Chilcotin Moose Recovery Plan

May 2, 2017

Prepared for:

BC Ministry of Forests, Lands, and Natural Resource Management

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Executive Summary

The goal of this report is to produce a plan that meets the intent of the Nenquay Deni Accord in facilitating a moose population recovery in the Chilcotin area of BC. While this moose recovery plan is not a Regional Action Plan for moose in the Cariboo as defined by the *Provincial Moose Framework*, it will contain information that may be used in the development of such a plan. It is important to note that several First Nations have overlapping territories in the Chilcotin, and groups such as resident hunters and guide-outfitters also have a keen interest in moose management plans for this area. Engaging all interested parties in future recovery planning will be an important factor in the successful implementation of any management or action plan for moose in the Chilcotin.

Moose populations in the Chilcotin have declined in recent years in response to a variety of factors that are not easily elucidated. This report discusses three main areas of potential management intervention: management of human caused mortality, habitat management, and predator management. In BC, predator control can be used to protect species at risk and to address livestock depredation, but policy prevents it from being used to enhance ungulate populations (BC FLNRO 2014). Despite this, there have been calls for predator management to increase moose populations in some areas of BC, and this report provides a discussion of issues related to implementing a predator management program. Management recommendations are proposed to address concerns in all three areas with the goal of increasing the Chilcotin moose population.

Sustainable management of human caused mortality relies on having accurate information on both moose population parameters and harvest numbers from all sectors of society. Investing in more frequent and regular inventories will allow wildlife managers to detect population trends more quickly and implement management changes promptly where appropriate. Initiatives that increase First Nations reporting of moose hunting success and capacity building are likely to result in improved wildlife management. These initiatives could take the form of incentives to participate in wildlife management activities and First Nations led strategies for legal enforcement of laws promoting sustainable wildlife.

Over the past decade, moose habitat in the Chilcotin has been impacted by mountain pine beetle and extensive salvage harvesting, as well as at a broader scale, changes to weather patterns associated with climate change. The *South Chilcotin Stewardship Plan* (2013) implemented changes in forest management intended to improve moose habitat. Those changes appear to be having a positive influence on moose populations in the area, and a similar process should be initiated across the remainder of the Chilcotin. This is a large area and prioritization should be given to landscapes where cumulative impact assessment has identified the greatest risks to moose. Current moose research should contribute to such a plan as information becomes known using an adaptive management approach. Exploring opportunities for forage enhancement may also be worthwhile, especially where efforts can also rehabilitate roads and help mitigate climate change impacts.

The Chilcotin is a multi-predator system supporting wolves, cougars, black bears and grizzly bears. Although there have been anecdotal reports of increasing predator populations in several areas of the Chilcotin, inventory data on predator populations in this area are sparse, and local research indicates that predation rates on adult cow moose are not high. Most research in North America has found that neonatal and juvenile moose are the life stages that have the lowest survivorship and that during the first few months of a moose's life bears (Grizzly and black) have the greatest impact on moose. Research is required to show if and how predators are limiting ungulate populations in the Chilcotin and which predators are responsible.

Current policy prevents predator control from being used to enhance ungulate populations except where species are at risk. Until research answers pertinent questions on the role predators have in the ecology of Chilcotin moose populations, the other areas of management intervention should be employed. Opportunities for more accurate estimates of moose harvest can be explored while continuing to conduct more frequent and regular inventories of moose populations. Current projections for the moose population in the Chilcotin are to increase over the next 5-year period, which may be due, in part, to shifts in First Nations harvest of cows to bulls and changes in forest management occurring in the South Chilcotin. Given this, continued involvement of the Tsilhqot'in National Government in promoting responsible moose management, and implementing a habitat and access control plan for the remainder of the Chilcotin should result in improved conditions for moose populations in the Chilcotin and contribute to moose recovery.

Contents

Executive Summary i
Introduction 1
Moose Population Assessment and Harvest Management 3
Objectives for moose management in Region 5 3
Population trends in GMZ 5C and 5D 4
Management of Human Caused Mortality 6
Moose Harvest Regulations 6
Current Information on moose harvest 8
Recommendations 13
Habitat Management and Restoration 14
Habitat Recommendations 23
Predator Management 25
Recommendations 33
Conclusions 34
References 37

Figures and Tables

Figure 1 Map of Tsilhqot'in Territory from Appendix A of the Nenqay Deni Accord. 2
Figure 2 Game Management Zones (GMZ) used in moose management in the Cariboo Region. 4
Figure 3 Population estimates by game management zones (GMZ) in the Chilcotin area of BC. 5

Table 1 Moose density estimates adjusted for sightability in Game Management Zones 5C and 5D (years with composition surveys only denoted with 'COMP'). 5

Introduction

In British Columbia, moose are an iconic symbol of wilderness that is valued by the public for aesthetic values, consumptive uses, and commercial harvesting opportunities. Likewise, moose are valued by First Nations for food, social, and cultural uses. Provincially, the moose population has remained relatively stable over the past 20 years, but localized declines have been observed in several Regions over the same period (Regions 4, 5, and 7A) (Kuzyk 2016). Hunter success has also decreased by roughly half during this period (Kuzyk 2016) causing concern among stakeholders and First Nations (Gorley 2016, GOABC 2016). Significant changes in forest conditions and accessibility to key moose habitats have also occurred during this time period, particularly in Regions 5 and 7A, due to the effects of mountain pine beetle and associated salvage harvesting. Warmer temperatures associated with climate change are thought to be negatively impacting moose both directly and indirectly. Moose near the southern extent of their range are likely to experience higher parasite loads, greater predation, habitat loss, and greater heat stress due to a future warmer climate (Rempel 2012, Brown 2011, Murray et al. 2006). Managing for sustainable moose harvest rates and conserving important habitats, while understanding the influences of predators is likely to be important in maintaining viable moose populations.

The Provincial Framework for Moose Management (MFLNRO 2013) recommends Regional Management Action Plans be developed in consultation with First Nations and stakeholders. Recent court decisions are also influencing moose management in the Chilcotin with the Province and the Tsilhqot'in National Government agreeing on a framework for addressing resource management including collaborative management of wildlife[1]. Under this Accord, collaborative management of wildlife includes developing species specific recovery/management plans. While this moose recovery plan is not a Regional Action Plan for moose in the Cariboo, it addresses this component of the Accord and will contain information that may be used in the development of such a plan. It is also important to note that the Nenqay Deni Accord applies to an area that also has territorial overlaps with other First Nations and involving those groups in any wildlife management planning would be prudent (Figure 1).

The Chilcotin Plateau is located west of the Fraser River in Region 5 and much of the area is used year-round by moose. The area represents a cross-section of moose winter range in the region that ranges from high to very low capability. The following biogeoclimatic zones are found within the survey area: Interior Douglas Fir (IDF), Sub-Boreal Pine Spruce (SBPS), Montane Spruce (MS), and Engelmann Spruce Subalpine Fir (ESSF) (Mendinger and Pojar 1990). Douglas-fir (*Pseudotsuga menziesii var glauca*), lodgepole pine (*Pinus contorta*), white spruce (*Picea glauca*), and trembling aspen (*Populus tremuloides*) are the dominant tree species. Wetlands dominated by willow (*Salix spp*.) and bog birch (*Betula glandulosa*) are relatively

[1] Nenqay Deni Accord. Available at: http://www.tsilhqotin.ca/PDFs/Nenqay_Deni_Accord.pdf

abundant habitats that are important sources of winter forage for moose in this area (Keystone 2006). Salvage harvesting, new road construction, and recent large-scale fires (2010) have affected large areas of forest in this MU resulting in many zones having relatively low amounts of security and thermal cover at this time.

Predators of moose in the area include wolves (*Canis lupus*), grizzly bear (*Ursus arctos*), black bear (*Ursus americanus*), and cougar (*Puma concolor*). Wolf populations are thought to be high in the Chilcotin; however, there is no firm data on population numbers for this area. A recent survey

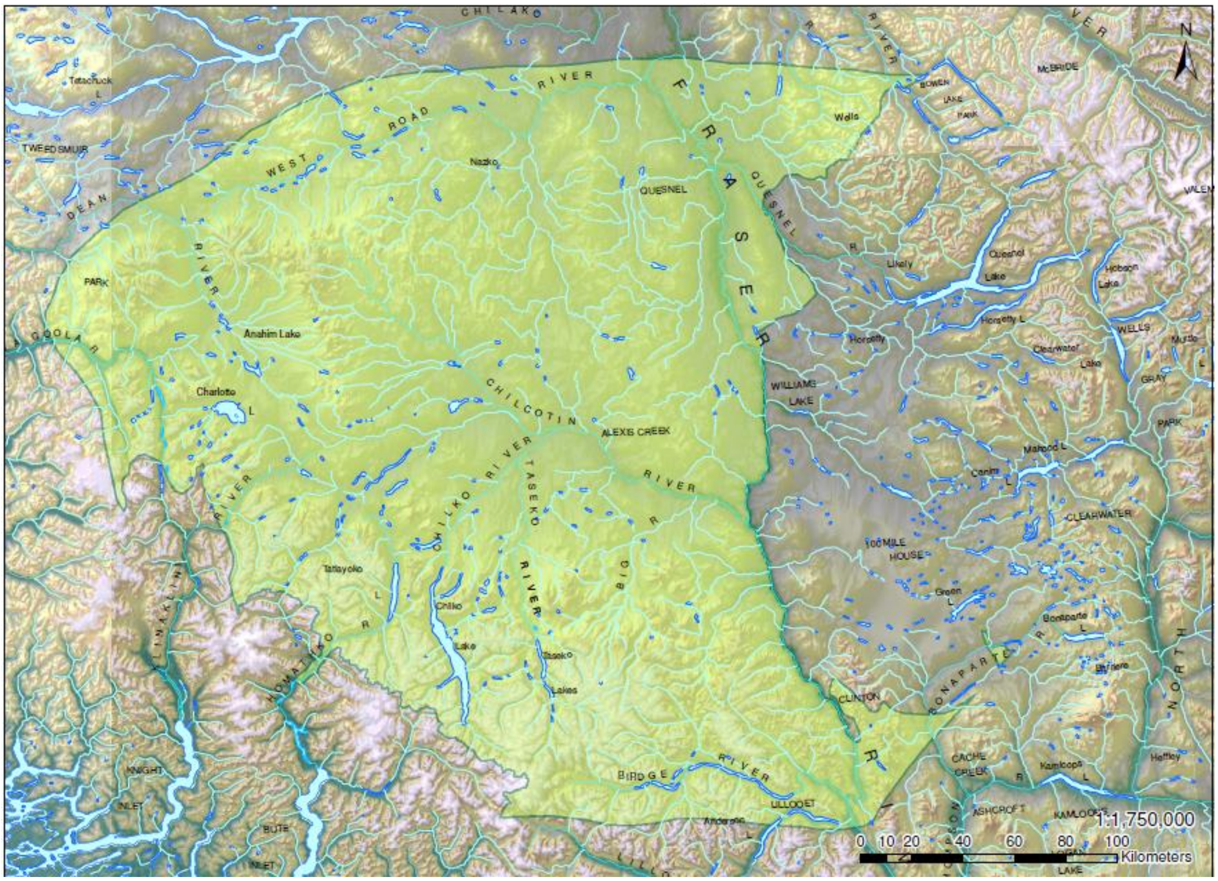

Figure 1 Map of Tsilhqot’in Territory from Appendix A of the Nenqay Deni Accord.

of wolves in the western portion of the Chilcotin estimated 5.6 – 7.6 wolves per 1000km^2 based on track observations. The surveyors noted that the estimated wolf density was low considering the apparent prey biomass observed during the survey[2]. Other prey that would support these predator populations include caribou (*Rangifer tarandus*), mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), feral horses, and domestic cattle.

[2] Personal communication with Dan Lirette, MFLNRO, Cariboo Region.

Several management units in the Chilcotin have experienced large decreases in moose abundance during the last 5-7 years based on recent surveys (Davis 2012, Environmental Dynamics 2012, Davis 2013, Davis 2017) raising concerns about this moose population. The declines have prompted Tsilhqot'in First Nations to push for changes in forest management practices in the South Chilcotin and a stewardship plan that addresses moose needs was developed for that area in 2013[3]. Under the Provincial Moose Framework (MFLRNO 2013), the Provincial government also initiated a research study examining factors affecting cow moose survival in relation to landscape change in 5 areas of the central interior affected by mountain pine beetle; including one study area located in the South Chilcotin. From 2012 to 2016, 336 cow moose have been radio-collared and monitored as part of this study (Kuzyk et al 2016). Recommendations have also been made by others for predator management to support moose population increases (Gorley 2016, GOABC 2016, McNay et al. 2013). Having a good understanding of predator population levels and trends is crucial to a predator management program; however, predators are generally low density species that are difficult to census. Wolves densities have been estimated at 10 – 44 per 1000 km^2 in northern British Columbia (MoE 2014) and in the Cariboo Region density estimates using ungulate biomass are 8 wolves/1000 km^2 (Kuzyk and Hatter 2014).

