Research Design to Determine Factors Affecting Moose Population Change in British Columbia: Testing the Landscape Change Hypothesis

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EXECUTIVE SUMMARY

In response to declining Moose numbers in central British Columbia, the Ministry of Forests, Lands and Natural Resource Operations initiated a five-year (December 2013–March 2018) Moose research program to investigate causes for the decline. This research design outlines the background and approach to how this research will be conducted. Adult female survival generally has the greatest proportional effect on ungulate population change so the approach is to maintain a minimum of 30 GPS-radio-collared (Global Positioning System) cow Moose in each of five study areas (i.e., 150 radio-collared cows). Monitoring of radio-collared animals will: 1) measure cow survival rate; 2) determine causes of mortality; and 3) examine how large-scale landscape characteristics and changes contributed to their death. Because Moose population declines coincided with a large-scale mountain pine beetle (MPB) outbreak, this research design specifically addresses landscape-level effects of pine tree mortality and associated salvage logging.

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1. INTRODUCTION

During the winter of 2013/14, Ministry of Forests, Lands and Natural Resource Operations (FLNRO) regional staff conducted 20 Moose population surveys. The results of those surveys, as well as those conducted in 2011/12 and 2012/13, indicated that certain areas of the province experienced a 50–70% decline in Moose numbers, while Moose populations in other areas remained stable or in some cases increased. A five-year (December 2013–March 2018) provincially-coordinated research program was initiated by FLNRO and its partners to better understand possible factors influencing Moose population change, particularly population declines. This document provides the background and approach to the research hypotheses, objectives, and methods of how this research will be conducted.

The causative factors associated with the decline in Moose numbers in some areas and not in others are unknown, but have coincided with a mountain pine beetle (MPB) outbreak (Bunnell et al. 2004; Chan-McLeod 2006) and an associated increase of salvage logging and road building. Extensive landscape change from MPB and associated logging may have positive effects for Moose 5–40 years post-logging because of increased food availability in regenerating forest stands (Bunnell et al. 2004; Janz 2006). However, there may be negative effects from increased vulnerability to hunters and predators (Ritchie 2008), both immediately post-logging and over the long term. The mechanisms for those negative effects may arise from: 1) increased search efficiency of predators and hunters when Moose are in cutblocks because they are more easily seen when moving or stationery; 2) increased search efficiency of predators and hunters when Moose are not in cutblocks because Moose will be increasingly concentrated; 3) increased energetic requirements for winter feeding because reduced density of mature trees provides less snow interception so Moose need to move through deeper snow; and 4) reduced thermal cover, especially in summer and fall, resulting in reduced body condition of Moose entering winter. If this landscape change hypothesis is correct, Moose population growth rates are predicted to increase as cutblocks regenerate where vegetation obstructs the view of predators and hunters, roads are rendered impassible, and Moose become more evenly dispersed throughout the environment.

This landscape change hypothesis assumes cow survival has a greater proportional effect on population growth rates than does calf survival, but this assumption may not be correct (Gaillard et al. 1998; Eberhardt 2002). Calf survival to 12 months of age is an important component in Moose population dynamics (Boutin 1992; Gaillard et al. 1998; Patterson et al. 2013) and most research projects focus on calf survival when there is chronic low calf recruitment (i.e., <10 calves/100 cows; Van Ballenberghe and Ballard 2007). Ministry surveys in the last three years have found calf/cow ratios to be about 20–30 calves/100 cows, with some exceptions, which is consistent with ratios required to maintain stable populations by replacing losses from predation and other natural causes (Bergerud and Elliot 1998). It would be ideal to examine both cow and calf survival to evaluate Moose population change, but Ministry efforts have focused on using GPS radio-collars to determine cow survival because:

1) the *a priori* assumption that population growth rate is primarily determined by changes in cow survival (e.g., magnitude and variation in non-licensed hunting) has been a general finding in studies of other large herbivores (Gaillard et al. 1998);
2) the a priori hypothesis is that changes in adult cow survival are influenced by their distribution and movement patterns that can be interpreted in relation to vulnerability to predation, food, and snow conditions at both fine scale and landscape scale; and these movement patterns are dictated by cows and not calves; and

Table 1. Moose and landscape status in Moose research study areas in central B.C. in March 2014.

Study Area	Region/ MU	Landscape	Moose Status
1. Bonaparte ($3408 km^2$)	3 (Thompson/Okanagan) MU - 3-29, 3-30B	Habitat Feature - MPB Logging - Yes Roads – Yes	335–582/1000 km^2 Stable
2. Big Creek ($4511 km^2$)	5 (Cariboo) MU - 5-04	Habitat Feature - MPB Logging - Yes Roads – Yes	251/1000 km^2 Declining
3. Entiako ($10,543 km^2$)	6 (Skeena) MU - 6-1, 6-2	Habitat Feature - MPB Logging - Yes Roads – Yes	268/1000 km^2 Stable
4. Prince George South ($5280 km^2$)	7A (Omineca) MU - 7-12	Habitat Feature - MPB Logging - Yes Roads – Yes	400/1000 km^2 Declining
5. John Prince Research Forest ($6461 km^2$)	7A (Omineca) MU - 7-14, 7-25	Habitat Feature - Spruce Logging - Yes Roads – Yes	390/1000 km^2 Stable

3) techniques are available for providing unbiased estimates of cow survival (Van Ballenberghe and Ballard 2007).

