Assessing Caribou Survival in Relation to the Distribution and Abundance of Moose and Wolves

Semi-annual Report September 2016

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Executive Summary

Our research is focused on quantifying the relationships among caribou, moose, and wolves across gradients of anthropogenic disturbances and moose and wolf densities in northeast (NE) British Columbia (BC). This project is using the fine-scale data provided by GPS monitoring to test hypotheses related to caribou resource selection and survival. Here, we provide an update on the research conducted to date during the second year of the project.

We have continued to process additional moose data and have built preliminary moose resource selection models using data collected as of July 2016. We plan to rerun those models as more data become available. Our primary interest is understanding how male and female moose respond seasonally to the most widespread anthropogenic disturbances (roads and seismic lines) in NE BC, and if the presence of these disturbances has any impact on moose selecting or avoiding habitats used by caribou. The response of moose to roads and seismic lines varies seasonally and by sex. Females avoided roads during calving and late summer, but selected for roads during winter. Males selected roads during calving and avoided roads in late winter. Females selected seismic lines in three of four seasons, while males avoided seismic lines in late winter. Males and females with more linear features in their home ranges tended to avoid treed bogs, except for females during calving. Females that had home ranges with higher densities of roads demonstrated a greater affinity for treed bogs during calving in comparison to females with lower densities of roads within their home ranges. Females living in areas with more roads showed increased selection for poor fens during calving and late winter, while males showed decreased selection for poor fens in late summer and increased selection in late winter as function of road density. Females with a higher density of seismic lines also increased selection for poor fens in late summer.

We used previously collected estimates of moose density to evaluate the influence of anthropogenic disturbances on moose densities in NE BC. We predicted that moose densities would be largely driven by habitat. Thus, we built competing models, which included the proportion of hardwood swamps and proportion of treed bogs, along with one of four

disturbance metrics. Our disturbance metrics included the proportion of cutblocks, proportion of burns, density (m/m^2) of roads, and the density (m/m^2) of seismic lines. As expected, there was a positive relationship between moose density and the proportion of hardwood swamp and a negative relationship between moose density of the proportion of treed bog. Moose density was positively associated with the proportion of burns, but there was no relationship between moose density and our other disturbance metrics.

We have finalized analyses exploring the influence of linear features on the probability of a caribou encountering a wolf and the probability of a caribou being killed given an encounter. We used caribou and wolf location data to contrast differences between caribou locations and potential wolf-caribou encounters and also contrasted wolf-caribou encounters to caribou mortality locations attributed to wolf predation. Based on this approach, caribou were more likely to encounter wolves near or in areas with higher densities of roads and seismic lines; there was no relationship, however, between linear features and the probability of being killed given an encounter. The probability of encounter increased in areas with more hardwood swamps and treed bogs and at lower elevations. The probability of being killed also increased in areas with more conifer and hardwood swamps, but decreased in areas with more treed bogs and rich and poor fens in winter. In summer, areas with more edges between vegetation classes decreased the probability of being killed, but areas with higher amounts of terrain roughness increased the probability of being killed given an encounter.

Once those two types of risk were established, we evaluated caribou responses to the risk of encounter and the risk of being killed by including them in resource selection functions. Although prime-aged and older adult caribou showed similar and strong patterns of risk avoidance to both the probability of encounter and probability of being killed, younger caribou demonstrated a weaker or ambivalent response to the probability of encounter in three of four seasons. Further exploration revealed that this difference appeared primarily related to the failure of young caribou to avoid areas with linear features suggesting that older caribou are capable of adjusting behaviours to avoid the increased risk associated with anthropogenic linear features.

Ultimately, our work is attempting to identify the drivers of caribou survival in the boreal with a particular interest in the direct and indirect effects of manageable anthropogenic activities. Specifically, we are interested in how development may alter risk via increased wolf search efficiency or apparent competition via changes in moose and wolf distributions or abundances, and how these interactions can be managed to reduce risk to caribou. During the remainder of this year, we plan to utilize our moose resource selection and wolf risk models as covariates in modelling caribou survival both at the core and individual level. These analyses will also include other landscape attributes, in order to tease apart these complex processes and interactions.

Project Overview and Objectives

Project Scope

Woodland caribou (*Rangifer tarandus*) are listed as threatened or of concern under the Species at Risk Act in Canada. Declining numbers of caribou have been linked to habitat alterations and to complex predator-prey interactions. Predators can disproportionately affect one prey species when those predators are numerically linked to another more abundant prey species (e.g., DeCesare et al. 2010; McLellan et al. 2010). This interaction has relevance to caribou on the boreal landscapes of NE BC because wolves (*Canis lupus*) are the principal predator of caribou, but moose (*Alces alces*) are the primary prey of wolves. Further, current patterns of landscape change in the boreal may be resulting in an increase in moose abundance and related increase in wolf abundance.

Our research is focused on quantifying the relationships among caribou, moose, and wolves across gradients of anthropogenic disturbances and moose and wolf densities — we are using the fine-scale data provided by GPS monitoring to test hypotheses related to caribou resource selection and survival related to moose presence and selection, and to anthropogenic disturbance. Our first step was to increase our understanding of the drivers of moose distribution and density, which enabled us to evaluate the spatial interaction between caribou and moose, and examine how this interaction changes under varying levels of disturbance. We will use a similar approach when developing wolf-risk layers, and ultimately, these layers in conjunction with both anthropogenic and natural disturbances (e.g., fire) will become covariates in our model of caribou survival to identify the attributes that affect the probability of caribou mortality.