It is important to reiterate that this Chilcotin moose recovery plan is not a regional moose management plan or an action plan as defined under the Provincial Moose Framework (MFLNRO 2013); however, it meets the intent of the Nenqay Deni Accord and components of this recovery plan may be used to inform an action plan for the Chilcotin. The remainder of the plan encompasses the following sections on: moose population assessment and harvest management, habitat enhancement and restoration, and predator management. Each section includes a discussion of relevant factors and a set of recommended actions.

Moose Population Assessment and Harvest Management

Objectives for moose management in Region 5

In BC, moose populations are to be managed to sustainably meet the consumptive use needs of First Nations, licensed hunters, and the guiding industry. This management is intended to maintain a diversity of hunting opportunities for moose using the guidance provided by provincial policies and procedures (MFLNRO 2013). Under the *Provincial Moose Framework*, regional moose action plans are also part of the toolkit where required (MFLRNO 2013, MFLRNO 2016). In the Cariboo Region, moose are valued for cultural, sustenance, economic, and ecological reasons. Regional management objectives for moose must reflect those values while using science to evaluate the sustainability of management options.

[3] South Chilcotin Stewardship Plan – Chapter 12.

Game Management Zones (GMZ) are the regional units that are used for management purposes that can also be subdivided into Management Units (MU). The Chilcotin is divided into 2 GMZs that are roughly on the north (GMZ 5C) and south (GMZ 5D) sides of the Chilcotin (Figure 1). Recent (2012 – 2014) population surveys in the Chilcotin have found significant declines in moose numbers (Davis 2012, Environmental Dynamics Inc 2012, Davis 2013). Given the recent trends in the Chilcotin, objectives are to increase moose populations and maintain >30 bulls/100 cows (MFLRNO 2016). While there is no set objective for calf/cow ratios under provincial moose management (MFLNRO 2013), generally, a moose population requires at least 25 calves per 100 cows to balance losses of adult moose from natural causes, including predation (Bergerud and Elliott, 1998). Calf survival is largely driven by predation and environmental factors, neither of which are under management control.

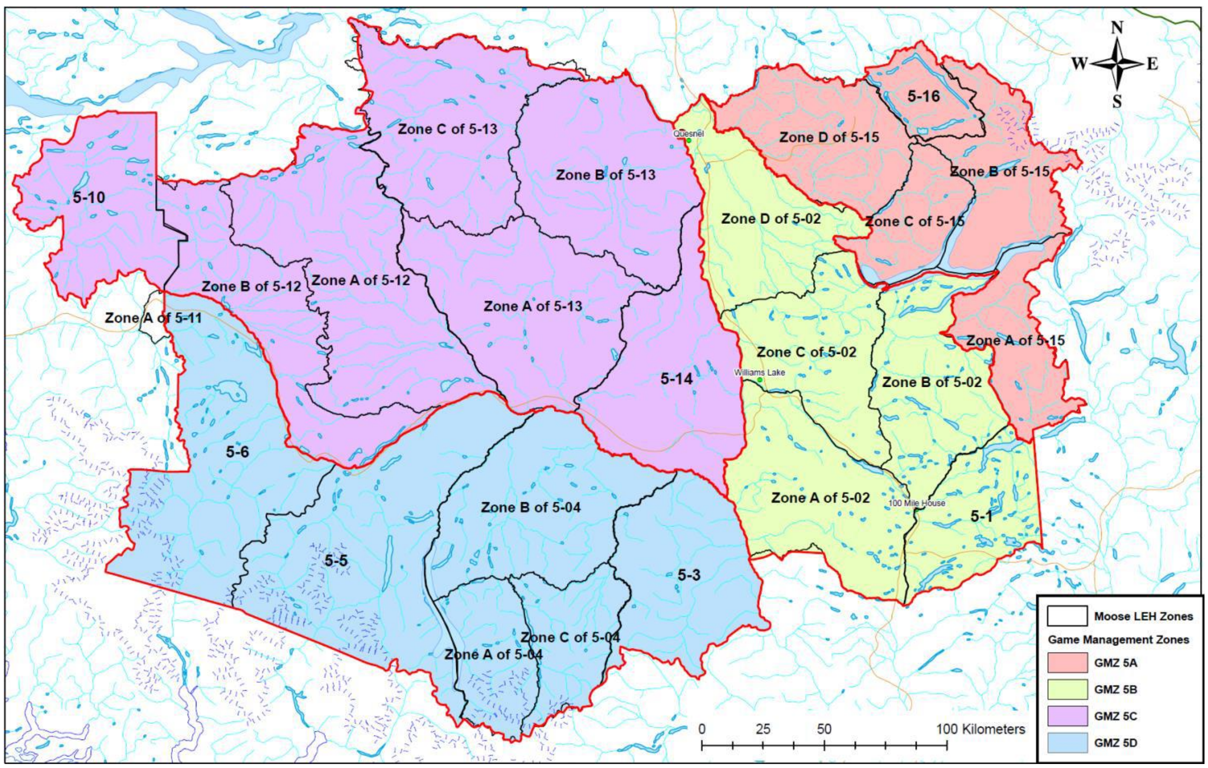

Figure 2 Game Management Zones (GMZ) used in moose management in the Cariboo Region.

Population trends in GMZ 5C and 5D

Moose population characteristics in the Cariboo Region are based on periodic abundance surveys (stratified random block/SRB) supplemented with composition surveys that document ratios of sex and age classes (e.g. calf/cow and bull/cow), and harvest-based metrics estimated using the results of hunter questionnaires. This population information has been collected since 1994, although several MUs have had no surveys and the frequency of SRB surveys has decreased substantially when the first 10 years of this period are compared to the last 14 years (Table 1). The survey results indicate that moose densities have decreased in several MUs when

Table 1 Moose density estimates adjusted for sightability in Game Management Zones 5C and 5D (years with composition surveys only denoted with ‘COMP’).

	GMZ 5D						GMZ 5C				
Year	MU 5-03	MU 5-04	MU 5-05	MU 5-06	MU 5-10	MU 5-11	MU 5-12	MU 5-13A	MU 5-13B	MU 5-13C	MU 5-14
1994		0.71									0.33
1995		0.39		0.18		0.26	0.38	0.31			
1996											
1997	0.35						0.34			0.40	
1998		0.41						0.44			
1999									0.31		
2000											
2001											0.46
2002							0.58				
2003								0.30			
2004											
2005		0.29									
2006											
2007	COMP										COMP
2008										0.49	
2011											
2012		0.14					0.23				
2013											0.25
2014		COMP									
2015		COMP									
2016		0.22						0.17			

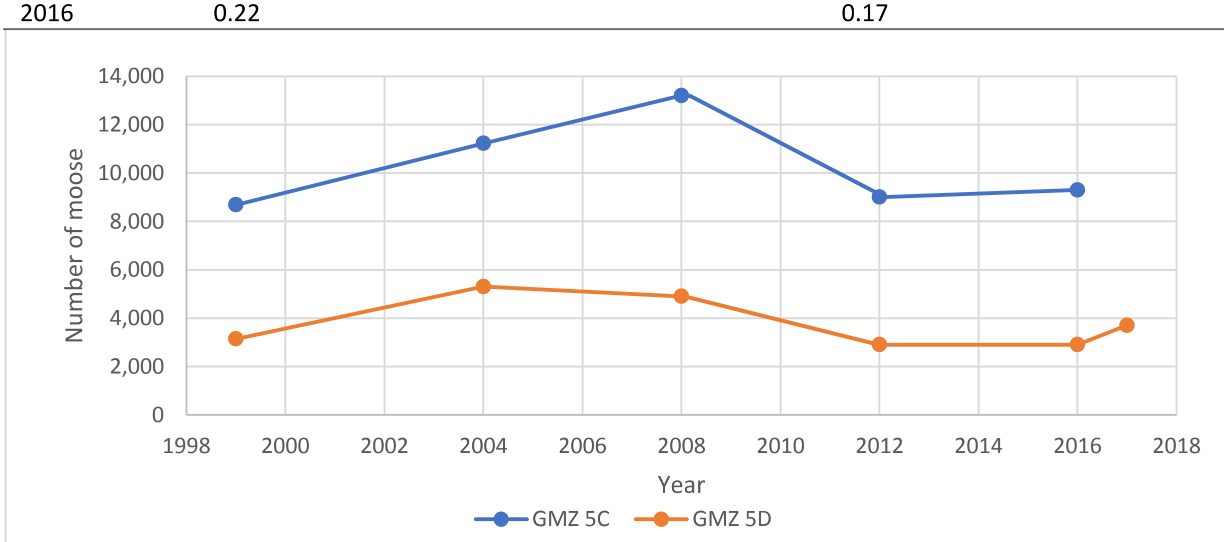

Figure 3 Population estimates by game management zones (GMZ) in the Chilcotin area of BC.

compared to historic estimates, although the population in MU 5-04 has rebounded slightly in 2016. Figure 3 illustrates the effect at the GMZ level with populations declining in the mid-2000s. Data from the most recent SRB in 2017 has not yet been incorporated into the GMZ 5C population estimate. In contrast, moose populations in GMZ B on the east side of the Fraser River are classified as stable to increasing based on recent (2010 – 2015) SRB surveys (MFLRNO 2016).

Management of Human Caused Mortality

Moose Harvest Regulations

The moose harvest in the Cariboo Region is set using estimates of population size, conservation requirements, and an estimate of the Annual Allowable Mortality (AAM). Prior to allocating moose to resident and guide outfitters, an estimate of First Nations requirements is set aside. First Nations requirements are generated based on consultations with the Ministry of Forest Lands and Natural Resource Operations (MFLRNO). MFLNRO biologists run population analyses based on the projected First Nations needs, moose survival and recruitment estimates, and varying levels of harvest to assess the AAM that can meet population goals. Once the analyses are completed, the surplus moose are designated as the Annual Allowable Harvest (AAH) which is allocated between the resident and commercial hunting sectors according to the Provincial Allocation Policy. The moose assigned to resident hunters are distributed using the Limited Entry Hunting (LEH) system, while quotas are allocated to the commercial hunting sector (MFLRNO 2016).

Population analyses are completed for allocation periods (e.g. 2017-2021) using a variety of existing data including: population size and variance estimates from SRB moose survey data, data on female survival rates from the ongoing Provincial Moose Research Project, recruitment rates based on cow/calf surveys, estimated wounding losses from the LEH harvest, First Nations harvest estimates, and measures of uncertainty generated to reflect stochastic environmental processes. These risk analyses are completed using probability simulations to help understand the risks and uncertainty associated with meeting population goals. The simulations are run through many iterations to help determine the probability that the moose population at a future point in time will meet population targets based on different management scenarios. Current Provincial and regional targets for moose in GMZ 5C and 5D are for *an increasing moose population* and *maintaining >30 bulls/100 cows* (FLRNO 2016).

The 2016 modeling was conducted on six alternative moose harvest options which included: maintaining 2016 AAH; 10% decrease in AAH; 20% decrease in AAH; 10% increase in AAH; 20% increase in AAH; and maintain 2016 AAH while shifting 17% of the First Nations harvest from cows to bulls (MFLRNO 2016). All scenarios show positive population growth with very low probability (1-4% in GMZ 5C and 4-9% in GMZ 5D) of the moose population decreasing by 2021. Shifting the First Nations harvest to a greater proportion of bulls resulted in the greatest growth rate (Lambda = 1.07 in GMZ 5C and 1.06 in GMZ 5D); however, this strategy also has a higher probability of not achieving the >30 bulls/100 cows objective for the population. Likewise, increasing the AAH had higher probabilities of not meeting the target for bull/cow ratio than the status quo or decreased harvest. The modeling was recently updated using data from this winter's MU 5-04 SRB survey. Under the status quo, the updated modeling is projecting a growth rate of 1.06 and a risk of not achieving >30 bulls/100 cows of 16%[4]. This suggests that the 5D population will recover to pre-decline (2008) abundance by 2021. The modeling has not yet been updated for GMZ 5C using data from the 2017 SRB survey.

