Keeyask Generation Project

Terrestrial Effects Monitoring Plan

Moose Population Estimate Report

TEMP-2018-20

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KEEYASK

Manitoba Sustainable Development Client File 5550.00
Manitoba Environment Act Licence No. 3107

2017 - 2018

KEEYASK GENERATION PROJECT

TERRESTRIAL EFFECTS MONITORING PLAN

REPORT #TEMP-2018-20

MOOSE POPULATION ESTIMATE

Prepared for

Manitoba Hydro

By

Knudsen Wildlife Management Systems

and

Wildlife Resource Consulting Services MB Inc.

June 2018

This report should be cited as follows:

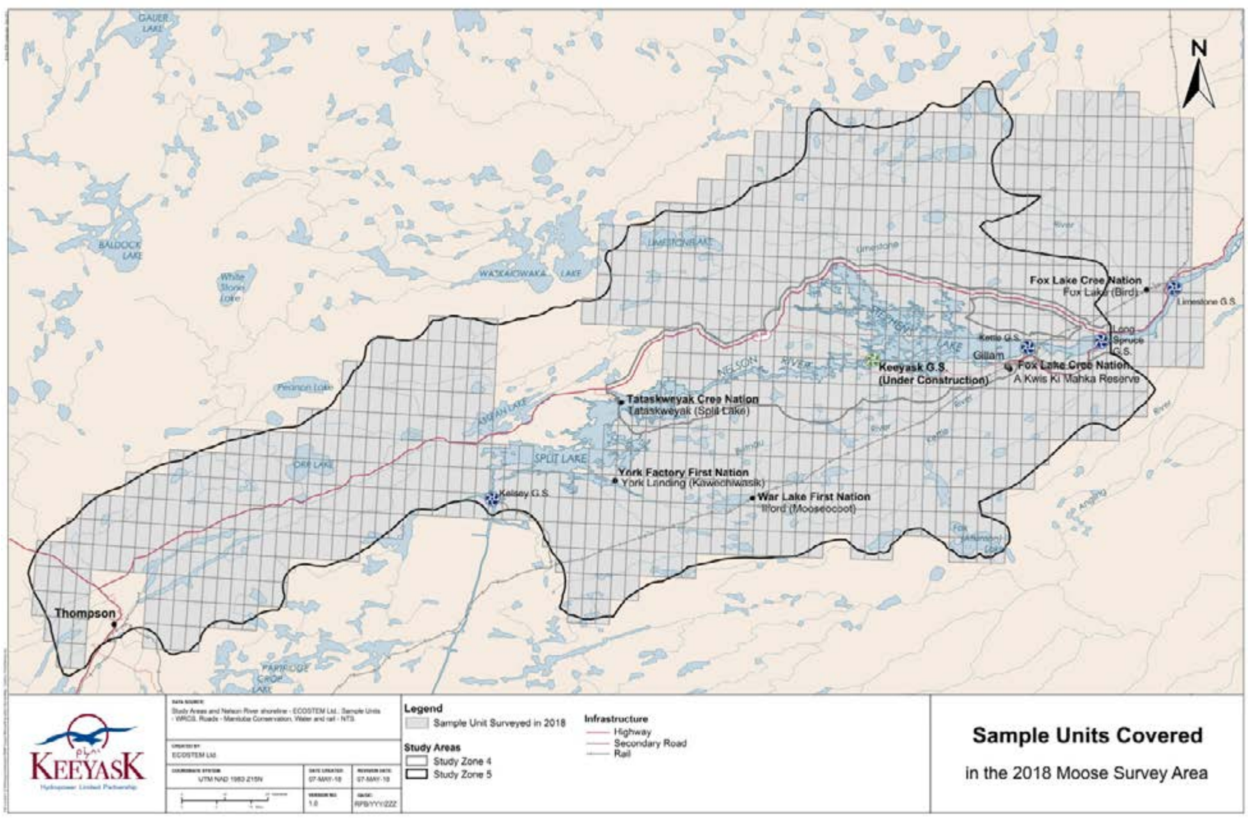
Knudsen Wildlife Management Systems and Wildlife Resource Consulting Services MB Inc. 2018. Keeyask Generation Project Terrestrial Effects Monitoring Plan Report #TEMP-2018-20: Moose Population Estimate 2018. A report prepared for Manitoba Hydro by Knudsen Wildlife Management Systems and Wildlife Resource Consulting Services MB Inc., June 2018.

SUMMARY

Background

Construction of the Keeyask Generation Project (the Project) at Gull Rapids began in July 2014. The Keeyask Hydropower Limited Partnership (KHLP) was required to prepare a plan to monitor the effects of construction and operation of the generating station on the terrestrial environment. Monitoring results will help the KHLP, government regulators, members of local First Nation communities, and the general public understand how construction and operation of the generating station will affect the environment, and whether or not more needs to be done to reduce harmful effects.

A moose survey was designed as part of the Project's Terrestrial Effects Monitoring Plan. The objective of the survey was to evaluate how the Project may be affecting patterns and trends in moose numbers, where they are found, and their population structure in the Keeyask region. This report describes the results of the aerial survey conducted for moose in the winter of 2017/18. The survey occurred in an area slightly larger than the Keeyask region, and focused mainly on areas with moderate to high moose densities.



Sample units covered by the moose aerial survey in 2018 (black outline shows the Keeyask region)

Why is the study being done?

Moose are widely distributed and common in the Keeyask region. While there was a high degree of certainty for predicted effects of the Project on moose, the partner First Nations expressed concerns about Project effects on moose habitat and populations. In 2010, the number of moose in the Split Lake Resource Management Area (RMA) was counted and the population was estimated. In order to estimate the moose population with Project construction underway, the Keeyask region was surveyed in 2015 and again in 2018.

What was done?

In January 2018, aerial surveys were conducted in the Keeyask region. A crew of three observers and a pilot flew regularly-spaced survey lines over the area in a fixed-wing aircraft, recording all instances of moose tracks. The area was divided into rectangular sample units, and the density of moose tracks in each unit was recorded or estimated based on the density of tracks in the adjacent units. Density was categorized as extra low (0-2), low (0-10), medium (0-14) or high (5-10). Following the fixed wing survey, a random sample of units from each density category was surveyed by helicopter, with a crew of three observers and a pilot. Each moose was counted and its age and sex were recorded if possible. These counts were used to estimate the size and composition of the moose population in the Keeyask region and in the two overlapping moose management units. The ratio of bulls and calves to cows were compared with previous moose surveys.

Pilot and Crew Leader in Fixed-wing Aircraft during the 2018 Aerial Survey

What was found?

The moose population in the entire survey area was estimated at 1,159 individuals and was unevenly distributed. There were an estimated 1,040 moose in the Keeyask region, a 10% decrease since the previous survey in 2015. The population structure also changed since 2015 with lower bull to cow and calf to cow ratios.

Moose Observed during the 2018 Aerial Survey

What does it mean?

The current moose population is considered to be stable in the Keeyask region. As of January 2018, no direct adverse effects from Project construction were identified on moose abundance, distribution or population structure. The lower ratio of bulls to cows than observed in 2015 and 2010 suggests that bulls are being selectively harvested, as recommended by the Cree Nation Partners in their 2013 Moose Harvest Sustainability Plan.

What will be done next?

The moose aerial survey will be repeated in 2021 for further evaluation of Project effects on the patterns and trends in moose numbers and where they are found in the Keeyask region.

STUDY TEAM

We would like to thank Sherrie Mason and Rachel Boone of Manitoba Hydro and Ron Bretecher of North/South Consultants Inc. for logistical assistance in the field. We would also like to thank James Ehnes of ECOSTEM Ltd. for GIS support and mapping. Biologists and other personnel who designed, participated in, and drafted the survey results included:

- Brian Knudsen, Knudsen Wildlife Management Systems – Design, analysis, and reporting
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- Mark Baschuk (M.Sc.), WRCS – Survey personnel
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- Kenneth Ouskun, (TCN) - Survey personnel
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1.0 INTRODUCTION

Construction of the Keeyask Generation Project (the Project), a 695 megawatt hydroelectric generating station (GS) and associated facilities, began in July 2014. The Project is located at Gull Rapids on the lower Nelson River in northern Manitoba where Gull Lake flows into Stephens Lake, 35 km upstream of the existing Kettle GS.

