FORT NELSON FIRST NATION GROUND BASED MOOSE (*ALCES ALCES*) SURVEYS

2018 Survey Results: Prepared for FNFN's Guardian Program

December 31, 2018

Fort Nelson First Nation and the Liard Basin Monitoring Initiative Team, 2018.

Fort Nelson First Nation Ground based Moose (*Alces alces*) Surveys

FINAL REPORT / December 31, 2018

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WHAT IS FORT NELSON FIRST NATION'S GUARDIAN PROGRAM?

FNFN'S GUARDIAN PROGRAM has been developed as a result of the Liard Basin Monitoring Initiative (LBMI), a three-year pilot initiative led by Fort Nelson First Nation to develop a cumulative effects monitoring program for the Liard Basin based on Fort Nelson First Nation (FNFN or the Nation) cultural and ecological values, incorporating FNFN traditional knowledge and scientific methods in a holistic combination.

The LBMI has been funded for three years (2016 - 2019) by Natural Resources Canada's Cumulative Effects Monitoring Initiative. The overarching goals of the LBMI are:

- To better understand the state of the environment (baseline conditions) in FNFN territory using traditional knowledge (TK) and science;
- To develop a monitoring framework that will allow FNFN members themselves to monitor and respond to changes in the environment over time, including impacts from industrial development, in FNFN territory;
- To help make informed decisions about human activities and land use in FNFN territory so that the long-term values of the FNFN are maintained while ensuring an appropriate level of resource use and development.

In an effort to identify "what matters most" to FNFN community members, initial work conducted through the LBMI identified key values of importance to the Nation, based on prior community studies and community engagement. This work—rooted in both traditional and scientific knowledge—remains the foundation for monitoring within the Guardian Program.[1] The priority values identified by FNFN community members are shown in the adjacent figure.

All data collected as part of FNFN's Guardian Program are stored in FNFN's Lands Department and used by the Nation in making decisions about how FNFN's territory should be managed to protect FNFN's values, while supporting industrial development where possible.

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[1] FNFN, 2017. Community Summary: Year 1 State of Knowledge Report, Fort Nelson First Nation Liard Basin Monitoring Initiative. URL: http://www.fortnelsonfirstnation.org/uploads/1/4/6/8/14681966/fnfn_sok_year_1_summary_jan_5_2018_web.pdf.

EXECUTIVE SUMMARY

This document summarizes results from the pilot year of ground-based moose pellet surveys for the LBMI, conducted in seven study areas within FNFN's area of interest.

How to use this report: This document is part of FNFN's LBMI external report series. FNFN Lands staff, members and leadership can use this report to answer the following questions:

Question	Management options
How is the relative abundance of moose populations impacted by hunting pressure in the Liard basin?	Internal discussions within Lands Department Consider developing FNFN policies on hunting
Where should we focus additional monitoring efforts?	Internal discussions within Lands Department and within FNFN community to guide monitoring efforts in 2019 and beyond. Initiate collaborative monitoring efforts with trapline holders in key study areas.
What management levers should be considered in key areas of FNFN's territory to address moose population concerns?	Reinitiate discussions with MFLNRORD regarding the Peace Liard Moose Management Plan. Work with MFLNRORD to safely monitor resident and non-resident hunter activity levels in each study area during fall 2019 through hunter surveys, game stops and/or hunter vehicle counts. Work with MFLNRORD to implement hunting restrictions in areas that are currently lower than expected.

Purpose of the study: This study provides a quantitative assessment of relative moose density in seven study areas within FNFN territory, to evaluate whether hunting pressure in key hunting areas corresponds with decreases in moose abundance. These monitoring efforts have been developed to promote the incorporation of traditional knowledge and science in making management decisions for moose in FNFN's territory.

Study area selection: We selected study areas for the 2018 fieldwork based on areas identified by FNFN community members as having high, medium, or low hunting pressure. Through a focus group held as part of FNFN's 2018 culture camp at Snake River Village, community members provided insights into discrete areas of the territory

with different observed hunting pressures. All seven study areas identified through this process are centred on a linear feature (a road or a river) that provides people with access into the area. The seven study areas were: South SYD Road, North SYD Road, Elleh Creek, Luyben Road, Highway 317 north of Luyben Road, Fort Nelson River, and Snake River.

Methods: We used ground-based pellet group surveys to estimate relative moose abundance in the seven study areas. Within each of the study areas, we calculated relative moose abundance based on counts of pellet groups along fixed width transects (3 m wide x 300 m long). We completed a total of 54 transects in summer 2018. We analysed the data using a simple statistical approach based on Harkonen & Heikkila (1999), which uses a chi-squared goodness of fit test to show whether moose pellet density is higher, lower or as expected for each study area, based on the total number of pellets observed and the area surveyed. We also characterized the density of linear features in each study area. Calculating these numbers was of interest because other studies have used linear feature density as a way of gauging the potential hunting pressure (e.g. Beazley et al. 2004). We were interested in seeing whether linear density accurately reflects hunting pressures identified by FNFN community members.

Results: Areas classified by FNFN community members as having high hunting pressure generally had fewer pellet groups than expected, while areas classified as having low hunting pressure had more pellet groups than expected. The relative degree of linear disturbance among the study areas did not correspond well with hunting pressure, or with pellet group abundance. The Fort Nelson River study area, for example, was characterized as a low hunting pressure area with a greater abundance of pellet groups than expected; however this site had the greatest average linear feature density out of the seven study areas. These results suggest that linear density is not a good proxy indicator of hunting pressure in this area.

Discussion: This preliminary study supports FNFN community members' observations that areas identified as having high hunting pressure have lower moose density. More effort is needed to understand how linear density is affecting moose populations in FNFN's territory. In particular, follow up work is needed to:

a) Correlate pellet group surveys with surveys of hunter effort in the same study areas: By looking at both the number of pellet groups and getting an accurate gauge of hunting effort / success rate in each study area, we can calculate more informed density and total abundance estimates.
b) Increase effort in all of the study areas by resurveying in 2019: Monitoring efforts in 2019 should aim to achieve a minimum of 10 transects in each study area, within specific traplines to be identified with trapline holders/families. Monitoring efforts may be best conducted in the vicinity of cultural areas identified as part of FNFN's developing Guardian program.
c) Conduct additional data analyses to explore the effects of other factors on moose density: A larger dataset from two years of sampling (2018 and 2019) will help us explore the influence of factors such as industrial development and habitat availability.
d) Identify an appropriate proxy for quantitatively gauging hunting pressure: 2019 fieldwork should test other proxies for hunting pressure, to find a feasible

quantitative measure that aligns well with local knowledge (e.g. counting vehicles along main roads and travel corridors during the 2019 hunting season).

Management implications: Based on the observed pellet group numbers and input received from community members, the findings of this report suggest the need for measures to reduce hunting pressure along Luyben Road and the southern portion of the SYD Road. At the same time, measures should be taken to ensure that this pressure does not simply shift to other areas. The findings speak to the need for management measures at smaller scales than the level of the Wildlife Management Unit (WMU).

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ACRONYMS AND ABBREVIATIONS

Acronym	Definition
BC	British Columbia
MFLNRORD	Ministry of Forests, Lands, Natural Resource Operations and Rural Development
FNFN	Fort Nelson First Nation
LBMI	Liard Basin Monitoring Initiative
PLMMP	Peace Liard Moose Management Plan
WMU	Wildlife Management Unit
TK	Traditional Knowledge

1. INTRODUCTION

This report outlines the methods and results for a targeted ground-based monitoring program focused on comparing moose density across areas of varying hunting pressure and linear disturbance, as part of the Liard Basin Monitoring Initiative (LBMI). Moose are a critical food source for Fort Nelson First Nation (FNFN) community members and a high priority concern. Despite their long-standing presence and importance in the region, there is limited baseline information on moose population size and trends in FNFN territory.