Other reasons to focus on using GPS radio-collars on cows include:

1) radio-collared cows will assist in estimating calf recruitment (presence of calves with radio-collared cows can be found regardless of vegetation cover density); and
2) radio-collared cows will help with stratification and sightability bias of density surveys.

2. STUDY AREAS

The five study areas range from 3000 to over 10,000 km^2 (Table 1). All have differing amounts of forest affected by MPB and associated salvage logging and roads (Figure 1). In 2014, three study areas had stable Moose populations and two had declining populations (Table 1). Moose are the primary ungulate in all study areas. Mule Deer densities are unknown but hunter kill estimates from 2004 to 2013 indicate that there are relatively few Mule Deer in the Entiako and John Prince Research Forest study areas (mean annual kill = 7 and 15 respectively), intermediate Mule Deer numbers in Big Creek and Prince George South (mean annual kill = 85 and 174 respectively) and relatively large numbers in the Bonaparte study area (mean annual kill = 450). Hunter kill estimates indicate that there are far fewer White-tailed Deer than Mule Deer, with the mean kill from 2004 to 2013 averaging 9/year, ranging from 1/year in Big Creek to 23/year in Prince George South. Caribou occur only in the Entiako study area, and elk are found in low densities in Prince George South and the John Prince Research Forest. Grey Wolves, Grizzly and Black bears are present in all areas, but Grizzly Bears are uncommon in the Bonaparte. Cougars occur in the two southern study areas. Feral horses are common in the Big Creek study area.

3. OBJECTIVES

The primary objective of this study is to test the landscape change hypothesis by identifying the causes and rates of cow Moose mortality, and examining those spatial and temporal factors that may have contributed to increased vulnerability (Table 2 and 3, Figure 2). There are few existing data on cow survival in B.C., but previous research in other areas of Canada and

Alaska where predation is considered to be the major factor influencing Moose populations suggests adult cow survival to range between 75-95% (Hauge and Keith 1981; Mytton and Keith 1981; Gasaway et al. 1983; Larsen et al. 1989; Ballard et al. 1991; Gasaway et al. 1992; Bertram and Vivion 2002). Understanding cow survival in this study will provide insight into the ecological processes that determine Moose population growth rates (Figure 2) and may explain past and current population declines. Calf survival may be more affected than cow survival by any increased vulnerability to predation within areas of salvage logging, suggesting calf survival as an important factor in understanding Moose population growth rates (see Section 6. Research Gaps). Secondary study area-specific objectives have therefore been developed to assess calf survival where there are regional and funding partner interests (Table 2). In addition, this study is intended to assist in determining what processes can be influenced by management actions and how to do so.