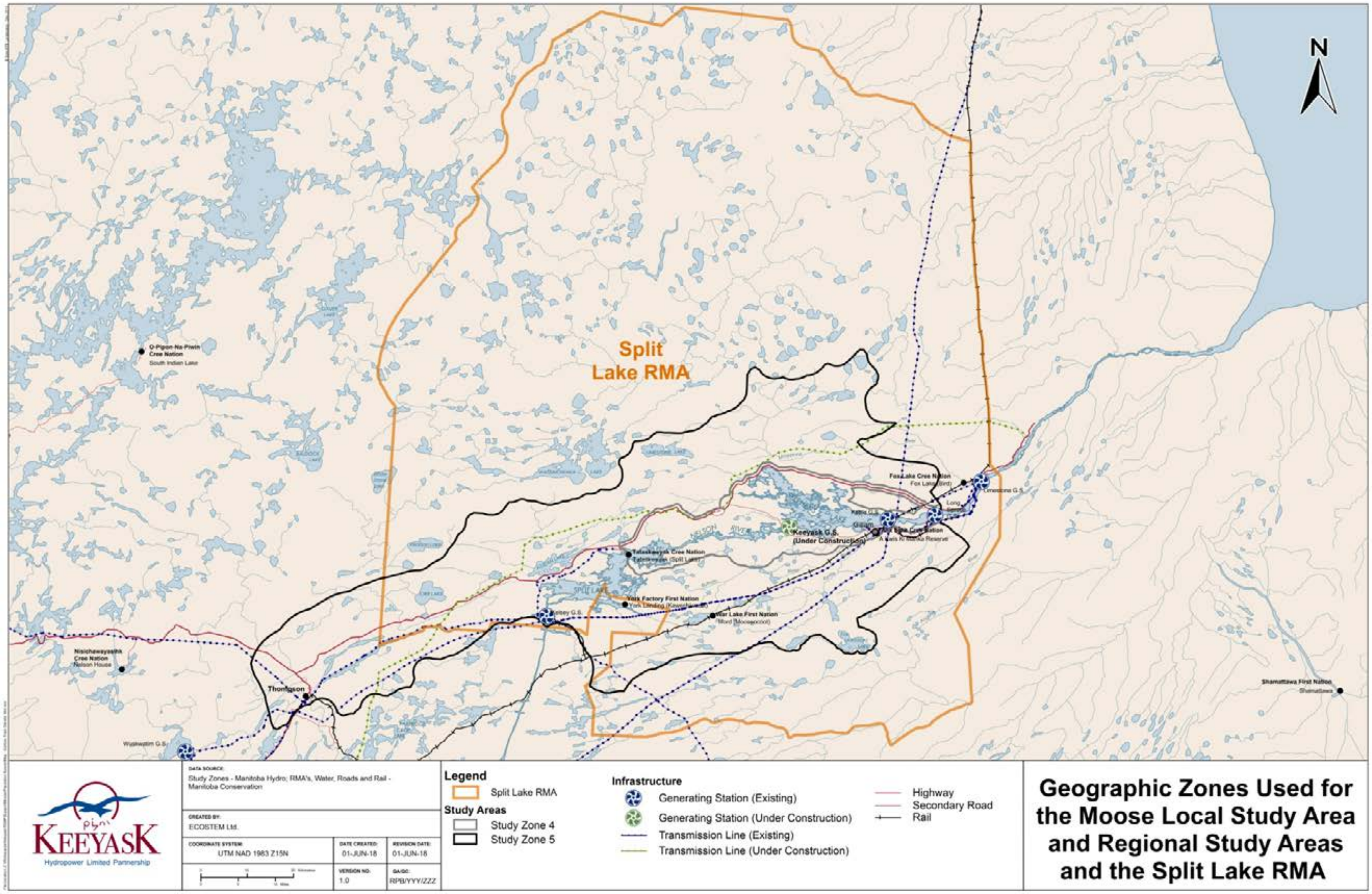
The *Keeyask Generation Project Response to EIS Guidelines* (the EIS), completed in June 2012, provides a summary of predicted effects and planned mitigation for the Project. Technical supporting information for the terrestrial environment, including a description of the environmental setting, effects and mitigation, and a summary of proposed monitoring and follow-up programs is provided in the *Keeyask Generation Project Environmental Impact Statement Terrestrial Supporting Volume* (TE SV). The *Keeyask Generation Project Terrestrial Effects Monitoring Plan* (TEMP) was developed as part of the licensing process for the Project. Monitoring activities for various components of the terrestrial environment were described, including the focus of this report, regional moose population estimates, during the construction and operation phases.

Predicted Project effects on moose in the EIS included the loss or alteration of habitat, sensory disturbance, and increased mortality due mainly to harvest and predation. Monitoring studies for moose focus in part on verifying Project effects predictions related to regional population estimates and on how moose distribution and abundance could be altered by habitat changes.

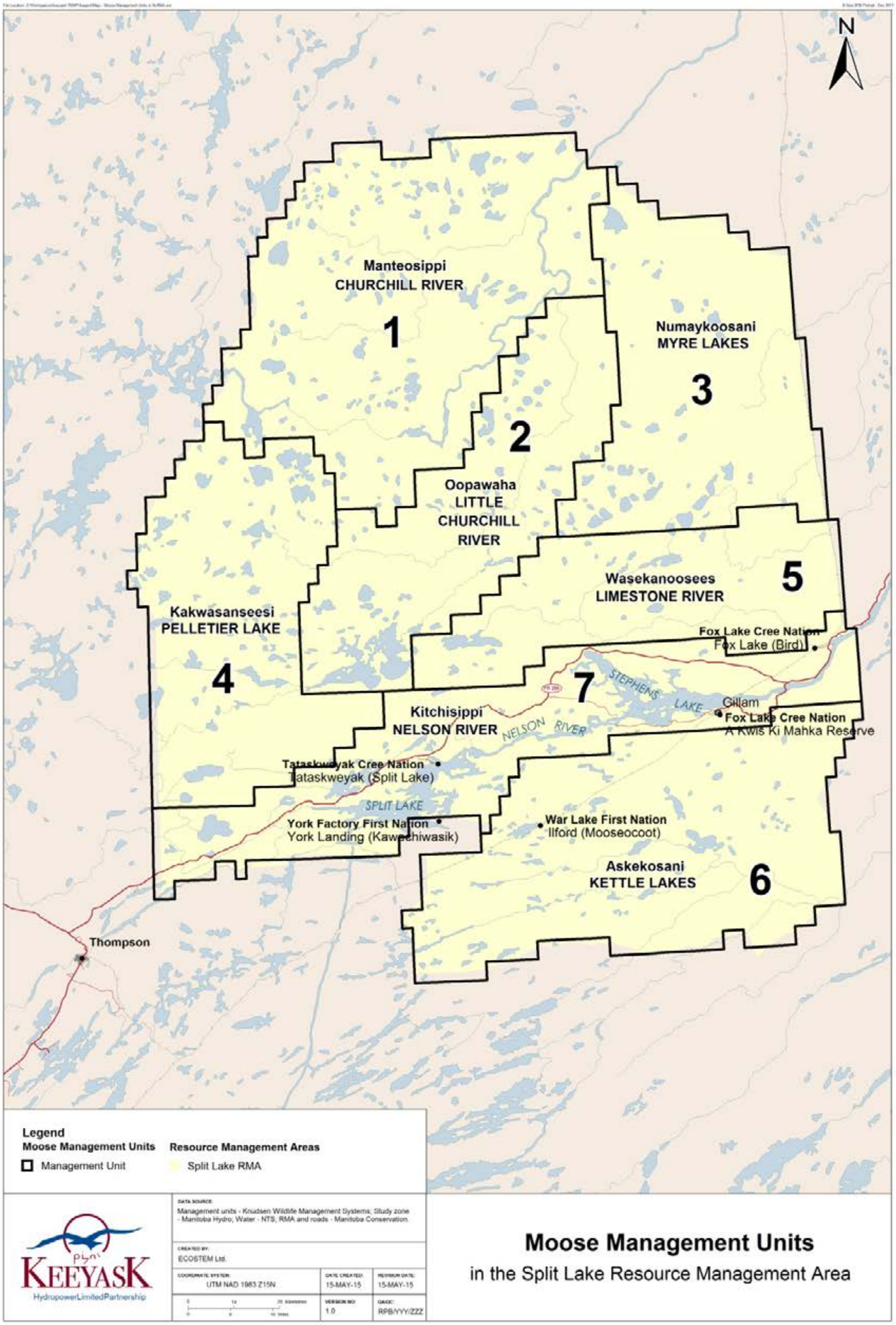
Moose are widely distributed and common in the Keeyask region. While there was a high degree of certainty for predicted Project effects on moose, the partner First Nations expressed concerns about effects on moose habitat and populations. A Moose Harvest Sustainability Plan was developed by the Cree Nation Partners (CNP) in 2013 and changes in moose abundance, harvest and habitat within seven Moose Management Units contained in the Split Lake Resource Management Area (RMA) is planned to be documented by the Cree Nation Partners. As outlined in Section 6.3.2 of the TEMP, the moose survey described in this report was conducted to evaluate how the Project could be affecting patterns and trends in moose distribution, abundance, and population characteristics. To that end, the size and structure of the mid-winter moose populations in Study Zones 4 and 5 were estimated (Map 1). The mid-winter moose populations in the Wasekanoosees and Kitchisippi Moose Management Units of the CNP Moose Harvest Sustainability Plan (Units 5 and 7, respectively; Map 2), which largely overlapped Study Zone 5, were also described.

During the preparation of the EIS, a moose survey was conducted in January and February 2010 in the Split Lake RMA (Knudsen et al. 2010). The RMA includes most of the moose regional study area (Study Zone 5). It also includes all of the moose local study area (Study Zone 4). The 2010 survey generated estimates of the moose populations in these study areas and in the RMA, which can be used for comparison with current results to quantify the trends in the number of moose in the local and regional moose study areas and to evaluate whether moose winter habitat use is affected by the Project.

In January 2015, a moose survey was conducted (Knudsen Wildlife Management Systems and Wildlife Resource Consulting Services MB Inc. 2016) to estimate the size and structure of the mid-winter moose populations of Study Zone 5, Study Zone 4, and the Wasekanoosees and Kichisippi Moose Management Units. Projections were created for the size and structure of the moose population of the Split Lake RMA for the period 2010 to 2015, against which cumulative effects can eventually be measured. This report documents a survey conducted in January 2018 that replicated the 2015 survey to monitor the ongoing status of the moose population in the Keeyask region.