This initial pilot monitoring program is part of a broader initiative by FNFN to use its Guardian Program to monitor moose populations in FNFN territory and promote sustainable moose populations over the long term. This longer term monitoring program aims to fill information gaps for moose by: establishing a population baseline for the region; investigating moose relative population numbers within key study areas in FNFN territory; and documenting potential factors associated with population declines.

As hunting pressure—primarily by resident and non-resident hunters—is considered by FNFN community members to be one of the key factors influencing moose population declines, the focus for this initial study is on investigating the relationship between hunting pressure and moose population density in discrete study areas within FNFN territory. Methods for this pilot program were selected to meet provincial standards for wildlife monitoring and best practices identified in the scientific literature, while also incorporating FNFN traditional knowledge, values, and participation in data collection.

This report presents the results of moose data analysis from the 2018 field season. A more extensive summary of the state of moose in FNFN territory is being prepared as an FNFN LBMI State of Knowledge Report[2].

1.1 STUDY AREA

The regional study area for all LBMI and FNFN Guardian Program related monitoring is FNFN territory, which is dominated by the Liard basin. Bordered by Yukon, Stikine, Peace and Hay River watersheds, the Liard basin includes all parts of the British Columbia that drain into the Liard River, which flows north into the Northwest Territories. The portion of the Liard basin which lies within BC is of interest to this project as it is entirely within FNFN territory. FNFN territory, which also includes a small south-western portion of the Hay River basin, is comprised of 53 sub-watersheds (Figure 1), and encompasses an area of approximately 150,000km^2.

[2] FNFN and the LBMI Team, 2018. Fort Nelson First Nation State of Knowledge Report: Moose. FNFN Report in Preparation. LBMI Report 2018-05.

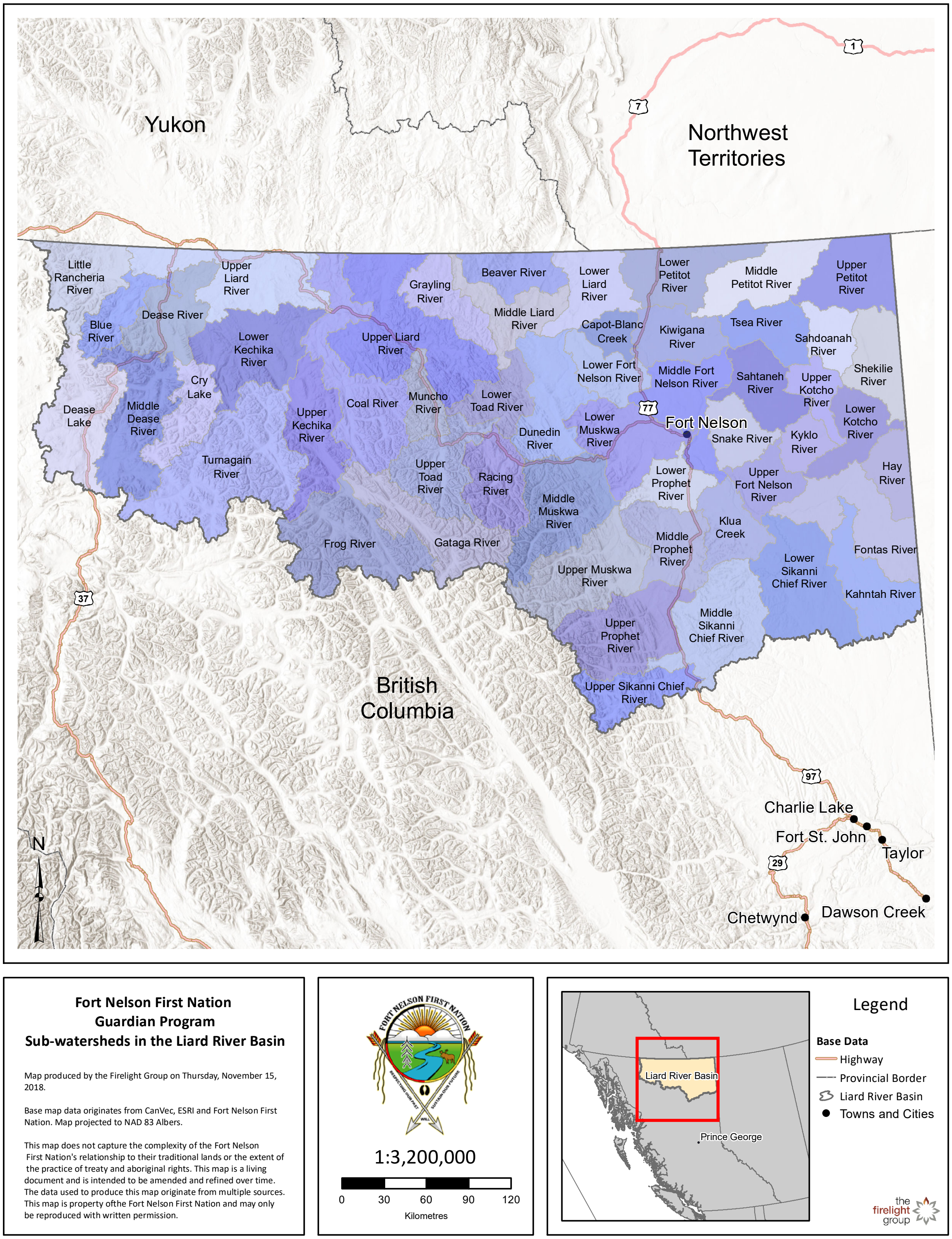

Figure 1. Sub-watersheds of FNFN territory.

The ecology of FNFN territory is described in some detail in the 2017 FNFN LBMI State of Knowledge Report (FNFN 2017). FNFN territory is generally comprised of two very different eco-cultural landscapes: the mountainous Boreal Cordillera or Northern Boreal Mountains to the west, and the Taiga Plains to the east. The dividing line between mountains and plains is shown in the topographic relief on Figure 1. These two areas have very different current states and pressures within them, as summarized in Table 1, below.

Table 1. Ecological and demographic characteristics of the Boreal Cordillera and Taiga Plains ecosections of FNFN territory.

Characteristics	Boreal Cordillera	Taiga Plains
Predominant ecosystems	Spruce Willow Birch: Old forests of white spruce and subalpine fir, with trembling aspen on lower slopes, and open grasslands in drier areas. Shrub-dominated ecosystems are commonly found. Large areas of alpine and glaciers.	Boreal White and Black Spruce ecosystems, and extensive wetlands: Mix of upland forests of aspen, white spruce, lodgepole and black spruce, intermixed with large areas of muskeg and other wetland dominated ecosystems (DeLong et al. 2011)
Human population	Estimated at less than 200 full-time residents	Estimated at approximately 4,500 full-time residents
Indigenous peoples	Fort Nelson First Nation Dene and Cree, Kaska Dene, Dunne zaa (Prophet River)	Fort Nelson First Nation Dene and Cree, Dene Tha'a, Fort Liard Dene (Acho Dene KOE), Dunne zaa
Important wildlife species	Moose, bison, elk, thinhorn stone's sheep, mountain goat, mountain caribou, deer, bear, wolf, beaver, fish, migratory birds, fur-bearers	Moose, boreal caribou, some elk and deer, beaver, marten, wolf, bear, bison, migratory birds and wetland birds, multiple fish species, fur-bearers
Percent Protected Areas*	~11%	~<1%
Industrial pressures and risk	Transportation via Alaska Highway; tourism, some mineral interests; some wind power; some oil and gas activity; Overall Low to Very Low Pressure	Transportation via Alaska Highway, Highway 77 (Liard Highway) and development roads (e.g., Sierra Yoyo Desan or SYD resource road); forestry, oil and gas exploration, transportation, minimal agriculture around Fort Nelson; High Pressure (primarily gas and some forestry)

*Protected areas includes only formally designated Provincial Parks and ecological reserves. The 11% figure for the boreal cordillera does not include the Muskwa-Kechika Management Area (M-KMA), which falls primarily within that ecosection. The M-KMA is a unique conservation area with some restrictions on industrial development and hunting (http://www.muskwa-kechika.com/).