Objectives

Using telemetry data from radio-collared moose, caribou, and wolves provided to UNBC, our moose-wolf-caribou interaction analysis is determining:

1. if moose distribution and abundance is related to human-caused habitat change inside and outside of core caribou habitat?;

2. if wolf use of caribou habitat is related to moose distribution and abundance?;
3. if predator and prey abundance and behaviour interact to put caribou at increased risk?; and
4. what biotic, landscape, and anthropogenic attributes affect the survival of boreal caribou — with particular reference to those attributes that can be managed?

Project Activities and Status for Year 1 of the Project

During the second year of this project, we continue to work on all five stated activities:

A1) receive and analyze moose telemetry data;

A2) develop initial moose use/selection layers (existing data);

A3) develop initial caribou risk layers using existing data;

A4) refine caribou risk layers using incoming moose, caribou, and wolf data; and

A5) conduct caribou survival analysis using all moose, caribou, and wolf data.

In this report, we address progress on activities 3 and 4 together, while all other activities are addressed separately.

Activity 1: Receive and Analyze Moose Telemetry Data

We continue to download, process, and assign landscape attributes to moose locations. We downloaded 16,329 additional moose locations through the Globalstar satellite system collected from January 2016 – July 2016 (Figure 1). After previously determining that additional locations, not transmitted via the Globalstar satellite system, are stored on the collars (Mumma and Gillingham 2016), we directly downloaded location data (553 additional locations) from 10 of 11 collars collected from moose mortality locations. Seven of the 10 collars contained locations (10 – 214 additional locations) not transmitted via the Globalstar satellite system. These additional locations brought the fix rates above 90% for six of the seven collars (Table 1) providing further justification for the retrieval and direct downloading of collars from all moose mortalities. We did not directly download data for the male moose killed immediately after capture during the winter of 2015. The short duration between collaring and mortality precluded its inclusion in further analyses.

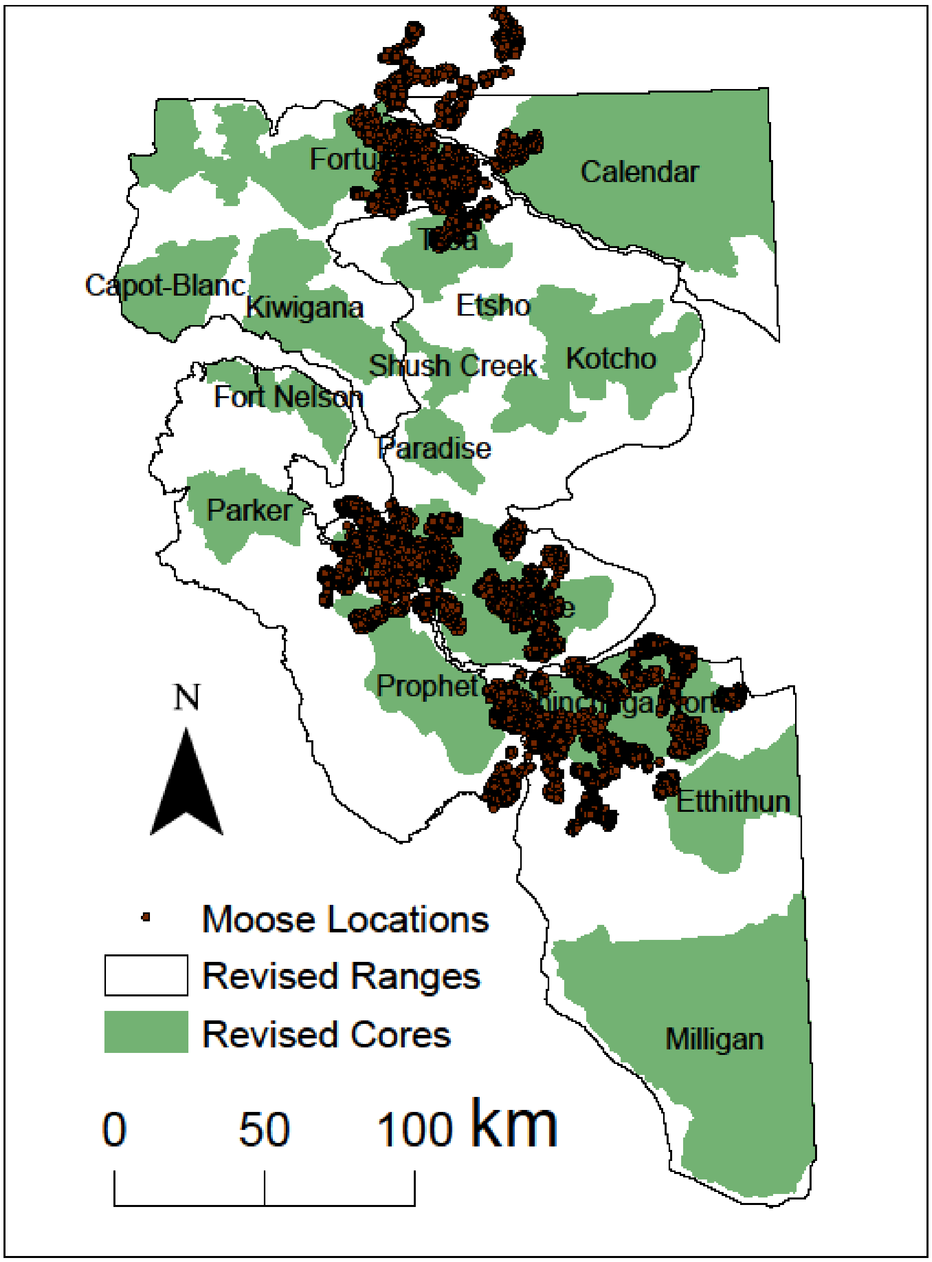

Figure 1. Distribution of moose telemetry fixes from 59 male and female moose collected from January 2016 through July 2016. The figure also contains the revised caribou ranges and cores.