Map 1: Geographic Zones Used for the Moose Local Study Area (Study Zone 4) and Regional Study Area (Study Zone 5) and the Split Lake RMA

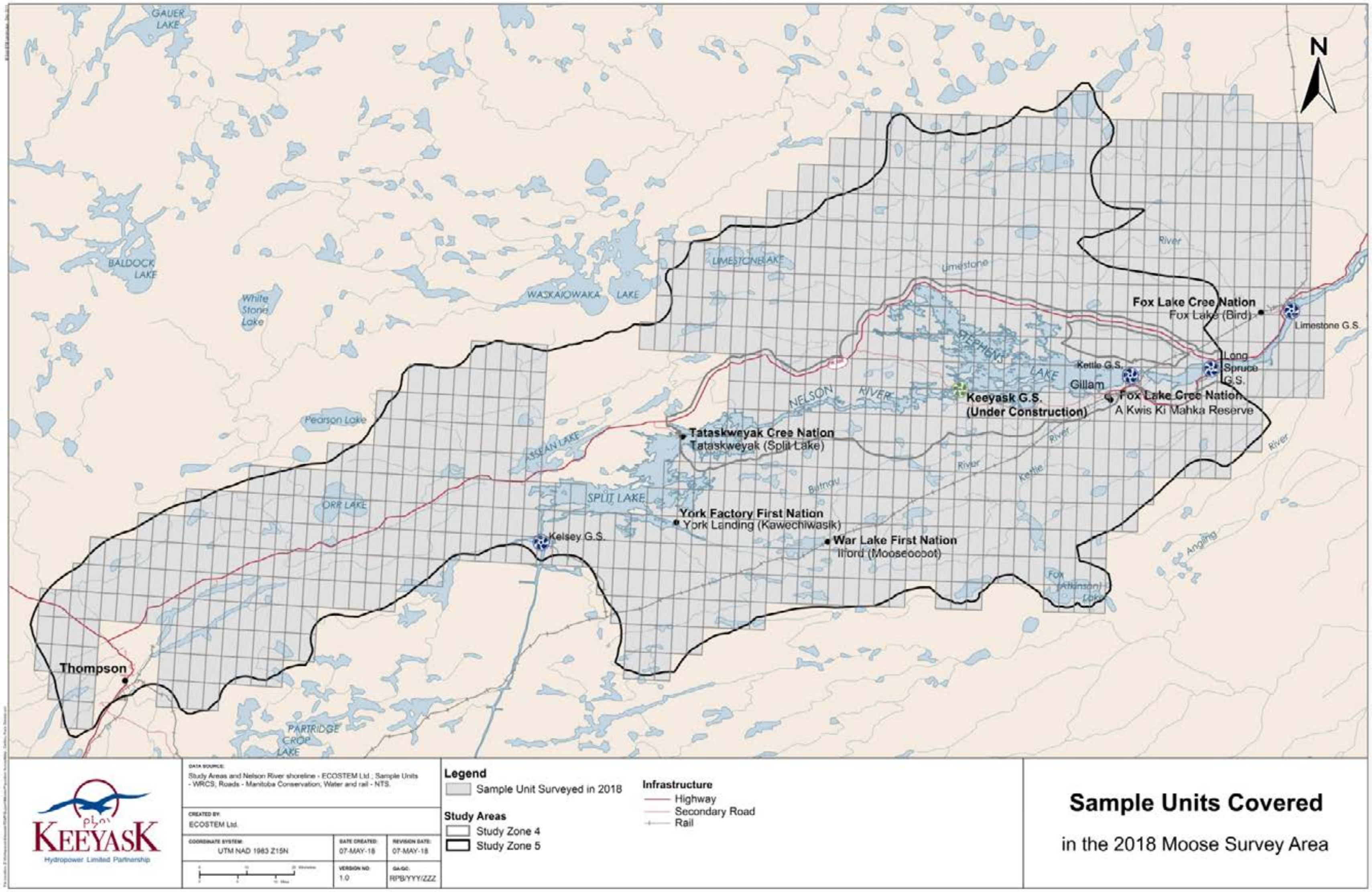


Map 2: Moose Management Units in the Split Lake Resource Management Area

2.0 METHODS

The aerial survey for moose conducted in January 2015 (Knudsen Wildlife Management Systems and Wildlife Resource Consulting Services MB Inc. 2016) was replicated in January 2018. Because Study Zones 4 and 5 have irregular boundaries (see Map 1), it was necessary to define regular boundaries that were approximately the same, but that aligned with a grid of three-minute cells (three minutes of latitude by three minutes of longitude), which was the framework of sample units for the survey. Each of these cells was approximately 3 km by 5.5 km. The width varied slightly with latitude, so the area of the cells ranged from approximately 17.5 km² in the southern portions to approximately 17.0 km² in the north. Grid cells were selected to define the regular boundaries. The sampling grid extended slightly outside of Study Zone 5 (Map 3) since the grid cells were rectangular and the study zone boundaries were delineated using other criteria. The total area of the survey (16,790 km²) was the combined set of 974 grid cells in Study Zone 5, Study Zone 4 (completely contained within Study Zone 5), and additional grid cells beyond the eastern boundary of Study Zone 5 that aligned with Moose Management Units 5 and 7 (Wasekanoosees and Kitchissippi, respectively) of the Split Lake RMA.

Gasaway et al. (1986) applied stratified random sampling specifically to the requirements of moose surveys. The methods used in this survey are fundamentally the same as Gasaway's, but incorporate GPS technology (see Section 6.3.2 of the TEMP). The survey began on January 11, 2018 and ended on January 29, 2018. Stratification and sampling were scheduled to minimize the number of idle days for aircraft and crew. The survey had two main components. The first was stratification, where a narrow area was surveyed from a fixed-wing aircraft and moose tracks were counted, so that each sample unit could be characterized as having a high, medium, or low density of moose. The second was sampling, where randomly selected sample units were searched with a helicopter and all moose within the units were counted. The allocation of sampling effort among the strata was determined by each stratum's mean track density and variance. Allocation of helicopter time was optimized with the Moosepop program (Reed 1989; Becker and Reed 1990). Nineteen aircraft-days were spent on stratification and nine helicopter-days were spent on sampling.

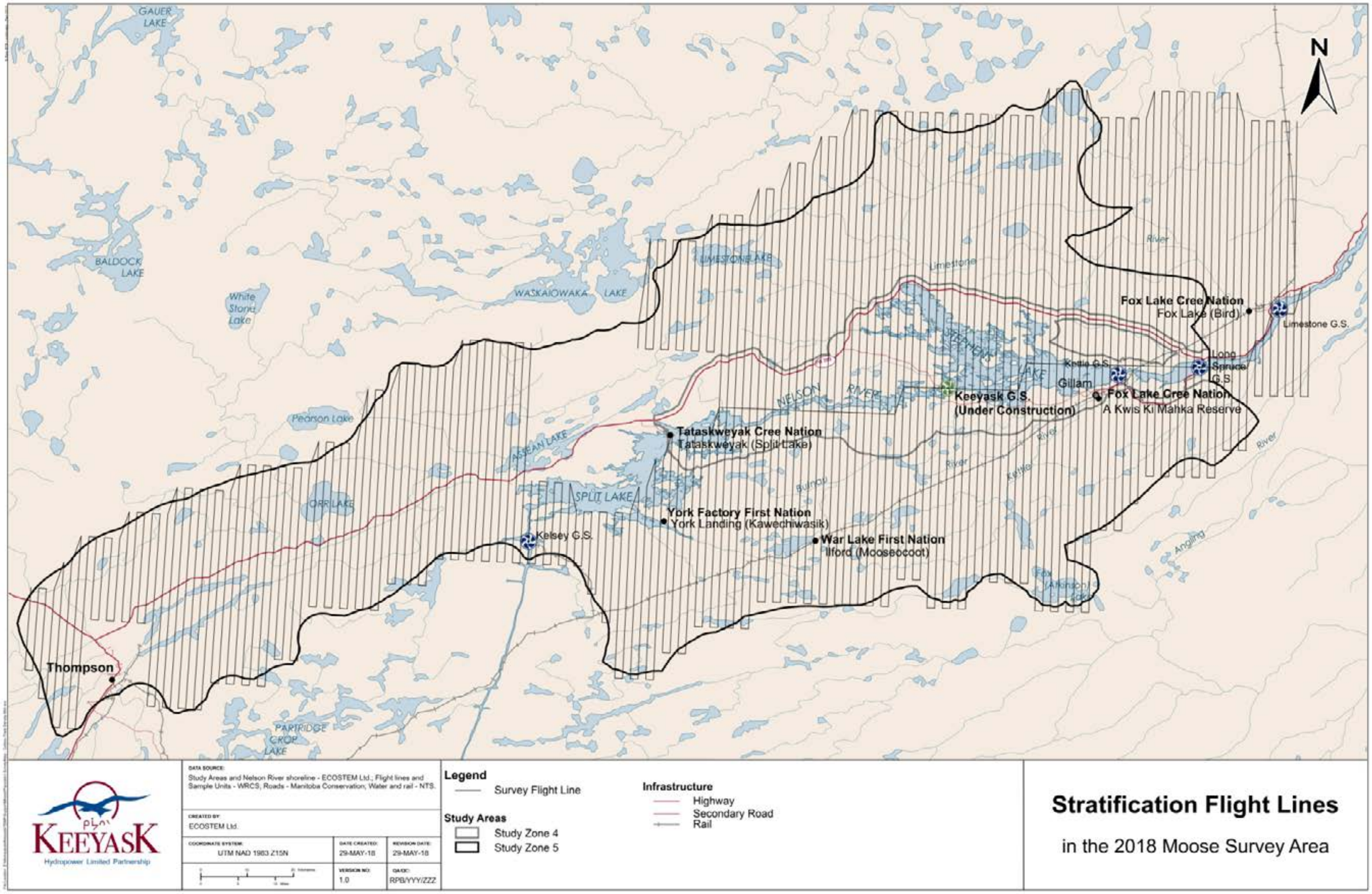


Map 3: Sample Units Covered in the 2018 Moose Survey Area

Stratification was based on moose tracks observed from a Britten-Norman Islander fixed-wing aircraft (Photo 1) with one pilot, a crew chief seated beside the pilot, and two observers in the back seats. Airspeed was approximately 160 km/hr and elevation was approximately 100 m above ground. Both airspeed and elevation varied with factors such as wind direction and terrain. Flight lines were north-south, 1.5 minutes of longitude apart (approximately 1.5 km), and were arranged so that two lines were flown through each of 902 sample units (Map 4). Seventy-two sample units were not flown in stratification. The area of Thompson and the Thompson Airport (13 sample units) was excluded, as it was in 2015. In 2018, 59 additional sample units were excluded in the area north of Split Lake because a large herd of caribou was present and being harvested in these sample units at the time of the survey.