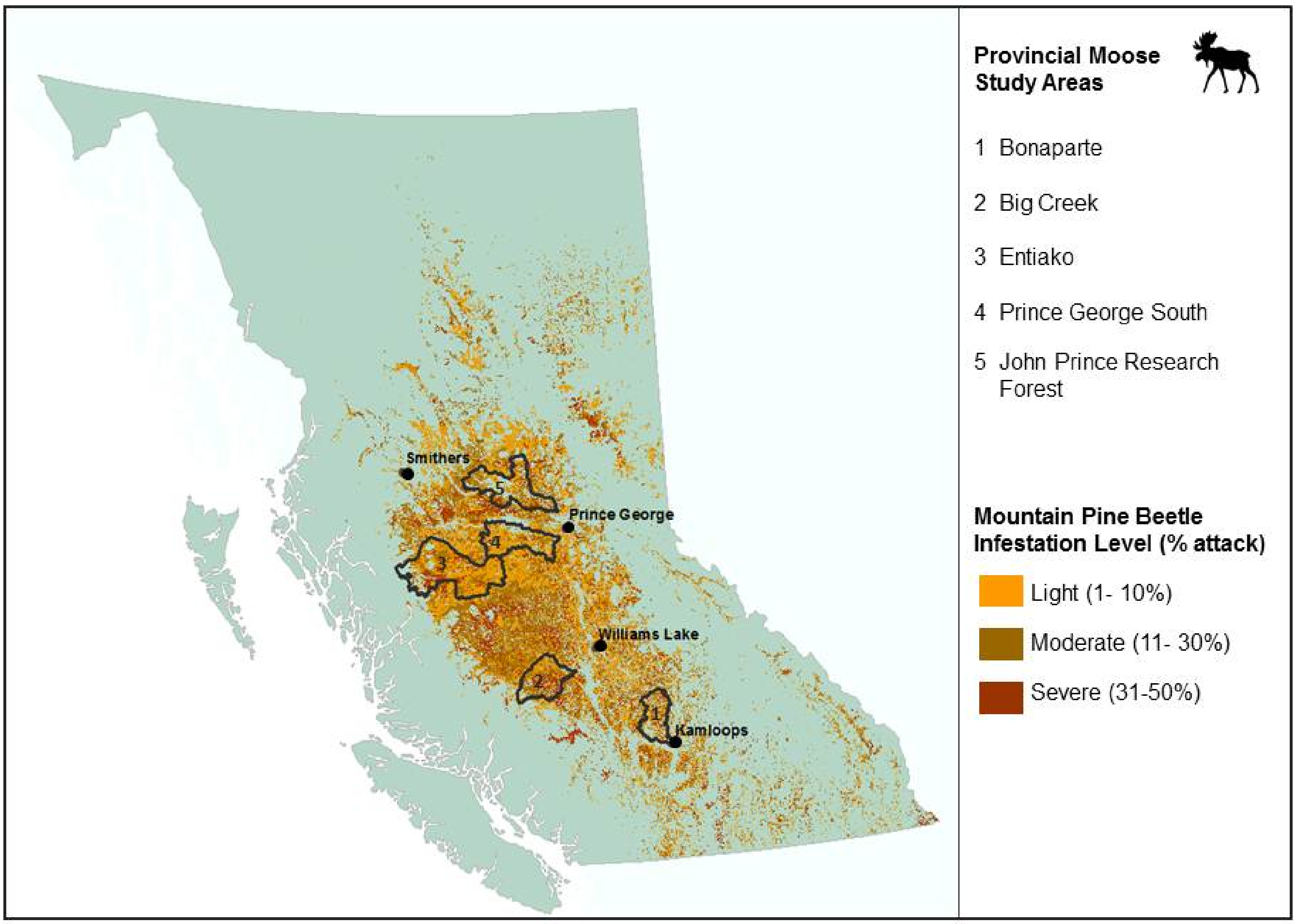

Figure 1. Study area in British Columbia where cow Moose survival will be monitored from December 2013–March 2018. The area consists of a gradient of Mountain Pine Beetle infestation levels.

Table 2. Regional objectives to assess Moose population change in five study areas in B.C. (December 2013–March 2018).

Study Area	Objectives
1. Bonaparte (Region 3)	1. Determine how factors relating to MPB salvage logging affect Moose behaviour and mortality or mortality risk
	2. Identify factors limiting Moose population growth: cow survival
	3. Identify factors limiting Moose population growth: calf survival
	4. Assess cow behaviour in response to temperature/climate
	5. Increase accuracy and precision of density surveys by improving sightability estimation and stratification
2. Big Creek (Region 5)	1. Identify factors limiting Moose population growth: cow survival
	2. Increase accuracy and precision of density surveys by improving sightability estimation and stratification
3. Entiako (Region 6)	1. Determine how factors relating to changes in the forest landscape (e.g., MPB salvage logging) affect Moose behaviour and mortality risk
	2. Identify factors limiting Moose population growth: cow survival
	3. Identify factors limiting Moose population growth: calf recruitment
	4. Define population units in MU's 6-01, 6-02 and 5-10 by documenting seasonal movements and distribution.
	5. Examine radio-collared Moose distribution and habitat use relative to sympatric GPS radio-collared caribou from the Tweedsmuir herd.
	6. Determine how Moose respond spatially and temporally to a large (>150,000 hectare) wildfire within the study area.
4. Prince George South (Region 7A)	1. Identify factors limiting Moose population growth: cow survival
	2. Increase accuracy and precision of density surveys by improving sightability estimation and stratification
5. John Prince Res. For. (Region 7A)	1. Identify factors limiting Moose population growth: cow survival
	2. Increase accuracy and precision of density surveys by improving sightability estimation and stratification

4. RESEARCH APPROACH

Over five years (December, 2013–March, 2018), the survival of at least 30 GPS radio-collared cow Moose will be monitored per year in each of five study areas of central interior B.C. (Figure 1). The five study areas are representative of a wide range in MPB effects on tree mortality, amount of salvage logging and road building. The research approach is to focus on these five areas (Table 1 and 2) and collaborate with others conducting Moose research elsewhere within and outside the province. The initial winter (2013/14) of fieldwork focused on captures to radio-collar and sample the first set of cow Moose. Over the next four years (April 2014 – March 2018), their survival will be monitored and assessed, and the sample size will be maintained or increased by further radio-collaring. Consideration will be given as to how the following five general factors might be linked to cow Moose survival: 1) hunting (Hatter 1999); 2) predation; 3) nutritional constraints; 4) age and health (i.e., parasites, disease, body condition); and 5) environmental conditions (i.e., snow, temperature, climate). How these factors might interact with MPB and associated salvage logging (Figure 2, Table 3) will be examined. It will then be possible to characterise factors affecting cow survival within the home range at various time durations (e.g., day, week, month) of those cow Moose that died and compare those factors to the home range attributes of the cow Moose that survived during the same time period, both within and among the five study areas (Figure 1). Field capture and mortality site investigations will be conducted primarily by FLNRO staff. The main academic collaborator for this study is the University of Northern British Columbia, with the University of Victoria partnering on regional objectives in the Bonaparte study area.