Table 1. Additional locations and corresponding increases in fix rates resulting from direct downloads of collars recovered from moose mortality locations.

Sex	Satellite fixes	Additional direct fixes	Total fixes	Potential fixes	Satellite only fix rate	Combined fix rate	Change in fix rate
M	47	0	47	88	0.534	0.534	0.000
M	0	10	10	76	0.000	0.132	0.132
M	585	214	799	854	0.685	0.936	0.251
F	137	0	137	148	0.926	0.926	0.000
F	531	57	588	604	0.879	0.974	0.094
F	539	68	607	618	0.872	0.982	0.110
F	510	100	610	648	0.787	0.941	0.154
F	105	0	105	140	0.750	0.750	0.000
F	686	89	775	784	0.875	0.989	0.114
F	210	15	225	242	0.868	0.930	0.062

As of September 2016, 51 of the original 63 collared moose are still transmitting data. Eleven moose have died to date and one collar has likely malfunctioned (Table 2). Samples were collected from eight of the 11 mortalities. Teeth from each of these individuals have been sent to Matson's Laboratory (Manhattan, Montana) for aging. Percent bone marrow fat (<50%) indicated that three of these individuals were in poor body condition, which was further confirmed for one individual via kidney fat (0%). Additional tissues for two individuals have been sent to Helen Schwantje (BC Wildlife Veterinarian) for further analyses. Wolf predation was implicated as the proximate cause of death for eight of the mortalities, although % bone marrow fat indicated diminished condition for one of these wolf-killed individuals. One individual died during labour in May 2015, and two individuals died of unknown causes in May 2016. In addition to the one collar that has malfunctioned (no viable locations since April 18, 2016), three previously malfunctioning collars were replaced last winter (Table 2). Although several individuals have undergone short forays into the Northwest Territories, only one individual remains north of the BC border at present (Table 2).

Table 2. Current status and fate of GPS radio collars deployed in NE BC through September 2016.

Area	Collared		Mortality		In NWT		Failed GPS/ replaced GPS		Active	
	F	M	F	M	F	M	F	M	F	M
Chinchaga RRA	13	7	1	2					12	5
Clarke core	15	7	4				2/1		10	7
Fortune core	14	7	2	2	1		2/2		12	5

Activity 2: Develop initial moose use/selection data

Several actions during the first year of our work contributed to the development of our moose selection layer. Our first step was to define biologically relevant seasons that were applicable to each species (Mumma and Gillingham 2016). Next, we established a means of defining availability and generated random available locations (Mumma and Gillingham 2016). We then determined a suite of landscape attributes hypothesized to drive selection patterns of moose (Mumma and Gillingham 2016). We then explored attribute distributions for used and available locations (Mumma and Gillingham 2016). During this reporting period, we built preliminary resource selection functions to increase our understanding of moose habitat selection in NE BC. We were particularly interested in the role of linear features on moose resource selection, given that roads and seismic lines are widespread across NE BC. Also of interest was the potential impact of linear features on the response of moose to preferred caribou habitats, such as treed bogs and poor fens. Changes in the selection by moose of these habitats might alter the amount of overlap between moose, wolves, and caribou leading to a potential mechanism by which caribou survival is reduced.

Moose resource selection functions

We built preliminary resource selection models using all data collected (30,910 used and 154,567 available locations) as of July 2016. As more data become available, these models will be updated and rerun. Our covariates included nine categorical vegetation classes that were reclassified from a Ducks Unlimited Canada (2013) layer using the methods detailed by DeMars (2015). These classes included conifer swamp, hardwood swamp, rich fen, poor fen, treed bog, upland conifer, upland deciduous and other as our reference category. The other class included several non-habitat or minimally-present vegetation classes (e.g., open water, anthropogenic, etc.). Natural landscape features modelled as continues covariates included elevation, northness, eastness, slope, standard deviation of slope within a 100-m buffer (measure of terrain roughness; Grohmann et al. 2011), density (m/m^2) of vegetation class edge within a 100-m buffer, and distance to water. Disturbance metrics included the proportion of cutblocks and burns within a 100-m buffer, distance to roads, and distance to seismic lines. We used these covariates to build competing models and selected the most parsimonious models (Burnham and Anderson 2002) by season and sex using Akaike's Information Criteria (Akaike 1998) for small sample sizes (AIC_c; Burnham and Anderson 2002).

In order to test if linear features were potentially increasing the selection of preferred caribou habitats (i.e., treed bogs and poor fens) by moose, we added interaction terms between the density of linear features within an individual's home range and categorical covariates of preferred caribou habitats to our most parsimonious models for male and female moose for each season. Before adding interaction terms, we had to determine seasonal home ranges and the density of linear features within each seasonal home range for each individual. We first buffered the location of each individual by its 90^{th} centile of movement distances for the corresponding season in the same manner that was used to establish availability (Mumma and Gillingham 2016). We then estimated seasonal home ranges for each individual by merging the resulting circular polygons of each season for each individual (see Figure 2). Next, the length of roads and the length of seismic lines were calculated and divided by the total area of each seasonal home range to determine the density (m/m^2) of roads and density (m/m^2) of seismic lines for each individual by season. We used the densities of roads and seismic lines in interaction terms that were added to the most parsimonious models for each season and sex. These interactions included road density by treed bog, road density by poor fen, seismic line density by treed bog, and seismic line density by poor fen. We used AIC_c to test if these interactions improved model fit, thereby determining if linear feature density altered the selection or avoidance by moose of preferred caribou habitats.