Photo 1: Britten-Norman Islander Fixed-wing Aircraft Used in the 2018 Aerial Survey for Moose

When moose tracks were seen (Photo 2), the observer called out the observation for the crew chief. The crew chief marked the location as a waypoint with a GPS unit, and noted the waypoint number on a data sheet, along with the associated data. Caribou tracks, which appear different from moose tracks from the air, were also noted, and densities were expressed as one approximate value for each stratification line flown (low, medium, or high; Photo 3 to Photo 5), rather than separately for each location where moose tracks were seen.



Map 4: Stratification Flight Lines in the 2018 Moose Survey Area

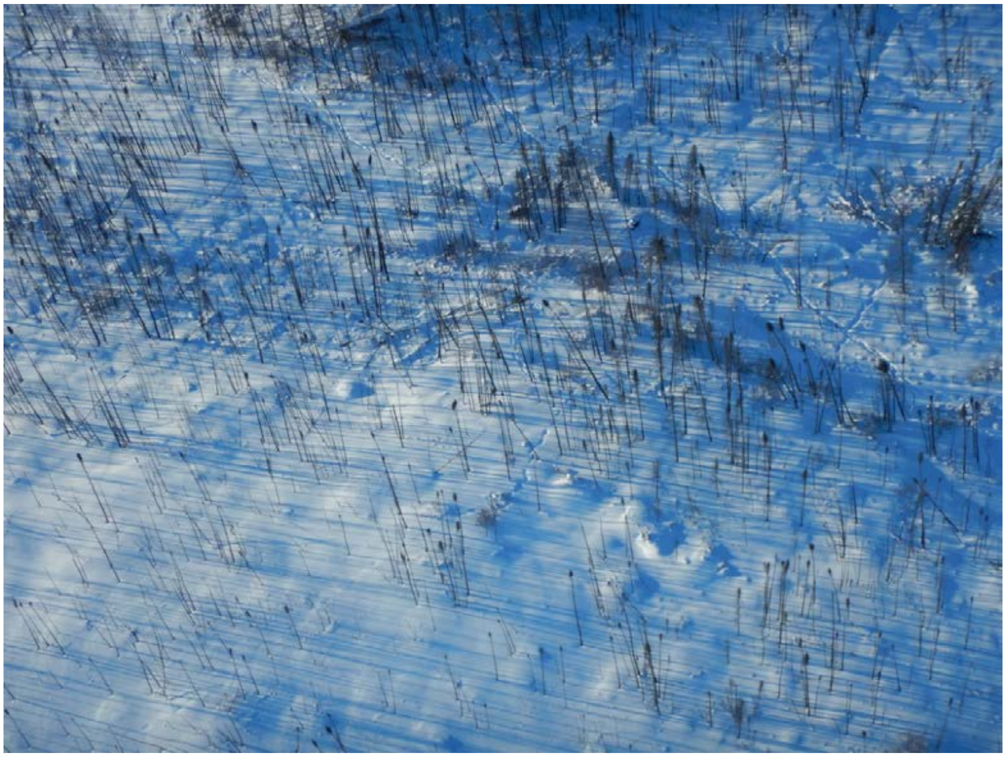


Photo 2: Moose Tracks (upper right) Observed during the 2018 Aerial Survey for Moose

Photo 3: Representative Pattern of Low Density Caribou Tracks

Photo 4: Representative Pattern of Medium Density Caribou Tracks

Photo 5: Representative Pattern of High Density Caribou Tracks

Moose (Photo 6) were counted in sample units using a Bell LongRanger helicopter, with crew arranged as in the Islander (Photo 7). Sample units were flown individually, each with six north-south lines, approximately 500 m apart, so that observers on each side were scanning a strip 250 m wide. When moose were sighted the crew chief was notified and animals were classified as bull, cow, calf or unknown age/sex. Altitude was approximately 50 m and airspeed varied from 100 km/h to 140 km/h.

Stratification flights were only conducted if there was no significant snowfall the previous day and if visibility was good. Sampling flights were conducted on all days with adequate visibility for detecting moose. As in 2015, on some days two fixed-wing aircraft were used, so that all available crew could complete stratification work in a section as quickly as possible.

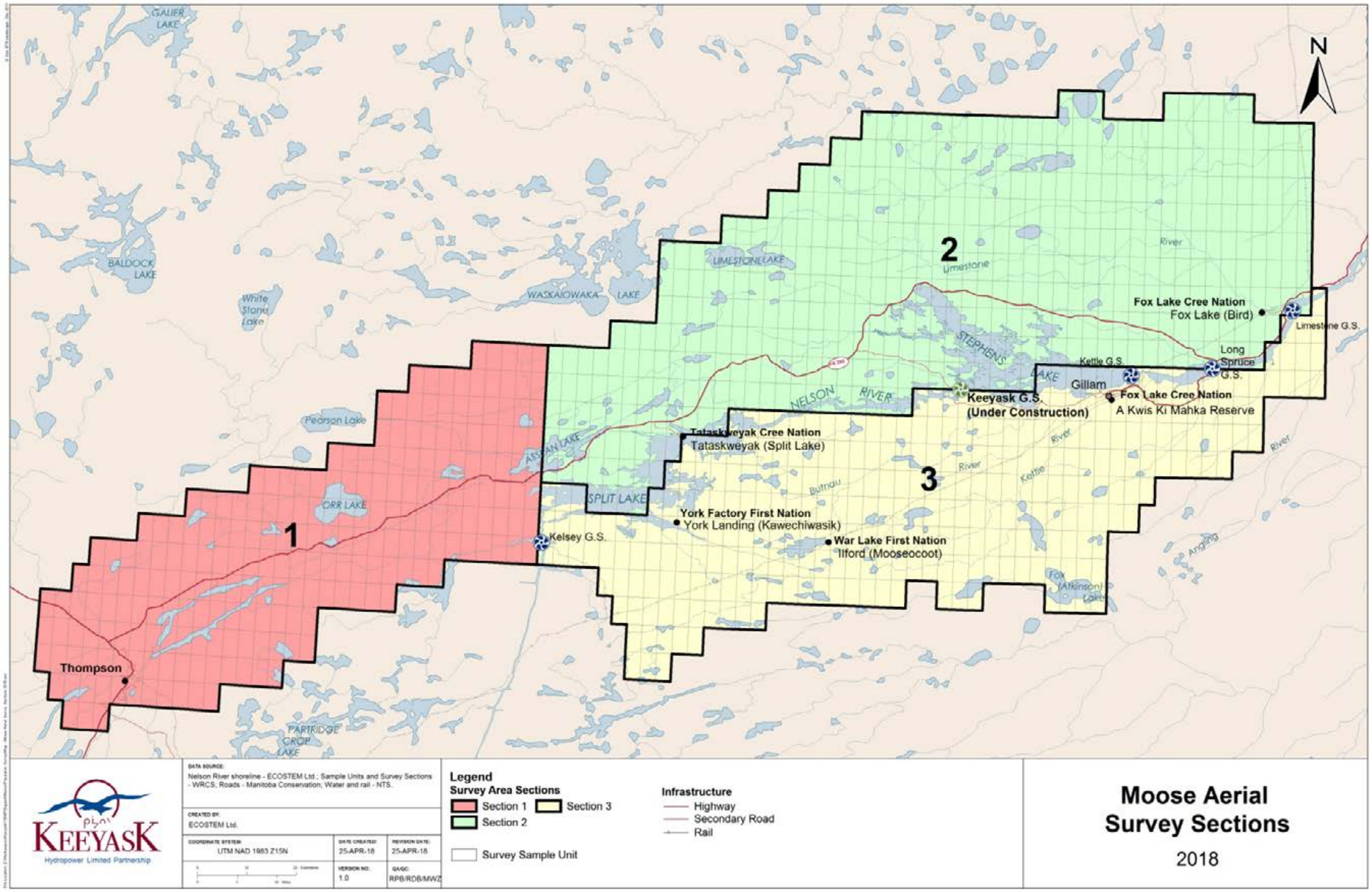
Photo 6: Moose Observed during the 2018 Aerial Survey

Photo 7: Observer in Helicopter during the 2018 Aerial Survey for Moose

Each evening, data were downloaded from the GPS unit and entered from the data sheets and transmitted as Garmin .gdb files and Excel spreadsheets to the survey's data manager. The data manager used the track data to stratify the survey area and used the moose observation data to allocate subsequent sampling with the helicopter. During sampling, Garmin route files for the next days' flying in the helicopter were prepared by the data manager and transmitted to the survey crew. For further details such as data sheets, observation methodology, data management methodology, GPS integration, flight patterns, aircraft used, speeds, and height, see Knudsen et al. (2010).

The total survey area was divided into three sections (Map 5), each of which was surveyed as if it were a separate study area. Boundaries were chosen to reduce the length of the north-south lines flown by the stratification aircraft to give observers frequent opportunities to rest their eyes and attention. Section 1 was flown out of the Thompson Airport, while Sections 2 and 3 were flown out of the Gillam Airport.

After the three sections were completed, their mean moose densities and variances were compared. The sample units from strata with the same characteristics were combined for the final population estimate, which were calculated with Moosepop using the estimates of bull, cow and calf densities and ratios.



Map 5: Moose Aerial Survey Sections

3.0 RESULTS

3.1 STRATIFICATION

3.1.1 MOOSE TRACKS

Moose tracks were seen in 492 of the 902 sample units that were flown in the stratification (Map 6). The number of tracks per sample unit ranged from 0 to 21, for a total of 1,650 track locations. The frequency distribution of track locations per sample unit is shown in Figure 1.