It is also important to note that not meeting the >30 bulls/100 cows target may have effects at the population level. Studies examining this issue have found no effect on the pregnancy rate (Aitkens and Child 1992), number of calves/100 cows (Laurian et al. 2000), and the size of calves (Tagquet et al. 1999), where the sex ratio is >30 bulls/100 cows. However, moose populations where the ratio falls below 25 bulls/100 cows can result in a proportion of females not being bred during the first estrus cycle (Saether et al. 2003). Females bred in later estrus cycles give birth later in the calving season leading to a prolonged and flattened distribution of parturition dates. Problems associated with this distribution include later born calves that are more susceptible to predation, calves that are smaller than those born earlier in the season, and calves that are a greater age before first reproduction (Saether et al. 2003, Keech et al. 2000). Predation by bears during the first 2 months of life can be an additive and limiting factor in population growth especially in low density populations (Zager and Beecham 2006). Early and synchronous birth in ungulates can lead to satiation in predators which allows a greater proportion to survive through the susceptible first 2 months of life. In contrast, later born calves provide a prolonged source of vulnerable prey for predators which can lead to higher predation rates on this component (Zager and Beecham 2006). Later born calves are also smaller in size during the first winter, which may reduce overwinter survival directly (e.g. starvation), make the calves more susceptible to over-winter predation, and result in smaller adults that are also more susceptible to predation (Mech et al. 2015, Saether et al. 2003, Keech et al. 1998). Finally, probability of pregnancy is also related to body size and small female moose may have a later first date of reproduction leading to lower growth at the population level (Keech et al. 1998, Saether et al. 2003).

Given the problems with reducing the bull/cow ratio below certain thresholds, First Nations' harvest can be considered as part of a selective system that includes all population components. Lynch (2006) compared three study areas in Alberta where moose were hunted by both licensed sport hunters and First Nations, and where sport hunters were only allowed to harvest bulls. The study found that the wildlife management unit where First Nations hunting was considered "heavy" had a less biased sex ratio, overall moose numbers maintained at a higher level, and increased pregnancy and twinning rates than the other study areas. In the Chilcotin, 64% of the AAM is allocated to First Nations who are reported to take a mix of bulls, cows, and calves[5]. Given this, the Chilcotin moose harvest is likely already operating under a heavy selection system. It is important to note that the moose populations Lynch (2006)

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[4] Personal communication with Dan Lirette, Biologist, MFLRNO.
[5] Personal communication with Dan Lirette, MFLNRO, Cariboo Region

studied all had densities of >0.4 moose/km^2, and he cautions that populations that are limited by predation should be managed using a male-only harvest. The Chilcotin is a multi-predator system and moose populations can be limited to low population levels where this condition exists (Heard et al. 1999, Messier 1994). The McNay et al. (2013) review of moose populations trends in the Cariboo recommended a voluntary reduction in the harvest of cows and calves by First Nations hunters to help reverse the decline in moose numbers. It is likely that this type of management will be required until populations recover sufficiently (e.g. >0.4 moose/km^2).

Both the bull/cow ratio and the population trend are key parameters for moose conservation that are generated using multiple variables all of which are subject to some uncertainty. Identifying how each of the various inputs affects these parameters would be valuable in supporting ongoing research and obtaining stakeholder consensus on management decisions. Risk analysis can provide tools that help identify sources of uncertainty that require additional research to better quantify the risks. An example of this may be in identifying how the bull/cow ratio, calf survival, and predation risk influence the model outcome. Sensitivity analysis may help reveal which parameters are highly influential and would be good candidates for additional research that reduces uncertainty.

Current Information on moose harvest

In the Chilcotin, both the AAH and harvest success have declined for consumptive users. TNG has reported that hunting success is low and sustenance needs for moose are not being met[6]; however, accurate numbers of the moose taken by First Nations are not readily available. Likewise, success rates for resident hunters have also declined, but over a longer period from a high of 50% in the early 2000s to approximately 30% in recent years (MFLRNO 2016). Resident LEH take of moose in the Chilcotin has declined from a high of approximately 550 animals in 2008 to 340 animals in 2015 based on hunter responses to questionnaires. It is important to note that the number of LEH authorizations issued between 2008 and 2015 has also declined from 2059 to 1265 (-39%) which is proportional to the decrease in harvest. The numbers taken by non-resident hunters (e.g. guide-outfitter portion of harvest) have also declined from 193 in 2008 to 87 in 2015[7] (55%) (FLRNO 2016).

First Nations provide government with information on harvest needs based on community consultation. The current need in the Chilcotin is estimated at 820 animals and has increased by approximately 10% since 2004 (FLRNO 2016). The Tsilhqot'in have recognizing that education and information on First Nations moose harvest is required to help manage moose sustainably. To help address this need, a community led information program on the importance of cow moose to population growth has been rolled out that includes large posters in many communities. The TNG is also developing a moose harvest and observation log for hunters to

[6] Personal communication with Luke Doxator, TNG
[7] Personal communication with Dan Lirette, FLNRO

document the number of moose seen and killed. This observation log also depicts the population benefits of choosing to harvest bulls rather than cow moose to help promote a shift in the harvest of moose from cows to bulls (e.g. the harvest of a cow impacts all the offspring that cow would have had going forward while harvesting a bull only impacts the population in the current season). The journal is in draft form and is expected to be rolled out in the fall of 2017[5].

The population modeling completed in 2016 suggests that the goal of increasing moose populations and maintaining suitable bull/cow ratios in the Chilcotin has the greatest probability of being attained by decreasing the AAH below the 2016 level (FLRNO 2016). However, recent survey information from GMZ 5D indicates that the population and bull/cow ratios have increased. It may be that the past reductions in AAH and changes in habitat management in the South Chilcotin[8] have resulted in improved population parameters. Rerunning population models using the new data may result in acceptable probabilities of meeting population targets at the current AAH.

Effective population management must also be accompanied by more accurate information on harvest rates of each population component (bulls, cows, and calves). Information from the commercial harvest sector is being submitted as part of the commercial licensing process. For resident hunters in B.C., historically, harvest reporting for moose has been based on a non-compulsory hunter questionnaire. Starting in 2016, however, all moose harvested by resident hunters in the Chilcotin (MU 5-03 to 5-06, 5-10 to 5-14) must be submitted for compulsory inspection (CI)[8]. The goals of moose CI program are to monitor the harvest for several seasons and compare these results with those of the questionnaire. Estimates of completion rates for the non-compulsory questionnaires are approximately 70% with accuracy assumed to be relatively high[9].

Despite having relatively good harvest records of the AAH component, the largest segment of the moose AAM in the Chilcotin is set aside for First Nations. LeBlanc et al. (2011) found that estimates of moose harvest by First Nations in Ontario had resulted in an underestimate of the total AAM by up to 40%. Given that the First Nations moose harvest in BC is also estimated, obtaining an accurate number of animals harvested by First Nations is critical in sustainably managing the moose population. The adoption of the TNG harvest log by First Nations hunters would help provide this data; However, the universal adoption of this questionnaire may be difficult to achieve. The TNG represents the Tsilhqot'in at the nation level, but cannot enforce the adoption of the harvest log at the band or individual levels. Under the Indian Act (Section 81) band councils have the authority to pass by-laws that include the protection and management of wildlife; however, this authority appears to be restricted to reserve land. Discussions with the BC Conservation Officer Service (COS) indicate that there are First Nations

[8] South Chilcotin Stewardship Plan – Chapter 12.
[9] Personal communication with Dan Lirette, Senior Wildlife Biologist, FLRNO, Cariboo Region.

that have requested enforcement for wildlife infractions that have occurred off reserve in the past and have received this help[10].

First Nations have at least two avenues to enlist the COS in enforcing First Nations hunting laws[11]. Where the Chief and council have passed laws applicable to their members related to wildlife and ask the COS to proceed with prosecution, traditional court enforcement or restorative justice can be used to inform and rehabilitate the offender to avoid future harm. Restorative justice allows members of the community that have been harmed due to the offence to educate the offender on the impacts of their actions and to identify future actions that will bring about restitution. This can lead to unique and creative solutions for the problems that led to the offence. At this time, there are no records of re-offense after participating in restorative justice processes for wildlife act and other environmental infractions[12]; however, this process can only proceed when all parties have agreed to participate. In cases where the offender does not agree to participate in restorative justice, the COS can proceed with charges through the court system. Prosecution of wildlife offences can be successful; however, penalties are generally lenient, even where offenders have been prosecuted multiple times for similar offences[13]. Ensuring that the court system delivers effective deterrents for wildlife offences is needed to effect real change.

Even with First Nations Band leaders endorsing hunting regulations for their band members, compliance will still rely on community buy-in. Methods to increase community buy-in have been constrained by existing institutional structures and historical legacies that can engender animosity and suspicion in First Nation communities (Kofinas et al. 2010, LeBlanc et al. 2011). However, recent developments, including the 2014 Tsilhqot'in Nation v. British Columbia court decision and the subsequent Nenqay Deni Accord[14], have resulted in the creation of processes that promote collaborative decisions for a variety of goals including wildlife management. The development of this Chilcotin Moose Recovery Plan is one outcome of these developments. Promoting other mechanisms that facilitate the involvement of First Nations in wildlife management may also help improve community buy-in.

The Ministry of Forests Lands and Natural Resource Management Operations (MFLRNO) is responsible for wildlife management policies in the Province and enforcement through the Conservation Officer Service. However, several First Nations have created their own Land Rangers or Guardian groups (e.g. Nuxalk and Nemiah Bands) to facilitate compliance with fish and wildlife regulations in their own areas[10]. These groups are funded by the Bands and their role is to inform resource users of existing fish and wildlife regulations in their area while also

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[10] Personal communication with Len Butler, BC Conservations Service, Cariboo Region.
[11] Personal communication with Andy McKay, Provincial Coordinator, Restorative Justice and First Nations, BC Conservation Service.
[12] Personal communication with Andy McKay, Provincial Coordinator, Restorative Justice and First Nations, BC Conservation Service.
[13] Personal communication with Len Butler, Conservation Officer Service, Cariboo Region.
[14] Nenqay Deni Accord. Available at: http://www.tsilhqotin.ca/PDFs/Nenqay_Deni_Accord.pdf

recording instances where regulations are being contravened. Members of the COS have helped train Land Rangers in their roles and how to collect information that would aid in prosecution. Land Rangers in the present context do not have any powers to make an arrest, but can aid the COS by disseminating information on wildlife regulations and recording pertinent information on any potential wildlife infractions[10]. Developing First Nations Conservation Officers is also possible; however, potential members would be required to undergo the rigorous training that all COS officers must complete[11]. The Tsilhqot'in feel that COS training should also reflect First Nations values to be of benefit[15] Provincially, liaison positions with less rigorous requirements are, on a limited basis, also being made available for First Nations to work with the BC Natural Resource Sector Compliance and Enforcement agency[16]. This is a monitoring position that reports back to their communities on the work that is being done in the field by the NRS agencies, and, in some cases, to assist with compliance monitoring. Encouraging greater involvement by First Nations in promoting and facilitating the conservation of fish and wildlife is likely to help engender community buy-in.

In addition to the opportunities outlined above, other initiatives to increase participation in wildlife management such as incentives to providing moose harvest information and educational opportunities that facilitate capacity development within First Nations communities could be provided. For example, participation could be promoted by creating a lottery for First Nations hunters who complete the TNG Moose Harvest Log where a prize would be randomly awarded to one of the participants. Under this initiative, participants would have to submit samples from any animals harvested, such as a tooth, leg bone, or reproductive tract from a female, that could subsequently be used to assess the animals age, condition, reproductive history, and contribute to local research on the moose population. Ideally, government would also train and fund First Nations groups to complete the analyses on the submitted body parts as part of capacity development, which would also fit with the intentions of the Neqay Deni Accord. Information generated by this initiative would be integrated into Regional moose management plans and presented back to the individuals and communities that have participated to help foster inclusive and collaborative management.

Currently, the main management levers available to Wildlife Managers are regulations and access restrictions (FLRNO 2013). Developing a sense of collaboration in wildlife management may also facilitate compliance with other management levers that are used by Wildlife Managers. Effective access restrictions can create areas with low hunting pressure that have positive effects on moose populations in all areas (Crichton et al. 2004, LeBonte et al. 1998, Rempel et al. 1997). Areas with low hunting pressure can be important source populations for surrounding areas with higher hunting pressure (Labonte et al. 1998). As moose populations build in areas closed to hunting, locations outside the closure area will benefit from dispersing moose. Additional access control measures have been implemented during forest development

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[15] Personal communication with Luke Doxator, TNG.

[16] Personal communication with Andy McKay, Provincial Coordinator, Restorative Justice and First Nations, BC

operations in the South Chilcotin[17] and these measures are likely to have been successful in limiting access to some areas. More discussion of the benefits and methods of access control are discussed in Section 3; however, the management of human access via the organizations that play a role in access management is also worth discussing here.