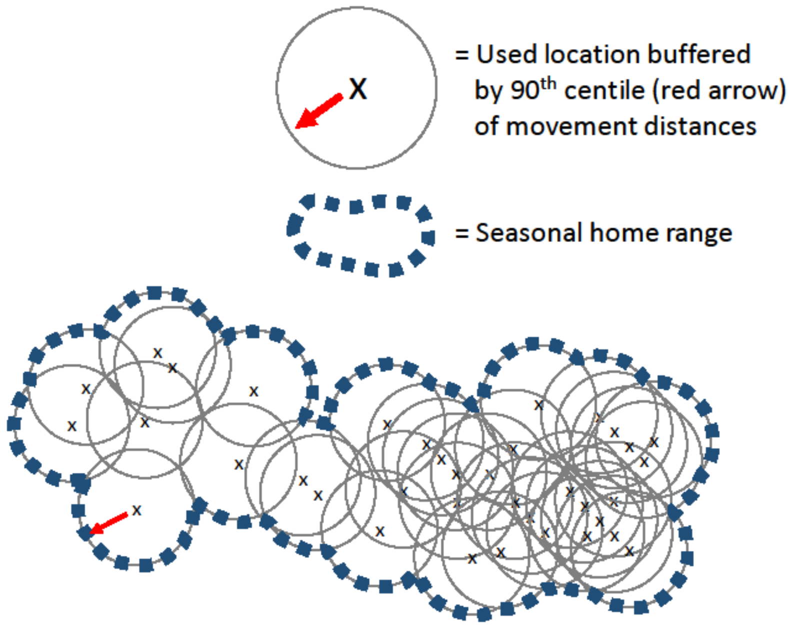

Figure 2. Seasonal home range was estimated for each individual by buffering the individual's used locations for each season by their corresponding seasonal 90th centile of movement distances and then merging the resulting circular polygons into a single home range.

Our models indicate that moose in NE BC generally selected both coniferous and deciduous uplands, hardwood swamps, and rich fens, although there is variability both seasonally and by sex. Less selection is demonstrated for uplands in early and late winter and rich fens are less selected by females during calving and late summer. Males and females also selected for areas with a higher density (m/m^2) of vegetation class edges (Figure 3) across all seasons and selected for areas near water (Figure 4) with the exception of females in late winter. Both sexes selected for areas with a high proportion of cutblocks and burns (Figure 5) with the exception of late winter when these areas were avoided.

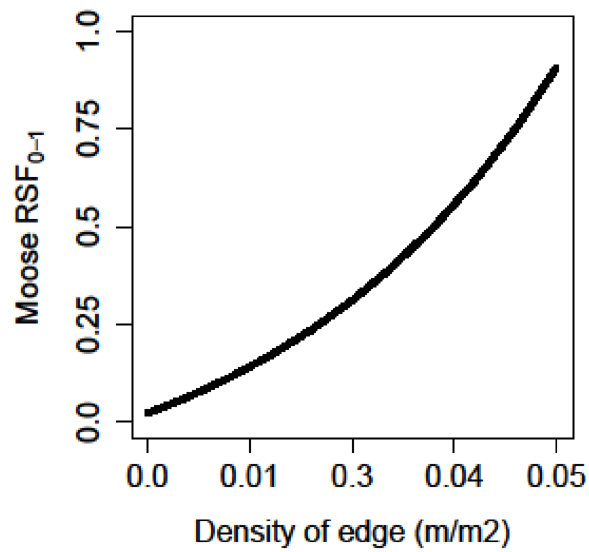

Figure 3. Relative likelihood of male moose selecting locations as a function of the density (m/m2) of vegetation class edge within a 100-m buffer. Likelihood values (Moose $RSF_{0\text{–}1}$) standardized across other covariates.

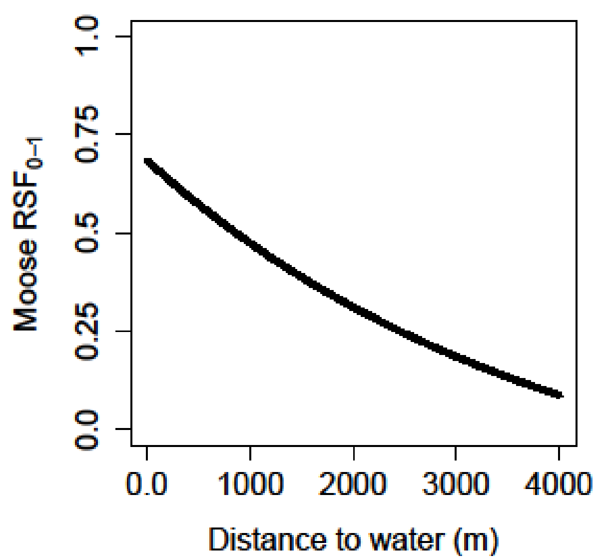

Figure 4. Relative likelihood of male moose selecting locations as a function of the distance to water (m). Likelihood values (Moose $RSF_{0\text{–}1}$) standardized across other covariates.

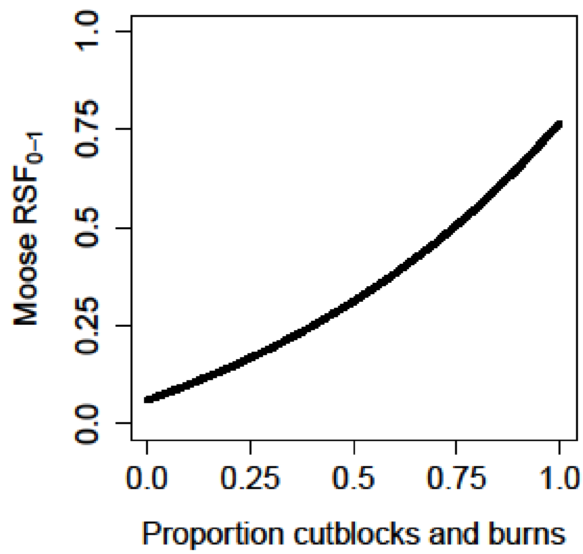

Figure 5. Relative likelihood of male moose selecting locations as a function of the proportion of cutblocks and burns within a 100-m buffer. Likelihood values (Moose RSF_{0-1}) standardized across other covariates.