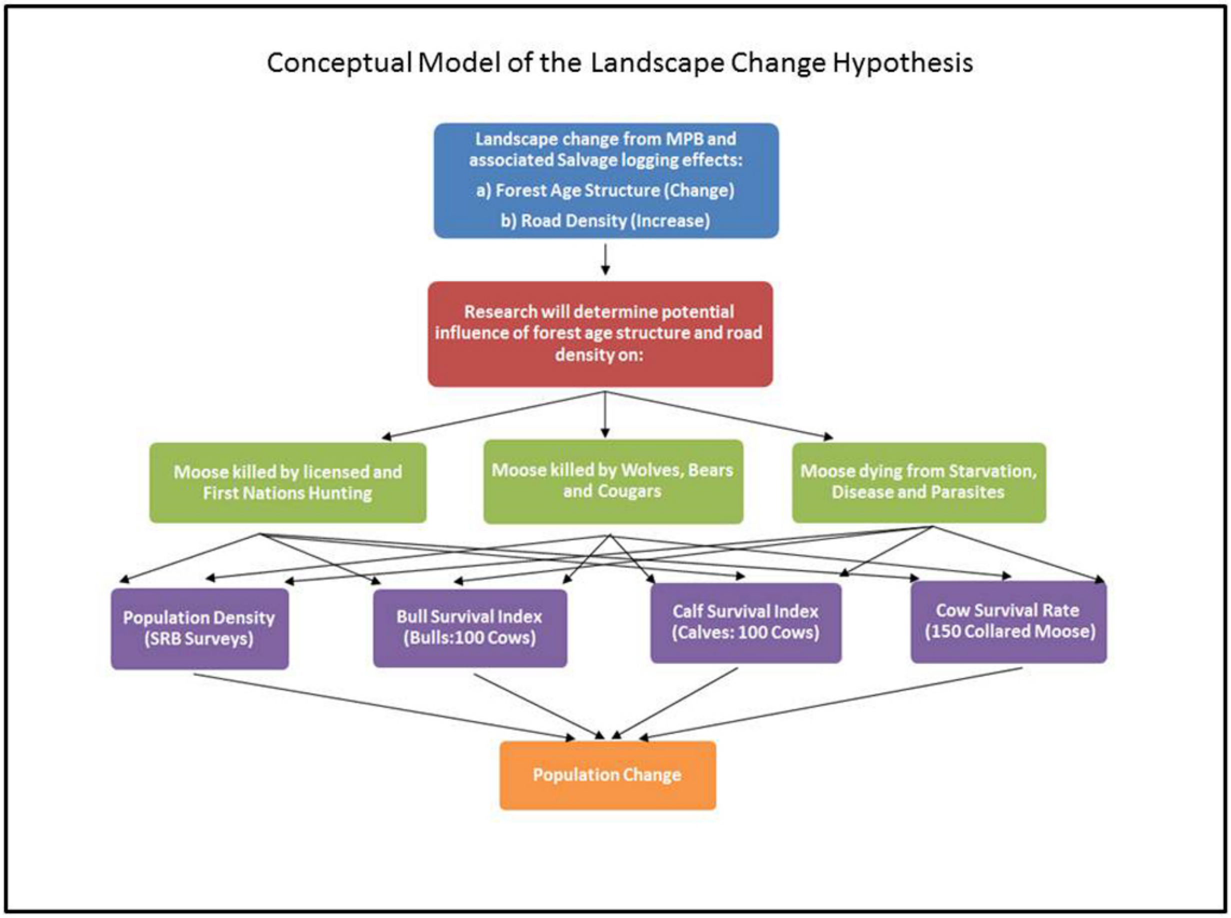

Figure 2. Conceptual model of the landscape change hypothesis representing factors affecting Moose population change in central B.C. (see Section 4. Research Approach for detail) (SRB is Stratified Random Block).

Table 3. Predictor and response variables that will be used to determine Moose population vital rates (based on Brown 2011) for this Moose research project in central B.C. (December 2013–March 2018).

