32	Clear	65 NW	1	Bright High	Comp	
10268	2/20/19	High	11:15 12:19	5.25	Good	-30	Clear	65 NW	1	Bright High	Comp	had to refuel-restarted this cell to get accurate count.
9860	2/20/19	High	12:28 12:37	2.25	Good	-30	Clear	65 NW	1	Bright High	Comp	
1634	2/20/19	High	12:41 12:52	2.75	Good	-30	Clear	65 NW	1	Bright High	Comp	
3694	2/20/19	High	13:00 13:10	2.5	Good	-32	Clear	65 NW	1	Bright High	Comp	
9839	2/20/19	High	13:14 13:21	1.75	Good	-31	Clear	65 NW	1	Bright High	Comp	bad stratification-some trees on edge
94	2/20/19	High	13:31 13:40	2.25	Good	-31	Clear	65 NW	1	Bright High	Comp	
1813	2/20/19	High	13:43 13:52	2.25	Good	-31	Clear	65 NW	1	Bright High	Comp	

10066	2/20/19	Low	13:54 14:06	3	Good	-30	Clear	65 NW	1	Bright High	Comp	Voisey's Bay airstrip running through western portion of cell
8178	2/20/19	Low	14:08 14:17	2.25	Good	-30	Clear	65 NW	1	Bright High	Comp	
4472	2/20/19	High	14:20 14:54	8.5	Good	-30	Clear	65 NW	1	Bright High	Comp	
10934	2/21/19	High	08:58 09:09	2.75	Good	-29	Clear	80 NW	2	Bright High	Comp	first flown 2/20, but ran out of fuel. Returned to cell 2/21 first thing, and did not resight, though tracks were identified.
1718	2/21/19	High	09:14 09:24	2.5	Good	-29	Clear	65 NW	2	Bright High	Comp	
6466	2/21/19	High	09:27 09:34	1.75	Good	-29	Clear	65 NW	2	Bright High	Comp	skipped last transect, all high altitude barren. Only southernmost transect was within trees.
10515	2/21/19	High	09:38 10:12	8.5	Good	-29	Clear	65 NW	2	Bright High	Comp	
9382	2/21/19	High	10:17 10:23	1.5	Good	-31	Clear	70 NW	2	Bright High	Comp	only southernmost transect within suitable habitat. Rest was barren upland (did first two transects)
4747	2/21/19	High	10:26 10:32	1.5	Good	-31	Clear	70 NW	2	Bright High	Comp	skipped northernmost transect (barren); only southernmost transect within tree
2709	2/21/19	High	10:49 10:59	2.5	Good	-28	Clear	65 NW	2	Bright High	Comp	

3146	2/21/19	High	11:11 11:42	7.75	Good	-27	Clear	65 NW	2	Bright High	Comp	began surveying on 2/17, found plenty of tracks but weather moved in on us quickly and we couldn't complete. Resurveyed on 2/21 and found 1 moose, plus a ton of tracks just off the NW corner of the cell.
10393	2/21/19	High	12:51 13:01	2.5	Good	-24	Clear	40 NW	2	Bright High	Comp	
9767	2/21/19	Low	13:14 13:22	2	Good	-24	Clear	40 NW	2	Bright High	Comp	
6732	2/21/19	High	13:24 13:32	2	Good	-24	Clear	40 NW	2	Bright High	Comp	bad stratification
8259	2/21/19	High	13:33 13:40	1.75	Good	-24	Clear	40 NW	2	Bright High	Comp	
452	2/21/19	High	13:42 13:51	2.25	Good	-24	Clear	40 NW	2	Bright High	Comp	
11220	2/21/19	Low	13:52 14:01	2.25	Good	-24	Clear	40 NW	2	Bright High	Comp	
4753	2/21/19	High	14:09 14:17	2	Good	-24	Clear	15-25 NW	2	Bright High	Comp	
4109	2/21/19	High	14:26 14:36	2.5	Good	-26	Clear	30 NW	2	Bright High	Comp	
11174	2/21/19	High	14:37 14:46	2.25	Good	-26	Clear	30 NW	2	Bright High	Comp	
401	2/23/19	Low	09:02 09:15	2.75	Good	-28	Clear	50 NW	4	Bright High	Comp	not much sun searching valley, sun was still low and the valley walls were high
10783	2/23/19	Low	09:27 09:30	.75	Good	-28	Clear	65 NW	4	Bright High	Comp	only did one transect (high altitude, sheer cliff, no habitat)
5983	2/23/19	Low	09:36 09:42	1.5	Good	-28	Clear	65 NW	4	Bright High	Comp	