The land is the backbone of FNFN culture—where community members have lived and thrived since time immemorial. FNFN Village sites and harvesting areas, most extensive in the Liard watershed portion of FNFN territory—such as Fontas, Snake River, and Nelson Forks—are connected through an extensive network of trails and rivers. Throughout their seasonal round, FNFN members travel across the region to harvest a vast array of plants and animals supported by the natural diversity of ecosystems in the Liard and Hay River basins. Travelling to access important hunting and harvesting areas remains a key component of FNFN culture today, with most harvesting focused within designated traplines in the Liard basin.

1.2 IMPORTANCE OF MOOSE TO FORT NELSON FIRST NATION

Moose was selected as a critical FNFN value to understand and monitor within FNFN Territory, based on FNFN members' reliance on moose for food security, concerns about moose population trends and distribution, and inadequate data to characterize baseline conditions (FNFN 2017). Moose are of high cultural priority to FNFN; under pressure and declining in the region; and feasible for on-the-ground monitoring and data collection by FNFN members.

Moose (*Golo* in Dene; *mooswa* in Cree) are critical to the physical and cultural survival of FNFN, providing members with sustenance, clothing, and other necessities. This species represents the bulk of harvested meat for FNFN, especially as other animal populations such as caribou have declined. Moose meat is central to building community in FNFN, and shared among members who are unable to hunt (FNFN 2017).

Moose are selective habitat generalists, using all of FNFN territory, from the high alpine ecosystems to the valley bottoms. Browsing primarily on shrubs and deciduous trees, moose are commonly found in recently disturbed or burned areas during the spring and summer. Aquatic and wetland areas, as well as mineral licks, also provide important sites for moose during the warmer seasons. In the winter, moose tend to use older forests, where larger trees provide shelter from the cold and prevent the accumulation of deep snowpacks.

FNFN community members have noted overall declines in the moose population in FNFN territory over the past 40 years, including their complete disappearance from areas where moose were once plentiful.

> *Just from when I was younger, in my teens, you could go out, drive an hour, and pretty well know you are going to get a moose. Now, you go out there for three or four days and you might see one. It is not worth shooting a cow moose. That just affects the population. So it is more challenging, likely because it is more accessible for – the area is more accessible through industry. There is more people that come up here because they see it when they are opening it up. Oh, look at all these moose. So if you have got a thousand people from northern B.C. that see all this game, maybe fifty of them come up, that is quite a few non-resident hunters. (RELAW Project 2017)*

Community members believe that these declines are a result of cumulative impacts from habitat loss due to industry development, increased predation from wolves and bears, increased human hunting pressure, as well as decreased moose health due to contamination from feeding/drinking water near industrial sites. Declines in other moose populations in BC have similarly coincided with increased logging and road building, altering the spatial dynamics of moose, predators, and hunters, and ultimately influencing moose abundance and harvesting (Kuzyk 2016).

Moose declines across the province have been documented by provincial monitoring programs, such as a 2015 report that estimated a province-wide decline of approximately 27,500 moose since 2011 (FLNRO 2015). Recent moose population surveys within FNFN territory are summarized in FNFN (2017) and shown below in Table 2. The 2015 winter survey of Wildlife Management Unit (WMU) 7-42, for example, reported the moose population has declined by 70% from 2011 to 2015, with an overall negative population trend from 1987 (Lirette 2015). Generally, Population trends for the Liard basin and FNFN territory, however, are unclear. There is a need to conduct more regular surveys of the WMUs in FNFN territory at a scale relevant to FNFN's use of the area, to determine population trends within key hunting areas using repeated, standardized methodologies**.**

Table 2. Comparison of recent moose surveys within FNFN territory (adapted from EDI 2016).

Area	Density (moose per km^2)	Calves:100 cows	Bulls:100 Cows	Year	Method	Reference
MU 7-42	0.24 ± 0.033*	12 ± 2.7*	44 ± 9.9*	2015	Stratified random block	Lirette 2015
MUs 7-55, 7-56, 7-47, 7-48	0.104 (0.080 – 0.136)+	45	54	2016	Distance sampling	Webster and Lavallee 2016
MU 7-49	0.14 (0.11 – 0.16)*	23 (18-30)*	51 (42-61)*	2016	Distance sampling	EDI 2016
MU 7-55, and portions of MU 7-49, 7-56	0.12 (0.10 – 0.14)+	32	72	2010	Distance sampling	Thiessen 2010
MU 7-48	0.12 (0.03 – 0.55)+	55 (33 – 77)+	27 (17 – 37)+	2013	Distance sampling	McNay, Webster, and Sutherland 2013
MUs 7-55, 7-56, 7-47, 7-49, 7-46	0.10 (0.08 – 0.12)+	51 (41 – 60)+	60 (43 – 76)+	2013	Distance sampling	McNay, Webster, and Sutherland 2013
MU 7-47	0.04 (0.03 – 0.06)*	9 (2 – 17)*	64 (35 – 92)*	2007	Stratified random block	Rowe 2008

+ Reported with 95% confidence interval
* Reported with 90% confidence interval

1.3 MONITORING APPROACH

A ground-based sampling approach was selected for this wildlife monitoring program given the size of the monitoring area and the mandate to maximize FNFN community member involvement. While aerial surveys are commonly used by provincial ungulate monitoring programs in BC and Alberta, this approach is costly, especially for large areas, and would limit FNFN community member participation. Fecal pellet counts and hunter knowledge surveys have been identified as relatively inexpensive and effective approaches for monitoring ungulate populations. When combined, these methods perform better than annual aerial surveys for monitoring ungulates, providing a considerably less expensive approach with equal or increased accuracy (Månsson, Andrén, and Sand 2011).

This report includes the results of pellet group surveys only. Hunter knowledge surveys will be conducted at a later date dependent on funding availability.

There are two primary methods for pellet-count sampling: bounded plot surveys, and transect sampling surveys. Bounded plot pellet surveys involve using linear transects with circular plots spaced at regular intervals along the transect (RIC 1998). Within these plots, the total number of pellet groups are identified, counted and cleared. While plots may be permanent and re-visited over time, temporary plots are generally preferred due to decreased monitoring costs and the efficiency of setup.

Transect sampling involves the counting of pellet groups along a series of transects, rather than within plots. This approach has been shown to achieve equal precision compared to bounded plot surveys, while also requiring less time and effort (Goulet 1984). There are two different approaches for transect sampling: strip transects and line transects. Strip transect sampling entails the counting of every fecal group observed within a given width (e.g. 1 m) along the length of the transect. Line transect sampling, on the other hand, involves measuring the perpendicular distance from the transect line to every visible fecal group observed from the transect line, regardless of distance from the transect.