In the South Chilcotin and other areas, there are existing access closures for hunting that are enforced with signage, gates, and other barriers to vehicle passage. Forest companies and their contractors working in areas of access restriction usually have keys to the gates and permission to work behind areas closed to vehicular access. Forest companies can help enforce these access closures by canceling contracts or banning individual workers who are hunting areas behind access closures. This would include First Nations contractors, but would require Band leadership passing laws against using vehicles in access closure areas. This type of enforcement would provide an economic incentive for hunters to adhere to laws implemented by First Nations and could also be supplemented with enforcement by the COS. Many of these areas had relatively poor access before the expansion of road networks associated with salvage harvesting, and the higher population numbers seen in the late 1990s and early 2000s likely reflected the presence of these large areas of low hunting pressure. Restoring effective access restrictions in these areas for all groups will re-create areas with low hunting pressure that could improve hunting in areas outside the restrictions.

Other measures to address human caused mortality were jointly reviewed by the Province and TNG in May 2016. The TNG has expressed concern over access to moose and competition with resident hunters. Several suggestions were put forward by TNG to address this situation including reducing the AAH, moving to a 1:1 ratio of LEH authorizations to AAH, the creation of First Nations only hunting areas, and annual surveys of moose abundance[18]. The government has tried to address these concerns by reducing LEH authorizations, limiting resident and commercial sector harvest to bulls only, and closing the early (September) LEH season in MUs 5-03, 04, 05, 12A, 13A, and 14 in 2017. This closure is expected to provide three weeks of sole access to moose during the pre-rut for First Nations hunters. This season generally has a higher success rate than later seasons, likely due to animals not having been hunted in prior to that season. Lastly, without First Nations leadership enforcing access closures for hunting on their members, we have de facto First Nations only hunting areas for those members that choose to hunt in areas with access restrictions. This results in very few areas in the landscape where there is low hunting pressure on moose. The long-term effects of this management on moose populations is dependent on many factors (e.g. intensity of harvest, how road systems are deactivated, etc.); however, the moose population benefits of having low density access areas are likely to be reduced.

The Province and TNG remain relatively far apart on the issue of frequency of abundance surveys. Time periods between surveys in some management units have been as high as 14

[17] South Chilcotin Stewardship Plan – Chapter 12.
[18] Personal communication with Luke Doxator, TNG.

years, and recent modeling on moose populations in the Cariboo found that the paucity of SRB data limited the power of statistical tests on the causes of the moose population decline (McNay et al. 2013). Aerial SRB surveys are the best method for estimating moose density (Peters et al. 2014, Boyce and Corrigan 2017); however, the surveys are expensive to conduct and determining the appropriate amount of effort is an optimization exercise balancing costs with competing needs for conservation and management. Moose composition surveys are less expensive to complete and modeling suggests that targets such as the number of bulls/100 cows can be reliably maintained using only this method (FLRNO 2013). Assumptions of using this method include a 50% survival of the calf population and First Nations harvest levels of 1-5% of post hunt moose. At this time, we do not have good data on calf survival, First Nations harvest levels are estimates that can be off by substantial margins (LeBlanc et al. 2011), and there is no guarantee that overall population numbers will not be maintained under this monitoring strategy. Population numbers are important from the perspective of the Tsilhqot'in as moose bring a nutritious and traditional source of meat to their diet. Despite this, increasing the frequency of moose surveys to a yearly basis will likely not yield data that can be used to change management options, due to small population changes and sampling error over this short of a time period. Other jurisdictions that have information on SRB survey frequency available include: Ontario with a goal of surveying each management unit every 3 years[19]; Alberta has no set schedule and allocates effort according to area specific needs (Alberta Sustainable Resource Development 2009); the Yukon surveys units every 5+ years (Yukon Environment 2016); while Saskatchewan has a variable schedule of 3 – 6+ years based on management unit priority (Arsenault 2000). Having a recommended SRB monitoring schedule set at an appropriate time period will help ensure that management can be applied promptly when required.

Recommendations

Managing human caused mortality of moose in the Chilcotin depends on having good information on and control of harvested numbers. Obtaining more accurate information on First Nations hunting success is one component that will aid in sustainably managing moose populations. Given recent survey information, the reductions in the AAH since 2012, access restrictions, and habitat management in the South Chilcotin appear to have helped improve moose populations in GMZ 5D. Population numbers in the Chilcotin are still relatively low (e.g. 0.17 – 0.22 moose/km^2 in 2016); however, modeling of moose population trends indicates that continued improvements can be attained by continuing to be conservative with AAH numbers until populations have rebounded sufficiently. The implementation of strategies such as effective access restriction and habitat management in other areas of the Chilcotin is also likely to aid in the recovery of moose populations. The following are specific measures to help manage human caused moose mortality.

[19] Ontario MNRF Provincial population monitoring plan 2015-2019. Available at: https://www.ontario.ca/page/provincial-wildlife-population-monitoring-program-plan

- Reanalyze the population modeling completed in 2016 to reflect the most recent data. The results suggest an improved outlook for GMZ 5D and it would be worthwhile to identify how this information affects the probabilities of meeting population targets. Additional composition surveys in this management unit (or entire GMZ) may also be warranted to validate improvements in bull/cow and calf/cow ratios.
- An additional 5 years of monitoring for the collared cow research program will yield important information on cow moose survival, reproductive output, and health issues.
- Monitoring of juvenile moose is beneficial for refining the population model and identifying mortality factors. Consider expanding the calf collaring to other study areas where calf/cow ratios may contribute to a declining population. Monitoring during the neonatal period may also be required to successfully address this issue.
- Allocate funds to support moose SRB surveys in every management unit at a minimum of 5-year intervals so that moose population trends can be managed promptly and effectively. This can be a challenge given recent winter cold weather patterns; however, the use of map based stratifications has allowed surveys to proceed during relatively short cold weather windows. Where significant decreases in a population occurs increasing the frequency to 3-years may be required to assess management responses. Where ratios of population components are low, completing additional composition surveys is also advised.
- Initiate programs to promote First Nations reporting of moose hunting success and support capacity building initiatives. Involvement of First Nations in research and management will be an important component of these initiatives. In addition, including traditional ecological knowledge in research and management is likely to increase community buy-in for collaborative moose management.
- Promote the adoption of Nation level strategies (e.g. compulsory reporting and access restrictions) as laws at the Band level. Previous high densities of moose in the 1990s and early 2000s were likely supported by the presence of large areas with low vehicle accessibility. Restoring these areas of low accessibility will be important in helping to recover the Chilcotin moose population.

Habitat Management and Restoration

Moose depend on habitat to supply forage, protection from weather, and security cover that aids in predator avoidance. The availability of food and effects of weather are the most critical parameters in winter (Keystone 2006). During winter, moose primarily forage on woody browse species such as willow, aspen, and birch, while succulent plants including sedges, forbs, and aquatic plants are eaten during summer (Blood et al. 2000). Within a season, moose home ranges are generally 5 – 10 km^2 although yearly home ranges can be much larger, especially for migratory moose (Blood 2000). In the Chilcotin, moose habitat is found in the Interior Douglas-fir (IDF), Sub-boreal Pine Spruce (SBPS), Montane Spruce (MS), and Engelmann Spruce

Subalpine Fir (ESSF) biogeoclimatic zones. In winter, the SBPS contains the highest value winter habitat with little use of the high elevation ESSF zone by moose, primarily due to excessive snow depths.

Areas with a mosaic of habitat types that includes aquatic habitats and wetlands, early seral foraging habitats (e.g. between 10 – 30 years), and adjacent security and thermal cover offer good habitat for moose (Wall et al. 2011, Maier et al. 2005). Moose have a relatively low upper critical temperature (14°C in summer and -5°C in winter) that makes them vulnerable to heat stress on warm days (Dussault et al. 2004). Moose avoid heat stress by seeking out habitats that provide thermal cover and cooler temperatures, while security habitat helps moose avoid predators (Mysterud and Ostbye 1999). Modeling of moose habitat in the Cariboo Region, has defined security cover as ≥ 3m tall live conifer and thermal cover as ≥ 19m height live conifer (Dawson et al. 2015). Wall et al. (2011) defined thermal habitat as coniferous stands (>60% conifers: preferably Douglas-fir or spruce) >60 years old (15m tall) with canopy closure of >40% in patches >4 tree lengths in width (Wall et al. 2011). It is also important to note that the cold, dry climate in the Chilcotin results in a relatively low site index when compared to areas east of the Fraser River. Because of this, the recovery of security and thermal cover values takes much longer after harvesting in the Chilcotin.

Many factors can influence the supply of habitat for moose in the Chilcotin including forest management activities, natural disturbances, the presence of access infrastructure, permanent land clearing activities (e.g. agriculture or industry), and climate change. The scale, intensity, and temporal aspects of these disturbances influence the strength of effects on moose habitat. Some factors have direct influences on moose mortality (e.g. vehicle collisions), several have indirect effects that will change with time (e.g. forest harvesting), and others have more permanent changes (land clearing for mines, agriculture, etc.). Climate change is often thought to be incurring a more gradual change in habitat with many models projecting the migration of organisms requiring cool temperatures to higher elevations and more northerly latitudes. However, as the recent MPB epidemic has shown, relatively small average global increases in temperature can have dramatic effects on the landscape. Ensuring that future forests are resilient to changes in climate will benefit all forest wildlife, including moose.

Of these factors, disturbances resulting from forest operations and access infrastructure have the greatest spatial extent. This has become especially evident during the rapid and widespread changes in forest structure that has been associated with mountain pine beetle (MPB) salvage harvesting. Given the geographic overlap between recent moose declines and the MPB outbreak, the Province has undertaken research to test the effects of landscape change on moose populations (Kuzyk and Heard 2014). While the other factors (e.g. mining, land conversion to other purposes, etc.) can have a much more intense impact on moose habitat, these impacts generally have a small spatial scale, leading to localized effects, and are best considered on a case by case basis. Given this difference in scale and intensity, this recovery plan focus' on strategies to mitigate the effects of forestry, roads, and MPB induced change on moose and moose habitat.

Winter is usually seen as the time of year when moose are most vulnerable because of weather and forage availability, although heat stress during summer may also impact moose (Van Beest et al. 2012, Lenarz et al. 2009). Management of moose habitat in the Cariboo has focused on the winter period and there have been several reports identifying management strategies for this species during winter. In 2004, mapping was completed to identify wetlands that received proportionately greater use by moose during winter (Stalberg 2004). Stalberg (2004) used the results of stratified random block winter moose surveys occurring between 1987 – 2002 and expert opinion to identify important wetlands and complexes. That report recommended updating the list of high value wetlands using future surveys and including areas that have never been surveyed. Most management units have been surveyed at least one additional time since 2002, especially if composition surveys are included. It is likely that there are additional high value wetlands that could be identified using this information. While each management area has been surveyed more than once, there are also cells within management areas that have not been surveyed (e.g. due to randomization during sampling) and other areas that are not part of existing grids (e.g. Redbrush area, area southwest of Nimpo Lake, etc.), but are known to support wintering moose. Obtaining relevant data from these areas would help ensure the all areas of moose winter range have been considered when making management decisions.

In 2006, Keystone reviewed moose management in the Cariboo and provided best management practices for winter range in the Cariboo Region. Keystone (2006) identified 3 different ecosystem types where moose habitat needs were slightly different (dry, moist, and wet). Within each zone, buffer widths and habitat objectives were specified (Keystone 2006). Within this framework, the Chilcotin is characterized as a dry ecosystem where buffers of up to 200 m are recommended on important wetland complexes. The buffers should contain mature forest over at least 40% of the of the wetland buffers. Methodology for identifying moose winter range were also recommended. The methodology is based on identifying suitable wetland complexes using GIS and then verifying moose use based on tracks during overview flights. No actual standards for quantifying use were provided; however, the number of tracks/moose seen on known high value wetlands could provide a standard for identifying new wetlands that require management as moose winter range.

More recently, Davis and Meisner (2013) provided recommendations for forest operations in the South Chilcotin to help address low moose populations identified during recent surveys. The *South Chilcotin Moose Habitat and Moose Vulnerability Management Plan* (Davis and Meisner 2013) examined the influences of forage, security cover, and thermal cover on moose vulnerability. Management recommendations and targets designed to address these factors were provided along with a discussion of operational considerations and Forest and Range Practices Act implications (Davis and Meisner 2013). Recommended minimum targets for the management of security cover are to design cutblocks in a manner that provides security cover over an average of 50% of the cutblock area as measured within 700m of through roads. Targets for thermal cover are to retain 30% of the area in forested home range around each cutblock (10 km^2) in stands meeting the definition for thermal cover. No definitive targets for access control were recommended. Instead, the recommendation was to decrease active or available road density to produce areas of reduced vulnerability for moose (i.e. create areas that are more difficult to access). Various methods of access control are necessary depending on requirements for future development. These methods can range from the use of gates where ongoing access is required, to the creation of obstacles to vehicle passage where no development is planned for a significant period of time, and ripping the roadbed for permanent removal of access.

