Review of wildlife effects monitoring programs in the Wildlife Management and Monitoring Plan for the Tłı̨chǫ All-Season Road.

Government of the Northwest Territories Environment and Natural Resources contract

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EXECUTIVE SUMMARY

This report is a technical review of the wildlife effects monitoring program components of the Wildlife Management and Monitoring Plan (WMMP) for the Tłı̨chǫ All-Season Road (GNWT-INF 2019).

The wildlife effects monitoring portion of the WMMP outlines two basic categories of monitoring programs: monitoring focused on wildlife and monitoring focused on the road. The road-focused monitoring includes: monitoring traffic levels; monitoring human use of the road for access to off-road areas; monitoring hunter harvest of moose and caribou; and monitoring wildlife activity on and near the road including wildlife-vehicle collisions. The methods outlined for road-focused monitoring appear able to deliver the key information for which they are designed and provide opportunities to add information and analyses that can enhance the ability to predict the relationships between wildlife and the road. The addition of a new Renewable Resources Officer in Whatì will be instrumental in delivering these monitoring programs as will collaborative relationships between the Department of Environment and Natural Resources and the Tłı̨chǫ Government, the Wek'èezhìı Land and Water Board, and the Department of Infrastructure.

The monitoring programs focused on wildlife include population surveys for moose, bison, boreal caribou, and wolves. It is unlikely that aerial surveys for boreal caribou will be effective at detecting population change. Aerial surveys will likely be limited to detecting large changes in bison and moose populations, changes that may arise from moderate annual changes that accumulate over many years. Bison survey data will also be used to track changes in the occupied bison range.

The wildlife monitoring programs also include tracking of radio-collared boreal caribou, use of radio-collar data from barren-ground caribou, and the possible tracking of radio-collared wolves. In each study with radio-collared animals the resulting data will provide the necessary information to monitor moderate changes in survival rates, recruitment rates, and population growth rates (generally using several years of data together). They will also provide the data to create resource selection functions and other associated wildlife-habitat relationships (e.g., step-selection functions) that will explain and predict wildlife behaviour, including the effect of the road and traffic on each species.

Beyond harvest and population dynamics, radio-collared caribou will provide some notice of animals approaching the road, though detection of animals with this method will be inadequate to predict most encounters of caribou with the road. However, in combination with resource selection analyses using radio-collar data and wildlife observations, predictive occurrence models and effective mitigation strategies should be possible.

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ABBREVIATIONS AND ACRONYMS

Term	Definition
CEA	Cumulative effects assessment
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CV	Coefficient of variation. A standardized measure of the precision of an estimate. Equal to the standard error divided by the mean.
CWS	Canadian Wildlife Service
DAR	Developer’s Assessment Report. For the TASR, the DAR consists of the Adequacy Statement Response plus the Project Description Report
DNA	Deoxyribonucleic acid
EA	Environmental Assessment
ECCC	Environment and Climate Change Canada
GNWT	Government of the Northwest Territories
GNWT-DOT	Department of Transportation, GNWT
GNWT-ENR	Department of Environment and Natural Resources, GNWT
GNWT-INF	Department of Infrastructure, GNWT
GNWT-Lands	Department of Lands, GNWT
GPS	Global Positioning System
MVEIRB	Mackenzie Valley Environmental Impact Review Board
NWT	Northwest Territories
Project	The Tłı̨cho All Season Road
SARA	Species at Risk Act
SARC	Species at Risk Committee (NWT)
SE	Standard error (of an estimate)
TASR	Tłı̨chǫ All Season Road
TG	Tłı̨chǫ Government
UD	Utilization Distribution
WLWB	Wek’èezhìı Land and Water Board
WMMP	Wildlife Management and Monitoring Plan for the Tłı̨chǫ All Season Road
WRRB	Wek’èezhìı Renewable Resources Board
WVC	Wildlife Vehicle Collision

1.0 INTRODUCTION

1.1 Tłı̨chǫ All-Season Road (TASR) Project Background

In March 2016 the Government of the Northwest Territories Department of Transportation (GNWT-DOT) prepared a Project Description Report (GNWT-DOT 2016) for the proposed Tłı̨chǫ All-season Road (TASR). The Project Description Report accompanied applications to the Wek'èezhìı Land and Water Board (WLWB) for a Type A Land Use Permit and a Type B Water Licence. Following various stages of review, comment, materials submission, and information requests the Mackenzie Valley Environmental Impact Review Board (MVEIRB) issued an Adequacy Statement to GNWT-DOT in October 2016. The Adequacy Statement detailed the outstanding information required to satisfy MVEIRB's terms of reference. In April 2017 the Government of the Northwest Territories Department of Infrastructure (GNWT-INF) submitted an Adequacy Statement Response (GNWT-INF 2017) to MVEIRB. Together, the Project Description Report and the Adequacy Statement Response constitute the Developer's Assessment Report (DAR) for the TASR.

1.1.1 TASR Description

The TASR will be a 94 km all-season road connecting Highway 3 to the community of Whatì (Figure 1). The TASR will be a two lane gravel highway (60 m wide right-of-way) with a designed speed of 80 km/hr and a posted speed of 70 km/hr (GNWT-DOT 2016). Of the 94 km, 17 km is located on Tłı̨chǫ land and the remainder on NWT land (GNWT-DOT 2016). Traffic estimates are for between 20 and 40 vehicles per day including traffic associated with a proposed mine northeast of Whatì. The four-year construction schedule runs from November 2018 to November 2022, with the project opening by the end of November 2022 (GNWT-INF 2017).

1.1.2 TASR Wildlife Management and Monitoring Plan (WMMP)

The original version of the TASR Wildlife Management and Monitoring Plan (WMMP) accompanied the permit application in 2016. The GNWT-INF submitted version 3.3 of the TASR WMMP on June 14, 2019. Version 3.3 of the WMMP (GNWT-INF 2019) incorporated revisions arising from: reviews by communities and First Nations; traditional knowledge reports; reviews by the Government of the Northwest Territories Department of Environment and Natural Resources (GNWT-ENR) and WLWB; the Adequacy Statement and the Adequacy Statement Response; and subsequent commitments made by GNWT-INF during the permitting process.

The WMMP conforms with the recent Process and Content Guidelines (GNWT-ENR 2019). Under the guidelines, the WMMP is required for developments if the activities are likely to:

> "*(a) result in a significant disturbance to big game or other prescribed wildlife;*
>
> *(b) substantially alter, damage or destroy habitat;*
>
> *(c) pose a threat of serious harm to wildlife or habitat; or*

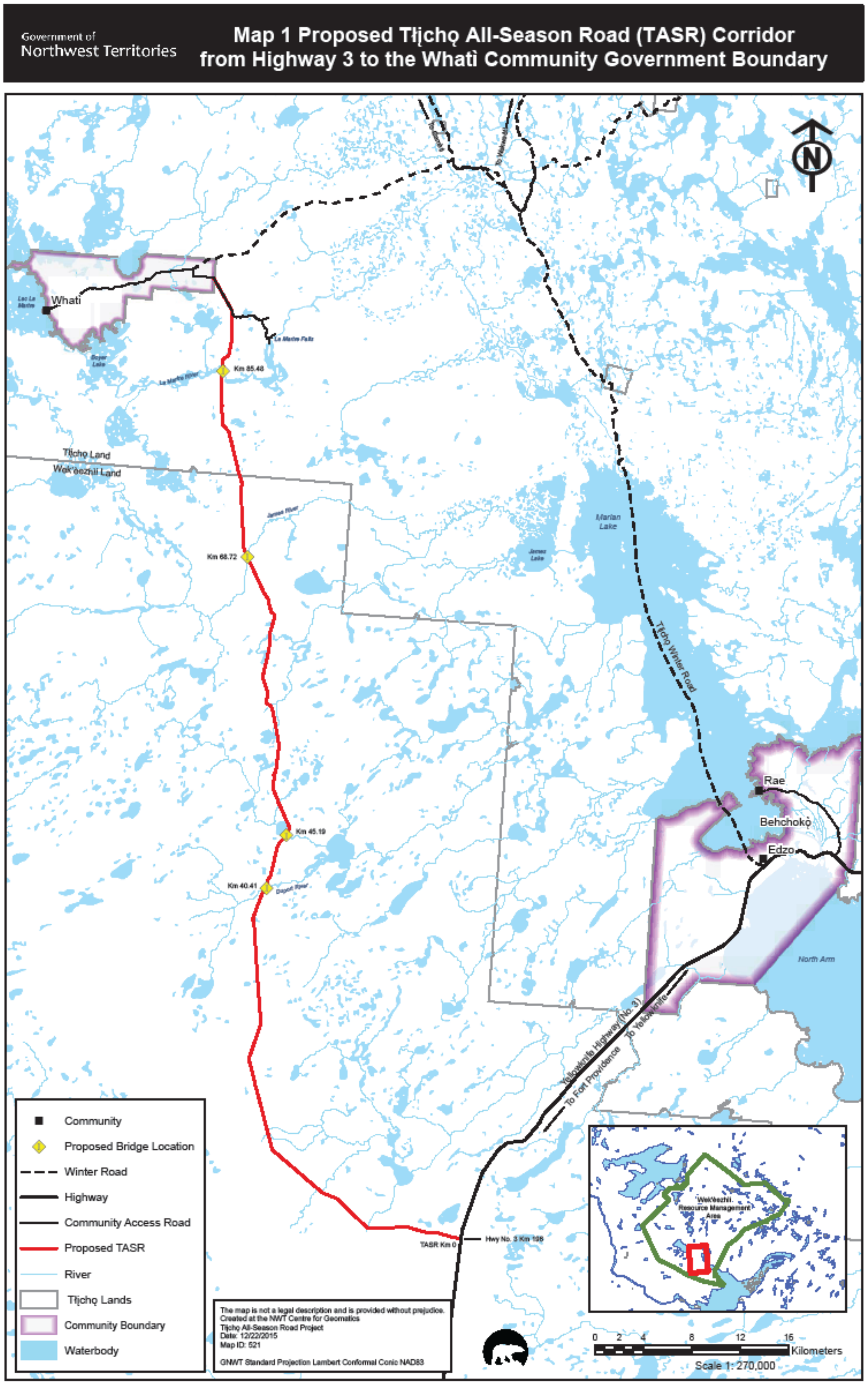

Figure 1: Map of the Proposed Tłı̨chǫ All-season Road. (From GNWT 2016: Proposed Tłı̨chǫ All-season Road Project Description Report)

(d) significantly contribute to cumulative impacts on a large number of big game or other prescribed wildlife, or on habitat."

(GNWT-INF 2019, p. 11)

The WMMP guidelines (GNWT-ENR 2019, pp. 37-38) distinguish among three different types of monitoring:

- Mitigation monitoring (regular inspections to verify the application of approved designs, procedures, and equipment);
- Wildlife effects monitoring (systematic tracking of indicators to quantify project-related effects on wildlife and wildlife habitat); and
- Regional scale wildlife monitoring (typically participation in, or contribution to, regional scale monitoring of cumulative effects consistent with any predicted project-related regional effects).

1.2 Report focus: Wildlife Effects Monitoring

This report is a technical review of the wildlife effects monitoring program components of the WMMP for the TASR (GNWT-INF 2019). The focal wildlife species identified in the WMMP for wildlife effects monitoring are:

- boreal caribou;
- barren-ground caribou;
- moose;
- bison; and
- wolves, by virtue of their role as a predator common to the other four species.

The wildlife effects monitoring program was designed to address the direct and indirect effects of the TASR on the habitat and distribution and abundance of these species, including mortality from predation, hunting, and accidents. The list of primary objectives of the wildlife effects monitoring activities are listed in Section 5.2 of the WMMP (GNWT-INF 2019, pp. 5-37 and 5-38).