Based on our review of the literature, the strip transect sampling methodology was selected for this monitoring program. Transect sampling was selected due to the increased efficiency of this approach over bounded plot surveys, especially for covering large areas. Strip transects were chosen over line transects largely due to the timing of the surveys. Because the surveys had to occur post-green up, there were concerns that the vegetation would limit our ability to detect pellet groups from the transect line. FNFN field technicians were trained in the methods through a combination of classroom-based lessons and hands-on field training prior to commencing data collection.

2. METHODS

Field monitoring programs for the LBMI, including moose wildlife surveys, were initiated in June 2018 and are designed to be repeated annually. Detailed, step-by-step instructions on site selection, transect establishment, and data collection for use in the field can also be found in the LBMI Guardian Program Monitoring Handbook (FNFN and the LBMI Team 2018a).

2.1 STUDY AREA SELECTION

The following criteria was developed by the lead LBMI researchers to identify high priority study areas for moose surveys within FNFN territory:

- Located within high pressure watersheds, as identified in the draft Watershed Scorecards (FNFN and the LBMI Team 2018b)[3];
- Located within, or near FNFN active traplines;
- Located within proximity to culturally significant FNFN Village sites; and
- Includes areas of conifer leading, old forest, riparian zones.

Based on these criteria, the following seven study areas were selected (Figure 2):

- North Sierra Yoyo Desan Resource Road (SYD Road)
- South SYD Road
- Liard Highway/Highway 77 (317 Road)
- Elleh Creek
- Fort Nelson River toward Fontas Village
- Luyben Road
- Snake River

For each of these study areas, community members provided local and traditional knowledge regarding access and hunting pressures, as well as moose distribution, habitat and harvesting in recent years. Based on this information, each study area was qualitatively categorized by community members as having low, medium, or high hunting pressure. Community members described areas of high hunting pressure as areas known to have good moose habitat, but that had been "hunted out", and had experienced declines in moose abundance due to high harvesting rates (primarily by non-indigenous, non-resident hunters).

[3] The Watershed Scorecards is currently a confidential internal working document that may be replaced with a public report in 2019.

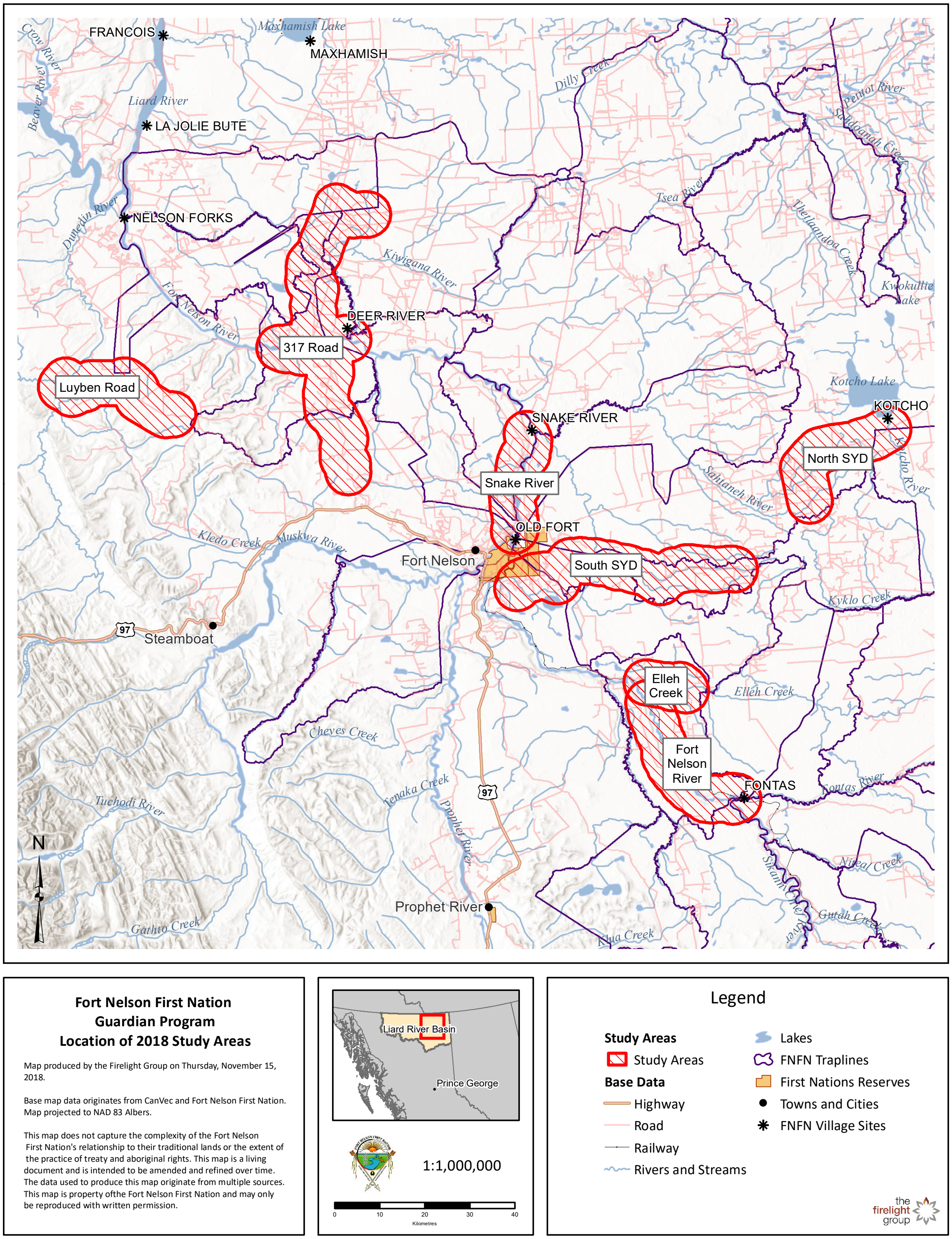

Figure 2. Map showing the seven study areas surveyed in the 2018 FNFN moose monitoring program

2.2 TRANSECT ESTABLISHMENT

A minimum of 4 transects were established within each study area. Additional transects (up to a total of 16) were established where access and field conditions permitted. Given the reportedly low density of moose in the region, transect locations within each study area were selected to maximize the number of pellet groups observed, while using a consistent approach across sites. We selected transect locations based on our knowledge of moose habitat use in the Liard basin, with a focus on winter habitat selection.

Forested riparian areas, particularly in low-lying river valleys and floodplains, provide a combination of shallow snow depths and abundance browse for moose in the winter (Ardrea Biological Consulting 2004). The combination of life requisite functions (foraging and cover) provided by this habitat type often results in selection for this habitat, particularly in winters with high snow loads. Transect placement therefore targeted accessible riparian areas, within spruce or aspen leading forested stands. The area was searched for up to five minutes prior to initiating the transect survey, in order to locate a game trail or moose tracks. If present, the trail or tracks were used as the starting point for the transect[4]. A bearing for the transect was set at the starting point, running parallel to the linear feature from which the site was accessed. Where possible, the bearing was established to follow game trails to the greatest extent possible. If no track or game trail was observed, the transects were run adjacent to the riparian zone in conifer or aspen leading old forest growth.

At the start of each transect, a hip chain was tied off and used to measure the distance travelled. Distance travelled was also tracked using a hand-held GPS device. The start and stop time, UTM location, and elevation was also recorded at the beginning and end of each transect.