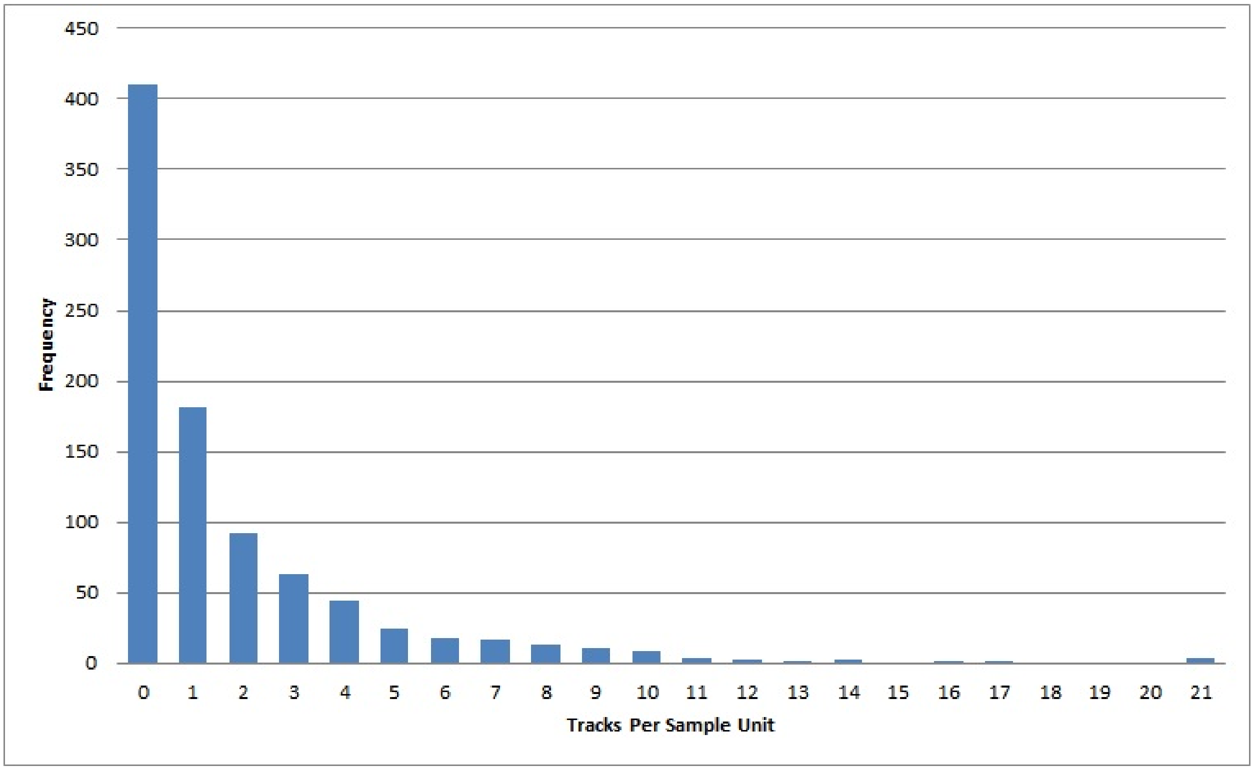


Figure 1: Frequency Distribution of Moose Track Locations per Sample Unit, 2018

Sample units were stratified by the number of track locations they contained and by the number of tracks in adjacent sample units. All 974 sample units were stratified; the 72 that weren't flown were assigned to the lowest-density stratum. The summary statistics of the number of tracks per sample unit in the five strata used in the analysis are shown in Table 1 (the distinction between HI and HI2 is explained in Section 3.2). The mean number of tracks per sample unit increases from XLO to HI2. Within each stratum, the coefficient of variation (CV) shows that the data are consistent (the high CV of the XLO stratum is an artifact of the data and the way the CV is calculated: 117 of the 122 sample units contained 0 tracks.)

Table 1: Moose Tracks per Sample Unit in the Five Strata Used for Analysis, 2018: Mean, Standard Deviation, Range and Coefficient of Variation

	Stratum				
	XLO	**LO**	**MED**	**HI**	**HI2**
Mean	0.05	1.09	1.81	5.64	7.00
Standard Deviation	0.25	1.60	2.70	5.06	1.69
Range	0-2	0-10	0-14	1-21	5-10
Coefficient of Variation	5.0	0.8	1.5	0.9	0.25
Number of Sample Units	122	375	382	88	7

Note: This map has been removed due to the sensitive nature of the information. This map will be provided to the regulators, but will not be included in the version of the report that is publicly available.

Map 6: Moose Track Locations Identified during Stratification Flights, 2018

3.1.2 CARIBOU TRACKS

The distribution of caribou tracks, as expressed by the colour blocks in Map 7, shows that the survey area can be divided into three zones of caribou activity. There were almost no caribou in the western half of Section 1, near Thompson. There were relatively uniform low densities of caribou tracks in the remainder of Section 1 and all of Section 2, which is normal in this area because of the usual diffuse presence of migratory caribou. South of the Nelson River, in Section 3, large numbers of the Southern Hudson Bay caribou subpopulation (formerly the Pen Islands herd) had, before the survey, moved into the area from the Hudson Bay coast (Photo 8). At the Nelson River, south of Split Lake, the westward movement of Southern Hudson Bay caribou stopped. The herd turned north and crossed Split Lake, where it was harvested. Stratification flights were cancelled in this area to avoid disruption of the hunt.

Caribou tracks in some parts of Section 3 were sufficiently dense to interfere substantially with spotting moose tracks. Observers reported that caribou tracks were sometimes so dense that any moose tracks would have been completely obscured. In these cases, the sample unit would have been placed incorrectly in a lower stratum, and when the moose that were present were subsequently seen during sampling, outliers on the high side would be generated. Conversely, if there were abundant patches of caribou tracks, some of them could have exhibited the characteristics of moose tracks and been recorded as such. This would generate outliers on the low side in sample units incorrectly placed in a higher stratum. Both of these situations are unavoidable consequences of an incursion of caribou into the survey area, and higher variances are the result.

Photo 8: Caribou Observed during the 2018 Aerial Survey for Moose

Note: This map has been removed due to the sensitive nature of the information. This map will be provided to the regulators, but will not be included in the version of the report that is publicly available.

Map 7: Caribou Track Density Recorded by Transect During Stratification Flights, 2018

3.2 SAMPLING

As in 2010 and 2015, the stratification of sample units and the optimization of effort were conducted within each of the three sections: Section 2, then Section 3, then Section 1. Within Sections 2 and 3, there were clusters of sample units with many moose tracks, many sample units with an intermediate abundance of tracks, and large areas with almost no tracks. These three levels of track abundance were used to create three strata, labelled HI, MED and LO. In Section 1, there were no areas of high track densities, so only two strata were created: LO and MED.

When sampling was finished, and the data for the three sections were used to create separate population estimates for each section, strata with equivalent moose densities were combined, merging the three sections and eight strata (3+3+2) into five strata for the entire survey area: XLO, LO, MED, HI and HI2. The LO from Section 1, with no moose at all, became XLO and HI from Section 3, which was uniquely disrupted by caribou tracks, became HI2.

3.3 POPULATION ESTIMATES

3.3.1 POPULATION ESTIMATE OF ENTIRE SURVEY AREA

The population estimate for the whole survey area is 1,159 moose (see Table 2 for more details on survey results). The complete Moosepop output is provided in Appendix 1.

The bottom rows of Table 2 show the various relationships among the total area of the strata, the stratum densities, and sampling effort. The simple random sample size shows the number of samples that would have been taken in each stratum without stratification. The expected number of samples from each stratum would have been proportional to the stratum's total area. The stratification sampling ratio shows the ratio of actual samples to samples that would have been taken under simple random sampling.

Table 2: Summarized Moose Population Estimate for the Entire Survey Area, 2018

	Stratum					
	XLO	**LO**	**MED**	**HI**	**HI2**	**Total**
Number of sample units	122	375	382	88	7	974
Total area (km²)	2,120	6,446	6,586	1,517	121	16,790
Sample size	7	34	38	18	7	104
Area surveyed (km²)	121	585	654	310	121	1,790
Moose observed	0	27	56	60	3	146
Density (per 100 km²)	0	5	9	19	2	7
Estimated population	0	298	564	294	3	1,159
Sampling intensity (%)	6	9	10	20	100	11
Percent of samples	7	33	37	17	7	100
Percent of population	0	26	49	25	0	100
Percent of area	13	38	39	9	<1	100
Simple random sample size	13	40	41	9	1	104
Stratification sampling ratio	0.54	0.85	0.93	2.00	9.33	-
95% confidence interval around population estimate	787 to 1,531 (± 32%)					

The LO and MED strata each had some sample units with counts far above the mean (Figure 2), generating high variances and contributing to the wide confidence interval of ± 32%. These samples, most likely caused by the confounding effects of caribou tracks, as noted above, cannot be disregarded as outliers. They appear to be a real component of the survey methods and of the distribution of moose in the survey area, but they are not amenable to being summarized by one or two statistical parameters. Their effects on the accuracy of the stated confidence interval are not known. A reasonable qualitative interpretation of the confidence interval would be to say that it is relatively wide around the point estimate of the population.