1.3 Report objectives

The report objectives are to:

1) Evaluate specific wildlife effects monitoring programs described in Sections 5.2.1 to 5.2.7 of the TASR WMMP to:
    a. Determine whether the study design and methods described for each monitoring program are appropriate to meet the monitoring objectives and to answer the specific monitoring questions listed,

b. Determine if the sample size, sampling frequency and spatial scale of each monitoring program will provide enough statistical power to detect changes in the parameters of interest and triggers for adaptive management within the time frame specified for the monitoring program. This may require some statistical power analysis using data previously collected for the TASR WMMP or from similar surveys previously conducted by GNWT-ENR;

2) Make recommendations on the methods and design of surveys to estimate abundance of boreal caribou, predators (wolves and black bears), moose, and bison;

3) Make recommendations on the statistical methods that can be used to analyze the monitoring data to answer the specific monitoring questions outlined in Sections 5.2.1 to 5.2.7 of the WMMP; and

4) Make recommendations on quantifiable triggers for adaptive management based on the results of monitoring programs in the sections of the WMMP described above (see Section 6.0 of the WMMP).

1.4 Report structure

In Section 2, a broad overview of the structure of effective monitoring programs is presented. It is followed by a description of sampling power and its importance in environmental monitoring, particularly in the context of adaptive management.

In Section 3, each element of the wildlife effects monitoring program in the WMMP is summarized including its stated monitoring objective and a description of methods. It is followed by an evaluation of the method and its strengths and weaknesses. A discussion of alternative methods is provided with an assessment of the method.

2.0 ESTABLISHING QUANTITATIVE MONITORING OBJECTIVES

To monitor the effects of a Project and to use the results of monitoring activities to evaluate and adjust mitigation actions (i.e., to adaptively manage) requires that the environmental variables being monitored are quantifiable and have an expected relationship to the effects of the Project. The necessary precision to identify important change in each metric (a measurable environmental variable or indicator) relates to the effect size requiring detection, the variance in the data to be collected, and the confidence and power desired. The precision in turn dictates sample size and distribution.

Consideration should also be given to the available management or monitoring response if the value of a metric crosses a threshold or reveals an effect size determined to be of concern.

2.1 Necessary elements for establishing quantitative objectives

The selection of metrics (indicators) for monitoring is guided by several related factors:

- The existence of an identified important threshold or important effect size for each metric;

- That the metrics be quantifiable;
- That variance can be reasonably estimated; and
- That the required precision of measurement is attainable with available methods, and affordable with the given budget.

2.2 Selection of statistical test, sampling power, confidence

In establishing a formal monitoring program it is important to consider the desired power and confidence of the program in advance, as they are integral to establishing effective monitoring methods for any performance indicator. Confidence, the probability of avoiding a Type I statistical error[1], provides a level of certainty that differences detected and reported through monitoring are true differences and not errors in measurement. Power, the probability of avoiding a Type II statistical error[2], is a measure of certainty that when important changes occur they will be detected (e.g., detecting if a population size has fallen below a pre-determined threshold or if a population growth rate has changed by more than a pre-determined important amount). Determining the ecologically important effect size (the value of a threshold that the indicator may cross, or the level of change in the indicator's value); the amount of change that you want to be able to detect, is an important step in power analysis.

The selection of power and confidence levels is largely a matter of convention. Research studies have routinely adopted confidence levels of 95% or 90% (alpha = 0.05 or 0.10 respectively). More recently, the convention for monitoring programs is to seek a power of 80% when designing studies. Ultimately, the power and confidence adopted must relate to the levels of acceptable risk, the likelihood of success, and the associated costs. These will vary in each case and are important considerations prior to initiating a monitoring program. Prospective power analysis will prepare those involved for the likely results, their strengths and weaknesses, and the associated costs.

Both power and confidence can be improved with reductions in the variance of data collected, with longer studies, with larger sample sizes, and with management actions likely to have larger effects on the performance indicators. An evaluation against a fixed value (i.e., a threshold) has an advantage over the comparisons of two or more estimates. A fixed threshold value has no error in the threshold measurement; hence the measured value of the performance indicator and its variance will influence the

[1] Type I statistical error. In the context of ecological monitoring over time, a Type I error occurs when a parameter (e.g., survival rate or population size) is determined to have changed through time when it has not, i.e., a false detection of change. Setting a higher confidence level for a monitoring program reduces the probability of making a Type I error.

[2] Type II statistical error. In the context of ecological monitoring over time, a Type II error occurs when a parameter (e.g., survival rate or population size) is determined not to have changed through time when it really has changed. The power is the probability that meaningful changes in the parameter of interest will be detected through the monitoring program (i.e., increasing power reduces the probability of a Type II error).

ability of a monitoring program to determine the value of the performance indicator relative to the threshold.

If monitoring a performance indicator value is through measurement between two (or more) periods, there is variance in each measurement of the performance indicator that influences the ability of monitoring to detect change. Accounting for the uncertainty in the performance indicator estimates requires either a larger effect to have occurred, improved precision (requiring larger samples, longer monitoring), or accepting a lower confidence that a change has occurred. When using an absolute threshold for comparison (e.g., determining if a population growth rate is consistent with a stable population), the uncertainty resides entirely within the performance indicator measurement at one point in time.

3.0 TASR EFFECTS MONITORING PROGRAMS

3.1 Traffic monitoring (WMMP 5.2.1)

The objective of the traffic monitoring program is to provide long-term averages of daily traffic levels for comparison with predictions in the DAR. The DAR included a cumulative effects assessment (CEA) that accounted for use of the TASR for access to the community and for cumulative effects including three reasonably foreseeable developments: the Fortune Minerals Ltd. Nico mine; the Nailii Hydroelectric Project at La Martre River Falls; and Tłı̨chǫ/Whatì Park Area at La Martre Falls (GNWT-INF 2017). While there were other factors considered in the CEA, none of them were factors that would affect traffic levels on the TASR or that anticipated the construction of other roads connected to the TASR.

The proposed approach for traffic monitoring is to operate a series of both permanent and seasonal mechanical traffic counters and to conduct visual counts and surveys periodically on a regular schedule to verify automated counts (GNWT-INF 2019, p. 5-39). The traffic monitoring program presented in the WMMP will be highly effective in meeting its objectives as it will count vehicles as they pass and will be validated for accuracy.

The traffic monitoring data that will be collected as described in the WMMP will meet or exceed the traffic data required for comparison with predicted traffic volumes. The availability of hourly traffic information throughout the year will equal or exceed the availability of all wildlife effects monitoring program data making detailed traffic data available as a covariate for other analyses. Traffic data will be a strong component of wildlife effects monitoring. The location of traffic counters can enhance both analyses of the effects of the TASR on wildlife and mitigation of the effects of the road. Similarly, locations for monitoring of seasonal access roads may enhance other monitoring programs. Consideration of needs related to other monitoring programs should be used to inform the locations for traffic data acquisition.

3.2 Access and harvest monitoring (WMMP 5.2.2)

The broad objectives of the access and harvest monitoring program are to monitor hunting along the TASR, hunting in newly accessible areas near the TASR, and the extension of seasonal access through use of the TASR. Both legal and illegal wildlife harvest are of concern. When harvest estimates are available, the sustainability of those harvests will be assessed. Collaborative wildlife monitoring and management between GNWT and the Tłįchǫ Government is proposed, as is collaborative access monitoring with Fortune Minerals. The specific questions for the program are to:

- determine if the highway is resulting in a pattern or level of harvest mortality for moose and caribou that would suggest a conservation concern or need for additional harvest management actions;
- identify who is using the road to access harvest opportunities;
- determine the sex and age structure of the harvested population of moose in the North Slave Region; and
- determine if and where moose are being harvested near the TASR.

3.2.1 Renewable Resource Officer in Whatì

As a result of TASR construction, a new GNWT-ENR Renewable Resource Officer (RRO) position will be created in Whatì. Scheduled patrols (e.g., weekly or semi-weekly throughout the year, more frequently during harvest seasons) by the RRO should be highly effective in documenting:

- points of access from the TASR (e.g., locations of newly established trails, access points to open areas or existing trails for snowmachines or all-terrain vehicles);
- a count of observed hunting groups and their vehicles;
- observations of, or evidence of, successful harvests based on loading points along the TASR;
- information from direct interactions with harvesters; and
- wildlife sightings and collisions (Section 3.6).

A GNWT checkpoint on the TASR is planned during the winter barren-ground caribou season if there is evidence that hunters are using the TASR to access barren-ground caribou.

3.2.2 Collaboration of GNWT-ENR with Tłįchǫ Government and Wek'èezhìı Renewable Resources Board

The ability to build relationships between GNWT-ENR and Tłįchǫ Government (TG) and the Wek'èezhìı Renewable Resources Board (WRRB) will be important for effective harvest management in the TASR study area. Moose and boreal caribou are not abundant in the area and will have limited ability to sustain harvest. Currently, the GNWT-ENR only has information on licensed resident harvest. Knowledge of indigenous harvest will be an important component in making appropriate decisions about licensed harvest in the area. The proposed approach of having community members collect information has been successful in other jurisdictions, such as with the Porcupine Caribou Management Board.

3.2.3 Aerial surveys to monitor harvesting activities

The use of aerial surveys to monitor barren-ground caribou harvesting activities should be effective in confirming hunting activity and identifying access points from the TASR. Coupled with RRO road patrols, access points should be well documented.

In addition to locating and monitoring access points, the effects of the TASR on the distribution of all ungulate species would benefit from knowledge of the spatial extent of hunting activity from the various access points along the TASR. The access trail network branching out from the TASR can be mapped in its current state from existing maps, aerial photographs, satellite imagery, and GIS layers of linear features. Coupled with patrols along the TASR that can identify access points, aerial surveys could be used to plot trail networks, signs of active hunting, and possibly harvest sites. Remotely sensed imagery and aerial photographs may also contribute to such a dataset. Any expansion of trail systems across years may coincide with changes in prey distribution and harvest mortality rates. Knowledge of the areas used by hunters and its relationship to wildlife distribution and abundance will be important in assessing the effects of the TASR and in designing effective mitigation strategies. Though not currently part of the WMMP, mapping the pre-construction trail network branching out from access points would provide baseline data for comparison should the interest and funding become available for future monitoring.

3.2.4 North Slave Region moose jaw collection

The jaw collection program currently operating in the North Slave Region provides an opportunity to collect additional information about number and locations of harvested moose and add sex and age structure to the population estimates for the region. All of these data are valuable:

- for population modelling and harvest management (age, sex, number of harvested moose); and
- for TASR road mitigation.

Additionally, direct interactions with hunters are an opportunity to acquire additional information and share harvest management information and objectives.

3.2.5 Population modelling and management

The information collected from hunters combined with ungulate population monitoring programs (Sections 3.3, 3.4, 3.5) provides the input data for population and harvest modelling. Population modelling can be useful in guiding management decisions, identifying potential harvest thresholds, and identifying information needs.

The GNWT-ENR is currently undertaking a boreal caribou modelling exercise to aid in determining sustainable harvest levels throughout the southern NWT.