Predictor Variables	Description	Response Variables
Population		
Density	Moose per 1000 km^2	CS, PGR, Ca:C, B:C
Calf:Cow	Calves per 100 cows	CS, PGR
Bull:Cow	Bulls per 100 cows	CS, PGR
Harvest		
All	Proportion All - harvested prior to survey	CS, PGR
Bulls	Proportion Bulls - harvested prior to survey	CS, B:C
Cows	Proportion Cows- harvested prior to survey	CS, B:C, Ca:C
Calves	Proportion Calves- harvested prior to survey	CS, Ca:C
Habitat		
Road density	km of roads/100 km^2 within each study area	CS, PGR, Ca:C, B:C
Forest depletion	% forest comprised of cutblocks or burns	CS, PGR, Ca:C, B:C
Cutblock Herbicide	% cutblocks treated with herbicide use	CS, PGR, Ca:C, B:C
Predators		
Grey Wolf, Grizzly Bear, Black Bear, Cougar	Relative Abundance of each predator in each Region as a proxy for study area	CS, PGR, Ca:C, B:C
Alternate Prey	Ungulate Biomass Index in Region (proxy study area)	CS, PGR, Ca:C, B:C
Age and health	Age, body condition, prevalence of disease and parasites	CS, PGR, Ca:C, B:C
Climate		
Winter heat stress	January (-5C threshold)	CS, PGR, Ca:C, B:C
Late spring heat stress	April-May (14C and 20C thresholds)	CS, PGR, Ca:C, B:C
Growing Season	Growing degree days	CS, PGR, Ca:C, B:C
Snow depth	Snow depth	CS, PGR, Ca:C, B:C

CS = Cow Survival, PGR = Population Growth Rate, Ca:C = Calf/Cow ratio, B:C = Bull/Cow ratio

5. METHODS

The research will concentrate on examining cow survival, supplemented by information on calf survival and population growth rate in order to test the landscape change hypothesis. Methodological details are described in the field methods section below.

5.1. Response Variables

5.1.1 Cow survival

By determining the cause of mortality for each radio-collared cow, this study will determine the ecological processes and mechanisms of how fundamental limiting factors operate (Table 3), e.g., determining if road density is higher in the home ranges of cows that are killed by Grey Wolves in winter. Consultation with UNBC will be ongoing to determine the most appropriate statistical methods for assessing the relative importance among variables related to MPB and associated salvage logging that influence cow survival. These variables include land cover attributes (e.g., road density), logging history (e.g., year harvested), MPB intensity, primary productivity and cow movement history (Table 3).

Table 4. Timing of stratified random block surveys to estimate Moose density for this five-year Moose study in central B.C.

Study Area	Date of SRB Survey	Proposed date of Next SRB (5-years)
1. Bonaparte (Region 3)	2013 – Jan	2018 – Jan
2. Big Creek (Region 5)	2012 – Jan	2018 – Jan
3. Entiako (Region 6)	2013 – Jan	2018 – Jan
4. Prince George South (Region 7A)	2011 - Dec	2017 – Dec
5. John Prince Research Forest (Region 7A)	2011 – Dec	2017 – Dec

Existing variation in conditions (e.g., amount of MPB salvage logging, road density and predator densities) will be used rather than ones that are manipulated. Adaptive management manipulations are not possible within the time frame of this study because if conditions changed (e.g., closed all road access) partway through the study in one study area, it is unlikely there would be sufficient numbers of cows dying to evaluate the effect of the closure and the associated mechanisms to determine appropriate management recommendations. Adaptive management, however, is something that could be considered if the study were to continue beyond five years. Age will be an important factor influencing cow survival, but because age will be estimated from tooth eruption and wear at capture, precise age will only be collected for radio-collared Moose that died and a tooth was recovered.

5.1.2 Calf survival

Calf survival will not be directly studied in this project, but calf/cow ratios will be measured during winter surveys and used as an index of calf survival to six months. Regions 3 and 6 have objectives to better understand calf survival (Table 2). In 2013 and 2014, biologists in Region 3 determined timing of parturition and gained insight into early calf survival from cow Moose instrumented with high fix-rate GPS radio-collars. This method entailed a combination of: 1) serum progesterone levels to determine pregnancy at time of capture; 2) movement rates (via GPS locations) to determine timing of parturition; and 3) aerial calf-at-heel survey of all radio-collared cows to assess calf survival shortly after median calving date.

5.1.3 Population growth rate

Population growth rate will be assessed using predictor variables (i.e., those variables that affect Moose population vital rates) and response variables (vital rates; Table 3) using multivariate statistical methods and General Additive Models similar to those used to describe patterns and causes of demographic variations in Moose populations in Ontario (Brown 2011). Detailed analysis of cow survival will use Kaplan-Meir analysis allowing a staggered entry of radio-collars over time (Pollock et al. 1989). Individual cow Moose will be entered into the analysis on the day after radio-collaring and removed the day they die or were censored due to radio-collar failures. Three competing survival risks will be evaluated: 1) predators; 2) hunters; and 3) other natural causes (i.e., disease, malnutrition) (Patterson et al. 2013). Stratified random block surveys (SRB) will be used to derive Moose density estimates and estimate population trends (Gasaway et al. 1986) within each study area (Table 4). SRB surveys and composition surveys will provide information on calf/cow and bull/cow ratios that are response variables (Table 3).