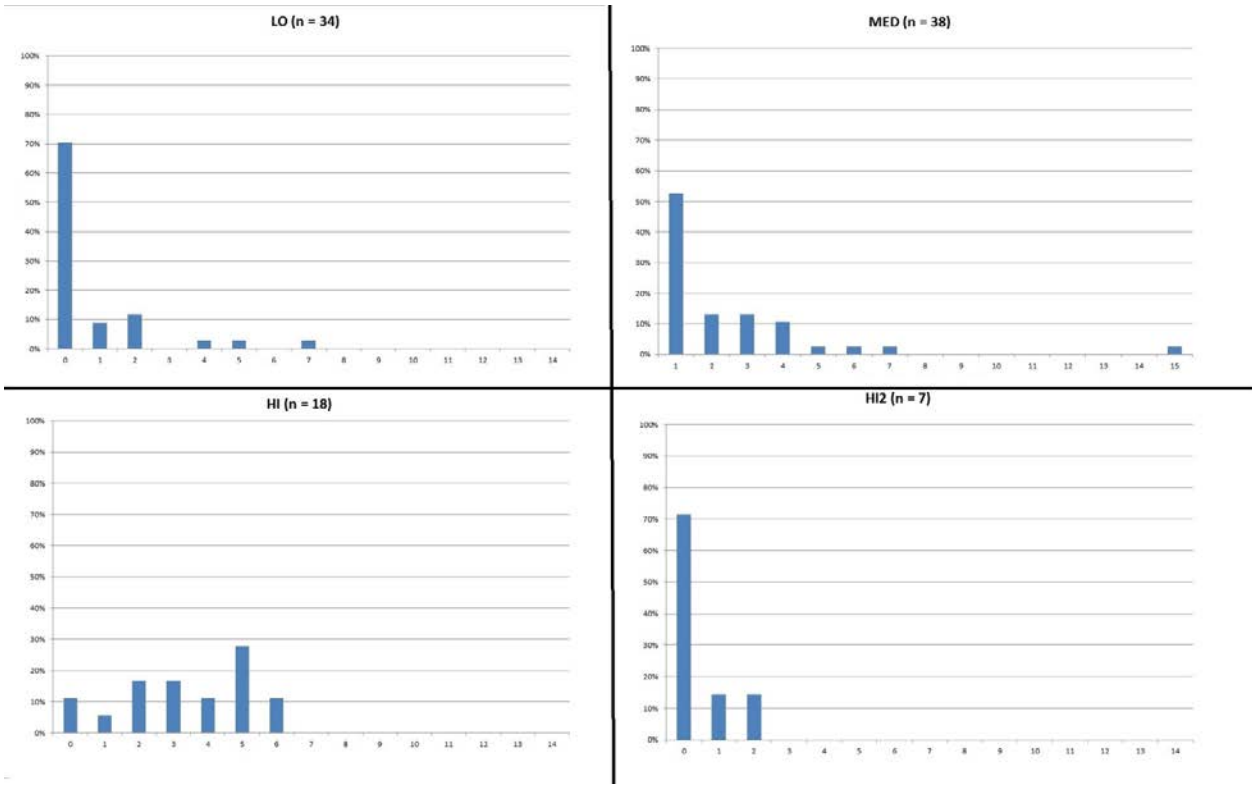


Figure 2: Frequency Distribution of Counts of Moose per Sample Unit for the Four Strata, 2018

In Section 3, the seven sample units with high track counts were assigned to a HI stratum after stratification flying was completed, with the expectation that moose counts would be commensurately high. All seven were sampled, to reduce the variance to zero. The counts of moose, however, were extremely low. The degree to which this deviated from the usual relationship of tracks and moose is shown in Figure 3. The plot should show continually increasing moose density with increasing track sightings. These results were attributed to the influence of caribou, and a separate HI2 stratum was created to isolate the effect from the HI sample units in Section 2.

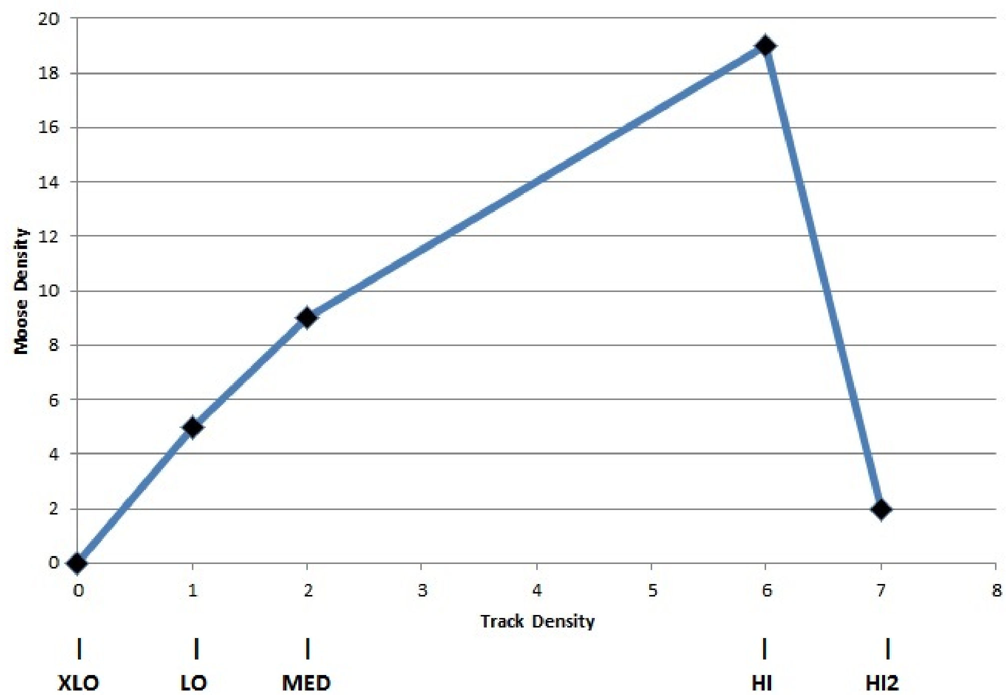


Figure 3: The Relationship between Track Density and Moose Density, 2018

Although two of the strata are labelled MED and HI, these names are intended to indicate only the relative abundance of moose in the area covered by this survey. The overall density of seven moose for every 100 km² is very low. Compared to many moose herds in North America, all of the survey area would be considered to have a low moose density. The distribution of moose over the entire survey area is shown in Map 8.

Note: This map has been removed due to the sensitive nature of the information. This map will be provided to the regulators, but will not be included in the version of the report that is publicly available.

Map 8: Moose Distribution in the Entire Survey Area, 2018

3.3.2 POPULATION STRUCTURE: ENTIRE SURVEY AREA

Observers were able to classify 75% of the 146 observed moose to an age/sex class: 19 bulls, 62 cows and 28 calves. These numbers should not be used to generate ratios such as bulls per 100 cows for the entire survey area, because the densities of the categories differ between strata, and the sampling effort was not the same in each stratum. Table 3 shows the unbiased estimates of the abundance of bulls, cows and calves, and the ratios among them. Totals do not always match the sums of stratum values, because the individual values are rounded to the nearest integer.

Table 3: Summarized Estimates of Population Structure for the Entire Survey Area[1]

	Stratum					
	XLO	LO	MED	HI	HI2	Total
Estimated bulls	0	33	60	49	0	143
Density (per 100 km²)	0	1	1	3	0	1
Estimated cows	0	132	252	108	3	495
Density (per 100 km²)	0	2	4	7	2	3
Estimated calves	0	77	81	64	0	221
Density (per 100 km²)	0	1	3	5	0	2
Estimated unknowns	0	55	171	74	0	300
Density (per 100 km²)	0	1	3	5	0	2
Estimated population	0	298	564	294	3	1,159
Density (per 100 km²)	0	5	9	19	3	7
Bulls/100 cows: 29 95% confidence interval: 15 to 43 (± 49%)						
Calves/100 cows: 45 95% confidence interval: 32 to 58 (± 29%)						

1. Densities are rounded to the nearest integer to facilitate comparisons.

Thirty-seven observed moose (25%) were classified as unknown age/sex class, and therefore in the estimated total population of 1,159 there were 300 moose labelled as unknown. This information is a useful indicator of the degree to which observers could confidently assign moose to an age/sex class, but in reality all of these moose are bulls, cows or calves. The proportions within this group are not known however, and in the absence of any further information, it was assumed that the unknowns had the same composition as the rest of the population: 12.3% bulls, 42.7% cows and 19.1% calves. After the unknowns were partitioned and added to the other three age/sex classes, the population of 1,159 was estimated to have 193 bulls, 668 cows and 298 calves.

Using the information in Table 3, it was possible to take the entire population of 1,159 and divide it into an expected number of bulls, cows and calves in each of the 974 sample units. The stratum-specific density for each age/sex class was multiplied by the area of the sample unit, and that number was stored in the sample unit's row in the attribute table of the GIS. These numbers were theoretical quantities, calculated to four decimal places. For example, a HI sample unit was expected to have 0.7327 bulls, 1.6116 cows and 0.9520 calves. For individual sample units these quantities are not useful, but if one were to select a group of 100 sample units, and they were all HI, one would expect to find in that group 73 bulls, 161 cows and 95 calves. This is the way that these sample unit-specific quantities were used to estimate the populations of the four areas of interest that were subsets of the entire survey area: the expected number of moose in the individual sample units was added up. All the precision in the density estimates was retained and used, to avoid accumulating rounding errors.

3.3.3 POPULATION ESTIMATES FOR SUBSETS OF THE SURVEY

Table 4 shows the estimated populations for Study Zone 5, Study Zone 4, and Moose Management Units 5 and 7. Map 9 and Map 10 show the pattern and abundance of moose densities in these four areas of interest. In Study Zone 5 there were 44 calves and 29 bulls per 100 cows and in Study Zone 4 there were 43 calves and 28 bulls per 100 cows.

Table 4: Moose Populations in Areas of Interest within the Entire Survey Area 2018, 2015 and 2010[2]

	2018				Total	Total	% Change
	Bulls	Cows	Calves	Total	2010	2015	2015 to 2018
Study Zone 5	176	601	263	1,040	961	1,162	-10
Study Zone 4	32	114	49	196	125	176	-10
Moose Management Unit 5	52	180	83	314	369	451	-30
Moose Management Unit 7	62	232	101	395	337	446	-11

2. Populations from 2010 and 2015 are given for comparison.

Moose populations in all four areas increased from 2010 to 2015. Moose Management Unit 5 is distinguished in Table 4 by its 30% decrease in the total number of moose from 2015 to 2018, and the other areas decreased approximately 10% from 2015 to 2018. The 2018 total number of moose in Study Zone 4 and 5 was still greater than that observed in 2010.

For Moose Management Units 5 and 7 there are 2010 baseline population estimates, predictions of January 2015 populations, and actual January 2015 survey results to which the 2018 survey can be compared (Table 5 and Table 6).