3.3 Boreal caribou (WMMP 5.2.3)

The deployment of radio-collars is indicated as a centerpiece of North Slave Regional boreal caribou monitoring. The monitoring objectives described in the WMMP are to help determine:

- *"Where collared boreal caribou are located in relation to construction activities;*

- *If boreal caribou avoid the road during and after construction;*
- *If and where boreal caribou cross the road;*
- *If the rate of boreal caribou movements changes in proximity to the road and, if sample sizes allow, the potential zone of influence of the road on boreal caribou habitat use;*
- *If rates of caribou mortality increase within the study area during and after highway construction; and*
- *The population trend of boreal caribou in the regional Tłı̨chǫ ASR study area"* (GNWT-INF 2019, p. 5-44)

The objectives fall into three broad categories addressed in Subsections 3.3.1 to 3.3.3:

3.3.1 Using collared animal locations to mitigate construction activities

The deployment of radio-collars and the subsequent behaviour of collared animals will give each adult animal in the population an equal probability of having a radio-collar, this may vary if a different proportion of each sex is collared and if gregarious behaviour is sex-specific, but for illustrative purposes I have chosen to consider all animals as equally likely to be collared. Mathematically:

$$p = \frac{i}{N}$$

Where *p* is the probability of a randomly selected animal in the population having a radio-collar, *i* is the number of radio-collars deployed, and *N* is the caribou population size. Conversely, the probability of a randomly selected animal to be without a radio-collar can be represented as:

$$q = 1 - p$$

If we assume that a group will be detected if it contains at least one collared animal, then the monitoring concern is the failure to detect a group because it contains zero collared animals. If we assume that collared animals are distributed at random among all the groups in the population then the probability of a group containing a collared animal will be related to group size. As group size increases it will be more likely that it will contain at least one collared animal. The collective probability of all animals in a group of size *g* being without radio-collars is:

$$q^g$$

and the probability of group containing at least one radio-collared animal is:

$$1 - q^g$$

Rettie (2019) summarized areas of interest for GNWT-ENR boreal caribou population monitoring, modelling, and harvest management. Included was a North Slave study area of 22,204 km^2, an area that includes most of the TASR study area for boreal caribou. If a minimum population density of 1 caribou per 100 km^2 is assumed for North Slave (TASR) study area, the population estimate is 222 caribou (N =222). The TASR WMMP commitment for monitoring is for 30 boreal caribou to be radio-collared at all times (i = 30). From the equations above the probability of a randomly selected caribou having a radio-collar is:

$$p = \frac{30}{222} = 0.135$$

and the probability of it not having a radio-collar is:

$$q = 1 - 0.135 = 0.865$$

Figure 2 shows a range of group sizes plotted against the probability of a group of that size containing at least one radio-collared individual. The North Slave (TASR) study area probabilities are based on 13.5% of animals being collared and three additional levels of collaring intensity (10%, 20%, and 25%) are plotted for reference. The probability of a group containing at least one radio-collared individual effectively represents the probability of detection of groups of various sizes when using telemetry data to locate groups.

Assuming 30 radio-collars in a population of 222 caribou, to have a 50% chance of detecting a group of boreal caribou in the North Slave (TASR) study area through its inclusion of at least one radio-collared individual, the group would need to have a minimum of 5 animals (Figure 2, red dashed lines). Average group sizes observed during GNWT-ENR winter classification surveys conducted in the TASR study area were 6.1 (Hodson and Patenaude 2018) and 5.1 (Hodson 2019); groups whose sizes make their likelihood of detection between 52% and 58% when 13.5% of the caribou in the North Slave (TASR) study area are radio-collared. The largest group observed during the two years of winter surveys was 16 caribou.

If the North Slave (TASR) study area population is larger than 222 caribou, the probability of each individual being without a radio-collar would increase and the probability of a group of a given size to contain at least one collared animal would decline; the effect would be to lower the solid black line plotted in Figure 2. Conversely, if the proportion of animals in the vicinity of the TASR with radio-collars is above the 13.5% calculated for the North Slave (TASR) study area then groups of each size will have a higher probability of being detected. Based on 2018 and 2019 survey results (Hodson and Patenaude 2018, Hodson 2019), and considering only animals likely to interact with the TASR (GNWT-ENR personal communication) yields a percentage of animals collared of between 22% and 25%; consistent with >50% detection of groups of ≥3 caribou (Figure 2).

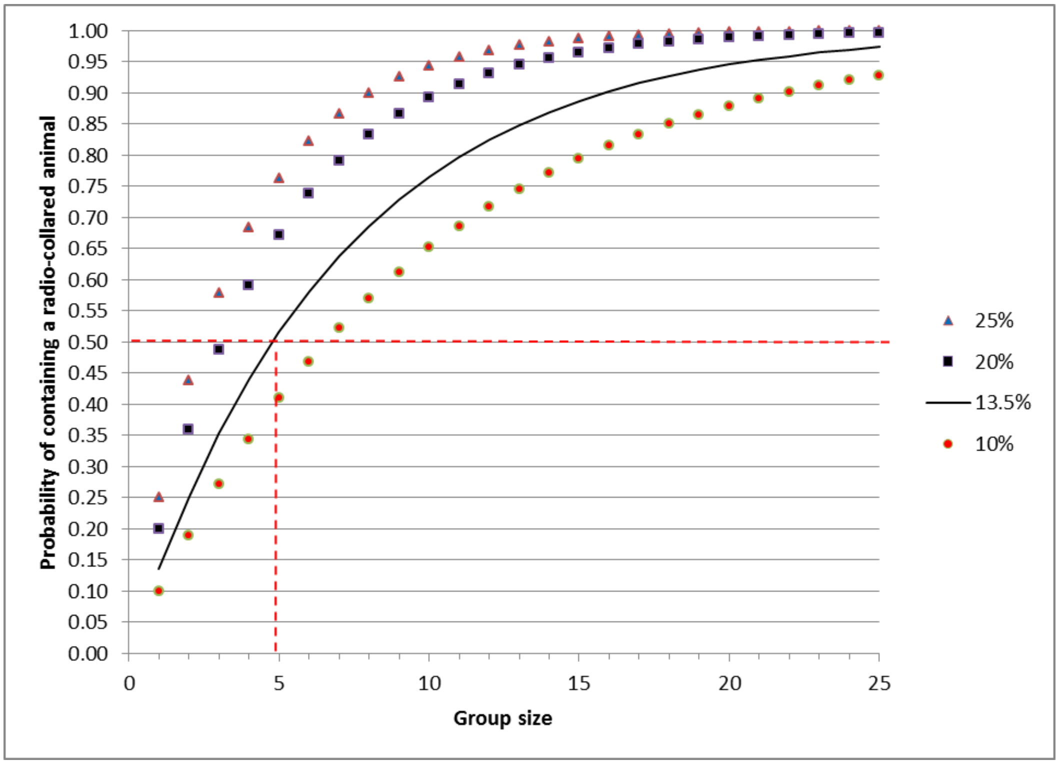

Figure 2: Probability of detection of different sized groups of boreal caribou (equal to the probability that the group contains one or more radio-collared caribou). The four sets of data indicate the percentages of all caribou in the area that are radio-collared (black line, 13.5% [North Slave (TASR) study area caribou currently collared]) and other potential percentages of animals collared (10%, 20%, 25%) Based on the 2019 aerial survey minimum population count, up to 25% of caribou likely to interact with the TASR are currently collared. Horizontal red dashed line shows 50% probability of detection.

The use of telemetry data to attempt to mitigate the effects of construction (or operations) activities in real-time is unlikely to be completely effective as:

- the majority of groups of ≤ 3 caribou will not contain a radio-collared individual. This is of particular importance during calving , post-calving, and summer periods when female boreal caribou are with a single calf or are solitary (i.e., a group size of 1 or 2);
- many larger groups will also not contain radio-collared individuals; and
- there is a time lag of up to two days between telemetry data acquisition by the radio-collar and data acquisition by GNWT-ENR.

It is important to use the telemetry data that are available as they will accurately track individuals and identify some groups close to the road; however the absence of telemetry locations close to the road will not indicate the absence of caribou in the area at any given time.

3.3.2 Resource selection by caribou relative to the TASR and other environmental factors

Three of the monitoring objectives can be grouped together as relating to determination of resource selection including the TASR as an environmental covariate. The commitment to deploy radio-collars on a minimum of ten animals in the vicinity of the road; to maintain data collection for a minimum of five years during TASR operation; and to increase the rate of data acquisition when collared animals are within 10 km of the road will generate a data set sufficient to allow resource selection functions to be determined for caribou in the region and to determine the effect of the road on caribou behaviour. The collection of hourly traffic flows will further enhance the analyses of caribou behaviour and the role not only of the presence of the road but the contributing role of traffic volume to any observed barrier effect. Effects on speed of travel, probability of crossing, and the relationships of these behaviours with other habitat covariates should all be possible under the data collection proposed. The fine spatial and temporal scales of the location and covariate data sets will lend themselves to step-selection analyses to identify key corridors, environmental covariates, and traffic patterns (e.g., Beyer et al. 2016; Prokopenko et al. 2017) and lead to the implementation of effective mitigation strategies.

The use of telemetry data to identify the effects of the Project on caribou behaviour and the relationships between behaviour and environmental covariates (including the TASR) has a high potential to contribute to effective long-term mitigation.

3.3.3 Caribou population and mortality monitoring

Population trend monitoring

The vital rate of greatest interest is Lambda (λ), the population growth rate (GNWT-INF 2019, Section 5.2.3). Lambda can be calculated in a number of ways, but combining adult female survival estimates from radio-collared animals with recruitment estimates from late winter composition aerial surveys (Hatter and Bergerud 1991; Hervieux et al. 2013) is the most common method used for boreal caribou in Canada (Rettie 2017). Estimates of adult female survival and recruitment are conducted annually by GNWT-ENR and combined to estimate λ. As noted in Section 3.3.1 above, the North Slave (TASR) study area for boreal caribou is largely within the North Slave study area monitored by GNWT-ENR, though the North Slave (TASR) study area also includes part of the Mackenzie boreal caribou study area (Figure 3). In a recent population and harvest modelling report (Rettie 2019), the boreal caribou vital rate data for the North Slave study area were combined with data from the Dehcho North and Mackenzie study areas for the period from 2008 to 2018 to represent vital rates in NWT Wildlife Management Zone R (Zone R). Combining the data from the three study areas was considered to:

1. provide a better representation of the variation in vital rates for the region;
2. compensate for there being only 1 year of vital rate data in the North Slave study area at the time; and
3. recognise that individuals from all three areas occasionally move across study areas.

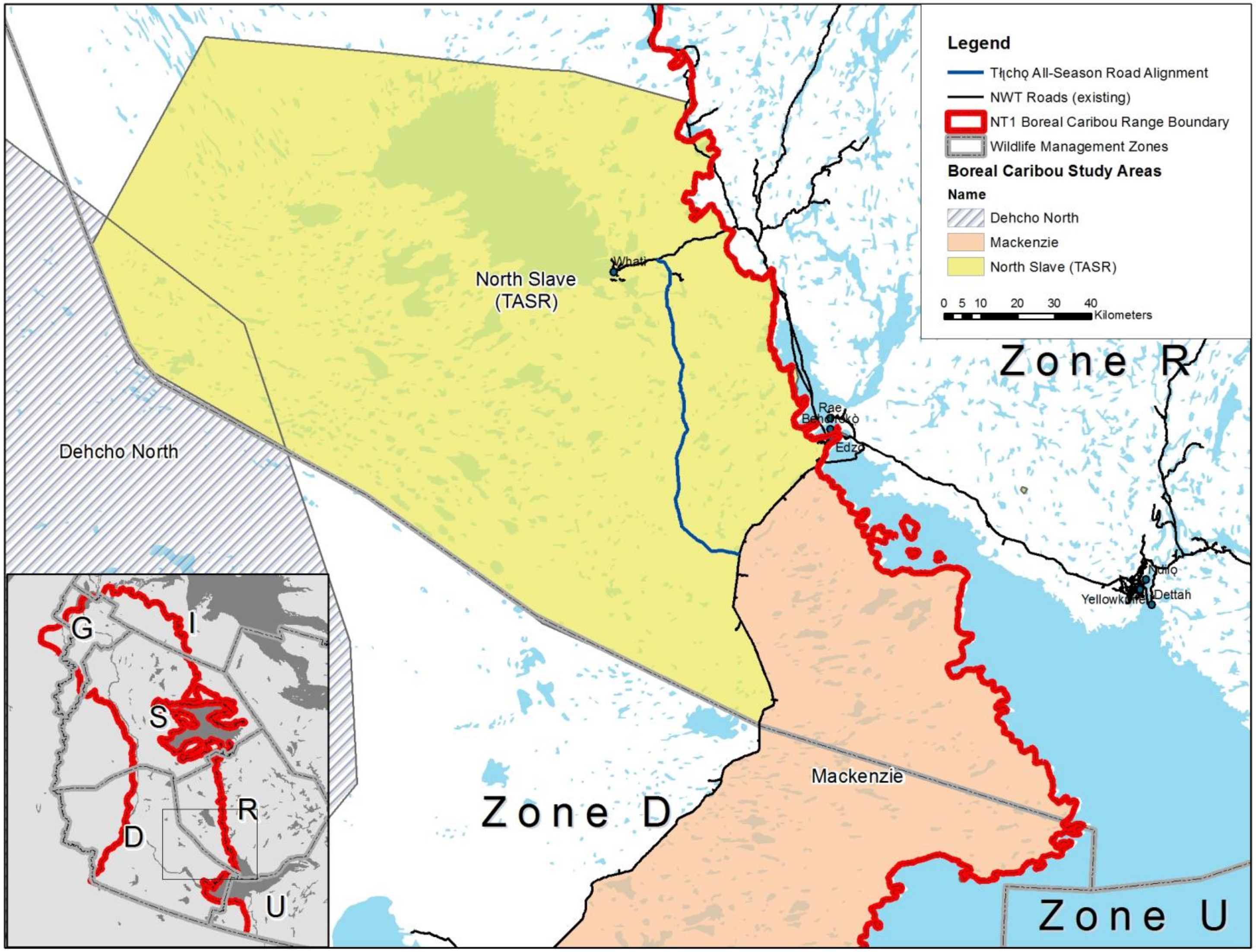

Figure 3: The North Slave (TASR) study area for boreal caribou.(GNWT-ENR).