5.2. Field Methods

5.2.1 GPS radio-collars

A minimum of 30 GPS-radio-collared cows will be maintained in each of the five study areas (n = 150 radio-collared cows) for five years (December 2013–March, 2018). Most Moose will be instrumented with Vectronic Aerospace radio-collars that are designed to last 3–5 years and collect one or two positional fixes per day. Mortality email messages will be sent when the radio-collar has not moved for 24 hours. Some Moose in the Bonaparte and Entiako study areas will have Advanced Telemetry Systems iridium GPS radio-collars that collect a higher number of fixes per day leading to shorter radio-collar life. Collars will be replaced on cows if they fail, lose battery power or the animal dies. Radio-collars are black (Vectronics) or brown (Advanced Telemetry Systems) so they are less likely to be seen, therefore reducing the chance of radio-collared Moose being selected for or against by hunters. This will help to ensure that the radio-collared Moose provide an unbiased estimate of hunting losses.

5.2.2 Capture and handling

Cow Moose will be captured by one of two methods: aerial netgunning (Carpenter and Innes 1995) or chemical immobilization with carfentanil citrate and xylazine hydrochloride (Roffe et al. 2001) using standard protocols (RISC 1998) and approved by the Ministry Animal Care Committee. Body condition score (BCS) will be evaluated by a protocol similar to Testa and Adams (1998) and DelGiudice et al. (2011) and the 10-point system developed by Franzmann (1977). For increased efficiency and repeatability, a 5-point system has been developed for this project that is standardized to Franzmann 1977 (Appendix A). Pregnancy will be determined by rectal examination where possible and confirmed with serum progesterone levels of ≥2.0 ng/ml (Haigh et al. 1982; Stewart et. al. 1985; DelGiudice et al. 2011). A standard suite of samples will be collected that include blood for serum (serological survey and progesterone) fecal pellets for parasitological assessment, a minimum of 100 hairs/Moose for cortisol levels, isotope analysis and DNA, an ear biopsy punch for DNA analysis, and any abnormalities will be recorded. Numbers of winter ticks will be estimated visually by separating the hair coat and counting ticks on transects in standard areas and recording any hair loss. Age will be estimated from incisor and molar tooth wear and eruption patterns and Moose classified as young adult, adult or aged; jaw length measurements will also be taken to assist in age estimates. Each cow will be marked with a FLNRO small yellow coded ear tag and instrumented with a GPS radio-collar.

5.2.3 Mortality site investigations

Mortality site investigations are a key component of this research. A protocol has been developed using information from other studies (Montgomery et al. 2013) and advice from international experts on the best approach to maximize inferences on cause of mortality. A dichotomous key will be used to differentiate mortalities from predation, accidents, disease and unknown. Within each category, there is a subset of protocols outlining appropriate photographs and biological samples to collect that include an incisor tooth for aging, an assessment of internal fat depots, the collection of jaw and long bone for marrow fat as indexes of nutritional condition, and ear tissue and muscle for genetics (Appendix B). Collection of predator DNA from wounds and scat (Mumma et al. 2014) is being considered.

5.2.4 Predator assessment

Predators will not be radio-collared as part of this research project. Mortality site investigations will be used to assess the impact of different predators on survival of cow Moose. The relative abundance of wolves, Grizzly and Black bears and Cougars will be indexed from hunter kill data specific to the Management Units where the Moose are radio-collared. Grizzly Bear and Grey Wolf densities will be based on those determined for larger spatial scales in B.C. (Mowat et al. 2013; Kuzyk and Hatter 2014).

5.2.5 Biological samples from non-radio-collared Moose

In addition to biological samples collected from radio-collared Moose mortalities, tissues and jaws (for age determination) and femurs/long bones (for estimating body condition by bone marrow fat percentage) will be collected from Moose from other sources (e.g., road kills and incidentally reported deaths and hunter kills). These samples will help in describing any within and among year pattern in Moose body condition, and in comparing these results with the marrow fat condition of radio-collared animals that die (e.g., McLellan et al. 2012). Age estimates will provide age structure for the live population for comparison with the age structure of the radio-collared Moose that die. Tissues from non-radio-collared Moose will be archived to enable future research opportunities.

5.2.6 Surveys to measure population change and composition

Density surveys will be conducted in each study area to estimate population change (Table 4) as well as composition surveys to provide an unbiased estimate of calf:cow and bull:cow ratios. All surveys will follow provincial standards that are based on scientific defensible techniques (RISC 2002).

5.3. Data management and confidentiality

A project database inclusive of all study areas will be developed. This database will link all capture data (including Moose capture and health data), GPS location data, mortality site investigation data and survey data. All data will be easily accessed by members of the Provincial Moose Management Team and all mentioned data will be uploaded at regular intervals into the Provincial Species Inventory Database (SPI). Research and data-sharing agreements will be developed and signed with professors and graduate students from University of Northern British Columbia and University of Victoria. Data released to the public will be only in the form of maps (i.e., never raw data) with spatial accuracy degradation by plotting relatively large (i.e., relative to home range size) location dots with long temporal delays before release. Maps showing concentrations of Moose will not be released.