Moose habitat was also included in the 2015 cumulative effects modeling (CEM) completed by the Ministry of Forest Lands and Natural Resource Operations (FLRNO) (Dawson et al. 2015). The CEM identified two different types of foraging habitat: dynamic and static. Dynamic foraging habitat is created by disturbances (e.g. fire, harvesting, etc.) that put forested sites into a shrubby successional stage that has higher forage availability for a relatively short period and that will rotate around the landscape over time. Static forage does not move and includes wetlands, riparian areas, and self-sustaining deciduous forests (Dawson et al. 2015). Given that forest cover for security, thermal protection, and snow interception are also important aspects of moose winter habitat, high value moose winter habitat was defined as areas containing both foraging habitat and shelter (thermal/snow interception habitat). This information was used with measures of ecological importance (% moose winter habitat), hazards to moose (road effects, lack of shelter, change in high suitability habitat), and current mitigation (area of moose habitat protected) to assess risks to moose winter habitat by assessment unit. This CEM provides an overview of the risks in each assessment unit that can be used to prioritize risks to moose for the different habitat components (Dawson et al. 2015).

In 2014, recommendations from the Davis and Meisner (2013) report, data from the moose CEM (Dawson et al. 2015), and information from prior moose habitat reports (Keystone 2006, Stalberg 2004) were incorporated into Chapter 12 of the *South Chilcotin Stewardship Plan* (SCSP). Chapter 12 of the SCSP was developed to mitigate the effects of forest operations on moose populations in the South Chilcotin while still allowing MPB salvage and access construction. Chapter 12 was developed by forest licensees with input from First nations. The chapter established an access management plan, connectivity and retention corridors, and stand level retention strategies to protect important aspects of moose habitat.

Access management practices under the SCSP includes closures of existing roads for non-industrial activities at specific locations using gates and signage. New access controls are to be established as new roads required for timber harvesting are constructed. The purpose of this is to ensure that there is no net gain in roads on the landscape. Access control structures were meant to prevent the use of the road by any vehicle except all-terrain vehicles (ATV). It is difficult to prevent ATV use entirely; however, licensees have committed to exploring options to impede ATV use of roads. Access restrictions for ATVs are also in place under the Wildlife Act with both time of day seasonal closures present depending on the management unit. However, the effectiveness of these closures will be dependent on enforcement effort. Non-status roads that cannot be immediately closed due to use by other groups will require consultation led by government.

The connectivity and retention corridors established under the SCSP are intended to provide connectivity, protection for important habitats, and facilitate the re-colonization of new stands by less mobile organisms as the stands mature. The corridors were intended to be approximately 200 m wide to provide some interior forest habitat and link existing no-harvest areas with sensitive habitats (OGMAs, riparian reserves, high value moose wetlands, etc.). The design of the corridors used principals based on Forest Ecosystem Networks (*Biodiversity Guidebook* 1995) to increase the chances of success. Corridors consist of mature-old forests where available with the next oldest available stand used where these are not present. Corridors are meant to be retained for at least 10 years or until adequate security cover has developed in the surrounding harvested area (conifers >3 m tall, Davis and Meisner 2013). Salvage harvesting can occur within the corridors for two reasons: salvage harvest where a replacement area ensures no net loss to moose habitat value; and sanitation harvesting where there is green attack that is a forest health concern.

The connectivity corridors established during the SCSP process are relatively narrow, the 10-year period for their retention does not allow sufficient time for security cover to develop on adjacent newly harvested stands, and they have been developed, at least partly, based on a distribution of remaining suitable habitats, which may or may not be functionally connected. Recent research on connectivity in a moose-caribou-wolf system in the boreal forest has shown that functional connectivity was decreased between foraging patches by forest harvesting (Courbin et al. 2014). Both ungulates avoided open areas such as cutblocks and used stepping stones of suitable habitat to travel between larger resource rich patches. Both species also selected for patches surrounded by a relatively lower proportion of roads and cutblocks than the surrounding landscape. Resource patches with greater numbers of connections were used preferentially, likely due to the greater choice in routes to traveling to other foraging locations and avenues to escape predators. Wolf selection for habitat patches was stronger for areas with an increased proportion of cutblocks and roads (Courbin et al. 2014). In undisturbed forest, moose selected the nearest foraging patch, but had an equal chance of moving short or long distances when in an area with harvesting. The authors attribute this difference to the greater predation risk in areas with harvesting (Courbin et al. 2014). This finding is also supported by Moffat (2012) who modeled wolf search efficiency in Ontario. Wolves moving along linear features, such as roads, can quickly navigate across their territory while targeting moose habitat near roads and, thus, put moose at greater risk in areas with high road densities (Moffat 2012). Road densities >0.6 km/km^2 have been identified as an apparent threshold above which moose populations decline in Nova Scotia (Beazley et al. 2004).

These studies (Courbin et al. 2014, Moffat 2012, and Beazley et al. 2004) illustrate the effects of the matrix quality and connectivity on the relationship between predators and prey. Moose and wolves are highly mobile animals and managed landscapes that retain the ability of moose to move safely between multiple forage patches are desirable in this system. Creating linkages in the forest matrix that support ecological processes are more likely to be successful in the long term (Cheryl-Leslie et al. 2006). In the Chilcotin, high value moose wetlands and other foraging areas require a network of linkages to support moose. Ideally, these resource patches would be identified using resource selection functions (RSF). The modeling completed by Dawson et al.

(2015) could supply the basis for a preliminary RSF; however, it should be verified using radio-telemetry on individual animals. Identifying how moose move between patches will aid in identifying important characteristics for these linkages. For instance, moose move rapidly and in straighter lines between patches of foraging habitat (Courbin et al. 2014). Under this scenario, corridors may require much less shelter habitat. Being able to use largely younger stands for security cover between foraging areas would allow shelter habitat to be used where it provides the greatest value for moose. Movement models have been developed for elk in Ontario (Morales et al. 2004) and Alberta (Frair et al. 2005) that characterize different movement states (e.g. resting, small scale intra-patch, and rapid long distance). Moose in Alaska were observed moving more quickly through habitats with lower forage availability; however, turning angles were the same in all habitats (Battle 2016). For moose, research may help unravel the needs for shelter, foraging, and security habitat between foraging areas and linkages. Further, this type of research can also reveal different patterns of movement between components of the population, such as cow-calf moose pairs. Cow-calf pairs often are located away from concentrations of moose and understanding their habitat needs is important in addressing recruitment. This may also result in linkages becoming flexible components of the matrix that would shift over time as the landscape changes instead of trying to maintain static areas of forest. Determining how moose are using different habitats will aid in designing core foraging areas, and effective linkages. The Province is using the data from the collared cow project to assess moose habitat use patterns[20]; however, addressing these gaps may require collars with higher fix rates than are employed in the current project.

The SCSP also addresses connectivity at the stand level to facilitate small mammal movement, decrease the time period until the opening can be used by large and small mammals, decrease sight lines for predators, provide perches for birds, and to provide seed sources for natural regeneration. Stand level connectivity uses wildlife tree patches (WTPs), retention of deciduous trees, protection of advanced conifer regeneration, and individual windfirm trees to create linkages across harvested openings.

Management for high value moose habitat identified by the CEM moose model (Dawson et al. 2015) have also been incorporated into the SCSP. Forest management inside modeled moose winter habitat (high value or MMWH) includes access closures, augmented riparian reserves, regeneration protection, and retention of thermal and security cover. Access closures are to be installed immediately after harvest and may include recontouring, piling debris, or rehabilitating sections of road to impede ATV access into MMWH. Riparian reserves on small streams (<1.5 m wide) with bull trout are to be increased to 20 m, while larger streams will have FRPA defined reserves. Thermal cover within MMWH should be maintained above 30% of a moose home range area (e.g. 10 km^2). Blocks within MMWH are to have regeneration protection to provide screening cover for wildlife.

[20] Personal communication with Becky Candsand, Biologist, FLRNO.

Under the SCSP, the intent of regen protection is to provide visual screening from roads, presumably to decrease the ability of road hunters from easily spotting moose. However, it is important to point out that advanced regeneration also provides security cover from other predators of moose (e.g. wolves and bears). Moose are reported to avoid recent clear cut areas until the vegetation recovers and provides sufficient hiding cover (Courtois et al. 2002, Potvin et al. 1999, Thompson and Vukelich 1981), and research from southeastern BC also noted that security cover levels were lower at kill sites than control sites (Kunkel and Pletscher 2000).

Field audits of the SCSP have been conducted by TNG that examined access control, regeneration protection, riparian buffers, connectivity, and management in modelled moose winter habitat (MMWH)[21,22]. Roads can have effects on moose habitat use patterns. Areas with greater road density were avoided by moose in Quebec (Corbin et al. 2014), and moose home ranges in Minnesota had lower road densities when compared to the landscape (Wattles and DeStefano 2013). In general, access control was implemented in the blocks examined. There is a No-Net-Gain policy associated with roads in the SCSP area. At this time, some forest licensees have provided road density amounts for the SCSP area; however, information is required on this target from all licensees to determine if the No-Net-Gain policy is being adhered to[23]. Further, specifying a target for road densities and subsequently decreasing road densities in areas near important habitats is likely to benefit moose populations.

The results of regeneration protection during the audit are mixed with some blocks found to have limited regen, and the auditors felt that more could have been left to reduce sightability across the blocks. There were also opportunities for additional buffering and wildlife tree patches adjacent to small wetlands that were not taken in one cutting permit. A second audited permit was thought to have good retention throughout the blocks. Connectivity in both permits was provided by corridors retained between openings. One of the permits was for the harvest of green timber and auditors had concerns about this. Green timber provides thermal cover for moose and thermal habitat in the area around the blocks is in deficit. However, harvesting was implemented to address spruce beetle green attack within the permit. The licensee adopted recommendations for the protection of moose security habitat[24] on this permit and used diameter limit harvesting to help retain some level of thermal habitat.

Overall, it appears that forest licensees are trying to address commitments made under the SCSP. Of the issues examined during the audit, reducing line of sight distances within cutblocks, the preservation of thermal habitat, and access control still appears to be a challenge. Not having a measure of the pre-harvest stems/ha of advanced regeneration makes assessing the

[21] Cooper, G. 2016. TNG and Caretaker Forestry activities field monitoring checklist - ID1066Tolko4500RoadXeniAudit. Unpublished report prepared for TNG.
[22] Cooper, G. and L. Solomon. 2016. TNG and Caretaker Forestry activities field monitoring checklist - ID10587FieldAuditBCTS. Unpublished report prepared for TNG.
[23] Personal communication with Luke Doxator, TNG Stewardship Dept.
[24] Davis, L.R. 2014. Moose habitat assessment on A84333 and A92845. Unpublished report prepared for BCTS Central Cariboo.

post-harvest protection of regeneration difficult. This could be addressed by including this measure during timber cruising. To make this measurement less onerous, the stem count could be done using meaningful classes of density that would not require full counts in many cases (e.g. have low, moderate, and high density classes where counts would only be required where the density was close to a class boundary). As stated previously, addressing the influences of forest harvesting on both the human and non-human predators of moose is likely to be important in a mitigation strategy. Natural disturbances usually have abundant woody debris and standing snags that provide screening cover for wildlife in all directions. An update to the SCSP (April 2016) still describes the intent of regeneration protection as being *to provide visual screening of a riparian feature associated with or adjacent to MMWH from a road within a block.* Calf moose are a particularly vulnerable segment of the moose population and forest practices that help moose hide from all predators in all directions is likely to benefit this portion of the moose population.

The 2017 moose survey results from MU 5-13A indicate that calf moose numbers are very low (15 calves/100 cows) in that unit (Davis 2017). The calf component of the population is the most vulnerable to predation and forest retention practices that help hide moose could improve calf survival. Further, overall moose density has decreased by approximately 30% since the last survey in 2003, while bull/cow ratios have remained stable (~50 bulls/100 cows) (Stalberg 2003) in that unit. In contrast, the moose population in MU5-04 where the SCSP was implemented appears to have recovered somewhat during the period since the last survey in 2012[25]. The population density has increased from 0.14 to 0.22 moose/km^2, the bull/cow ratio has increased (38 bulls/100 cows in 2012 and 45 bulls/100 cows in 2017), and the calf ratio has also improved slightly from 27 to 30 calves/100 cows in 2017. It is important to note that juvenile survival in ungulates is highly variable when compared to the survival of adults and will vary on a yearly basis (Gaillard et al. 1998).