The power of the proposed TASR monitoring to detect changes in λ was assessed through simulations using existing data presented in Rettie (2019). To assess the relationship between data from TASR study area radio-collared caribou survival and aerial composition surveys and the precision of survival, recruitment, and population trend estimates, a Monte Carlo modelling exercise was undertaken in R version 3.3.3 (R Core Team 2017). Empirical survival and recruitment data from 2008 to 2018 were pooled and as described above and used to provide input values for the simulations for Zone R. The simulations followed those used by Rettie (2017) to determine the likely variation in key vital rates when a sample of 30 radio-collars is maintained on a boreal caribou population (in March 2019 the TASR study area contained 30 radio-collared boreal caribou [Hodson 2019]). Knowledge of variation in survival, recruitment, and population growth rates over monitoring periods of different lengths determines the power of the monitoring program to detect changes in those parameters. The coefficients of variation (CV) for survival, recruitment, and λ were calculated for each simulation and are presented in Figure 4.

Figure 4a presents the CVs of annual adult female survival based on simulation of three- to nine-year monitoring programs with 30 radio-collared caribou. The results show that three-year monitoring programs are likely to include considerable variation in annual survival estimates; that the precision of those estimates improves for five- and seven-year programs; and that nine-year programs produce stable results with a CV of approximately 3%. Recruitment estimates (Figure 4b) have higher CVs for all monitoring time periods than those observed for annual survival, revealing that recruitment is more highly variable year-to-year than is survival. There is a reduction in recruitment CV with longer term monitoring and the CV for nine-year monitoring is approximately 10%. With Zone R recruitment values of between 0.20 and 0.45 calves per cow annually (Rettie 2019), a 10% CV represents a 95% confidence interval of between 0.04 to 0.09 calves per cow. For the purposes of WMMP objectives, λ is the most important parameter for evaluation. From simulations based on pooled data to represent Zone R data there is a decrease in the CV of mean λ from 5.4% to 3.2% between 3-year and 9-year studies (Figure 4c).

The geometric mean population growth rate of boreal caribou in Zone R (based on pooled data) between 2008 and 2018 was λ=1.038 (Rettie 2019). Figure 5 shows the power to detect change between λ=1.038 and a range of potential future λ values (determined in the computer program PASS with confidence set at 0.80 [Hintze 2008]). The power of detection is determined by the degree of change in λ and the CV of λ. Figure 4 presents precision in terms of CV of each parameter; while Figure 5 uses standard deviation; when the mean value is 1.00 the standard deviation and the CV are equal. For the purposes of comparisons presented here, all of which hold λ near 1.00, the CV and sample standard deviation have been considered equivalent. The standard deviations plotted in Figure 5 cover the range observed for three- to nine-year simulations. Figure 5 shows that a nine-year monitoring program (standard deviation=0.032) has 50% power to detect a decline to λ = 1.00 and 80% power to detect a reduction if λ declines to 0.975. With a five- or seven-year monitoring program (where simulated λ CVs are approximately 0.043), the power to detect a reduction of λ to 1.00 is approximately 38% and λ would need to decline to approximately 0.93 before there was an 80% chance of it being detected.

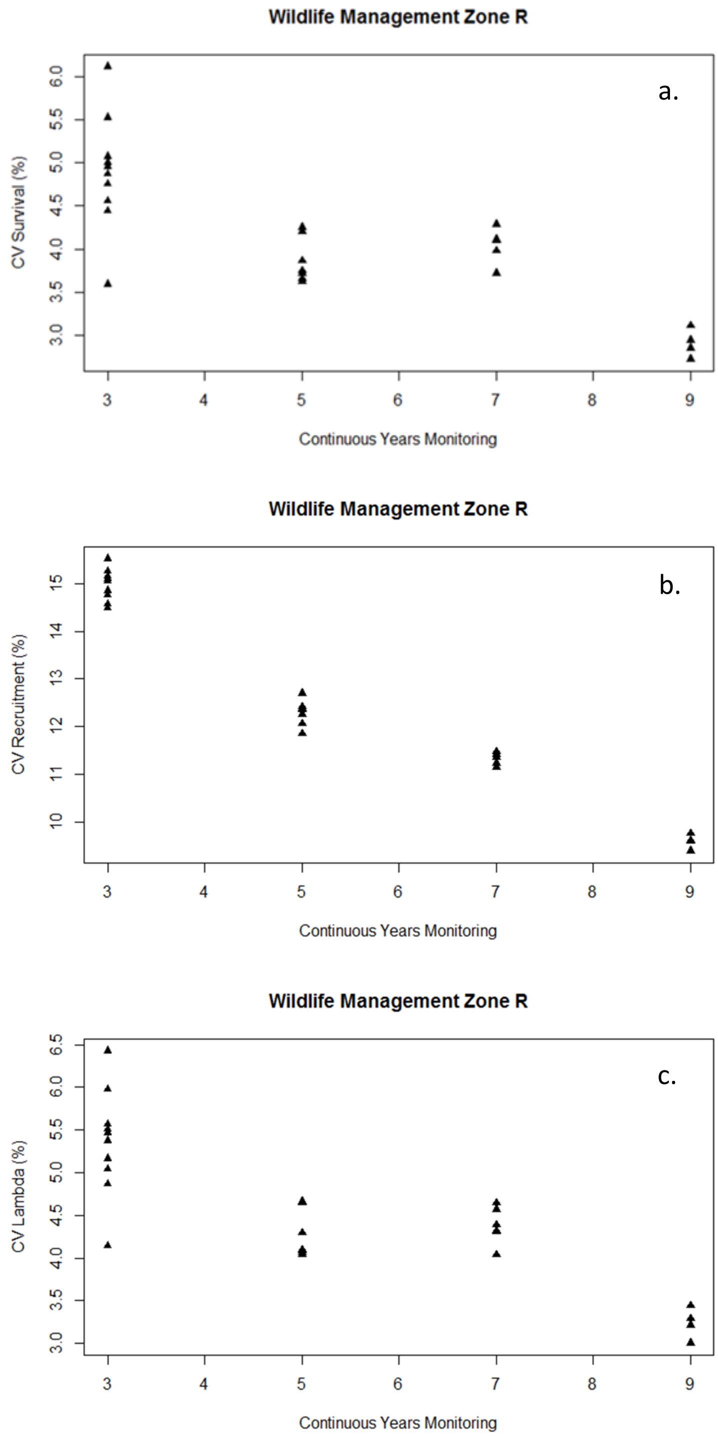

Figure 4: Coefficients of Variation for vital rates calculated through 3-, 5-, 7-, and 9-year simulations of data from a study with 30 radio-collars. Based on boreal caribou data from Dehcho North, Mackenzie and North Slave (TASR) study areas pooled to represent Wildlife Management Zone R; (a) adult female survival rate, (b) recruitment rate, and (c) population growth rate [Lambda].

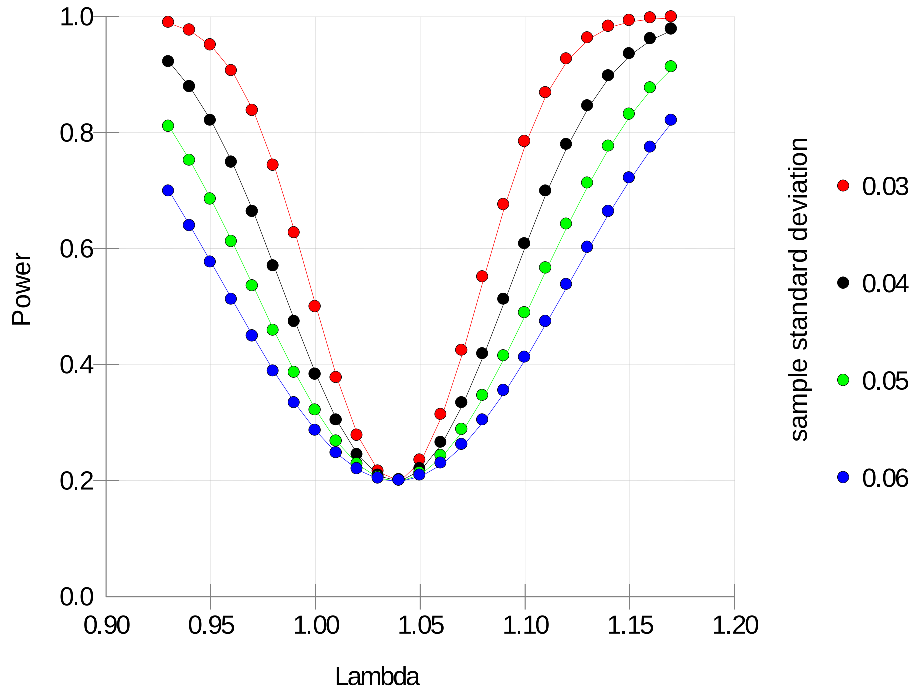

Figure 5: Power to detect change from 2008 to 2018 Wildlife Management Zone R Lambda of 1.038 relative to the sample standard deviation of Lambda from radio-collared caribou survival and aerial survey recruitment rates. Alpha is set to 0.20 (80% confidence).

The methods identified in the WMMP to calculate survival, recruitment rate, and λ are all appropriate and supported by the literature and standard practices for determining boreal caribou demographic parameters (Rettie 2017). Ongoing population trend monitoring using radio-collared adult female survival and annual recruitment surveys can be reasonably effective in detecting a decline of boreal caribou below a self-sustaining level within wildlife management Zone R. Any changes to survival, recruitment, and λ determined through these methods will be most representative of the changes in the areas containing radio-collared animals and monitoring may not reflect population changes in Zone R as a whole; the results should be interpreted carefully. Several scenarios are possible:

- Currently the radio-collared caribou in Zone R are in the southern half of the Zone, within the North Slave (TASR) study area. Other animals in the northern part of the study area are less likely to be affected by the TASR and are not included within the portion of the population being monitored. Consequently, the demographic parameters derived from monitored individuals will better represent the effects within the North Slave (TASR) study area rather than the effects within Zone R as a whole; collectively, Zone R caribou will be less affected by the TASR than monitoring results will suggest;

- At a finer scale, the North Slave (TASR) study area (Figure 3) is large enough that only some animals may interact with the TASR. Changes in survival and reproduction within the North Slave (TASR) study area may vary relative to proximity to the TASR at this scale, though inferences to the entire North Slave (TASR) study area may be appropriate;
- Overall, the effects on caribou in the region are likely to be localized in the parts of the North Slave (TASR) study area closest to the TASR where caribou density may be expected to decline and where behavioural changes are more likely to be observed. The distribution of radio-collared animals and recruitment survey effort will affect calculations of demographic parameters and the area about which inferences should be made.