2.3 PELLET GROUP SURVEYS

Transects were surveyed for pellet groups using a fixed width of 3 m (1.5 m to either side of the transect line). Surveyors worked in teams of two, with one team member responsible for either side of the transect. Data collection focused on recording observations of moose pellet groups, but included incidental observations of moose tracks and browse. Incidental observations of animal signs were also recorded for elk, white-tailed deer, caribou, black bear, lynx, cougar, wolf, coyote and beaver.

For each animal sign, we recorded the sign type (e.g. pellet group) and species responsible. Once recorded, the sign was marked with biodegradable paint to prevent double counting. When the entire length of the transect had been scanned, the surveyors switched side and surveyed the transect a second time in reverse.

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[4] Due to the relatively low densities of moose in the Liard basin, we opted for an approach that increased our likelihood of observing moose pellets along the selected transect. As the same approach was used across all of the study areas, comparisons between study areas are still valid. However, we acknowledge that the approach is biased towards locations with known moose presence and may not represent the study area as a whole.

2.4 DATA ANALYSIS METHODS

2.4.1 Moose Density

Moose density (number of moose per km^2) was calculated for each of the seven study areas, based on the total number of pellet groups recorded in the surveys. Pellet group observations were converted to density estimates by correcting for the number of days over which pellet groups could have accumulated, and the number of pellet groups likely deposited per individual moose, per day. Because accumulation time and defecation rates can vary, we repeated this analysis with two sets of values for each factor.

All moose pellet group observations were pooled by study area to calculate moose density estimates. Moose density was calculated using the formula: (D/A)/(T*F), where D is the number of pellet groups found, A is the total area sampled (km^2), T is the number of days the pellet groups had accumulated, and F is the average number of defecations per day and individual (Härkönen and Heikkilä 1999).

Given that T and F can vary spatially and temporally, moose density calculations were repeated with two sets of values for each of these variables. This allowed us to evaluate the sensitivity of our estimates to changes in T and F. The number of days during which the pellet groups had accumulated (T) was set at 210 and 240 days, while the average number of defecations per day and individual (F) was set at 14 and 20.9 (Härkönen and Heikkilä 1999).

2.4.2 Use by Study Area

Pellet group observations by study area were compared to assess whether there were differences in moose abundance among the areas surveyed. For each study area, we calculated the number of pellet groups we would have expected to observe if all pellet group observations had been evenly distributed across the study areas. We then compared the expected number of pellet groups to the actual number of pellet group observations for each study area. Finally, we assessed whether the observed value was greater or less than what would have been expected if there were no differences in moose abundance.

A Chi-squared statistic was calculated to evaluate if the observed abundance of pellet groups across study areas corresponded to the expected number based on availability (i.e., total area surveyed within a given study area), based on methods applied by Harkonen & Heikkila (1999)[5]. Where the null hypothesis was rejected (alpha = 0.05), Agresti-Coull binomial confidence intervals[6] were used to determine which study areas

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[5] This approach assumes that habitat suitability is the same across all study areas; this should be verified for study areas in FNFN territory in subsequent work.
[6] Adjustments, such as Bonferroni-adjusted alphas can be used in the creation of confidence intervals to minimize Type I error due to the number of simultaneous comparisons. These adjustments provide a more conservative approach, but also reduce the ability to detect differences between study areas. Because this study was exploratory, and the results will be used to inform hypotheses for future investigations, we did not use a correction (See: Armstrong,

had higher or lower use than expected, based on their availability (Brown, Cai, and DasGupta 2001). Where the expected proportion of usage did not fall within the confidence interval, we concluded that the expected and actual use of the study area was significantly different (Byers, Steinhorst, and Krausman 1984).

2.4.3 Linear disturbance density by study area

Linear feature density has been used as a proxy for hunting pressure in multiple studies, because areas with higher linear feature densities are believed to provide more access for hunters (e.g., Beazley et al. 2004). We were therefore interested in exploring whether linear density accurately reflected hunting pressure classification for each of the study areas, as identified by FNFN community members. Using publicly available data from DataBC[7], we calculated the density of linear features in each study area using boundaries of 1 km, 5 km and 10 km on either side of the access route (road or river) used to access the transect sites. Boundary areas encompassed all transect sites belonging to a given study area, including the space between them along the access route.

3. RESULTS

3.1 STUDY AREA CHARACTERIZATION

Three study areas (North SYD, South SYD, and Luyben Road) were characterized as having high hunting pressure by FNFN community members, while two study areas were characterized as medium (317 Road and Elleh Creek). The remaining two were identified as having relatively low hunting pressure (Fort Nelson River and Snake River) (Table 3). These areas are currently of high importance to FNFN members: all of the study areas except Luyben Road overlap with FNFN-held traplines, while the Luyben Road study area overlaps with FNFN's guide outfitting territory.

Table 3. Overlapping traplines and hunting pressure by study area. FNFN-held traplines are indicated in bold. Degree of hunting pressure was identified by community members based on local knowledge.

Study Area	Hunting pressure	Traplines
North SYD Road	High	TR0756T012, **TR0756T013**
South SYD Road	High	TR0756T007, **TR0756T009**
Luyben Road	High	TR0754T005, TR0749T006
317 Road	Medium	TR0749T007, TR0749T008, **TR0749T009**, **TR0749T012**, **TR0755T004**
Elleh Creek	Medium	**TR0756T006**
Fort Nelson River	Low	TR0748T001, **TR0756T006**

Richard A. 2014. When to use the bonferroni correction. Ophthalmic and Physiological Optics 34 (5): 502-8.)
[7] https://data.gov.bc.ca/

Snake River	Low	TR0749T010, **TR0756T011**

3.2 PELLET GROUP OBSERVATIONS

Pellet group surveys were conducted over nine days from July 5 to July 17, 2018. A total of 54 transects were surveyed across the seven study areas (Table 4). The number of pellet group observations were relatively low across all study areas, ranging from 0 at Luyben Road, to 2.6 (± 3.5 SD[8]) at Snake River. Overall, the abundance of pellet group observations tended to be higher in study areas characterized as having low hunting pressure (Table 4).

Table 4. Average number of pellet group observations per transect, by study area.

Hunting pressure	Study Area	# of Transects	Pellet Group observations		
			Total	Average per transect	1 SD
Low	Fort Nelson River	8	15	2.5	4.8
	Snake River	8	21	2.63	3.5
Medium	317 Road	16	14	0.88	1.54
	Elleh Creek	6	7	1.17	0.98
High	Luyben Road	6	0	0	0
	North SYD	4	2	0.5	1
	South SYD	6	2	0.33	0.82

3.3 MOOSE DENSITY ESTIMATES

Moose density estimates differed substantially among study areas, ranging from 0 moose/km^2 in the Luyben Road study area, to 0.6 moose/km^2 in the Snake River study area (Table 5). Moose density estimates varied by up to 0.3 moose/km^2, however, when different values were used for the number of days the pellet groups had accumulated (T), and the average number of defecations per day and individual (F). A T value of 210 days, and an F value of 14 defecations per day per individual, provided the highest density estimates and indicated greater differences among study areas. These values were therefore used to make subsequent comparisons between study areas, with the caveat that higher T and F values resulted in lower density estimates and differences.