The difference in population parameters between the two management units (MU 5-04 and 5-13A) may be due to the changes in forest management associated with the SCSP. However, it is important to note that the SCSP was not designed to test this hypothesis and there may be other factors that could influence this comparison. For instance, the units are located south and north of the Chilcotin River and, in general, MU 5-04 slopes to the north while MU 5-13A slopes to the south. This difference in topography may have some effect on habitat availability, snow cover, and winter temperatures that could influence moose abundance. There may also be a bias caused by the difference in survey history between the units. MU 5-04 was surveyed in 1998, 2012, and 2017, while it has been 14 years since MU5-13A was last surveyed. We do not know if during the intervening time period (e.g. ~2012) the MU 5-13A moose population had also decreased to an even lower level than it is currently. If that was the case, MU 5-13A would also be showing an increase in population without an SCSP type intervention. It is likely that there are many more differences between the two units that confound this comparison.

[25] Personal communication with Becky Cadsand, Biologist, FLNRO

While there are differences in physiography between Chilcotin wildlife management units, all the units contain a large proportion of plateau habitat that contain wetland complexes that supply important moose winter habitat. Further, these plateaus have aspects that face all directions at a meso-scale, resulting in pockets of similar habitat across the region. The measures implemented by the SCSP are designed to help mitigate the effects of salvage harvesting and the recent survey indicates that there has been some improvements in population parameters in the South Chilcotin. Implementing a similar process in other areas of the Chilcotin may also be of benefit. With that said, using scientifically rigorous and defendable methods to select high value habitats and design corridors is desirable. Further, additional research may help identify how moose are using different aspects of habitat that could be relevant to the design process. For instance, designing Chilcotin landscapes to facilitate moose travel throughout the forest matrix is more likely to succeed over time than static reserves.

Lastly, Keystone (2006) suggested that the limited area in high value wetlands and riparian areas in dry regions such as the Chilcotin make forage a limited resource. Recent research on cow moose in the Chilcotin and other areas of BC has found 16% of the animals died of apparent starvation. In the Big Creek portion of the study area, 2 out of 39 cow moose are thought to have died of apparent starvation (Kuzyk et al. 2016); with a third animal that died of wolf predation having low marrow fat reserves indicative of malnutrition. My own observations of moose use of wetlands in the Chilcotin, indicate that there are many wetlands that appear to have high value (e.g. abundant willows), but were not receiving much use by moose during winter. This observation may be partly due to the lower density of moose observed over the last 5-10 years in the Chilcotin. However, it may also be compounded by over growth of willow and impacts on nutritional value. The nutritional value of browse in winter is low and moose are operating in a deficit state during this period. Speath et al. (2002) found that smaller diameter twigs in Barklay's willow (Salix barclayi) had higher protein and digestibility than larger twigs. Modeling comparing moose foraging on young twigs (<1-year-old) versus older twigs found that moose required a 15% greater mass of older stems. Such a diet would also have greater volume that would influence passage rate through the gut which may further affect energy stores (Speath et al. 2002). Assessing high value moose wetlands for forage availability and quality may provide information that could be used to develop treatments that enhance forage.

It has also been suggested that decreased moose use of seemingly productive shrub-carr meadows in the Chilcotin may also be influenced by the presence of feral horses. Moose and feral horses in Alberta were found to have high habitat overlap during most of the year (90%) except spring when the overlap decreased to 25% (Salter and Hudson 1980). Salter and Hudson (1980) analyzed fecal samples of feral horses and found very little use of willow (<1% in seasonal diet). No measure of moose dietary components was completed during that study; however, since moose diets rely heavily on browse (Bamfield 1974) and they had made an observation of an adult moose feeding with 5 horses, the authors concluded that there was ecological separation even where the two species coexisted. Similarly, a study in the interior of BC found significant ecological separation between moose and feral horses (Storrar et al. 1977, as reported by Salter and Hudson 1980). Despite a separation in diet, feral horses may have behavioral effects on moose that have not been rigorously examined. Feral horses in the Chilcotin occupy areas used by moose in winter and large numbers of feral horses are regularly seen during moose inventories. Anecdotal reports from Chilcotin First Nations also indicate that horses are displacing moose from suitable habitat[26]. Understanding if feral horses are displacing moose would require research on this relationship.

Improving forage availability away from wetlands may also provide benefit for moose. Moose cow-calf pairs often locate away from high concentration areas such as wetlands (Thompson et al. 1981). This behavior may decrease predation risk for cow-calf pairs. The Alexis Creek First Nation supports a road deactivation plan that includes forage production using direct seeding[27]. The plan includes spreading logging debris on the road to limit access and improve moisture retention. Secondary logging roads in the Chilcotin are often minimally developed with no ditches and contain low areas that hold water for portions of the year that could help in sustaining forage species. This type of management may help address several goals for moose management and forest productivity. Improving forage in areas away from high value moose wetlands may result in lower predation risk for moose using these areas and be of benefit to the vulnerable calf component of the population. The spreading of woody debris on the road is also likely to be an effective deterrent for ATV use. The SCSP had licensee commitments to explore this element of access control; however, there does not appear to have been any rigorous attempt to address this issue. In addition to access control objectives, regenerating the roads with a mix that includes both forage species and conifers would increase the timber available for future harvests and contribute to meeting the Province's Forest Carbon Strategy[28] while aiding moose recovery. Planning that incorporates all of these objectives into a landscape level moose recovery plan is desirable.

Habitat Recommendations

A process like that of the South Chilcotin Stewardship Plan should be implemented across the Chilcotin to help address concerns regarding moose habitat and population numbers. The original process involved primarily industry with input from the TNG. The process would benefit from additional data on moose habitat use in the Chilcotin using radio-telemetry and the development of RSF habitat models. Properly parametrized models may help identify additional areas of high value moose habitat, the different processes moose use, and delineate linkages that reflect ecological processes. While the broad strokes of moose habitat needs are known from the various reports that have been prepared in BC and elsewhere, having a moose

[26] Personal communication with Dan Lirette, Biologist, FLNRO.
[27] Bravi, B. Deactivation plan for forest roads in the Alexis Creek Indian Band Traditional Area. E-mail communication January 30, 2017.
[28] Natural Resources Climate Change Mitigation – Forest Carbon Strategy. Available at [http://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/natural-resources-climate-change/natural-resources-climate-change-mitigation].

biologist review and comment during the process would help ensure that the best-known information is being used and that the information is being interpreted correctly. This expertise would help avoid any misconceptions that could arise from interpretations of recommendations, gaps in understanding, and facilitate the design of monitoring protocols.

Key characteristics of such a plan are presented below:

- Design a network of core habitat zones in the Chilcotin using RSF models for winter moose habitat. The habitat model defined by Dawson et al. (2015) along with known High Value Moose Wetlands can be used as a preliminary model to help identify core winter habitats. That model uses best known information on moose habitat use and was vetted using expert opinion and data from winter moose surveys in the Chilcotin. However, the model is based on GIS mapping of capable and suitable habitat and not on habitat selection by individual animals. Obtaining data on moose habitat selection using radio-telemetry would help validate this model and better inform management decisions in the Chilcotin.
- Within core habitat areas, forest management should adhere to the following guidelines: 100 m minimum width forested reserve with a further 300 m management zone. Within the management zone, limit stands lacking security cover (conifers averaging >3 m tall) to 40% of the zone and 30% of the zone should be maintained as shelter habitat (e.g. stands with coniferous cover >15 m tall). Patches of security/shelter habitat should be distributed around the management zone so that moose are always within 200 m of patches of cover that are >100 m wide (Tomm et al. 1981). Where stands >15 m tall not currently present, stands >8 m tall may provide habitat until the forests recover sufficiently. Roads in the management area would be made impassable immediately following harvesting by ripping and planting or spreading debris and planting within 1 km of core habitat areas.
- Linkages between core habitat areas should follow modeled moose winter habitat (MMWH) which should provide patches of forage and shelter. The linkages do not have to provide continuous shelter habitat and should be 200-500 m wide. The linkages would have security/thermal cover distributed so that moose are always within 200 m of patches of cover that are >100 m wide (e.g. within a linkage, moose would not have to cross an opening lacking security cover >400 m wide before entering cover >200 m wide). Wider linkages (e.g. 500 m) should be placed on larger riparian systems whereas more narrow linkages (e.g. 200 m) would connect to peripheral foraging areas.
- Linkages are parts of the forest matrix and would shift as adjacent stands achieve adequate levels of cover.
- MMWH should be managed using the same commitments as in the SCSP including prompt access closures, augmented riparian reserves, regeneration protection, provisions for maintaining thermal cover, and security cover. Moose winter range should have 30% thermal cover at the level of a moose home range (e.g. 10 km^2) and this retention should be focused near foraging areas such as wetlands. It is likely that much of the MMWH will be located in core habitat areas and within linkages between core habitat areas.

- Determine if more high value moose wetlands are present on the landscape and incorporate these into the core habitat areas. Use GIS analysis to identify new wetlands that are more likely to have winter moose use and conduct surveys to assess these new areas. Assessments could be conducted while completing composition surveys. The number of tracks and moose seen on known HVMW could be used as a benchmark for inclusion of additional wetlands and complexes. Again, obtaining data on moose habitat selection using radio-telemetry would also help identify important wetlands in the Chilcotin.
- Access control in the Chilcotin should also follow the process developed as part of the SCSP. Goals of this management should be to decrease active or available road density to produce areas of reduced vulnerability for moose (i.e. create areas that are more difficult to access). Currently, the SCSP has a No-Net-Increase in road density policy; however, where road networks are already extensively developed this may not be effective in producing areas of reduced moose vulnerability. Areas where there is >0.6 km/km^2 should be the focus of deactivation efforts. Providing relatively large areas (e.g. >10 km^2) where there is no effective vehicular access for significant periods of time (e.g. ~20 years) would create refuges from which moose populations could expand. Locating these areas around core habitat areas would provide the greatest benefit.
- Enhancement of forage may be of benefit to moose populations in some areas. Assessing high value wetlands for enhancement opportunities may identify prospects for increasing forage quantity and/or quality. There is also a proposal to increase forage and facilitate access control in locations outside of high value wetlands. A significant portion of the moose population is found at lower densities away from high value wetlands, and improvements in forage availability may benefit this component of the population. A pilot study examining the potential for direct seeding of forage species and conifers on deactivated roads would help evaluate this proposal.
- Lastly, implementation of the management recommended above should be prioritized by landscape unit using information from the CEM process for moose. The planning required will take time and high risk landscape units are likely most in need of management intervention.

Predator Management

The recent decline in moose numbers across central BC has prompted speculation about the role of predator populations in this decline and calls for predator management to restore moose populations (GOABC 2016, Gorley 2016). Predator control programs can be socially divisive (Way and Bruskotter 2012) and controversial even among wildlife professionals (Boertje et al. 2010). Recent news reports on wolf control efforts to support endangered mountain caribou in BC show how this issue can divide society into camps on either side of this issue[29]. In North America, public acceptability of lethal control measures appears to depend on the type and severity of the impact. Way and Bruskotter (2012) report greater public support for lethal control on wolves that prey on livestock than when wolves are negatively impacting big game populations. Likewise, the severity of impacts on moose and caribou populations and how those impacts would be experienced by residents influenced public support for wolf and grizzly control in Alaska (Decker et al. 2006). Similar patterns have been observed in other jurisdictions where the acceptability of lethal control of problem wildlife in North America has been examined (Whittaker et al. 2006, Loker et al. 1999). In BC, predator control can be used to protect species at risk and to address livestock depredation, but policy prevents it from being used to enhance ungulate populations (MFLNRO 2014). Two projects are currently underway that involve predator control to support endangered caribou populations (Hervieux 2014, MoE 2014). However, changes in government policy would be required before predator control could be used to support moose population increases in the Chilcotin.

Despite the current policy concerning predator control, it is worthwhile to examine efforts in other jurisdictions where predator control has been used for guidance on program efficacy and the conditions required for the programs to work. There is good evidence from Alaska that predation can be a major limiting factor on moose populations especially where populations are low density (see review by Boertje et al. 2010). Out of 10 studies that were reviewed, only one found that density-dependant food limitations had a major contribution in maintaining the moose population level and that study area had the highest moose densities examined (Boertje et al. 2010). This is supported by a review of wolf-ungulate studies by Cariappa et al. (2011) which found that wolf populations had density-dependent regulation only at high densities of ungulates. It is also important to note that predators rarely kill prime aged moose (2-8 years) regardless of predator density (Mech et al. 2015, Boertje et al. 2009, Gasaway et al. 1983). Moose calves are the primary target of predators, likely due to the formidable defence that healthy adult moose can maintain (Mech et al. 2015, Boertje et al. 2010). Both wolves and bears prey on moose calves; however, a review of 8 studies on calf mortality in Alaska all concluded that combined predation by bears was the major cause of mortality on that age class (Boertje et al. 2009). In that review, bears killed an average of 44% of collared moose calves (24-67%) compared to 11% killed by wolves (2-25%). Grizzly bears killed an average of 25% of collared moose calves (3-52%) and black bears killed 20% (2-40%) (Boertje et al. 2009).