In the future, if the affected portion of the Zone R population resident in the North Slave (TASR) study area contains few radio-collared animals, then there will not be sufficient power to confidently detect a localized population decline with these methods. Finally, if some limiting factors are biased in radio-collared caribou then the population trend will misrepresent population growth. Of particular concern is the potential for hunter harvest to be underestimated if hunters avoid shooting radio-collared animals, as has been observed for other species (Jacques et al. 2011). Harvest monitoring (Section 3.2) will provide information that may be useful to adjust survival estimates from radio-collared animals.

Population surveys

Methods are under consideration for population surveys including aerial surveys and genetic-based methods using DNA obtained from fecal pellets surveys (GNWT-INF 2019, Section 5.2.3). For all population survey methods, including fecal pellet surveys, a key factor is that sightability of less than 100% adds uncertainty to all wildlife survey estimates, including the estimates that would result from the methods being considered for TASR boreal caribou.

Two-stage population surveys (Courtois et al. 2003) have been widely employed in Quebéc. These consist of first stage survey with fixed-wing aircraft to assess population size, followed by helicopter surveys to determine composition. In their original survey work Courtois et al. (2003) had 20 radio-collared caribou in their survey area and determined sightability from observations of radio-collared animals in each stage of the survey. Overall, they determined sightability at 85% (SE = 8%) for all caribou, a value that has been applied as a correction factor for some other caribou population survey estimates in Quebéc. Fieberg and Giudice (2008) cautioned against applying a common sightability correction factor outside survey units with similar covariate values. As factors that influence sightability vary among surveys, this caution should be extended to avoid use of common correction factors for different survey years. The application of a standard correction factor will not correct the uncertainty associated with imperfect sightability as multiple survey-specific factors affect sightability including vegetation cover, animal behaviour, group size, snow cover, sunlight, topography, and observer experience (e.g., DeMars and Boutin 2013; Zabransky et al. 2016). Additionally, the application of the same correction factor to data from every survey will not alter the ability to detect change in the population as each population estimate will simply be scaled up by the same value. Consequently, a sightability correction factor should be determined for each population survey. Though not detailed in the WMMP, the calculation of survey-specific correction factors is planned by GNWT-ENR (personnel communication).

Despite the high sightability results of Courtois et al. (2003), it is not uncommon for fewer than half the animals in an area to be seen by observers in aerial ungulate surveys (e.g., elk, Vander Wal et al. 2011; moose, Peters et al. 2014; mule deer, Zabransky et al. 2016) and sightability can vary substantially from survey to survey. Serrouya et al. (2017) reported high winter sightability for some local population units of the Southern Mountain population of woodland caribou; the survey conditions in their study area differed from those for boreal woodland caribou populations in the study area.

There are several methods to determine sightability using mark-and-resight methods (e.g., Mahoney et al. 1998; Courtois et al. 2003, Adams and Roffler 2005, 2007; Hegel et al. 2016). Adams and Roffler (2005, 2007) worked with populations with 98 and 138 radio-collared caribou (in 2005 and 2007 respectively) providing them with a large number of potential sightings in blind surveys. They determined sightability in each of the two surveys relative to group size: for single animals sightability was 45% and 47%; and sightability increased with increasing group size to 96% when group size was ≥20 caribou. The CVs of their final population estimates were 4.5% and 7% for the two years. In each survey year there was extensive survey effort and a population where between 14% and 18% of the population (98 and 138 animals) were radio-collared.

The current deployment of 30 radio-collars in the TASR with additional collared animals in the adjacent Mackenzie study area provides a reasonable sample size (approximately 40 radio-collared caribou) for building a sightability correction factor for boreal caribou in the TASR study area. However, even repeated, relatively precise surveys (e.g., Adams and Roffler 2005, 2007) have low power to detect changes in a population over time. To demonstrate the power to detect relative differences between two consecutive population estimates, a simulation was completed with standard errors (SEs) of between 5% and 20% of the initial population mean. A hypothetical estimate of 1.00 was adopted and compared with a range of values between 0.50 and 1.50 (equivalent to between 50% population reduction and 50% population increase). A two-sample t-test (Hintze 2008) was used to compare the ratio between two values, each value with SEs between 0.05 and 0.20 (note that the SEs are absolute values; they are equal to CVs of 0.05 to 0.20 for the initial population level of 1.00, but the CV range increases to 0.10 to 0.40 when the population has declined to 0.50 and the CV range declines to 0.03 to 0.13 when the population has increased to 1.50). With alpha = 0.20, and an SE = 0.20 (Figure 6, blue line) there is 69% chance (i.e., power = 0.69) of detecting a 50% change in the population (i.e., a decline to 50% of the initial estimate or increase to 150% of the initial estimate). With an SE in each estimate of 0.10 (Figure 6, black line) the power of the monitoring program improves but would still require a population increase or decrease of approximately 30% to have 80% power. Even with precise population estimates with SEs near 5% as obtained by Adams and Roffler (2005, 2007), the ability to detect population change through the comparison of separate population estimates has little probability of detecting population changes unless they are approaching 20%. Further, the simulated range of SEs (0.05 to 0.20 [5% to 20% of the initial population value]) is precise compared to empirical results for forest ungulates where population survey results may yield SEs in excess of 50% (e.g., DeMars and Boutin

2013), though Courtois et al. (2003) report an SE of 9.4%; SEs > 20% reduce the power to detect differences between two population survey estimates below those plotted in Figure 6.

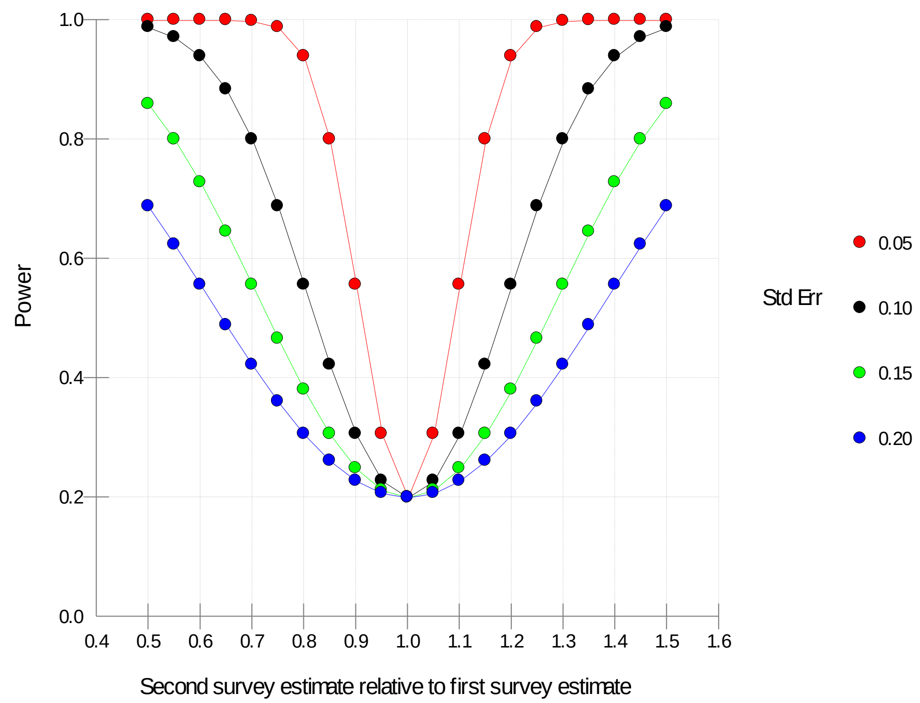

Figure 6: Power to detect a change in population size between two independent population survey estimates relative to the standard error of the population estimates. The estimates are scaled against each other such that the first estimate is assumed to be 1.00 and the second estimate reflects proportional increase or decrease. Alpha was set to 0.20 (80% confidence).

Overall, imprecision of population estimates for boreal caribou makes comparison of population estimates an inefficient method of detecting population changes over time except when the population changes are extremely large.

The 40 radio-collared caribou in and near the TASR study area will likely provide adequate data from which to construct a reasonable sightability estimates to assist in correcting for missed observations. Though repeated surveys are likely to lack power to detect population changes of less than 30%, an initial population estimate corrected for sightability will assist in assessing the potential effects of actual or proposed levels of harvest in the study area. It will also serve as a pilot study for the method in the NWT. Should more precise population estimates be desired, DeMars et al. (2015) proposed a pilot study to investigate sightability from multiple source of information (including occupancy estimation, double observer aerial surveys, detection probability from pellet surveys, and mark-resight surveys of radio-collared caribou) to provide improved precision in boreal caribou population estimates. The results of such a project may lead to improvements in survey precision.

Mortality surveys and investigations

The use of GPS radio-collars with same-day satellite data delivery will provide timely acquisition of mortality event and location information. The pooled data used to represent Zone R adult female boreal caribou had an annual mortality rate of 12% from 2008 to 2018 (Rettie 2019). At the same mortality rate, with 30 radio-collars deployed in TASR study area there would be an average of three or four mortalities of collared caribou per year, to an estimated total of 18 caribou in a five year period. A commitment to daily monitoring of mortality status and rapid response of staff to investigate each mortality site might yield cause of death for each of these animals, but any delays in site investigations and the varying circumstances of each mortality will reduce the number of mortalities where cause of death is certain; the number of mortalities from known causes is the sample size. Between 2004 and 2017 there were 44 recorded mortalities of radio-collared caribou in the pooled data representing Zone R (GNWT-ENR unpublished data); cause of death was determined for 34 animals, of which 21 (approximately 60%) were attributed to wolf predation. Power analysis to determine the ability of the monitoring program to identify changes in the proportion of mortality from any one cause was run using an inequality test for two proportions (Hintze 2008); the baseline mortality rate for the cause of death was set at 60%. The results are presented in Figure 7.

Power analysis suggests that, with modest sample sizes, a large change in the numbers of mortalities attributed to a single cause would need to occur to have reasonable probability of being detected. E.g., with 25 mortalities in each group (Figure 7, black line), 80% power of detection is achieved only when an initial proportional cause of mortality of 0.60 falls to 0.30 or rises above 0.85. With 30 radio-collared boreal caribou and an annual mortality rate from all causes of 0.12, the small sample sizes that might be attributed to each cause of death make it unlikely that the effects of TASR on changes in the percentage of mortalities from each source will be possible to determine.

Radio-collaring of caribou in the TASR study area began in March 2017. To December 2019 there had only been two mortalities of collared animals (GNWT-ENR unpublished data).