The relationship to linear features was highly variable across seasons and between sexes. Females avoided roads during calving and late summer, but selected roads in late winter (Table 3). Males demonstrated an opposing trend, selecting roads during calving and avoiding roads in late winter (Table 3). Females selected seismic lines in late summer, early winter, and late winter, while males avoided seismic lines in late winter (Table 3). These relationships may

Table 3. The response of male and female moose to areas near roads and seismic lines by season. Blank cells in the table indicate no significant response.

Season	Near roads		Near seismic lines	
	Female	Male	Female	Male
Calving	Avoided	Selected		
Late summer	Avoided		Selected	
Early winter			Selected	
Late winter	Selected	Avoided	Selected	Avoided

reflect differences in vulnerability between sexes. Linear features are used by wolves as travel corridors (Latham et al. 2011), thereby females may want to avoid linear features during summer to protect vulnerable calves. Conversely, males may be in a weakened state following the energy-expenditures of the fall rut and may seek to avoid linear features in late winter.

The influence of linear features on the selection by moose of preferred caribou habitats was equally complex. Generally, individuals with a higher density of roads or seismic lines within their home ranges demonstrated reduced selection for treed bogs or no change in selection in comparison to individuals occupying areas with lower linear feature densities, except for females during calving (Table 4). Females with higher densities of roads in their home ranges demonstrated increased selection for treed bogs during calving (Table 4). Because females avoid areas near roads during calving, this response may be reflective of reduced road densities in treed bog habitats, thereby making these habitats more attractive to female moose. Roads also increased female selection for poor fens during calving and in late winter, while seismic lines increased selection of poor fens during late summer (Table 5). Males demonstrated decreased selection in late summer and increased selection for poor fens in late winter (Table 5).

Table 4. The response of male and female moose to treed bogs dependent on the density (m/m2) of roads and seismic lines within an individual's seasonal home range.

Season	More roads		More seismic lines	
	Female	Male	Female	Male
Calving	Increased		Decreased	
Late summer		Decreased		Decreased
Early winter	Decreased	Decreased		
Late winter		Decreased		

Table 5. The response of male and female moose to poor fens dependent on the density (m/m2) of roads and seismic lines within an individual's seasonal home range.

Season	More roads		More seismic lines	
	Female	Male	Female	Male
Calving	Increased			
Late summer		Decreased	Increased	
Early winter				
Late winter	Increased	Increased		

Although the influence of linear features on the selection by moose of preferred caribou habitats is highly variable, we are most interested in understanding how these factors influence overlap with caribou. Of particular interest is moose-caribou overlap during snow-free seasons (i.e., calving and late summer) when the threat of wolf predation is likely increased as was demonstrated by research in a similar system in Alberta (Latham et al. 2013). We plan to finalize these models once additional data are collected, explore individual variability regarding the selection of preferred caribou habitats by moose, and determine how linear features increase or decrease seasonal overlap between moose and caribou.

Moose density as a function of disturbance

Our project is primarily focused on examining the influence disturbance has on moose and wolf distributions, in conjunction with the corresponding implications for caribou survival. The potential for disturbances to impact moose densities, however, may be equally important. We used linear regression to evaluate if moose densities could be explained by different types of disturbances in NE BC. Moose densities (Figure 6) were estimated through surveys (McNay et al. 2013; Thiessen 2010) previously initiated and supported by Forest Lands and Natural Resources (FLNRO). Although we were interested in understanding the impact of disturbances on moose density, we anticipated that moose density would be largely driven by habitat. Thus, we built models that included the proportions of a selected vegetation class (i.e., hardwood swamps) and a vegetation class (treed bog) that is not selected by moose (Mumma and Gillingham 2016), along with one of our four disturbance metrics. Our disturbance metrics included the proportion of cutblocks, proportion of burns, density (m/m^2) of roads, and density (m/m^2) of seismic lines. We used AIC_c to determine the most parsimonious model. The only model that outperformed the habitat only model (proportion of hardwood swamp + proportion of treed bog) included the proportion of burns. As expected higher moose densities were found in areas with higher proportions of hardwood swamps, lower proportions of treed bogs, and higher proportions of burns (Table 6). The limited sample size, however, precluded us from examining interaction terms in the models.