Predator control studies in Alaska, Yukon, Manitoba, Saskatchewan, and British Columbia have all recorded increases in moose numbers following treatments (Boertje et al. 2010, Hayes et al. 2003, Kotchorek 2002, Stewart et al. 1985, Elliot 1985). Treatments in Alaska included control of wolves, bears, and locations where both species were managed (Boertje et al. 2010) while the Yukon studies only involved the removal of wolves (Hayes et al. 2003). Control of black

[29] Examples include the globe and mail (http://www.theglobeandmail.com/news/british-columbia/bc-wolf-cull-program-will-continue/article24496415/) and an article from CBC news (http://www.cbc.ca/news/canada/british-columbia/wolf-cull-save-elk-moose-1.3450522) among many others.

bears in Manitoba (Kotchorek 2002) and Saskatchewan (Stewart et al. 1985) both resulted in increased calf/cow ratios. Wolf control in the Kechika area of northeastern BC also had strong positive responses on the juvenile survival of moose, mountain sheep, and caribou where wolf numbers were substantially reduced (Elliot 1985). However, wolf populations recover quickly after cessation of control efforts in most studies and multiple interventions may be required to maintain prey populations at high levels.

The studies referenced above indicate that predator control can be effective, at least in the short term, and an examination of factors leading to successful programs is warranted. In Alaska where predator control to enhance ungulate populations has a long history, the following guidelines and recommendations have been provided for predator control programs (NRC 1997). Additional research on predator control from other sources has been added where appropriate.

1. **Wolves and bears in combination can limit prey populations**. Reducing predator numbers can release this control; however, evidence for the existence of a high density stable state following predator control is limited. There is only one study with evidence of a prey population being released from a 'predator pit'. Moose populations in Game Management Unit 20 in central Alaska increased 4-fold following wolf control and were maintained at that level after the cessation of control efforts (Titus 2007). Wolves recovered to pre-control numbers while moose numbers have further increased necessitating cow harvest to help regulate the population. These results indicate that a high-density equilibrium is possible (Titus 2007). However, it is also important to note that where bears are the dominant predator on moose, wolf reductions may result in only slow increases in moose numbers (Ballard et al. 1991).

2. **Wolf control has resulted in prey increases only when wolves were greatly reduced over a large area for at least 4 years.** Adequate funding and an adaptive management approach are required to increase the probability of success. Successful research programs are likely to require even greater lengths of time. A review of predator control programs in Alaska found that after 5 years of predator control, 5 of 5 programs began in 2003-2004 required an additional 5 years of control to meet objectives (Russel 2010)**.** The area required to successfully implement predator control is estimated at 10,000 km^2 (ADFW 2007).

3. **Expectations that managed populations will remain stable are not justified.** Major population fluctuations are typical in northern ecosystems. Before beginning any predator management, the status of predator and prey populations should be fully evaluated, population trends determined, and the carrying capacity of the prey's environment assessed. Wolf populations have rebounded in most management units following control and required additional treatments. Research on a recovering wolf population in the Yukon illustrates this effect (Hayes and Harestad 2003). Wolves

increased from 29 to 245 over a 6-year period primarily by recolonization of vacant territories by young wolf pairs during early population recovery.

4. **Ensure that adequate data on habitat quality has been collected prior to beginning predator management**. Predator control will only be successful when prey populations are well below the habitat carrying capacity. Research on tools that increase the carrying capacity of the environment may also be needed.

5. **Modeling of population dynamics will enhance the use of data already collected and enable more efficient use of limited resources.** Long term data sets and modeling can improve attempts to identify causal factors in predator and prey trends at reduced cost.

6. **Wolves, bears, and their prey are vulnerable to human actions but in different ways.** Moose and caribou have relatively low reproductive rates and can easily be overharvested. Similarly, bear populations can be more vulnerable to human activities, generally due to low reproductive rates and difficulties in censusing. In contrast, wolves can respond rapidly following population reductions. Wolf populations can sustain harvest rates of up to 35% while keeping their numbers stable year to year, necessitating large reductions in numbers to achieve a numerical increase in prey populations.

   There have also been some suggestions that wolf control at levels <30% can destabilize wolf populations, cause pack splitting, and increase impacts on vulnerable prey (Bradley and Pletscher 2005, Brainerd et al. 2008, Wielgus and Peebles 2014). The effects of loss of a breeding wolf can affect pack structure and breeding success especially in small packs with a greater chance of pack dissolution and reduced reproductive success the following breeding season (Borg et al. 2015, Brainerd et al. 2008). However, a review using a 26-year data set from Alaska found that population growth was largely unaffected by breeder loss, indicating that strong compensatory mechanisms can reduce negative impacts at the population level (Borg et al. 2015). Brainerd et al. (2008) also predicted that the fracturing of pack structure resulting from wolf mortality may increase the number of breeding pairs, which could increase livestock depredation as breeding pairs are tied more tightly to den sites and less able to follow natural prey for a portion of the year (Bradley and Pletscher 2005). Wielgus and Peebles (2014) examined livestock depredation the year after wolf control and found that depredation events on cattle increased 5-6% where control efforts removed <25% of the wolf population. When the proportion of the wolf population removed was >25%, reduced depredation was experienced. An increase in the number of breeding pairs due to pack destabilization is thought to be the cause of increased depredation when <25% of wolves are removed (Wielgus and Peebles 2014). No research is available on the effects of low-moderate wolf control (e.g. <25% of the population) on natural prey populations.

7. **The design of most past experiments and the data collected do not allow firm conclusions about whether wolf and bear reductions caused an increase in prey populations that lasted long after predator control ceased.** Experiments/management should be based on thorough assessment of baseline conditions and should be designed so that the causes of subsequent population changes can be determined.

8. **Perfect prediction is unattainable.** Estimates of population parameters are subject to error, and stochastic events can dramatically impact on the animal's environment resulting in unanticipated changes. Therefore, failures to meet intended goals will always be part of wildlife management and this should be conveyed to the public. The Hayes et al. (2003) test of wolf control as a tool to increase populations of caribou, moose, and sheep in the Yukon illustrates this point. In that study, wolf control resulted in increased population growth for both caribou and moose, but not for sheep. Other factors, such as harvest levels and differences among treatment and control areas confounded interpretation of responses. Hayes et al. (2003) recommends public involvement in management decisions concerning wildlife to ensure the support of stakeholder groups and local communities. Such management should integrate biological information and rigorous research design with the diversity of social values held by these groups.

9. **Many past predator control and management activities have been insufficiently monitored.** Control activities should be viewed as experiments that are designed with clearly established monitoring protocols of sufficient duration to enable determination of whether the predictions are borne out and why.

Even if policy allowed predator control, it seems clear from research and management recommendations that a substantial investment in research and inventory is required prior to deciding whether to employ predator control activities to support ungulate populations. A clear understanding of both predator and prey population numbers, population dynamics, and trends can be used to model the responses and help identify causal factors. Over the past 5-7 years, there has been renewed investment in moose inventory and a 5-year research project on the causes of cow mortality in BC (Kuzyk et al 2016). The research is examining if landscape change is influencing cow moose mortality, specifically in relationship to security cover, deactivation of roads, and moose distribution. Preliminary results found yearly survival rates of 86-95% for collared adult cows, and an average of 11% of moose have been killed by wolves on a yearly basis. In the Big Creek study area, a total of 59 adult cows have been radio-collared over the duration of the study, there have been 6 moose that have died of predation (5 wolf predation events and 1 cougar). Two additional animals died due to infections from predator related wounds (1 wolf, 1 Grizzly Bear). When all 5 study areas are considered, late winter calf surveys of radio-collared cows found from 14 – 39 calves/100 cows overall and 27-37 calves/100 cows in the Big Creek study area (Kuzyk et al. 2016). The Big Creek (MU 5-04) census in January 2017 found an increasing moose population and 27 calves/100 cows supporting these estimates. In contrast, a concurrent census near Alexis Creek (MU 5-13A) found a decreasing moose population and 14 calves/100 cows in January 2017. Generally, a moose population is thought to require at least 25 calves per 100 cows to balance losses of adult moose from natural causes, including predation (Bergerud and Elliott, 1998). The research has also found approximately 6% of collared moose die of starvation and other health related effects when all study area mortalities are considered (Kuzyk et al. 2016). Recommendations are to continue this program for an additional 5 years (2019-2023) to fully examine factors that influence moose survival.

As part of the larger moose research program, a pilot program has also recently been initiated to radio-collar and monitor 7+ month old moose calves in the Bonaparte area of the Thompson Region. The program is collaring calves in the early winter when the young animals are expected to be more robust than shortly after parturition This project will examine true survival to breeding age and primary causes of mortality of that age class, as well as trial methods related to monitoring calf moose (i.e., capture protocols and expandable collars). If the project is considered successful, other study areas may be established provincially in areas with consistently low calf/cow ratios. Developing a better understanding of juvenile survival is an important component in understanding moose population dynamics.

The current population model used in BC assumes that juveniles surviving to the start of winter will have a survival rate that is 10% less than adult females going forward. Refining the model to reflect actual data from BC should increase our ability to forecast moose population numbers. While this will improve on the current model, the highest mortality for moose calves occurs in the first two months after parturition (Ballard et al. 1991, Larsen et al. 1989) and identifying significant factors in calf survival may be important in areas with low calf survival to the first winter (e.g. Alexis Creek, 14 calves/100 cows; John Prince Research Forest, 17 calves/100 cows; Entiako, 14 calves/100 cows, Kuzyk et al. 2016). Given that the fix rate of collars is high enough, the movement behaviour of collared cow moose during late May can be used to infer parturition rates, as well as when and where calves are being born. Understanding factors influencing pregnancy and parturition rates in systems with low recruitment will also be important. Testa and Adams (1998) found that poor body condition in cow moose can lead to reproductive losses during gestation and the neonatal period. While daily aerial surveys with a helicopter during this time may be too intrusive, the use of small drones may provide a more discreet method of monitoring during this period. Drones are increasingly being used in wildlife conservation and research, and have been used with radio telemetry antenna to track collared wildlife (Bird 2015). Research on whether this technique could be used with a camera to monitor the status of cow-calf pairs may be valuable for assessing the cause of mortality, including predation, in the first month of life. Understanding if predation by bears is a limiting factor for moose is likely to be important before attempting to change policy and implement a predator management program.

Despite considerable investment in moose research, we are still lacking standardized cost-effective methods of providing reliable estimates of wolf abundance that are effective across BC. Kuzyk and Hatter (2014) have estimated the number of wolves at the Provincial and Regional levels using an ungulate biomass regression model; however, this method would not be suitable for providing precise estimates of abundance that would be required for predator control programs. A pilot project was conducted in the West Chilcotin to address this gap using aerial surveys of the wolf population. The project was conducted in January 2017 around Itcha-Ilgachuz Park where it was hoped that open pine forests, large burns, and wetlands would provide suitable visibility for spotting wolf trails and wolves under winter conditions[30]. Despite good conditions for tracking wolves (e.g. complete snow cover and a fresh snowfall), survey crews were not able to spot wolves. Wolf trails were followed by helicopter and estimates of numbers generated based on locations where wolves separated creating individual trails. The wolf density was estimated at 5.6 – 7.6 wolves per 1000km^2 based on track observations. The surveyors noted that the estimated wolf density was low considering the apparent prey biomass observed during the survey. The estimated density was also low compared to densities observed in other study areas. Although the technique has been used successfully in the northeast of BC (Serrouya et al. 2015), thicker forest cover and a high density of tracks from other species (e.g. caribou, moose, horses, deer) in the Chilcotin may limit the suitability of the methodology. Developing a statistically defendable method of censusing wolves will be important in showing the public that the species is being properly managed.

Noninvasive genetic sampling (NGS) has been used to monitor wolves in Europe (Marucco et al. 2009) and more recently in the USA (Stanbury et al. 2014). Stanbury et al. (2014) collected scat and hair samples from wolf rendezvous sites in Idaho. The success of species identification was high (>90%) while individual identification rates varied between 66-72%. A comparison of population estimates derived from NGS with estimates from a concurrent telemetry based study found good agreement with minimum count estimates; however, mark-recapture analyses using NGS had higher and more variable population estimates. Violation of the assumption that recapture events are independent is likely to have influenced these results (Stanbury et al. 2014). The collection of samples at rendezvous sites where wolves congregate and spend considerable time may make the data more prone to violating this assumption. Using other survey methods to collect scat may help address this issue.