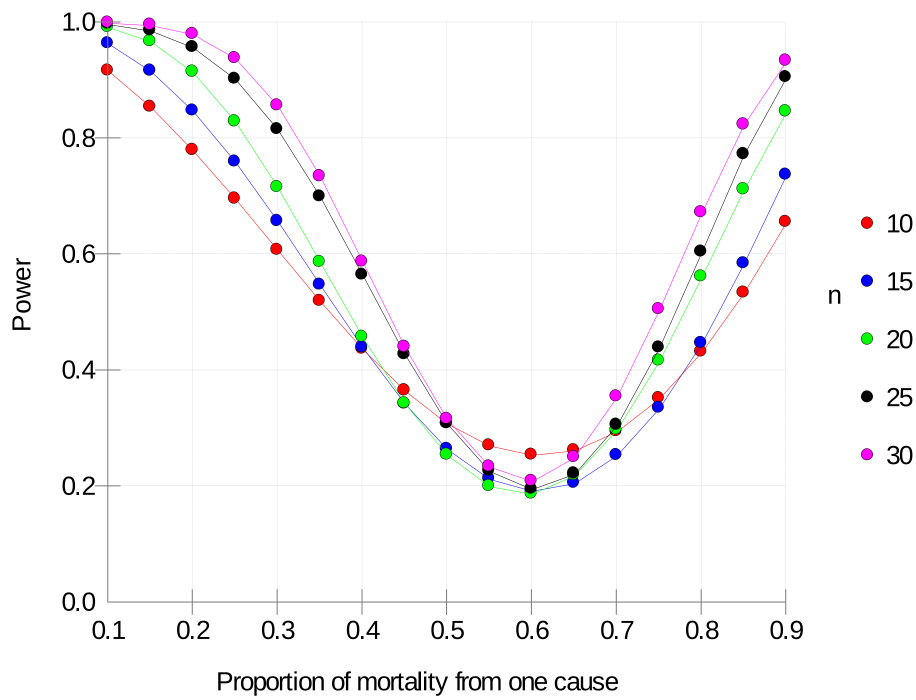

Figure 7: Power to detect a difference between the proportion of animals dying from a single specific cause of mortality in two separate samples (e.g., mortalities before and after an event, or mortalities from two different locations). The sample size is identical for both groups. In the reference population the cause of mortality (e.g., wolf predation) is assumed responsible for 60% of all deaths of animals in the sample. The proportion dying from the same cause was varied from 0.10 to 0.90 in the second group. Sample sizes (*n*) of between 10 and 30 in each sample were modelled and are represented by different coloured symbols and lines. Alpha was set to 0.20 (80% confidence).

3.4 Barren-ground caribou collaring (WMMP 5.2.4)

3.4.1 Use of individual radio-collared animals to monitor proximity to TASR

As with boreal caribou, the use of radio-collared caribou to detect animals and provide warning of animals near the road is dependent on the herd population size, the number of radio-collars deployed, and the group size. See Section 3.3.1 above for the details on the general efficacy of using radio-collared animals to detect group proximity to the TASR. Table 1 shows the relevant data for both the Bluenose East and Bathurst herds while Figures 8 and 9 show the relationship between group size and its detection probability within each herd.

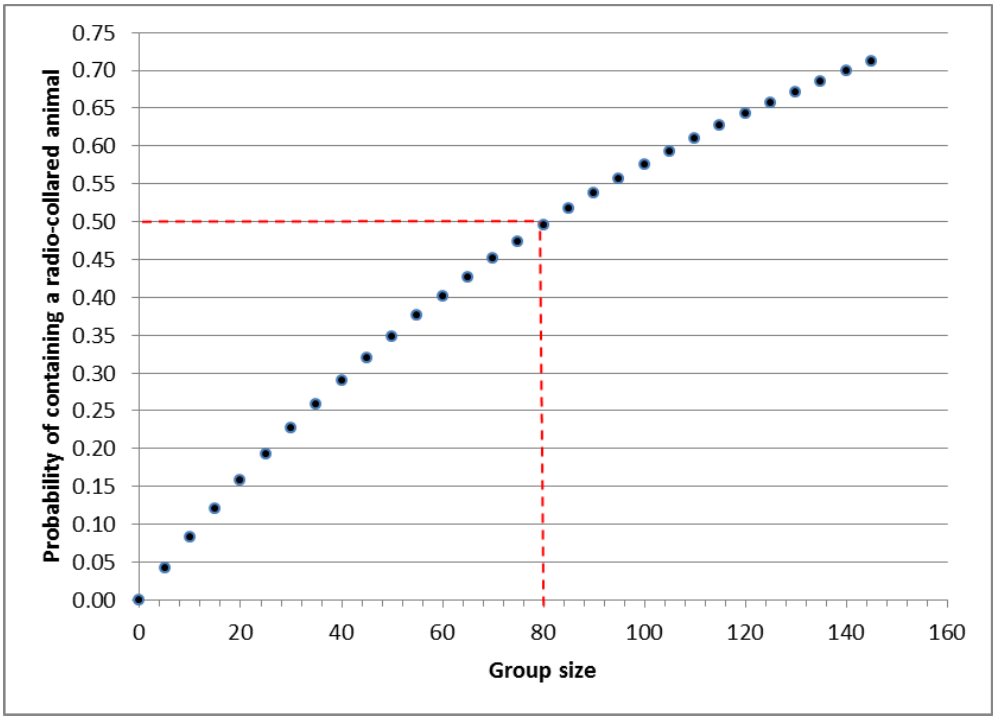

Figure 8: Probability of detection of a group of Bathurst caribou based on its inclusion of at least one radio-collared animal.

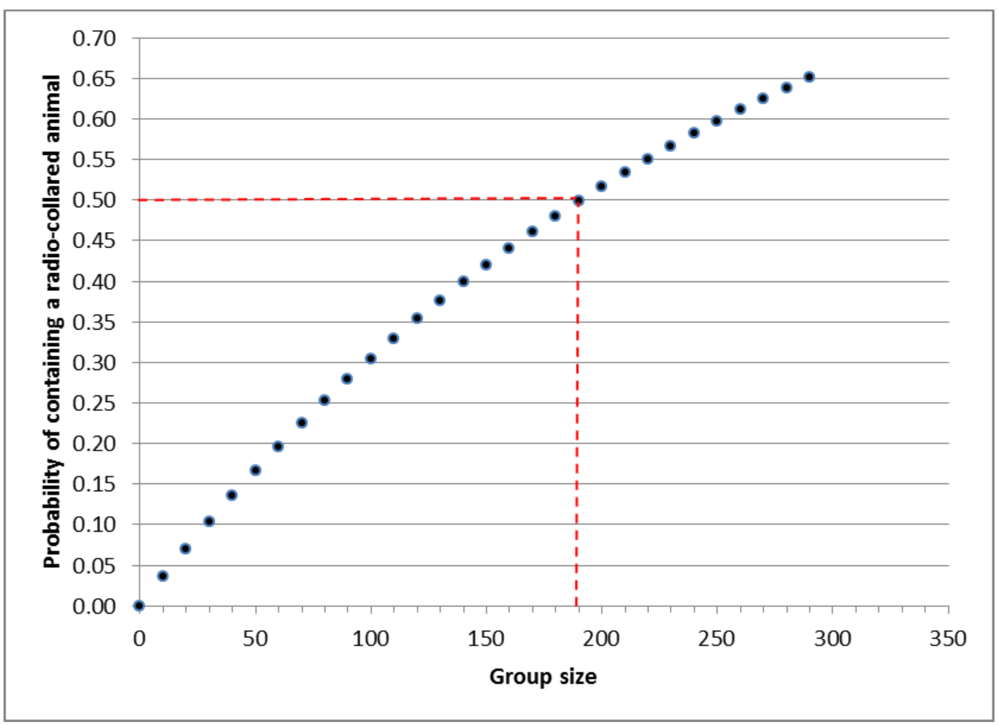

Figure 9: Probability of detection of a group of Bluenose East caribou based on its inclusion of at least one radio-collared animal.

Table 1: Radio-collaring probabilities for Bluenose East and Bathurst caribou herds

Parameter	Bathurst herd	Bluenose East herd
Population size[1]	8207	19,294
Number of collars recommended[1]	70	70
Probability of being collared	0.009	0.004
Probability of not being collared	0.991	0.996

[1] Bathurst herd data from Adamczewski et al. 2019. Bluenose East data from Boulanger et al. 2019.

As observed for boreal caribou, the group sizes required to have a 50% probability of detection are quite large; 80 animals for the Bathurst herd and 190 animals for the Bluenose East herd. Depending on telemetry locations to attempt to mitigate the effects of TASR construction or operations activities in real-time is unlikely to be effective as it is unlikely that any given group of animals will contain a radio-collared individual.

Aerial surveys of the Bluenose East and Bathurst caribou herds were conducted by GNWT-ENR in November 2019 and provide recent evidence of group sizes for the two herds. The Bathurst herd survey result was 2009 individual caribou in 43 groups of between 6 and 290 animals (GNWT-ENR unpublished data). The Bluenose East herd survey result was 3436 caribou in 144 groups of between 2 and 209 caribou (GNWT-ENR unpublished data). From the November 2019 survey observations, 7 of the 43 groups (16%) observed in the Bathurst herd had more than 80 animals, each group with ≥50% chance of having a radio-collared animal in them and being detected through radiotelemetry; the 7 groups contained 1127 caribou (56% of all animals observed). From the Bluenose East survey observations, 2 of the 144 groups had more than 190 animals, each group with ≥50% chance of having a radio-collared animal in them and being detected with radiotelemetry; the 2 groups contained 401 caribou (1.3% of all animals observed). These results illustrate the limitations of relying on radio-collared animals to detect caribou groups and mitigate effects of the TASR.

Alternatively, an effective use of barren-ground caribou location data to identify times and locations of concern for caribou interactions with TASR might be a process similar to that used to define the Mobile Core Bathurst Caribou Management Zone. The set of current location data (e.g., daily or weekly) from each of the two herds could be used to create herd-specific polygons or utilization distributions (UDs) that could be compared with the 10 km threshold established for the TASR (GNWT-INF 2019, Section 5.2.4). When either an individual radio-collared animal or a herd-specific polygon comes within 10 km of the TASR, the mitigation action of patrols to monitor caribou along the road could be initiated.

3.4.2 Other uses of barren-ground caribou telemetry data for mitigation

The Bluenose East and Bathurst caribou herds have distinct seasonal ranges that may shift among years. The proximity of caribou from both herds to the TASR is highly seasonal. Seasonal ranges for the Bluenose East herd do not overlap with the Project area (GNWT-ENR, 2008 to 2017 unpublished data); coming south to the northern tip of Lac La Martre in winter and during spring migration. The seasonal

90% UDs for the Bathurst herd have never overlapped the Project area (data collection began in 1996) and have not come within 100 km of the Project area since at least 2008 (GNWT-ENR unpublished data). As for the Bluenose East herd, Bathurst animals have historically been closest to the Project area in winter and spring migration seasons.

Calculating seasonal UDs for each season for each year for each of the Bathurst and Bluenose East herds will provide information necessary to track long-term shifts in range distribution for each herd. Concerns of interactions between barren-ground caribou and the TASR can be reserved until a time when a pattern of seasonal range shifts indicates movement towards the TASR. The current sample sizes of radio-collared animals in both the Bluenose East and Bathurst herds and the frequency of location acquisition will be effective to yield the necessary telemetry data to track long-term changes in seasonal range UDs for the Bathurst and Bluenose East herds.

3.5 Moose and bison population monitoring (WMMP 5.2.5)

Under the WMMP, aerial surveys to estimate populations of both wood bison and moose are scheduled for the TASR study area every three years.

"Data obtained from population monitoring conducted in the regional Tłı̨chǫ ASR study area will help to determine:

- *If the relative abundance of moose in the Tłı̨chǫ ASR regional study area changes over time. This will help to identify potential conservation concerns related to the road and hunter access.*
- *Whether changes in the abundance of moose in the Tłı̨chǫ ASR regional study area are qualitatively similar to what is observed in North Slave Regional surveys.*
- *If and at what rate bison expand their range northward along the road corridor.*
- *If the relative abundance of bison in the Tłı̨chǫ ASR regional study area changes over time."* (GNWT-INF 2019, p. 5-52)

3.5.1 Aerial population surveys

Recent aerial surveys for bison and moose in the NWT have used distance sampling to correct for imperfect detection of animals, including the 2016 North Slave moose survey and the 2019 Mackenzie wood bison survey (GNWT-ENR unpublished data).