6. IDENTIFIED RESEARCH GAPS FOR THIS PROJECT

The research design does not include the following three subject areas due to financial and logistical constraints; however, these areas are important factors for understanding Moose population change in central B.C.

Calf survival/behavior from 6-12 months of age - Survival and behavior of calves from 6–12 months of age is an important research gap due to the importance of variation in juvenile survival in determining population trend (Gaillard et al. 1998). There is a general lack of information on Moose calf survival and behavior from 6–12 months (Van Ballenberghe and Ballard 2007). The implication for our study is that calf recruitment surveys are conducted in early winter because cows and calves normally occupy dense forest in February-April, therefore calf recruitment could be underestimated as Grey Wolves may prey predominately on Moose calves late into the winter (Mech et al. 1998; Hayes et al. 2000). Patterson et al. (2013) found calf recruitment estimated by radio-collared calves was higher than calf-at-heel surveys. The difference may be due to visibility bias of calves in dense vegetation and a reduced maternal bond as calves mature (Bonenfant et al. 2005; Gundersen et al. 2008). Radio-collaring cow Moose and their 6-month old female and male calves would enable understanding the importance of: 1) variation in calf survival to 12 months of age in relation to population trend; 2) indices of nutritional condition of cows (i.e., body condition, pregnancy) in relation to calf survival to 12 months; 3) cow-calf bond in relation to calf survival to 12 months; 4) cow and calf selection of habitats (especially dense cover) in relation to survival and behavior of calves to 12 months, and 5) aerial survey bias of calves. There are many logistical challenges capturing 6-month-old calves as their mothers are protective, and because calves are growing, expandable radio-collars are required but can be subject to increased losses. This is especially true for male calves that could retain their radio-collar through to breeding age with a wide variation in neck size during the rut. Last, it should be noted that due to the lack of field studies, this approach of comparing relative importance of survival of calves and cows concurrently would fill an important knowledge gap in ungulate ecology.

Influence of nutritional constraints on Moose survival - The effects of improved habitats on nutritional condition of cow Moose, their subsequent maternal care of calves, and thus potential to increase calf recruitment has been noted as an important area of future research (Patterson et al. 2013). A better understanding of how Moose are affected by nutritional constraints during variable seasonal environments (Gasaway et al. 1992; Heard et al. 1997; Dussault et al. 2005 a, b) would be useful as nutritional quality and quantity can diminish over winter due to snow depth, browsing and lack of new vegetation, but this study does not include specific objectives to address this. Also, Moose may migrate to higher elevation to calve and benefit from enhanced nutrition (Poole et al. 2007; White et al. 2014) or use areas after forest fires to take advantage of enhanced nutrition of early seral vegetation (Gasaway et al. 1989). Specific questions could focus on forest harvesting which can influence nutrition quality and quantity of forest age classes, thermal and snow interception cover, application of mechanical treatments and herbicides, silviculture practices (Wall et al. 2011) and human and predator access to special habitats such as mineral licks and wetland complexes.

Relative importance of Moose in diet of predators - Direct study of predators is not included in this research program due to budgetary constraints but their important role in regulating Moose populations is acknowledged (Ballard et al. 1991; Gasaway et al. 1992; Messier 1994; Van Ballenberghe and Ballard 1994). For example, experimental evidence determined a strong numerical response of Moose calves and cows after Grey Wolf numbers were reduced by ~80% in the Yukon (Hayes et al. 2003). In Alaska, Moose population growth responded positively to reduced Grey Wolf, Black Bear and Grizzly Bear densities (Keech et al. 2011). Cougars may be an important predator of Moose calves in some areas as they removed an estimated 16–30% of Moose calves up to early winter in southwestern Alberta (Ross and Jalkotzy 1996). The importance of Moose in the diet of predators could be quantified using isotope analysis of predator hair (Milakovic 2008).

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Appendix A. Characteristics used to determine body condition of live-captured Moose in this study in relation to Franzmann's (1977) scores in central B.C. (December 2013–March 2018).

BODY CONDITION SCORING SYSTEM		
Body Condition	SCORE (Franzmann 1977)	PHYSICAL DESCRIPTION (Franzmann 1977)
	10	Prime, fat animal with thick, firm rump fat by sight. Well fleshed over back and loin. Shoulders and rump round and full.
	9	Choice, fat Moose with evidence of rump fat by feel. Fleshed over back and loin. Shoulders round and full.
Excellent	8	Good, fat Moose with slight evidence of rump fat by feel. Bony structures of back and loin not prominent. Shoulders well fleshed.
Good	7	Average Moose with no evidence of rump fat, but well fleshed. Bony structures of back and loin evident by feel. Shoulders with some angularity.
Fair	6	Moderately fleshed Moose beginning to demonstrate one of the following conditions: (A) definition of neck from shoulders; (B) upper foreleg (humerus and musculature) distinct from chest; or (C) rib cage prominent.
Poor	5	Two of the characteristics listed in 6 are evident.
Emaciated	4	All three of the characteristics in 6 are evident.
	3	Hide fits loosely about neck and shoulders. Head carried at a lower profile. Walking and running postures appear normal.
	2	Signs of malnutrition. Outline of the scapula evident. Head and neck low and extended. Walks normally but trots and paces with difficulty; cannot canter.
	1	Point of no return. Generalized appearance of weakness. Walks with difficulty; cannot trot, pace or canter.
	0	Dead.