Overall, moose density estimates were highest for sites with FNFN-identified low hunting pressure, ranging from 0.4 to 0.6 moose per km^2 (or 0.2 - 0.3 moose per km^2 with the highest T and F values). Moose density estimates of 0.2 moose per km^2 (or 0.1 moose per km^2 for the highest T and F values) were calculated for both sites characterized by FNFN members as having medium hunting pressure. Moose density

[8] The standard deviation (SD) is a measure of the amount of variation or dispersion in a dataset (i.e. how spread out a distribution is). In a normal distribution, 95% of the observed values are within two standard deviations to either side (+ or -) of the mean.

estimates for study areas with FNFN-identified high hunting pressure, on the other hand, were consistently equal to or less than 0.1 moose per km^2 for all study areas, and all values of T and F.

Table 5. Moose pellet group (PG) observations and density estimates by study area.[9]

Hunting pressure	Study Area	Area surveyed (km^2)	# of PG	Moose density estimates			
				T1*F1	T1*F2	T2*F1	T2*F2
Low	Fort Nelson River	0.01225451	15	0.4	0.3	0.4	0.2
	Snake River	0.01245621	21	0.6	0.4	0.5	0.3
Medium	317 Road	0.02536213	14	0.2	0.1	0.2	0.1
	Elleh Creek	0.00982089	7	0.2	0.2	0.2	0.1
High	Luyben Road	0.01010337	0	0	0	0	0
	North SYD	0.00696989	2	0.1	0.1	0.1	0.1
	South SYD	0.01088656	2	0.1	0	0.1	0
Total		0.08785356	61				

3.4 USE BY STUDY AREA

Pellet group abundance was greater than expected in both study areas with low hunting pressure (Table 6, Figure 3). For study areas identified as having a medium hunting pressure (317 Road and Elleh Creek), on the other hand, no significant difference was found between the observed and expected number of pellet groups. Two out of the three areas with high hunting pressure (Luyben Road and South SYD), had a lower abundance of pellet groups than expected, while the North SYD study area had no detectable difference.

[9] Density was calculated as: (D/A)/(T*F) where D is the number of pellet groups found, A is the total area sampled (km2), T is the number of days the pellet groups had accumulated, and F is the average number of defecations per day and individual. Calculations were repeated using two values were used for T (T1 = 210, T2=240) and F (F1=14, F2=20.9).

Table 6. Chi-squared test and Agresti-Coull binomial confidence intervals for the number of observed pellet groups by study area.

Hunting Pressure	Study Area	Area surveyed (km^2)	Proportion of total area surveyed[1]	Pellet group observations					
				# obs.	# exp.	Proportion	Lower CI	Upper CI	Observed, relative to expected
Low	Fort Nelson River	0.0123	0.14	15	9	0.25	0.15	0.37	Greater
	Snake River	0.0125	0.14	21	9	0.34	0.24	0.47	Greater
Medium	317 Road	0.0254	0.29	14	18	0.23	0.14	0.35	No Difference
	Elleh Creek	0.0098	0.11	7	7	0.11	0.05	0.22	No Difference
High	Luyben Road	0.0101	0.12	0	7	0	0	0.07	Lower
	North SYD	0.0070	0.08	2	5	0.03	0	0.12	No Difference
	South SYD	0.0109	0.12	2	8	0.03	0	0.12	Lower

[1] A total area of 0.088 km^2 was surveyed across the seven study areas.

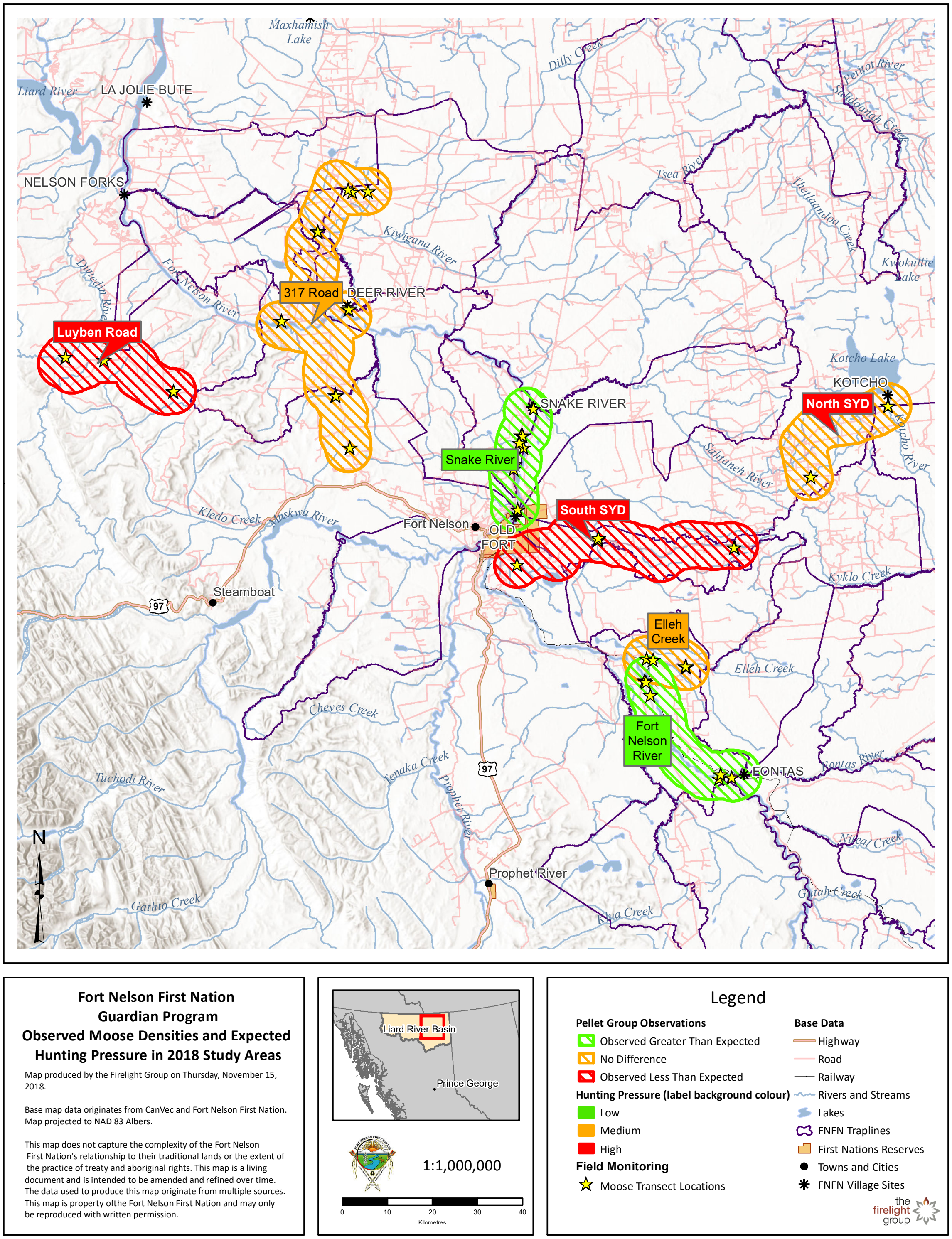

Figure 3. Map of the seven study areas, including transect locations. Study area labels indicate the level of hunting pressure (high = red, medium = orange, or low = green), as characterized by FNFN community members. Study area polygons indicate whether the numbers of pellet groups observed was less than expected (red), not significantly different (orange) or greater than expected (green).

3.5 LINEAR DENSITY BY STUDY AREA

Linear features included all mapped linear infrastructure, such as roads, transmission lines, pipeline right of ways, and seismic lines. Average linear feature densities differed slightly with spatial grain, but remained largely consistent across study areas (Table 7). The Fort Nelson River study area, for example, had the largest average linear density (8.96-18.87 km/ km^2), regardless of the spatial grain used. Elleh Creek, North SYD, and South SYD study areas also had consistently high linear densities (6.49-9.96 km/km^2), while Snake River, 317 Road, and Luyben Road had the lowest linear densities across all spatial grains (0.90 to 2.64 km/km^2).