In February and March 2018 the GNWT-ENR completed a multi-species (moose, bison, wolf, and boreal caribou) survey within a 10,000 km^2 study area centred on the TARS alignment and within the broader TASR study area for boreal caribou (Hodson and Patenaude 2018). The fixed-wing survey had 2-km transect spacing and required 47 hours of survey time. There were 27 observations of bison (groups sizes ranged from 1 to 54 bison) in the southern half of the study area. Moose were observed in 34 groups of 1 to 3 animals, distributed throughout the study area. Buckland et al. (2001, p. 240) recommend at least 60 to 80 independent observations of a species in order to estimate a reliable detection function; hence, sample sizes were inadequate to estimate a detection function for either species.

In their review of applicable methods for NWT bison monitoring, Boulanger et al. (2015) supported distance sampling as the best approach for population surveys of NWT bison and noted the opportunity to pool data across years to create a detection function. In the same study area, with the same covariates, this may be an option for the TASR study area. Another option is to include the TASR study area with bison and moose surveys being conducted in adjacent areas. The TASR study area is adjacent to the Mackenzie bison population range and could be integrated into Mackenzie range surveys with a common detection function calculated for bison. The TASR study area is also within the broader area of previous North Slave region moose surveys and an integration of moose surveys between the two areas would produce the sample sizes required to estimate reliable detection functions for moose in both areas. Though not surveyed in the same year, the 2018 TASR data and the 2016 North Slave moose data were combined experimentally to provide a sufficient number of moose observations to estimate a detection function (GNWT-ENR unpublished data); the result was an estimate of 125 moose within the TASR survey area with a CV of 24%.

3.5.2 Wood bison monitoring

Boulanger et al. (2015) conducted power analysis on the ability to detect change in the Mackenzie bison population from successive distance sampling estimates. They looked at both regression analyses across multiple survey years and using t-tests for two surveys in different years. The modelling conducted by Boulanger et al. (2015, p. 56-57) for paired sample t-test comparisons of estimates, while presented differently, is essentially the same as the analyses presented in Section 3.3.3 for boreal caribou: adopting Boulanger et al.'s (2015) target CV of 15%, 80% power is attained when the population declines to approximately 54% of its initial value (Figure 6). A persistent annual decline of 19% would lead to a three year overall population decline of 47%. If that is an acceptable detectable effect, and if a population estimate CV of 15% is attainable, then distance sampling appears adequate to monitor wood bison in the TASR study area.

Rather than a more intensive occupancy survey to determine range expansion, simple plotting of survey observations may be adequate to provide change through time, augmented by local observations and observations made during other surveys. A more precise estimate of range expansion could be obtained through occupancy estimation. One option is restricted spatial regression occupancy estimation (Johnson et al. 2013), an approach that accounts for spatial autocorrelation where the probability of occupancy of a sampling unit is based on observations made in that unit, sample unit covariates, the detection covariate, and observations and covariates of nearby units. If conducted within a reasonable time after population surveys, the population survey data might serve to establish the survey area near the limit of distribution and provide an initial set of observations in the occupancy cells.

3.5.3 Moose monitoring

Combining the North Slave and TASR moose surveys would serve at least two purposes:

- To increase the sample size of observations for calculating detection functions;

- To provide comparable data (i.e., same survey crews, same sampling year, same survey conditions) for comparison of the North Slave and TASR study area populations.

As with boreal caribou and wood bison, the ability to detect changes through time is dependent on the magnitude of change and the precision of the survey estimates. Figure 6 shows the power to detect proportional changes in a population with a range of SEs of the estimates (as the reference value in the figure is a population of 1.0, the SE is the same as the CV for the reference population). The experimental combination of 2016 North Slave moose survey data with 2018 TASR moose survey data produced an estimate of 125 moose (SE = 30 moose, CV = 0.24 or 24% [GNWT-ENR unpublished data]). It may be possible to reduce the CV if future surveys are combined intentionally. The WMMP does not specify an effect size (i.e., degree of population change) for detection, but the relationships among SE, degree of population change, and power presented in Figure 6 hold for any species surveyed in two separate periods.

Another alternative might be to consider a stratified random block survey (Gasaway 1986) or a geospatial population estimate (Kellie and DeLong 2006, DeLong 2006, Davison and Callaghan 2019) for moose as it might reduce and focus the survey area. A desktop exercise to stratify the area and estimate survey costs might be a good investment of time. In this way, the moose survey could be run independently of the bison survey and the bison survey could be added to the Mackenzie bison survey.

3.6 Wildlife Sighting and Collisions (WMMP 5.2.6)

Wildlife-vehicle collisions present a risk both to wildlife and to people driving on the TASR. Presently GNWT-INF and GNWT-ENR do not pool their data and there is not a single, reliable database with geographically referenced records of wildlife records and wildlife observations. The proposed monitoring approach (GNWT-INF 2019, p. 5-55) is to construct a wildlife collision and sighting reporting system smartphone app for employees and contractors who are on the road frequently, designed after a program in Alberta. The objectives for monitoring wildlife sightings and collisions are to:

- quantify wildlife-vehicle collisions (WVCs) on the TASR relative to other NWT highways;
- identify areas with frequent WVCs;
- identify areas with frequent sightings of wildlife (to provide a leading indicator of potential risk areas);
- identify any changes in wildlife distribution, especially of Mackenzie bison; and
- identify areas where wildlife crossing is hindered by snow cleared from the TASR.

The proposed approach to acquire sighting and collision information from frequent road users will provide useful information. While the acquisition of data from frequent road users will aid in monitoring the distribution of wildlife and WVCs, there is a risk that familiarity of observations will lead to a reduction in reporting after an initial period of diligence. Scheduled patrols by the RRO or other GNWT-ENR employees to systematically search for and record wildlife, WVC sites, and wildlife tracks adjacent to the road will create a comprehensive record of wildlife activity on a fixed interval.

The data from a GNWT-ENR patrol will differ from voluntary reporting. For example, if a driver chooses not to report a WVC it may go unreported as the injured animal may retreat into the bush (Snow et al. 2015). Regular patrols by GNWT-ENR staff can be used to survey the road and roadsides for evidence of wildlife activity and signs of WVCs in a manner that other employees asked to provide observations cannot. If snow is a potential barrier, identified by tracks that approach but do cross snowbanks, then snowbank monitoring at those locations can provide information on barrier effects. Mitigation by snow clearing crews at safe crossing locations can reduce the barrier effect as well as increase visibility of wildlife.

In a test of concerns about underreporting of WVCs, Snow et al. (2015) showed that predictive ability of models created from reports from as few as 25% of WVCs in an area still enabled them to identify hotspots for collisions. Wildlife and WVCs are non-randomly distributed, and databases with only a fraction of available data can still generate valuable predictive models from habitat covariates.

A combination of WVC data, volunteer monitor reporting, reporting by road maintenance contractors and INF patrols, and GNWT-ENR road patrol observations in a common database can be used as inputs for resource selection modelling to identify hotspots for mitigation actions (e.g., reduced speed limits, increased snow clearing, signage). Trained GNWT-ENR employees can identify wildlife sign by species, and records from scheduled patrol activities can be effective at recording the distribution of bison and other species along the road and throughout the year.

3.7 Predator Monitoring (WMMP 5.2.7)

Under the WMMP, the GNWT has committed to monitor predator population densities, movements, and predation rates. The only prey species mentioned explicitly is boreal caribou and the only predators mentioned explicitly for wildlife effects monitoring are wolves.

3.7.1 Mortality investigations

The investigation of radio-collared boreal caribou mortality sites is discussed in Section 3.3.3 above. To summarize that discussion: the number of mortalities that can be expected is small (perhaps three or four caribou per year based on the recent mortality rate in the region) and it will not be possible to determine cause of death in each case. The sample sizes for analysis will be small and the SEs of the estimates will be high, suggesting that monitoring will have low power to detect changes in cause-specific mortality rates (Figure 7). Monitoring radio-collar data for mortality and conducting mortality site investigations should be included in the WMMP program; spatial distribution of mortalities and mortality site habitat characteristics and relationship to the TASR may reveal patterns over time but adequate data will require years to acquire, perhaps as much as a decade.

3.7.2 Aerial population surveys

The wolf survey methods developed and tested by Serrouya et al. (2016) are a proposed approach for evaluating distribution and abundance of wolf densities in the TASR study area. Serrouya et al. (2016) are clear that ideal survey conditions with respect to snow cover, recent snow and wind events, and light are necessary for consistent survey results.

The TASR study area surveyed in 2018 for moose and bison (Hodson and Patenaude 2018) was approximately 10,000 km^2 and was surveyed using a DHC-2 Beaver at 167 km/hr. Serrouya et al., using smaller aircraft, took 16 hours of survey time to survey the 5571 km^2 Hay River Lowlands wolf survey unit (350 km^2 / hr) and had survey intensities below 300 km^2 / hr for most of their wolf survey units. For a 10,000 km^2 survey area, this suggests 30 to 35 hours of survey time. A challenge in implementing this method may be to find sufficient survey days that meet the survey condition standards. An additional challenge within government, where surveys occur near the end of the fiscal year, is to resist the temptation to conduct surveys under sub-optimal conditions when there is a fear of losing funds at the end of the fiscal year. Adherence to standards for survey conditions will be an important factor in producing survey results that are at least relative among years.

This is a promising approach, especially if there is an opportunity to periodically validate sightability with radio-collared wolves in the study area. The surveys will also serve to document wolf distribution in the study area.

3.7.3 Movement rates and predation rates

Predator movement rates and predation rates are listed as objectives in WMMP Section 5.2.7. Determining movement rates will require radio-collared animals. If wolves in the TASR study area are radio-collared then a number of objectives may be possible to address. These include:

- Movement rates as required under the WMMP. These can also be employed to determine the effects of the road on wolf behaviour and resource selection;
- Assessment of sightability estimates for aerial surveys (e.g., Serrouya et al. 2016);
- Distribution of wolves relative to distribution of ungulate prey (e.g., Klaczek et al. 2016);
- Predation rates (as required under the WMMP) from radio-collar location distribution and backtracking radio-collared wolves (e.g., Woodruff and Jimenez 2019); and
- Wolf vital rates.

4.0 SUMMARY AND RECOMMENDATIONS

The following is a summary of recommendations and observations for each wildlife effects monitoring item in the WMMP:

Traffic Monitoring

- A complete census of information will be acquired with the planned approach to traffic monitoring.
- Consideration of traffic data needs related to other monitoring programs should be used to inform the locations for traffic data acquisition.

- The availability of hourly traffic information throughout the year will equal or exceed the availability of all wildlife effects monitoring program data, making detailed traffic data available as a covariate for all other analyses.

<u>Access and Harvest Monitoring</u>

- Consider creating an explicit list of monitoring objectives for RRO patrols on the TASR and providing a data sheet with mandatory fields. In this way a standardized set of data will be collected through time.
- Annual mapping of trails detected through aerial surveys or via remotely sensed data will provide a measure of the rate of incursion into the surrounding area from the TASR.
- Link RRO patrols with wildlife sightings and collisions data collection.

<u>Boreal Caribou</u>

- The use of radio-collars to provide information on the proximity of boreal caribou to the TASR will generally not be effective. When detected near roads, the data will be accurate, but probability of any specific group of animals containing a radio-collared animal makes it unlikely that most groups and most animals will be detected with this method. No alternatives are suggested. This is one element in detection of animals. Other information will come from observations made along the road (and habitat based resource selection modelling in future).
- Determination of resource selection will be possible with the quantity of data being selected. Step-selection functions are recommended to address movement near the TASR. Traffic data will also be available to use as a covariate. These analyses will be valuable in developing effective mitigation.
- Survival and recruitment rates will be appropriately used to detect population change. The current rate of population growth in the TASR area (λ=1.038) would need to decline to approximately 0.93 to have an 80% chance of detection based on a five- to seven-year pooled data set.
- Aerial surveys are unlikely to be effective in evaluating population change over time.
- An initial aerial survey including calculation of a sightability correction factor will provide an initial estimate to guide harvest management decisions.
- Mortality site investigations are highly unlikely to detect a statistical change in the cause of death over time. The sample size (the number of mortalities with an assigned cause of death) will be small (e.g., 10 to 20 animals in a five year period). Site investigations will require a commitment to rapid deployment of staff and may be expensive when they require helicopter access. I do not believe the results will be worth the expense. If such a study is initiated a quantitative threshold or effect size should be established at the outset and the data should be revisited annually to determine the power to detect the desired effect.