Table 5: Moose Population in Management Unit 5: Wasekanoosees[3]

	2010 Actual	2015 Projected Sustainable	2015 Actual	2018 Actual
Bulls	176 (48%)	96 (23%)	116 (26%)	52 (17%)
Cows	147 (40%)	217 (52%)	222 (49%)	180 (57%)
Calves	46 (12%)	102 (25%)	113 (25%)	83 (26%)
Total moose	369	414	451	314
Density: 7/100 km²				

3. Total area = 4,269 km².

Table 6: Moose Population in Management Unit 7: Kitchissipi[4]

	2010 Actual	2015 Projected Sustainable	2015 Actual	2018 Actual
Bulls	154 (46%)	76 (22%)	113 (25%)	62 (16%)
Cows	133 (39%)	178 (53%)	222 (50%)	232 (59%)
Calves	50 (15%)	84 (25%)	112 (25%)	101 (26%)
Total moose	337	338	446	395
Density: 6/100 km²				

4. Total area = 6,207 km².

Moose Management Unit 5 had a density of 11 moose per 100 km² in 2015. This was a density higher than the regional/Study Zone 5 mean density of approximately 7 per 100 km². These factors could make it relatively more attractive to wolves and to licensed hunters.

Note: This map has been removed due to the sensitive nature of the information. This map will be provided to the regulators, but will not be included in the version of the report that is publicly available.

Map 9: Pattern of Moose Densities in Study Zones 4 and 5, 2018

Note: This map has been removed due to the sensitive nature of the information. This map will be provided to the regulators, but will not be included in the version of the report that is publicly available.

Map 10: Pattern of Moose Densities in Moose Management Unit 5 (Wasekanoosees) and Unit 7 (Kitchisippi), 2018

4.0 DISCUSSION

4.1 SURVEY DESIGN AND INTERPRETATION

The count of moose from the helicopter during sampling in 2018 is assumed to be a total count. The sightability correction factor involved in the Gasaway method, which is intended to compensate for moose that were not seen, was not applied. The reason for this approach is tied to the overall density of moose in northeastern Manitoba. Stratified random sampling was first applied to moose in the Kenai area of Alaska, where densities of moose per 100 km² ranged from 40 in the LO stratum to 300 in the HI stratum. In this survey, the comparable numbers were five to 19. Observers in Alaska would be seeing moose approximately every one to two minutes, and there would almost always be tracks underneath them. In northeastern Manitoba, observers see moose approximately every 10 to 15 minutes, and tracks are rare. In Alaska, because tracks would not provide useful cues to observers about the presence of moose in the field of view, observers had to remain attentive and actually see the moose as the aircraft passed over them. In Manitoba, tracks are conspicuous (see Photo 2) and alert observers to the presence of moose in the immediate area. Studies that have attempted to estimate the probability of sighting moose during aerial surveys have not been conducted in areas with densities as low as those reported here, so their probabilities do not apply. Moreover, the studies were conducted in southern areas, often where other ungulates, particularly deer, were present, contributing more tracks to the snowscape and further reducing the chance to use tracks as indicators of nearby moose.

Because the survey was conducted in three sections, the randomization of sampling in the survey was not complete. By taking samples in each section approximately in proportion to the area of the section, sampling had a systematic component. Green (1979) discusses systematic and random sampling, and suggests that even completely systematic sampling rarely differs from random sampling enough to justify the additional logistic difficulty of complete randomization, so long as the systematic pattern does not follow some pattern in the environment. Green (1979) was followed regarding the systematic allocation of samples to sections, but complete randomization within each section was adhered to.

4.2 POPULATION ESTIMATES

The moose population in Study Zone 5 increased 21% from 2010 to 2015, an average annual increment of approximately 4%. However, most recently between 2015 and 2018, there was a decline of 10%. The ratio of calves to cows in Study Zone 5 (44:100) was greater than the 36 calves:100 cows in the Split Lake RMA in 2010 (Cree Nation Partners 2013), but down slightly from 50 calves per 100 cows in 2015 (Knudsen Wildlife Management Systems and Wildlife

Resource Consulting Services MB Inc. 2016). Because almost all cows produce one or more calves each year (Schwartz 2007; Cree Nation Partners 2013), half of the calves born in spring 2017 did not survive (Cree Nation Partners 2013). However, a ratio of approximately 30 calves:100 cows is required for a sustainable moose population (Benn 2001; Lirette 2014), which was exceeded in 2010, possibly accounting in part for the increased moose population in 2015.

The ratio of bulls to cows in Study Zone 5 (29:100) was considerably lower than the 118 bulls: 100 cows in the Split Lake RMA in 2010, which was considered a surplus and indicated that too many cows were being harvested (Cree Nation Partners 2013). In 2010 there were 120 bulls: 100 cows in Moose Management Unit 5 (Wasekanoosees) and 111 bulls:100 cows in Moose Management Unit 7 (Kitchisippi) (Cree Nation Partners 2013), which roughly correspond with Study Zone 5. The selective harvesting of bulls advocated in the Moose Harvest Sustainability Plan (Cree Nation Partners 2013) could have accounted, at least in part, for the improved population structure and increased moose population. A greater proportion of females in a population can result in greater recruitment rates (Courtois and Lamontagne 1999; Solberg et al. 1999; Solberg et al. 2000; Sæther et al. 2001; Milner et al. 2007) because a single bull can impregnate more than one cow in a breeding season (Schwartz 2007). Moose harvest by licensed hunters increased in the area in 2014 and 2015, but the changes were not linked to the Project (Eaton 2015, 2016). The number of licensed moose hunters was the same in 2016 as in 2015, and no appreciable changes in hunting pressure were linked to the Project (Eaton and Bretecher 2017).

The current bull:cow ratio is lower than the management objectives in British Columbia, which promote a minimum of 50 bulls:100 cows in low density (<200/1,000 km^2) moose populations (Ministry of Forests, Lands and Natural Resource Operations 2015), 67 bulls:100 cows (40:60) suggested by the Ontario Ministry of Natural Resources (2009) and the approximately 90 bulls:100 cows recommended by the Saskatchewan Ministry of Environment (2015) for a sustainable moose population, but it is within the range of 30 bulls:100 cows recommended by Environment Yukon (Yukon Renewable Resources 1996; Jessup et al. 2014). Although the ratio of bulls to cows is decreasing, the data from this survey suggest that there are still sufficient bulls to keep the pregnancy rate high. Given that the mortality of moose calves is extremely high in the first three months of life, the estimate of 45 calves per 100 cows in January in this survey indicates that a very high percentage of cows were pregnant in 2017.

In addition to the improved population structure and greater recruitment of calves into the population since 2010, reduced mortality could have influenced the increased moose population. Predators such as bears and gray wolves can take 50% or more of moose calves born each spring (Ballard and Van Ballenberghe 2007; Schwartz 2007). Deep snow can hinder wolf movement, and lack of food can reduce survival. Reduced hunting efficiency or a diminished gray wolf population would reduce predation on moose; fewer individuals would be taken (e.g., Bergerud et al. 1983) and more would survive to be added to the population and/or to reproduce. As there is no information about gray wolves specific to the survey area, the role of predation in the increased moose population is unknown.

Caribou are alternative prey for gray wolf in Study Zone 5, but are generally sparse when the large migratory herds that occasionally occupy the area are absent (Keeyask Hydropower Limited Partnership 2012). The large migration of forest-tundra woodland caribou through the region in the winter of 2012/13 (LaPorte et al. 2013) and in the winter of 2017/18 (unpubl. data) could have resulted in resident wolves shifting from moose to the more abundant caribou. In southeastern British Columbia, the wolf diet switched from moose to caribou in summer when moose, caribou, and wolves occupied the same areas (Seip 1992). In Alaska, wolves switched from moose to a diet that was almost entirely caribou when a migratory herd moved into their territory (Ballard et al. 1997 in Cree Nation Partners 2013). Such a shift could have resulted in reduced predation on moose and an increased birth rate in the following years.

Changes in habitat availability could have contributed to the increased moose population in the entire survey area. A changing mosaic of recently burned and older, regenerating areas could have resulted in shifts in carrying capacity and moose distribution (e.g., Lord and Kielland 2015) within and beyond Study Zone 5. Moose return to burned areas shortly after a fire, with population increases in the first two years (Peek 1974). Increased recruitment due to improved habitat did not account for the relatively large population increase observed in northern Minnesota after a fire; individuals also immigrated to the area after only six months (Peek 1974). Moose may have moved into Study Zone 5 following the forest fires in 2013, accounting for some of the population increase in 2015. Moose density typically peaks 11 to 30 years post-burn (Maier et al. 2005), as regenerating vegetation provides good moose forage (Weixelman et al. 1998; Lord and Kielland 2015), particularly after 11 to 30 years (Kelsall et al. 1977 in Peek 2007). Immigration to older regenerating habitat in Study Zone 5 could also have contributed to the population increase.

5.0 SUMMARY AND CONCLUSIONS

Although the moose population in Study Zone 5 has decreased since 2015, it increased and has remained higher than 2010. The largest decrease (30%) was in Moose Management Unit 5 (Wasekanoosees), the area with the most road access. The lower ratio of bulls to cows than observed in the 2015 survey suggests that bulls continue to be selectively harvested, as recommended by the Moose Harvest Sustainability Plan (Cree Nation Partners 2013). Although the ratio of bulls to cows is decreasing, the data from this survey suggest that there are still a sufficient number of bulls to keep the pregnancy rate high. Given that the mortality of moose calves is extremely high in the first three months of life, the estimate of 45 calves per 100 cows in January in this survey indicates that a very high percentage of cows were pregnant the previous year. The proportion of cows and calves in the populations of Moose Management Units 5 and 7 are at or above those projected as sustainable in 2015. Factors such as harvest, increased predation, and decreased habitat availability could have contributed to the decreased population. No adverse Project effects on moose abundance, distribution, or population structure were identified. The regional moose population is considered to be stable.

As indicated in the TEMP, the aerial survey for moose will be repeated in 2021 for further evaluation of Project effects on patterns and trends in moose distribution and abundance in Study Zone 5. The survey will be coordinated with any aerial surveys for moose being done within the Split Lake RMA to support the Moose Harvest Sustainability Plan (Cree Nation Partners 2013).