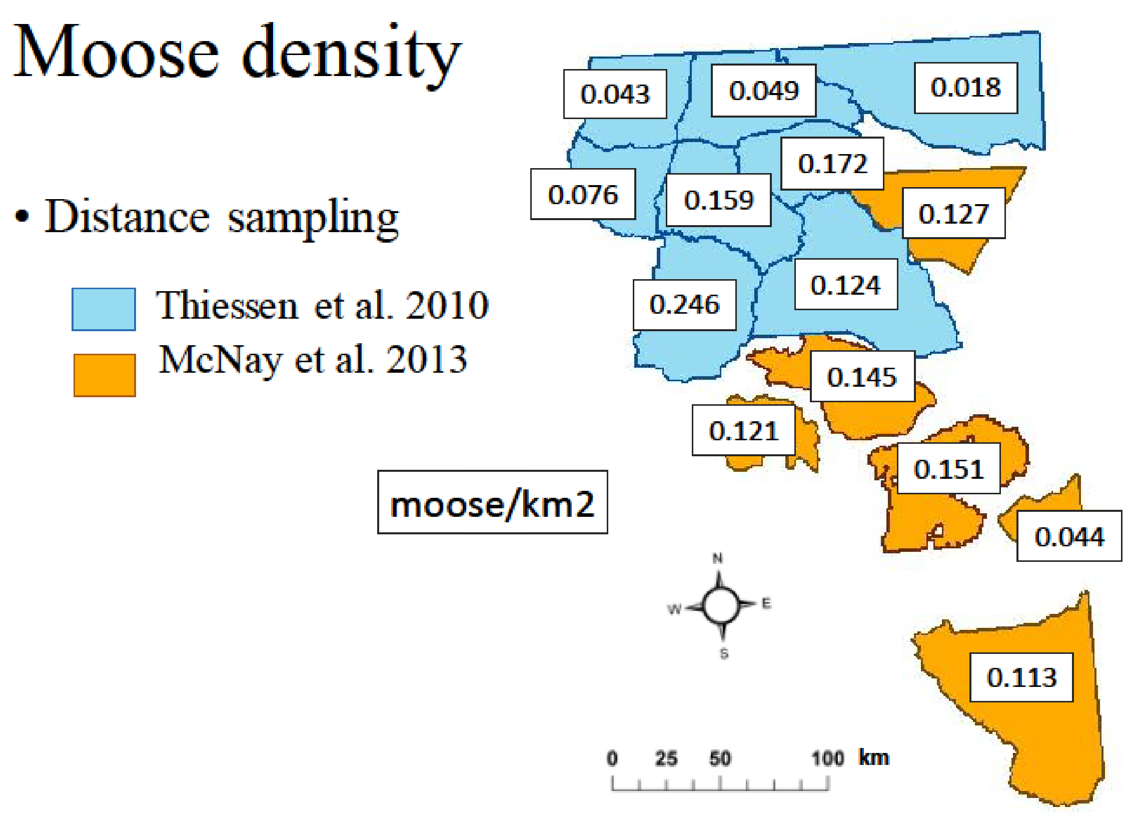

Figure 6. Moose densities (moose/km2) across NE BC as estimated by McNay et al. (2013) and Thiessen (2010).

Table 6. Most parsimonious disturbance model explaining moose densities in NE BC.

Covariate	Coefficient values
Intercept	0.095
Proportion of hardwood swamp	0.826
Proportion of treed bog	-0.478
Proportion of burns	0.419

R^2 = 0.547

Activity 3 and 4: Develop and Refine Caribou Risk Layers with Moose, Caribou, and Wolf Data

Predation risk can be characterized as the joint probability of encountering a predator and the probability of being killed by a predator following an encounter (Hebblewhite et al. 2005). Frequently, researchers model predator resource selection as an index of risk. This may be a reasonable approximation of risk for a primary prey species if we assume that the importance of the probability of encounter far outweighs the probability of being killed following an encounter. In the boreal, caribou are an alternative prey species for wolves, and as a result, the two species demonstrate different habitat selection patterns (Latham et al. 2013), which reduces the likelihood that a wolf resource selection model alone will be a good indicator of predation risk for caribou.

We are currently in the process of assigning attributes to wolf locations and building wolf resource selection models that will be incorporated as covariates in downstream analyses of caribou survival. Given the complexity of risk, we have also conducted analyses modelling the landscape attributes that predict the probability of encountering a wolf and the probability of being killed given an encounter. Further, we have explored the response of caribou to these two types of risk.

Analyses of Encounters and Risk

We used locations from 28 collared wolves and 104 collared caribou to identify nonlethal wolf-caribou encounters as defined by a wolf location being within 1971 m (average 24-h caribou movement distance) of a caribou location within a 24-h period (Figure 7). We used logistic regression to compare caribou locations to wolf-caribou encounters in order to predict landscape attributes that increase the probability of an encounter. To model the probability of being killed following an encounter, we used logistic regression to compare wolf-caribou encounters to caribou mortality locations assigned to wolves. We used AIC_c to identify the most parsimonious models for the probability of encounter and probability of being killed.

Our analyses suggest that caribou are more likely to encounter wolves near or in areas with higher densities of roads and seismic lines, but found no relationship between linear features and the probability of being killed given an encounter (Table 7). We also found that the probability of encounter increased in areas with more hardwood swamps and treed bogs and at lower elevations (Table 7). The probability of a collared caribou being killed by wolves increased in areas with more conifer and hardwood swamps, but decreased in areas with more treed bogs and rich and poor fens in winter (Table 7). In summer, areas with more vegetation class edges decreased the probability of being killed, but areas with higher amounts of terrain roughness increased the probability of being killed given an encounter (Table 7).

Age-specific caribou responses to spatial risk

Once models were established for the probability of encounter and the probability of being killed, we evaluated caribou responses to the two types of risk by including them as covariates in caribou resource selection functions. Prime-aged and older adult caribou showed similar and strong patterns of risk avoidance to both the probability of encounter (Figure 8A) and probability of being killed (Figure 8B). In contrast, younger caribou demonstrated a weaker avoidance or positive selection to the probability of encounter (Figure 8A) and a stronger avoidance to the probability of being killed (Figure 8B) in three of four seasons. Further exploration revealed that these findings corresponded to strong responses by younger caribou to natural landscape features associated with risk, but weak responses to anthropogenic linear features. Thus, caribou seem to alter their responses to anthropogenic linear features associated with risk as they transition to prime-age adults.