Appendix B. Mortality site investigation form used to assess cause of mortality for Moose in central B.C. (December 2013-March 2018).

BC MOOSE RESEARCH - MORTALITY INVESTIGATION FORM

Date:_______________ Date of Mortality (signal):_______________ Days elapsed since death: ________

Personnel:____

General Location:____

Waypoint:________ UTM: Zone ____ E: _________________ N _____________________

Lat: __________________ Long _____________________

Wildlife Health ID:______________

Ear Tag # :________________ Collar Recovered: Y / N Ser. No.: _____________

Carcass Located: Y / N Collar Condition: ☐ Functional ☐ Damaged ☐ Destroyed

Sex:_____ Age:______

DESCRIBE THE MORTALITY SITE and TAKE PHOTOS (Tracks, Scat, Blood, Signs of Struggle, etc)

____

____

____

____

Snow Crust: ☐ Heavy ☐ Light ☐ Fluffy ☐ None Snow Depth (cm): ___ Sinking Depth (cm) __________

EXTERNAL - Describe abnormalities, collect samples, take photos

Choose all that apply

Carcass Location	Carcass Condition	Carcass State	Body Condition	Skin / Hair Coat
☐ In Open ☐ Concealed ☐ Buried ☐ ________	☐ Fresh ☐ Frozen ☐ Decomposed ☐ __________	☐ Intact ☐ Disarticulated ☐ Scattered ☐ Scavenged ☐ __________	☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ Emaciated ☐ Undetermined	☐ Normal ☐ Hide Inverted ☐ Missing Hair ☐ External Parasites ☐ Abnormal Skin ☐ Lumps / Warts ☐ ___________
Discharge / Blood	**Diarrhea / Feces**	**Hoof Condition**	**Bones / Legs / Joints**	**Mouth / Teeth**
☐ None ☐ Mouth ☐ Nose ☐ Anus ☐ ___________	☐ None ☐ Normal Pellets ☐ on Tail + Hind-legs ☐ ___________	☐ Normal Wear ☐ Worn ☐ Overgrown ☐ ___________	☐ Normal ☐ Chewed ☐ Fractured ☐ Compound ☐ __________	☐ Normal Wear ☐ Irregular / Worn ☐ Broken ☐ ___________

Comments / Details

____

____

____

____

INTERNAL - Record all abnormalities, collect samples and take photos

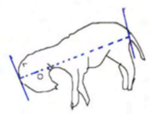
	Normal	Abnormal	Comments
Lungs / Trachea	☐	☐	____________
Heart	☐	☐	____________
Muscle	☐	☐	____________
Liver	☐	☐	____________
Kidney	☐	☐	____________
Spleen / Lymph nodes	☐	☐	____________
Stomachs / Intestines	☐	☐	____________
Skull / Spine	☐	☐	____________
Reproductive Tract	☐	☐	____________

If Pregnant: Record sex and crown rump length(s) of fetus(es)

Sex: ___ CR Length (cm): _____

Sex: ___ CR Length (cm): _____

Back Fat Depth (mm): ___________



Comments/ Details

____

____

____

CAUSE OF DEATH (follow key and check appropriate boxes)

Confidence Level	Predation	Non-Predation	Unknown
☐ Definitive	☐ Wolf	☐ Collision	☐ Unknown
☐ Probable	☐ Bear	☐ Hunter Kill	
☐ Possible	☐ Cougar	☐ Hunter Wounded	
	☐ Unknown	☐ Accident	
		☐ Other	

Comments/ Details

____

____

SAMPLES (check if taken)

SAMPLES	STORAGE	REASON for COLLECTION
☐ Long Bone	Freeze	For Body Condition Inex (Bone Marrow Fat)
☐ Jaw	Freeze	For Size and Growth
☐ Teeth	Freeze	For Aging
☐ Head (if Intact)	Freeze	For CWD
☐ Kidney + Fat	Freeze	For Body Condition Index (Kidney Fat)
☐ Liver (3 x 3 cm)	Freeze	For Toxicology
☐ Kidney (3 x 3 cm)	Freeze	For Contaminants
☐ Intestines	Freeze	For Parasites
☐ Muscle	Formalin	For moose measles / Parasites
☐ Predator DNA swab	Dry	For Predator Identification
☐ Predator Hair	Dry	For Predator Identification
☐ Predator Scat	Freeze	For Predator Identification

☐ Photos Taken?

Send Samples to:
Cait Nelson
2080 Labieux Road
Nanaimo, BC
V9T 6J9