Barren-ground Caribou Collaring

- As for boreal caribou, the use of radio-collars to provide information on the proximity of barren-ground caribou to the TASR will generally not be effective. When detected near roads, the data will be accurate, but probability of any specific group of animals containing a radio-collared animal makes it unlikely that most groups and most animals will be detected with this method.

  An effective alternative might be to use barren-ground caribou location data in a process similar to that used to define the Mobile Core Bathurst Caribou Management Zone; the creation of a minimum convex polygon or short-term (e.g., 1 week) UD for each of the Bluenose East and Bathurst herds. Over the longer term, calculation of seasonal UDs for each herd and monitoring their change among years may provide an advance indication of seasonal range shift towards the TASR.

Moose and Bison Population Monitoring

Bison

- Aerial population surveys will require a large effect to have sufficient power to detect a change in bison populations. Pairing the TASR bison survey data with data from the Mackenzie bison surveys should produce a better detection function for distance analyses. Ideally the two surveys would be run in the same year with the same survey crews.
- Bison range expansion analyses is not addressed in the WMMP. Consideration should be given to evaluating range expansion either with: a) basic survey data plus anecdotal data; or b) formal occupancy estimation near the range limit.

Moose

- Aerial population surveys will require a large effect to have sufficient power to detect a change in moose populations. Pairing the TASR moose survey data with data from the North Slave moose survey should produce a better detection function for distance analyses. Ideally the two surveys would be run in the same year with the same survey crews.
- Another alternative is a stratified random block survey or geospatial population estimate. A desktop exercise to stratify the area and estimate survey costs is recommended.

Overall

- For effective coverage of the TASR study area, moose and bison are presently scheduled to be surveyed in the same flights. Consideration should be given to surveying TASR bison with Mackenzie bison. The TASR moose survey could be combined with the North Slave moose survey or run as an independent stratified random block survey.

Wildlife Sighting and Collisions

- The proposed metrics and data acquisition are fine. Adding RRO patrols for WVCs and wildlife sightings will improve the available data as it will provide a consistent effort and consistent record. Including animal tracks relative to snowbank heights in the RRO patrol will assist in determining barrier effects in winter. The use of RSF analyses with WVC and wildlife sighting data will allow the creation of predictive models of wildlife-road interactions.

Predator Monitoring

- As noted above regarding boreal caribou, mortality site investigations are highly unlikely to detect a statistical change in the cause of death over time.
- The planned aerial wolf surveys appear to be a promising approach to monitoring wolf distribution and abundance.
- Consideration should be given to radio-collaring wolves. The desired movement and predation rate data will be possible to acquire if wolves are radio-collared. If wolves are collared, then determining wolf vital rates, distance to collared caribou, and RSFs in the TASR study area are possible.

5.0 LITERATURE CITED

Adamczewski, J., J. Boulanger, H. Sayine-Crawford, J. Nishi, D. Cluff, J. Williams, and L.M. LeClerc. 2019. Estimates of breeding females & adult herd size and analyses of demographics for the Bathurst herd of barren-ground caribou: 2018 calving ground photographic survey. Government of Northwest Territories, Yellowknife, NT. Environment and Natural Resources Manuscript Report No. 279.

Adams, L.G., and G.H. Roffler. 2005. Chisana caribou census – 15-16 October 2005. Unpublished report, United States Geological Survey. 9 pp.

Adams, L.G., and G.H. Roffler. 2007. Chisana caribou census – 13-14 October 2007. Unpublished report, United States Geological Survey. 9 pp.

Beyer, H. L., E. Gurarie, L. Börger, M. Panzacchi, M. Basille, I. Herfindal, B. Van Moorter, S. R. Lele, and J. Matthiopoulos. 2016. 'You shall not pass!': quantifying barrier permeability and proximity avoidance by animals. Journal of Animal Ecology 85:43-53.

Boulanger, J., K. Poole, and C. DeMars. 2015. Review of bison monitoring program for the Northwest Territories. Report prepared for the Government of the Northwest Territories by Integrated Ecological Research, Nelson, BC. 96pp.

Boulanger, J., J. Adamczewski, J. Nishi, D. Cluff, J. Williams, H. Sayine-Crawford, and L.M. LeClerc. 2019. Estimates of breeding females & adult herd size and analyses of demographics for the Bluenose-East herd of barren-ground caribou: 2018 calving ground photographic survey. Government of Northwest Territories, Yellowknife, NT. Environment and Natural Resources Manuscript Report No. 278.

Buckland, S.T., D.R. Anderson, K.P. Burnham,. J.L. Laake, D.L. Borchers, and L. Thomas. 2001. Introduction to distance sampling. Oxford University Press, Oxford. 432 pp.

Courtois, R., A. Gingras, C. Dussault, L. Breton, and J.-P. Ouellet. 2003. An aerial survey technique for the forest-dwelling ecotype of woodland caribou, Rangifer tarandus caribou. The Canadian Field-Naturalist 117:546–554.

Davison, T., and K. Callaghan. 2019. Moose (*Alces alces*) population size and density in the Inuvik Region of the Northwest Territories, March 2017. Government of Northwest Territories, Yellowknife, NT. Environment and Natural Resources Manuscript Report No. 280.

DeLong, R.A. 2006. Geospatial population estimator software user's guide. Alaska Department of Fish and Game. Fairbanks, Alaska, USA.

DeMars, C.A., and S. Boutin. 2013. Counting ghosts: testing a new aerial survey method for estimating population sizes of boreal caribou. Habitat Conservation Trust Fund, Victoria, BC. Unpublished report 28 pp.

DeMars, C., J. Boulanger, and R. Serrouya. 2015. A literature review for monitoring rare and elusive species, and recommendations on survey design for monitoring boreal caribou. Final report submitted to NWT. 58 pp.

Fieberg, J., and J. Giudice. 2008. Variance of stratified survey estimators with probability of detection adjustments. Journal of Wildlife Management 72:837-844.

Gasaway, W.C., S.D. DuBois, D.J. Reed, and S. Harbo. 1986. Estimating moose population parameters from aerial surveys. Biological Papers of the University of Alaska No. 22, 108 pp.

GNWT-DOT. 2016. Project Description Report for the Proposed Tłı̨chǫ All-Season Road. Government of the Northwest Territories, Yellowknife . NT. 227 pp. + Appendices.

GNWT-ENR. 2019. Wildlife Management and Monitoring Plan (WMMP) Process and Content Guidelines. Government of the Northwest Territories, Yellowknife, NT. 52 pp.

GNWT-INF. 2017. Adequacy Statement Response for the Tłı̨chǫ All-Season Road Project. Government of the Northwest Territories, Yellowknife, NT. 641 pp.

GNWT-INF. 2019. Wildlife Management and Monitoring Plan for the Tłı̨chǫ All-Season Road. Government of the Northwest Territories, Yellowknife, NT. 153 pp.

Hegel, T, K. Russell, W.J. Rettie, and D.P. Tate. 2016. South Nahanni and Coal River northern mountain caribou herds; population status and demographic characteristics. Yukon Fish and Wildlife Branch Report TR-14-06. Whitehorse, Yukon, Canada.

Hervieux, D., M. Hebblewhite, N.J. DeCesare, M. Russell, K. Smith, S. Robertson, and S. Boutin. 2013. Widespread declines in woodland caribou (Rangifer tarandus caribou) continue in Alberta. Canadian Journal of Zoology 91:872-882.

Hintze, J. 2008. PASS 2008. NCSS, LLC, Kayesville, UT. www.ncss.com.

Hodson, J. 2019. Summary of winter 2019 field work carried out under Wildlife Research Permit WL5005580 – "Wildlife Effects Monitoring for the Proposed Tłı̨chǫ All-Season Road". Internal

Report, Wildlife Division, Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. 6 pp.

Hodson, J., and A. Patenaude. 2018. Summary of winter 2018 field work carried out under Wildlife Research Permit WL5005580 – "Wildlife Effects Monitoring for the Proposed Tłı̨chǫ All-Season Road". Internal Report, Wildlife Division, Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. 8 pp.

Jacques, C.N., T.R. Van Deelen, W.H. Hall Jr., K.J. Martin, and K.C. Vercauteren. 2011. Evaluating how hunters see and react to telemetry collars on white-tailed deer. Journal of Wildlife Management 75:221-231.

Johnson, D.S., P.B. Conn, M.B. Hoten, J.C. Ray, and B.A. Pond. 2013. Spatial occupancy models for large data sets. Ecology 94:801-808.

Kellie, K. A., and R.A. DeLong. 2006. Geospatial survey operations manual. Division of Wildlife Conservation, Alaska Department of Fish and Game, Fairbanks, Alaska, USA.

Klaczek, M.R., C.J. Johnson, and H.D. Cluff. 2016. Wolf–caribou dynamics within the central Canadian Arctic. Journal of Wildlife Management 80:837-849.

Mahoney, S.P., J.A. Virgl, D.W. Fong, A.M. McCharles, and M. McGrath. 1998. Evaluation of a mark-resighting technique for woodland caribou in Newfoundland. Journal of Wildlife Management 62:1227-1235.

Peters, W., M. Hebblewhite, K.G. Smith, S.M. Webb, N. Webb, M. Russell, C. Stambaugh, and R.B. Anderson. 2014. Contrasting aerial moose population estimation methods and evaluating sightability in west-central Alberta, Canada. Wildlife Society Bulletin 38:639-649.

Prokopenko, C. M., M. S. Boyce and T. Avgar. 2017. Characterizing wildlife behavioural responses to roads using integrated step selection analysis. Journal of Applied Ecology 54:470-479.

R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Rettie, W.J. 2017. Summary of current and historical boreal caribou population monitoring methods and recommendations for future population monitoring. Report prepared for Environment and Climate Change Canada by Paragon Wildlife Research and Analysis Ltd., Winnipeg, MB. 43 pp.

Rettie, W.J. 2019. Northwest Territories boreal caribou population and harvest models. Report prepared for Government of the Northwest Territories Environment and Natural Resources by Paragon Wildlife Research and Analysis Ltd., Winnipeg, MB. 77 pp.

Serrouya, R., H. van Oort, C. DeMars, and S. Boutin. 2016. Human footprint, habitat, wolves and boreal caribou population growth rates. Report prepared by the Alberta Biodiversity Monitoring Institute, Edmonton, AB. 22 pp.

Serrouya, R. S. Gilbert, R.S. McNay, B.N. McLellan, D.C. Heard, D.R. Seip, and S. Boutin. 2017. Comparing population growth rates between census and recruitment-mortality models. Journal of Wildlife Management 81:297-305.

Snow, N.P., W.F. Porter, and D.M. Williams. 2015. Underreporting of wildlife-vehicle collisions does not hinder predictive models for large ungulates. Biological Conservation 181:44-53.

Vander Wal, E., P.D. McLoughlin, and R.K. Brook. 2011. Spatial and temporal factors influencing sightability of elk. Journal of Wildlife Management 75:1521-1526.

Woodruff, S., and M.D. Jimenez. 2019. Winter predation patterns of wolves in northwestern Wyoming. Journal of Wildlife Management 83:1352-1367.

Zabransky, C.J, D.G. Hewitt, R.W. DeYoung, S.S. Gray, C. Richardson, A.R. Litt, and C.A. DeYoung. 2016. A detection probability model for aerial surveys of mule deer. Journal of Wildlife Management 80:1379-1389.