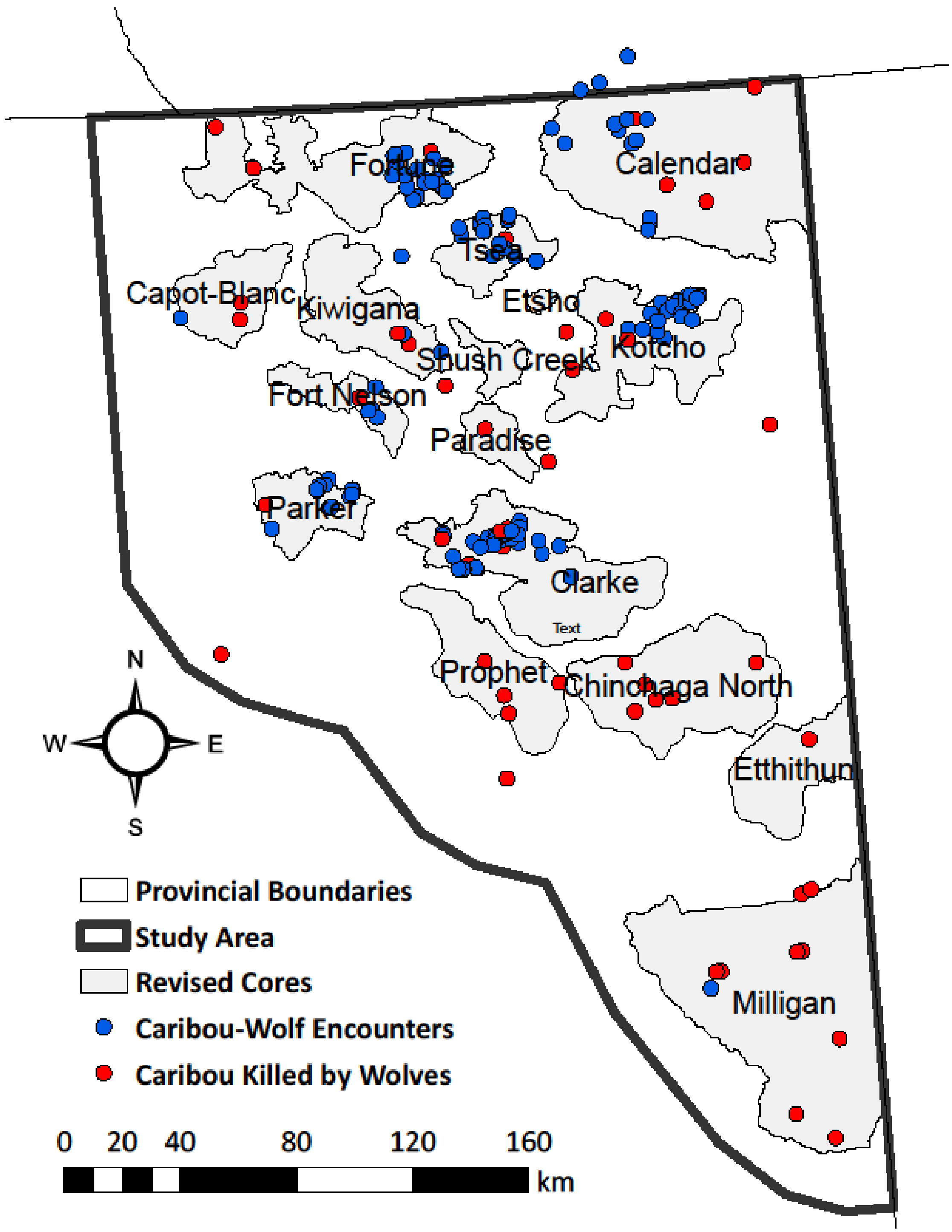

Figure 7. Locations of encounters (based on proximity of radio-collared wolves and caribou; see text) and caribou mortality locations attributed to wolves within the study area.

Table 7. Covariates (and direction of effect) in the most parsimonious models of the probability of encounter and the probability of being killed given an encounter.

Probability of encounter	Summer	Winter
Proportion of hardwood swamp	Increased	Increased
Proportion of treed bog	Increased	Increased
Elevation	Decreased	Decreased
Density of roads	Increased	
Density of seismic lines	Increased	
Distance to roads		Decreased
Distance to seismic lines		Decreased

Probability of being killed	Summer	Winter
Proportion of swamps	Increased	Increased
Proportion of treed bogs		Decreased
Proportion of fens		Decreased
Density of vegetation class edges	Decreased	
Terrain roughness	Increased	