A pilot study in the West Chilcotin collected wolf scat and recorded the presence of tracks (predators and ungulates) along road/trail transects during winter (Davis 2009). The survey utilized local First Nations surveyors to collect the data using snowmobiles. The project collected 46 samples of wolf scat and documented the number of wolf tracks/100 km of transect. The intent was to conduct both dietary analysis and a DNA-based population estimate; however, insufficient funds were available to conduct these analyses in the year after

[30] Personal communication with Dan Lirette, Biologist, FLNRO.

data collection. This type of information may also be analyzed using occupancy modeling to yield abundance estimates for wolves (Latham et al. 2014, Webb and Merrill 2012, Rich et al. 2013). Exploring opportunities for non-invasive surveys, mark-recapture population estimates, and estimates using occupancy modeling may yield wolf density estimates with sufficient accuracy for management and to satisfy public expectations for managed species. Further, these methods can readily involve local First Nations in data collection and sample preparation. This collaboration may also be important in promoting inclusion in wildlife management activities.

There are several predator control methods available if adequate information on both predator and prey dynamics are available and the information indicates that predator control is a viable method of increasing prey populations (Boertje et al. 2010). Aerial shooting during winter is the most often used strategy in North America (McLaren 2016) and is one of the current methods used in BC (Hervieux 2014, MoE 2014). Trapping and ground shooting programs have also been used and often include financial incentives to increase participation; however, this method often fails to remove sufficient wolves to release ungulates and may result in fragmentation of wolf packs (McLaren 2016). McNay (2009) suggested that lethal control measures targeted in areas where prey were most vulnerable may be as effective as broad scale predator reduction policies while still meeting the expectations of recovery plans.

Alternative methods used to control predator populations have had some success although costs can be prohibitive. Where bears are the primary predator on calves, diversionary feeding has been successful in increasing calf/cow ratios. This method requires having an abundant source of carcasses, has high costs for transporting carcasses to treatment areas, and the effects are likely to be short term once feeding ceases (ADFG 2007, Boertje et al. 2010). Likewise, relocation of bears has also led to increases in calf survival in Alaska (Boertje et al. 2010). Again, the costs of such a translocation program are prohibitive, the project may not be supported by the public, and such a program may shift predation pressure to other ungulate herds (McLaren 2016). A combination of sterilization of the breeding pair and lethal methods was judged to be effective in reducing the rate of population increase in wolves (Hayes et al. 2003) and in increasing the size of the Fortymile caribou herd in the Yukon (Farnell 2009). However, the results of a similar program in the Quesnel Highlands during the period between 2001 and 2012 did not conclusively increase caribou abundance (Hayes 2013).

The Quesnel Highland wolf sterilization project utilized a combination of fertility treatments and lethal methods to effectively reduce wolf density as part of a project to protect mountain caribou (Hayes 2013). Sterilized adult wolves maintained territories, sustained sexual pair bonds, and had normal survival rates. Wolf densities were reduced by 39-48% using a combination of lethal and sterilization techniques, and wolf densities were maintained in the last two years of the study by sterilization alone (Hayes 2013). Monitoring of caribou populations in the Quesnel Highlands found an increase in abundance from 2006-2012; however, the increase was not statistically different from comparison caribou herds. Hayes

(2013) recommended that the project be continued for another 3 years and include radio-tagged adults to help monitor changes in adult survival, seasonal calf/cow ratios, and supply a sightability correction for abundance surveys. Finally, in addition to mixed results, wolf populations can quickly rebound when sterilization programs are completed (Hayes 2013). In locations with an endangered caribou herd, a rebounding wolf population can further imperil the population. Hervieux et al. (2014) found that wolf control in Alberta stabilized an endangered caribou herd, but without continued wolf control the population was likely to decline. Mediation of other factors, such as habitat restoration and moose population reduction, are likely to be required to increase caribou populations. Given this, increases in both moose and caribou populations may not be achievable goals when populations are in close geographic proximity.

Recommendations

In addition to a policy change on acceptable predator control goals, the dialogue above outlines several conditions that must be met before embarking on a predator control program. It must be shown that predators are limiting ungulate populations, the habitat must be able to support more ungulates, sufficient information on predator populations exist to gauge control efforts, control efforts must target the predators responsible for limiting the moose population, and control must be conducted for long enough and over a large enough area to remove sufficient predators to release the prey population. While there is general consensus that moose populations in the Chilcotin are under the area's carrying capacity, it has not been shown that predators are limiting the moose population. Predation levels on adults is similar to levels reported elsewhere (e.g. Larsen et al. 1989, Bangs et al. 1989, Ballard et al. 1991); however, we do not have good data on calf or juvenile moose survival past 7 months of age at this time. The collared cow moose project has also identified losses from starvation and other health related effects that are not inconsequential (Kuzyk et al. 2016). Poor body condition in cow moose can lead to reproductive losses during gestation and the neonatal period (Testa and Adams 1998). Winter ticks can be a problem in BC that affects moose body condition, and the Province is currently trying to establish a baselines for the extent of the infestation in BC[31]. Understanding what the limiting factors are for the Chilcotin moose population will take time and considerable research effort. Finally, we need accurate census and trend information on predator populations to assess the success of management efforts.

At this time, policy prevents predator control from being used to augment ungulate populations except for species at risk. Before attempting to change policy regarding predator control, it would be prudent to fill the information gaps outlined above. Filling these gaps will require

[31] BC Wildlife Health Program Moose Winter Tick Survey: http://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-health/wildlife-health-matters/moose-health/moose-winter-tick-survey

continued investment in research on moose survival and developing survey techniques to census predator populations. The research, depending on results, will also form an important component of the justification for or against such a policy change. Specifically, the following recommendations are made regarding these gaps:

- An additional 5 years of monitoring for the collared cow research program will yield important information on cow moose survival, reproductive output, and health issues.
- Monitoring of juvenile moose is beneficial for refining the population model and identifying mortality factors. However, the different study areas appear to have different factors influencing the populations. Consider expanding the calf collaring to other study areas where calf/cow ratios may contribute to a declining population. Monitoring during the neonatal period may also be required to successfully address this issue.
- Research effective methods for censusing wolves and other predators of moose in forested landscapes. Wolves are a managed species and knowledge of the population size and trends will be important in showing that sustainable wildlife management is being practiced in BC.

Conclusions

The goal of this report is to produce a plan that meets the intent of the Nenquay Deni Accord in facilitating a moose population recovery in the Chilcotin area of BC. This plan is not a a regional moose management plan or an action plan as defined under the Provincial Moose Framework (MFLNRO 2013); however, components of this recovery plan may be used to inform an action plan for the Chilcotin. It is important to note that other First Nations have overlapping territories with the Chilcotin, and groups such as resident hunters and guide-outfitters also have a keen interest in moose management plans for this area. Engaging all interested parties in future recovery planning will be an important factor influencing the successful implementation of any management or action plan for moose in the Chilcotin.

Moose populations in the Chilcotin have declined in recent years in response to a variety of factors that are not easily elucidated. The Chilcotin, along with other areas in the Central Interior of BC, has been affected by climate change that likely has impacted moose populations through increasing temperatures, increasing parasite loads, and changes to forested landscapes (Brown 2011, Murray et al. 2006). Efforts to recover economic value from mountain pine beetle killed timber are resulting in large salvage harvesting openings across the landscape in a short period of time and associated extensive road networks that further complicate these effects. The distribution of moose in North America suggests that the species has some capacity for adaptation to different environmental conditions. However, humans are the most adaptive species on the planet[32], and we have the behavioural plasticity to respond much more quickly to environmental changes than most other species. This report outlines changes to *our* social-ecological system that are likely to support resilient moose populations in the Chilcotin.

Sustainable management of human caused mortality relies on having accurate information on animal population parameters and accurate harvest numbers from all sectors of society. Investing in more frequent and regular inventories will allow wildlife managers to detect population trends more quickly and implement management changes promptly where appropriate. Initiatives that increase First Nations reporting of moose hunting success and capacity building are likely to result in improved wildlife management. These initiatives could take the form of incentives for participating in reporting, training that increases the capacity to collaborate on wildlife management, and reporting of findings back to contributing communities to raise awareness on wildlife management issues. Nation level strategies that provide legal enforcement of laws promoting sustainable wildlife management are also needed. Where these are implemented, restorative justice programs may provide the greatest benefit, especially where other initiatives have already raised community awareness on wildlife issues.

Habitat management is an ecological component that is being influenced by climate change and socio-economic systems. Designing our forests to be resilient to climate change is likely to preserve important aspects of moose habitat and maintain socio-economic development. A process like the South Chilcotin Plan should be initiated across the remainder of the Chilcotin. This is a large area and prioritization should be given to landscapes where cumulative impact assessment has identified the greatest risks to moose. Current research should contribute to such a plan as information becomes known using an adaptive management approach. Managing for core moose habitat areas that have minimal access will decrease the vulnerability of moose populations. Access control should be prioritized to areas where there is >0.6 km of road/km^2 and concentrations of high value winter moose habitat. Linkages between core areas need not be continuous, and should be managed to shift over time as forests mature. Exploring opportunities for forage enhancement may also be worthwhile, especially where efforts can also rehabilitate roads and help mitigate climate change. These management changes are likely to create habitats where moose populations can be resilient to further changes in climate. Resilient moose populations have a greater capacity to deal with temperature induced stresses, increased parasites, and predator populations.

Moose in the Chilcotin are immersed in a multi-predator system whose populations are generally thought to be relatively high. However, little hard data is available on predator populations in this area, and the only available local research indicates that predation rates on adult cow moose are not high (e.g. ~10%). Most research in North America has found that neonatal and juvenile moose are the life stages that have the lowest survivorship. Bears (Grizzly

[32] Massey, N. 2013. Climate – Humans may be the most adaptive species. Scientific American. Accessed March 29, 2017 [https://www.scientificamerican.com/article/humans-may-be-most-adaptive-species/].

and black) have the greatest impact on young moose killing an average of 44% of moose calves compared to 11% killed by wolves in Alaska (Boertje et al. 2009). Where bears are the dominant predator on moose, wolf control may result in only slow increases in moose populations (Ballard et al. 1991). Despite this, predator control has worked to increase moose populations in Alaska where wolves and bears limited moose populations. Recommendations from Alaska before beginning a predator control program include: research must show which predators are limiting ungulate populations; the habitat must be able to support more ungulates; sufficient data on predator populations exist to gauge control efforts; control efforts must target the predators responsible for limiting the moose population; and control must be conducted for long enough and over a large enough area to remove sufficient predators to release the prey population. These recommendations clearly show that we need good research on predators and moose for successful management of this predator-prey system.

Research on cow moose in BC is ongoing and recommendations are to continue the project for an additional 5 years. Low recruitment of juvenile moose also appears to be a problem in some areas of BC. In addition to losses from predation, low calf recruitment can result from a variety of other causes including stochastic variations in climate and cow moose body condition (Solberg et al. 1999). The pilot project radio-collaring juvenile moose is likely to help determine the causes of mortality from this segment of the population. Combined, data on cows and calves will help elucidate the causes of moose mortality in BC. However, the neonatal period is the most vulnerable for moose and we are still lacking methods to study this age class. Expanded research on neonatal moose may also be required to fully understand which factors are limiting moose populations. Likewise, the forested landscapes of the Chilcotin make estimating elusive predator populations difficult, and research on cost effective methods to accurately census predators is also required. Finally, policy prevents predator control from being used to augment ungulate populations in BC, except for species at risk. It makes sense to fill information gaps on moose and their predators before attempting to change policy regarding predator control.

Current projections for the moose population in the Chilcotin are to increase over the next 5-year period (FLNRO 2016), which may be due, in part, to shifts in First Nations harvest of cows to bulls and changes in forest management occurring in the South Chilcotin. Conducting regular (e.g. 5 year intervals) moose inventories with more frequent composition surveys where inventory shows potential problems will allow wildlife managers to respond more rapidly to changing conditions. Likewise, implementing a habitat and access control plan for the remainder of the Chilcotin will improve moose resilience to climate induced changes. The results of the current research on moose should be used to support the habitat plan using an adaptive management framework. Lastly, predators are managed species in BC and having accurate data on population numbers and trends will support sustainable management of all wildlife. Again, humans have shown the capacity to adapt our behaviours to reflect changing environments and employing such adaptation will ensure sustainable management of our natural resources.

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