Table 7. Average linear density by study area, using three spatial grains (1 km, 5 km, and 10 km buffer areas).

Hunting pressure	Study Area	Average linear density (km per km^2)		
		1 km	5 km	10 km
Low	Fort Nelson River	8.96	13.33	18.87
	Snake River	1.90	1.55	2.44
Medium	317 Road	2.64	2.53	2.64
	Elleh Creek	8.05	8.41	9.95
High	Luyben Road	1.66	1.15	0.90
	North SYD	9.21	8.26	8.59
	South SYD	9.66	7.25	6.49

Average linear density did not correspond well with hunting pressure or moose pellet group observations at the spatial grains used in this assessment (Table 7, Figure 4). The Fort Nelson River study area, for example, was characterized as having low hunting pressure, but has the highest density of linear disturbance. Similarly, the Luyben Road study area was characterized as having high hunting pressure, but has consistently low linear density values.

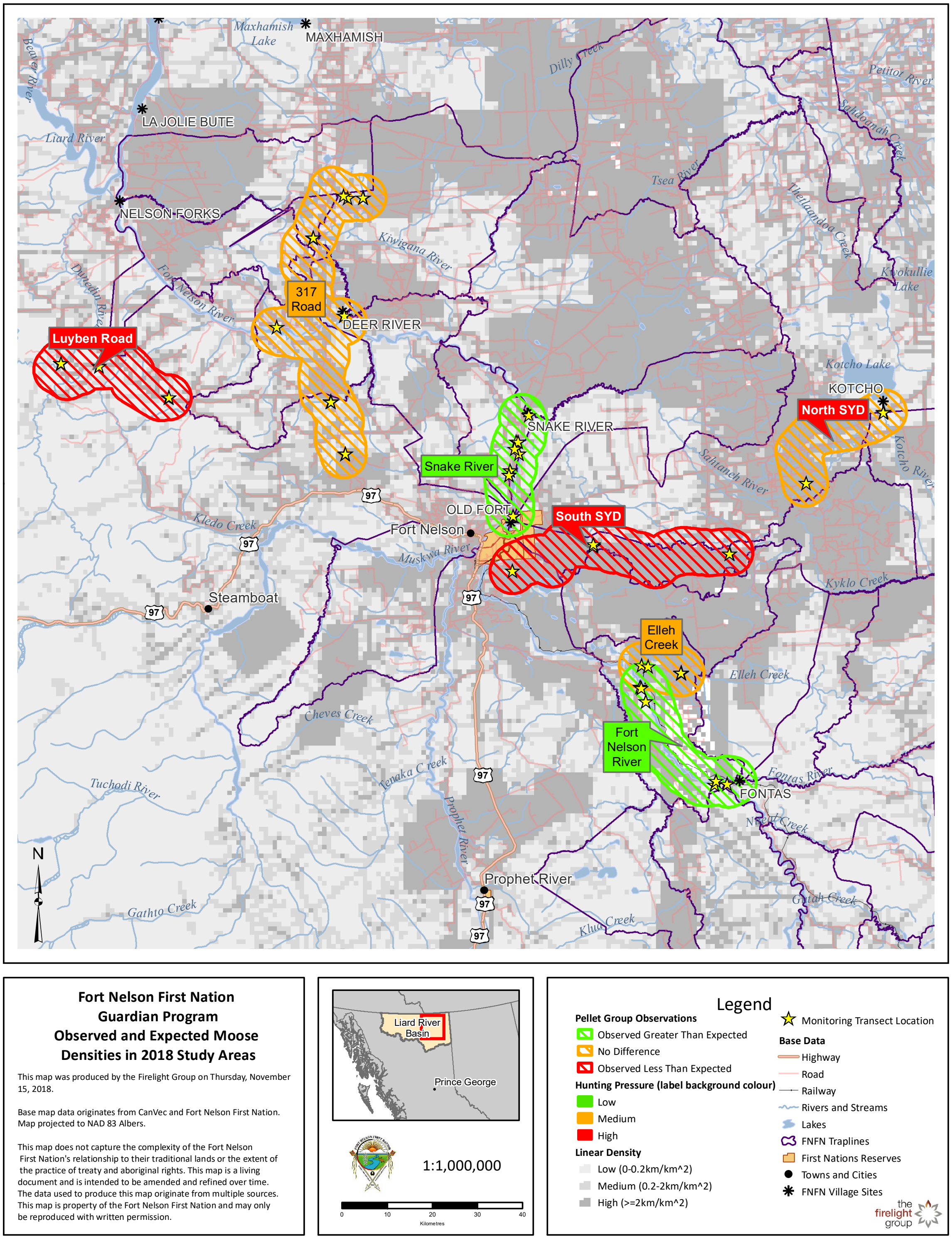

Figure 4. Study areas and relative abundance of moose pellet groups, overlaid on linear feature density.

4. DISCUSSION

4.1 MOOSE DENSITY

Notable differences in moose density among study areas points to the importance of monitoring and managing moose on smaller spatial scales than existing WMUs in FNFN territory. Moose density estimates varied substantially, ranging from 0 moose/km^2 in the Luyben Road study area to 0.6 moose/km^2 in the Snake River area. The continuity of harvesting by FNFN community members requires that moose densities remain above acceptable thresholds for community use in key moose hunting areas (e.g. at the sub-watershed level). Implementing refined monitoring and management at this scale is particularly important in the face of reported declines in moose populations.

FNFN community members report that moose populations in FNFN territory have been in decline for roughly 40 years (FNFN community meeting, July 2018), and that the moose are no longer present or available in sufficient numbers, where it was once plentiful. These observations are consistent with the findings of provincial WMU monitoring programs (e.g. Lirette 2015). Cumulative impacts from habitat loss, predation, human hunting pressure, and decreased moose health due to contamination, have been identified by community members as contributing factors to these declines. More research is needed, however, to understand how these impacts influence moose abundance, distribution, and population trends in FNFN territory.

Future monitoring should aim to improve our understanding of moose density at sub-regional/sub-WMU scales, including spatial and temporal trends across key moose hunting areas (e.g., at the FNFN sub-watershed level or within key cultural areas). These monitoring activities should incorporate measures of habitat quality and selection, as well as cultural indicators and observations, to further inform moose management decisions. Potential cultural indicators of moose population trends include:

- percentage of successful hunting trips;
- number of FNFN families getting moose meat;
- level of non-Indigenous hunting competition;
- presence of disease and other moose health concerns;
- level of potential contamination from unfenced industrial sites;
- level of herbicide spraying in key hunting areas; and
- the number of actively-used mineral licks.

4.2 HUNTING PRESSURE

Patterns in moose pellet group abundance and density estimates mirrored FNFN community input on hunting pressures in each of the study areas. Study areas classified by FNFN community members as having high hunting pressure had consistently lower density estimates, and fewer pellet groups than expected. Areas classified as having low hunting pressure, on the other hand, had the highest density estimates and a greater number of observed pellet groups than expected. These findings stress the importance of incorporating local and traditional knowledge in monitoring initiatives and management decisions. Furthermore, this study emphasizes the need for continual monitoring and the identification of thresholds that can be used to reduce hunting pressure before areas become "hunted out".