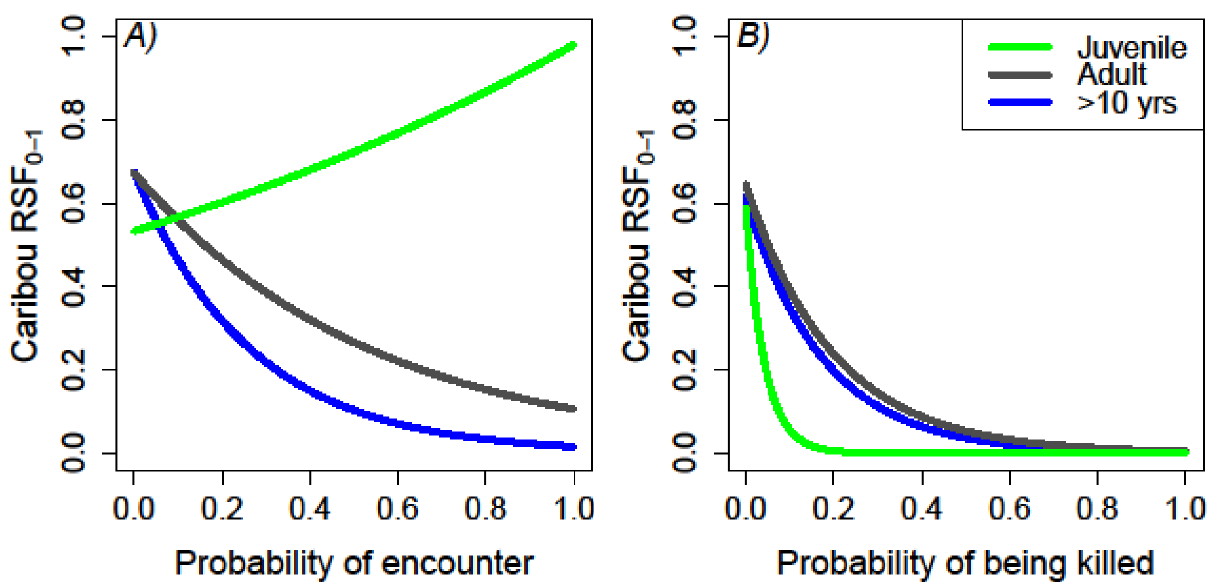

Figure 8. The response to the *A)* probability of encounter and *B)* probability of being killed for juvenile, adult, and older adult caribou during calving estimated in resource selection functions.

Activity 5: Conduct caribou survival analysis using all data

Our work is attempting to identify the drivers of caribou survival in the boreal with a particular interest in the direct and indirect effects of manageable anthropogenic activities. Specifically, we are interested in how anthropogenic disturbance alters risk via increased wolf search efficiency or apparent competition via changes in moose and wolf distribution or abundance, and how those interactions can be managed to reduce risk to caribou. During the remainder of year two, we plan to utilize our moose resource selection and wolf risk models as covariates in modelling caribou survival. Our analyses will also include other landscape attributes, in order to examine these complex processes and interactions.

Our current plan is to run two separate analyses, which together will allow us to fully utilize the available data and better understand drivers of adult survival. Because of the way that the Research and Effectiveness Monitoring Board (REMB) caribou-monitoring program developed, caribou survival data fall into different categories of data collection. Initially, caribou were affixed with primarily VHF collars, which required monthly (or sometimes less frequent) monitoring flights to ascertain the position of the collared animal and whether that animal was alive or dead. Fifteen GPS collars, however, were affixed during initial caribou captures. More recently, the collaring program transitioned to using GPS satellite collars (Table 5), which provide continuous information about location and remote notifications of mortalities. Including the VHF collars greatly expands our sample size, but prevents us from capitalizing on the fine-scale location data provided by GPS collars. Therefore, we are first planning on conducting a high-level analysis utilizing all collars (VHF and GPS) that will examine the relationship between core attributes and the survival of individuals within each core. Subsequently, we will conduct a second, fine-scale analysis using only GPS collars and Cox-proportional hazard models (sensu DeCesare et al. 2014) to address more detailed information about factors that contributed to mortalities of GPS-collared animals. We think this approach will illuminate the mechanisms contributing to declines in caribou abundance and provide reliable information for future management decisions.

Extension Plan and Activities

Throughout the first year and a half of this research, we have liaised regularly with Megan Watters (FLNRO) in terms of mortality investigations and other project related issues – both via conference calls and during face-to-face meetings. These meetings included project-specific consultations with Megan, Steve Wilson (REMB Board), Kathy Parker (UNBC), and Chris Johnson (UNBC) and sessions regarding the direction of REMB-funded research, along with the strategic planning research activities. Additionally, we have provided support roles by providing data and consultation to guide moose distance surveys completed by FLNRO staff and contractors in Region 7B (Peace) and Matt Mumma has participated with FLNRO on several RFP review teams related to contracts for moose data collection.

This research has culminated in several presentations to date. Consistent with our extension plan, we presented a summary of our approach, findings, and implications (Title: Preliminary moose resource selection models by sex and their implications for wolf distributions in the boreal) in June 2016 as part of the REMB Spring Webinar Series. A link to this presentation is available on the extension page (http://www.bcogris.ca/boreal-caribou/extension) of the BC OGRIS website. We presented our work examining the risk of encounter and the risk of being killed (Title: Understanding the impact of linear features on predation risk and avoidance of wolves by boreal caribou) at the North American Caribou Workshop in May 2016 and our analysis of moose resource selection (Title: Anthropogenic drivers of moose resource selection and implications for the boreal ecosystem) at the North American Moose Workshop in September 2016. Future extension activities include a presentation further exploring the responses of caribou responses to risk (Title: Learning leads to increased risk in an altered landscape - accepted) to be presented at The Wildlife Society Conference in October 2016 and a manuscript of the same title to be submitted to the Proceedings of the Royal Society of London B. We are also hoping to contribute another REMB webinar (Tentative Title: Direct and indirect drivers of boreal caribou survival) in the spring of 2017.

Plans for Next Reporting Period

Work will continue on all activities:

A1) receive and analyze moose telemetry data;

A2) develop initial moose use/selection layers (existing data);

A3) develop initial caribou risk layers using existing data;

A4) refine caribou risk layers using incoming moose, caribou, and wolf data; and

A5) conduct caribou survival analysis using all moose, caribou, and wolf data.

with emphasis on activities 4 and 5.

Recommendations

Based on our work to date, we offer the following recommendations:

- Throughout the balance of the project, all recovered collars (dropped off, mortalities, recollaring, etc.) should be directly downloaded (whether from moose, caribou or wolves) before those collars are either redeployed or sent in for any refurbishment.
- If opportunities arrive, additional wolves should be collared in the southern half (Chinchaga RRA, Etthithun Core, and Milligan Core) of the boreal study area.
- Monitoring and timely assessment of moose and caribou mortality locations should continue to provide accurate cause of death assessments.

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