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APPENDIX 1: RAW OUTPUT TABLES FROM MOOSEPOP POPULATION ESTIMATES

Moose Survey, Jan 2018

*** * * * ESTIMATED POPULATION SIZE * * * ***

Moose Survey, Jan 2018

PAR/STRAT	XLO	LO	MED	HI	HI2	TOTAL
N	122	375	382	88	7	974
Tot area	2119.60	6445.50	6586.00	1517.30	121.20	16789.60
n	7	34	38	18	7	104
Area sur	120.75	585.00	653.70	309.60	120.75	1789.80
# seen	0	27	56	60	3	146
Density	0.0000	0.0462	0.0857	0.1938	0.0248	0.0690
To	0.0	297.5	564.2	294.1	3.0	
V(To)	0.00	9955.36	23616.70	1174.12	0.00	
SCFo	1.000000	1.000000	1.000000	1.000000	1.000000	
V(SCFo)	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
SCF df	9999	9999	9999	9999	9999	
To df	6	33	37	17	6	

Te= 1158.7 V(Te)= 34746.17 df(Te)= 66

80% CI around Te = (917.4, 400.1) is +/- 20.83%

90% CI around Te = (847.6, 1469.9) is +/- 26.85%

95% CI around Te = (786.5, 1531.0) is +/- 2.12%

CALCULATE SEX AGE RATIOS AND COMPOSITION PARAMETERS

Numerator = Tot.Bull

PAR/STRAT	XLO	LO	MED	HI	HI2	TOTAL
N	122	375	382	88	7	974
Tot area	2119.60	6445.50	6586.00	1517.30	121.20	16789.60
n	7	34	38	18	7	104
Area sur	120.75	585.00	653.70	309.60	120.75	1789.80
# seen	0	3	6	10	0	19
Density	0.0000	0.0051	0.0092	0.0323	0.0000	0.0085
Wen	0.0	33.1	60.4	49.0	0.0	
V(Wen)	0.00	311.06	662.11	130.37	0.00	
SCFo	1.000000	1.000000	1.000000	1.000000	1.000000	
V(SCFo)	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
SCF df	9999	9999	9999	9999	9999	
df	6	33	37	17	6	

Wen= 142.5 V(Wen)= 1103.54 df(Wen)= 77

80% CI around Wen = (99.6,185.5) is +/- 0.13%

90% CI around Wen = (87.2,197.8) is +/- 38.82%

95% CI around Wen = (76.4,208.7) is +/- 46.42%

CALCULATE SEX AGE RATIOS AND COMPOSITION PARAMETERS

Denominator = Tot.Cows

PAR/STRAT	XLO	LO	MED	HI	HI2	TOTAL
N	122	375	382	88	7	974
Tot area	2119.60	6445.50	6586.00	1517.30	121.20	16789.60
n	7	34	38	18	7	104
Area sur	120.75	585.00	653.70	309.60	120.75	1789.80
# seen	0	12	25	22	3	62
Density	0.0000	0.0205	0.0382	0.0711	0.0248	0.0295
Wed	0.0	132.2	251.9	107.8	3.0	
V(Wed)	0.00	2020.31	6063.07	507.98	0.00	
SCFo	1.000000	1.000000	1.000000	1.000000	1.000000	
V(SCFo)	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
SCF df	9999	9999	9999	9999	9999	
df	6	33	37	17	6	

Wed= 494.9 V(Wed)= 8591.36 df(Wed)= 65

80% CI around Wed = (374.9, 615.0) is +/- 24.25%

90% CI around Wed = (340.2, 649.6) is +/- 31.26%

95% CI around Wed = (309.8, 680.1) is +/- 37.41%

```
          CALCULATE SEX AGE RATIOS AND COMPOSITION PARAMETERS
        Numerator = Tot.Bull
        Denominator = Tot.Cows
        Ratio:  p = Numerator / Denominator

p= 0.2880     V(p)= 0.00493921     df(p)= 65

80% CI around p = (0.1969, 0.3790) is +/- 31.61%
90% CI around p = (0.1706, 0.4053) is +/- 40.74%
95% CI around p = (0.1476, 0.4283) is +/- 48.75%

          CALCULATE SEX AGE RATIOS AND COMPOSITION PARAMETERS
        Numerator = Tot.Bull
      Denominator = TotMoose
        Ratio:  p = Numerator / Denominator

p= 0.1230     V(p)= 0.00058625     df(p)= 66

80% CI around p = (0.0916, 0.1543) is +/- 25.49%
90% CI around p = (0.0826, 0.1634) is +/- 32.86%
95% CI around p = (0.0746, 0.1713) is +/- 39.31%
```

CALCULATE SEX AGE RATIOS AND COMPOSITION PARAMETERS

Numerator = Tot.Cows

PAR/STRAT	**XLO**	**LO**	**MED**	**HI**	**HI2**	**TOTAL**
N	122	375	382	88	7	974
Tot area	2119.60	6445.50	6586.00	1517.30	121.20	16789.60
n	7	34	38	18	7	104
Area sur	120.75	585.00	653.70	309.60	120.75	1789.80
# seen	0	12	25	22	3	62
Density	0.0000	0.0205	0.0382	0.0711	0.0248	0.0295
Wen	0.0	132.2	251.9	107.8	3.0	
V(Wen)	0.00	2020.31	6063.07	507.98	0.00	
SCFo	1.000000	1.000000	1.000000	1.000000	1.000000	
V(SCFo)	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
SCF df	9999	9999	9999	9999	9999	
df	6	33	37	17	6	

Wen= 494.9 V(Wen)= 8591.36 df(Wen)= 65

80% CI around Wen = (374.9, 615.0) is +/- 4.25%

90% CI around Wen = (340.2, 649.6) is +/- 31.26%

95% CI around Wen = (309.8, 680.1) is +/- 37.41%

CALCULATE SEX AGE RATIOS AND COMPOSITION PARAMETERS

Numerator = Tot.Cows

Denominator = TotMoose

Ratio: p = Numerator / Denominator

p= 0.4271 V(p)= 0.00104738 df(p)= 65

80% CI around p = (0.3852, 0.4690) is +/- 9.81%

90% CI around p = (0.3731, 0.4811) is +/- 12.65%

95% CI around p = (0.3625, 0.4918) is +/- 15.13%

CALCULATE SEX AGE RATIOS AND COMPOSITION PARAMETERS

Numerator = Tot.Calf

PAR/STRAT	XLO	LO	MED	HI	HI2	TOTAL
N	122	375	382	88	7	974
Tot area	2119.60	6445.50	6586.00	1517.30	121.20	16789.60
n	7	34	38	18	7	104
Area sur	120.75	585.00	653.70	309.60	120.75	1789.80
# seen	0	7	8	13	0	28
Density	0.0000	0.0120	0.0122	0.0420	0.0000	0.0132
Wen	0.0	77.1	80.6	63.7	0.0	
V(Wen)	0.00	859.67	1719.50	356.18	0.00	
SCFo	1.000000	1.000000	1.000000	1.000000	1.000000	
V(SCFo)	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
SCF df	9999	9999	9999	9999	9999	
df	6	33	37	17	6	

Wen= 221.4 V(Wen)= 2935.35 df(Wen)= 78

80% CI around Wen = (151.4, 291.5) is +/- 31.63%

90% CI around Wen = (131.2, 311.7) is +/- 40.74%

95% CI around Wen = (113.6, 329.3) is +/- 48.71%

CALCULATE SEX AGE RATIOS AND COMPOSITION PARAMETERS

Numerator = Tot.Calf

Denominator = TotMoose

Ratio: p = Numerator / Denominator

p= 0.1911 V(p)= 0.00069770 df(p)= 66

80% CI around p = (0.1569, 0.2253) is +/- 17.90%

90% CI around p = (0.1470, 0.2352) is +/- 23.07%

95% CI around p = (0.1384, 0.2438) is +/- 27.60%

CALCULATE SEX AGE RATIOS AND COMPOSITION PARAMETERS

Numerator = Unknown

PAR/STRAT	XLO	LO	MED	HI	HI2	TOTAL
N	122	375	382	88	7	974
Tot area	2119.60	6445.50	6586.00	1517.30	121.20	16789.60
n	7	34	38	18	7	104
Area sur	120.75	585.00	653.70	309.60	120.75	1789.80
# seen	0	5	17	15	0	37
Density	0.0000	0.0085	0.0260	0.0484	0.0000	0.0179
Wen	0.0	55.1	171.3	73.5	0.0	
V(Wen)	0.00	712.08	2008.96	253.16	0.00	
SCFo	1.000000	1.000000	1.000000	1.000000	1.000000	
V(SCFo)	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	
SCF df	9999	9999	9999	9999	9999	
df	6	33	37	17	6	

Wen= 299.9 V(Wen)= 2974.20 df(Wen)= 69

80% CI around Wen = (229.3, 370.5) is +/- 23.54%

90% CI around Wen = (208.9, 390.8) is +/- 30.33%

95% CI around Wen = (191.1, 408.7) is +/- 36.29%

```
          CALCULATE SEX AGE RATIOS AND COMPOSITION PARAMETERS
        Numerator = Unknown
        Denominator = TotMoose
        Ratio:  p = Numerator / Denominator

p= 0.2588     V(p)= 0.00127196     df(p)= 66

80% CI around p = (0.2126, 0.3050) is +/- 17.84%
90% CI around p = (0.1993, 0.3183) is +/- 23.00%
95% CI around p = (0.1876, 0.3300) is +/- 27.52%

          CALCULATE SEX AGE RATIOS AND COMPOSITION PARAMETERS
        Numerator = Tot.Calf
        Denominator = Tot.Cows
        Ratio:  p = Numerator / Denominator

p= 0.4474     V(p)= 0.00414712     df(p)= 65

80% CI around p = (0.3640, 0.5308) is +/- 18.64%
90% CI around p = (0.3399, 0.5549) is +/- 24.03%
95% CI around p = (0.3188, 0.5760) is +/- 28.75%
```