4.3 LINEAR DISTURBANCE

Linear features are often used as a proxy for hunting pressure and the development of management strategies. Road densities exceeding 1.2 km/km^2, for example, have been found to impact ungulate habitat value by promoting wolf access and movement (GOABC 2016). This metric has been used for impact assessment of industrial developments in BC, as well as directing the caribou recovery strategy (Environment Canada 2012) in habitat enhancement and predator control initiatives. Moose have been found to be negatively impacted when road density exceeds 0.6 km/km^2 and this has been identified as a cautionary threshold for degradation to moose habitat (Beazley et al. 2004).

Our findings suggest that linear density alone was not the strongest proxy for hunting pressure in these study areas. This finding is likely due to the lumping of linear features (i.e., grouping road density, pipelines and seismic lines), each of which may have different effects on moose (Bartzke et al. 2015). Roads are known to influence human access into remote areas. Future analyses should focus on characterizing key roads that are used to access the territory and monitoring use of these linear features by hunters. Local and traditional knowledge can add to our understanding of how heavily linear features are used in a given study area, and how this might influence moose density and use.

Understanding the cumulative effects and relative impacts of different linear features is critically important. All seven study areas have been substantially impacted by linear features, with densities exceeding 8 km/km^2 in many areas. Improving our understanding of how these features affect moose abundance and density will help inform future monitoring programs and management decisions.

4.4 LIMITATIONS

There are several limitations and sources of inaccuracy associated with the use of pellet group counting techniques for estimating moose density. Use and moose defecation rates, for example can vary by habitat, as can observer search success and dung decay rates (Neff 1968). There were varying degrees of expertise and qualifications among the observers, who were trained through this community-based program.

The moose density estimates reported in this study may provide an overestimate of the general moose population, due to our selection for high value habitat while establishing transects. Winter surveys in the Liard River Valley, for example, reported higher use of riparian/alluvial habitats compared to other habitat types (Goulet and Haddow 1985). A large winter survey during heavy snow conditions in north-eastern BC similarly recorded 70% of observed moose in riparian habitats and cutblocks of valley bottoms, with the remaining 30% observed in upland habitats.

The timing of the surveys, however, may have impeded the detection of pellet groups, leading to an underestimation of moose abundance and density. Our surveys were performed in the summer, following green up, which likely contributed to reduced visibility of pellet groups. The best time to perform these surveys is in the early spring, before pellet groups are obstructed by vegetation growth (RIC 1998).

Our conclusions are further limited by a lack of information about the abundance and quality of moose habitat in each of the study areas. Our analysis of the data assumes that habitat suitability is the same across all of the study areas, and while this approach has been used in similar studies (e.g., Härkönen and Heikkilä 1999), additional work will be required to verify this assumption. If substantial differences in habitat availability exist among study areas, for example, this could be reflected by differences in moose density.

This study examined only a small portion of FNFN territory. Future work should build on these surveys to provide a more extensive assessment of moose density and distribution across the region, and multiple habitat types.

4.5 MANAGEMENT RECOMMENDATIONS

FNFN envisions a future in which the Nation's inherent rights to protect, manage and conserve their lands and resources according to their own laws are respected and upheld. Moose are an integral part of FNFN culture, and critical to the continuity of FNFN's way of life. Based on findings from this study, the following management recommendations have been developed to promote the conservation of moose in FNFN territory:

4.5.1 Habitat Protection

1. Old forest riparian and upland areas should be conserved wherever possible to ensure that adequate refuge habitat exists for moose during high snow periods.
2. Old forest and riparian areas that are in close proximity to forage habitat (i.e., areas with willow and other shrubs that are taller than the normal peak snow depth) are particularly important habitat for moose.
3. 300 m buffers should be established around all rivers, lakes and wetlands. No forestry harvesting or other development should be permitted in these areas.

4.5.2 Habitat Enhancement

4. Priority areas for habitat restoration should include forested riparian areas important for cover and foraging.
5. Habitat restoration treatments is recommended in areas that have been cleared of shrubs and are not currently revegetated (e.g., heavily impacted seismic lines, old campsites with little vegetation regrowth).

6. FNFN recommends that all forms of industrial development avoid herbicide use in their operating areas and adopt standard operating procedures that include replanting operating areas to native species.

4.5.3 Reduce Hunting Pressure

7. Areas of high hunting pressure and low moose density, such as Luyben Road and the southern portion of the SYD Road, should be targeted by management measures to reduce hunting pressure (e.g., restrictions on all-terrain vehicle use; bull-only harvesting measures; or hunting closures).
8. Areas with high densities of accessible roads should be targeted by management measures to prevent or reduce hunting pressure as a result of increased access (e.g., restrictions on all-terrain vehicle use, or hunting closures), before these areas become "hunted out".
9. Increase capacity for FNFN members to conduct monitoring and enforcement of hunting management recommendations. We recommend establishing joint FNFN-provincial conservation officer game stops during hunting season along high pressure hunting areas. These game stops should be integrated with ongoing monitoring work, such as hunter vehicle counts and non-FNFN hunter surveys, to target peak hunting periods.

4.5.4 Monitoring and Adaptive Management

10. Annual FNFN-led monitoring of moose abundance and distribution within FNFN territory should address the following goals:
    - Track trends in moose abundance and density over time, ideally at culturally relevant scales (e.g., traplines within areas of high, medium and low density hunting pressure);
    - Correlate pellet group surveys with FNFN hunter survey results;
    - Evaluate the impacts of other factors, such as habitat loss and industrial development;
    - Assess other quantitative measures that could be used as a proxy for hunting pressure, such as the number of hunters parked along main roads in the 2019 hunting season;
    - Confirm the locations of critical winter habitat for moose in priority areas, such as important hunting areas for FNFN community members; and
    - Continue to incorporate local and traditional knowledge in monitoring programs and management decisions.
    - In the coming year (2019-20), develop a moose habitat suitability model and tracking changes in moose habitat over time.

4.5.5 Data management and reporting

11. FNFN is committed to continued data collection, management, and reporting on moose population numbers. Efforts to collaborate with the provincial government to establish restrictions on non-member hunting and promote a conservation ethic in hunting practices are ongoing.

5. CONCLUSION

5.1 SUMMARY

This study supports FNFN community members' observations that areas identified as having high hunting pressure have lower moose abundance and density. Follow up work is needed to:

e) Correlate pellet group surveys with surveys of hunter effort in the same study areas: By looking at both the number of pellet groups and getting an accurate gauge of hunting effort / success rate in each study area, we can calculate more informed density and total abundance estimates.
f) Increase effort in all of the study areas by resurveying in 2019: Monitoring efforts in 2019 should aim to achieve a minimum of 10 transects in each study area, within specific traplines to be identified with trapline holders/families. Monitoring efforts may be best conducted in the vicinity of cultural areas identified as part of FNFN's developing Guardian program.
g) Conduct additional data analyses to explore the effects of other factors on moose density: A larger dataset from two years of sampling (2018 and 2019) will help us explore the influence of additional factors, such as industrial development and habitat availability.
h) Identify an appropriate proxy for quantitatively gauging hunting pressure: 2019 fieldwork should test other proxies for hunting pressure, to find a feasible quantitative measure that aligns well with local knowledge (e.g. counting vehicles along main roads and travel corridors during the 2019 hunting season).

5.2 CLOSURE

Should you wish to discuss any aspect of this Report further, please do not hesitate to contact:

Katherine Capot-Blanc (E: katherine.capotblanc@fnnation.ca, P: 250-774-7257) for questions about moose management and monitoring in FNFN territory, or about this Report in general.

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