3447	2/23/19	High	09:44 09:55	2.75	Good	-25	Clear	65 NW	4	Bright High	Comp	light intensity medium at times
2588	2/23/19	High	10:08 10:18	2.5	Fair	-30	Partial	50 NW	4	Bright Medium	Comp	
10524	2/23/19	High	10:20 10:31	2.75	Good	-30	Partial	65 NW	4	Bright Medium	Partial	fair light and good visibility, ceiling was decreasing as we went west into Fraser River Canyon
4314	2/23/19	High	12:15 12:48	8.25	Good	-25	Clear	80 NW	4	Bright High	Comp	1 female and 1 young possible male
8859	2/23/19	High	12:52 12:59	1.75	Good	-25	Clear	70 NW	4	Bright High	Comp	
2171	2/23/19	High	13:02 13:11	2.25	Good	-25	Clear	70 NW	4	Bright High	Comp	
2504	2/23/19	High	13:13 13:22	2.25	Good	-25	Clear	70 NW	4	Bright High	Comp	
6952	2/23/19	High	10:34 13:34*	8.5	Good	-27	Partial	15-25 NW	4	Bright Medium	Comp	1 cow and 1 possible bull, was not able to identify the latter.
10574	2/23/19	High	13:41 13:49	2	Good	-28	Clear	65 NW	4	Bright High	Comp	
4790	2/23/19	High	13:55 14:03	2	Good	-25	Clear	15 NW	4	Bright High	Comp	
2484	2/24/19	High	09:09 09:15	1.5	Good	-22	Clear	80 NW	5	Bright High	Comp	
2318	2/24/19	High	09:17 09:25	2	Good	-22	Clear	80 NW	5	Bright High	Partial	
10306	2/24/19	High	09:29 09:33	1	Good	-22	Clear	80 NW	5	Bright High	Comp	skipped some transects due to steep bare cliffs and barren lands.
9388	2/24/19	High	09:42 09:52	2.5	Good	-22	Clear	80 NW	5	Bright High	Comp	

Appendix C

Sex and age classification of moose observed on and off-transect during an aerial survey of Moose Management Area 92 from February 12-24, 2019.

Date	Subunit Number	Stratum	On or Off Transect	Group Number	Adult Cow	Adult Bull	Calf	Unknown Adult	Total
February 13, 2019	8896	Non	Off	1	1		1		2
February 13, 2019	11163	Non	Off	2		1			1
February 14, 2019	5666	High	Off	3		1			1
February 15, 2019	10855	Non	Off	4	1				1
February 20, 2019	10934	High	On	5	1				1
February 20, 2019	4472	High	On	6	1				1
February 20, 2019	10268	High	On	7	1		1		2
February 20, 2019	1634	High	On	8	1		1		2
February 21, 2019	3146	High	On	9	1				1
February 21, 2019	10515	High	On	10	1		1		2
February 21, 2019	10515	High	On	11	1		1		2
February 23, 2019	6952	High	On	12	1			1	2
February 23, 2019	8611	High	Off	13	1				1
February 23, 2019	4314	High	On	14	1				1
February 23, 2019	4314	High	On	15		1			1

Appendix D

Breakdown of expenses incurred during an aerial survey of Moose Management Area 92 from February 12-24, 2019 from a total budget of $67,500 CAD.