Assessing Spatial Factors Affecting Predation Risk to Boreal Caribou Calves: Implications for Management

2012 Annual Report

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EXECUTIVE SUMMARY

Boreal caribou (*Rangifer tarandus caribou*), an ecotype of woodland caribou, are federally listed as *Threatened* and provincially designated as *Red-listed* in British Columbia. Throughout much of their distribution, a primary demographic factor contributing to population declines is a low rate of calf recruitment (survival to one year of age). For many populations, calf mortality is particularly high during the neonate period (0-4 weeks of age) with the number of calves surviving this period often insufficient for population stability. Through a partnership of government, industry, academia, and non-governmental organizations, we initiated this project in 2011 to assess spatial factors affecting predation risk to boreal caribou calves in northeast BC. For 2012, the project's second year, we had three primary objectives: *i*) to continue our analyses of calving habitat selection by female caribou, *ii*) to assess calving habitat quality by relating neonate calf survival to calving habitat selection, and *iii*) to assess predator habitat use during the calving season.

In 2012, we collected GPS data from 23 radio-collared female caribou of which 21 were females captured in 2011. Through movement analyses, we estimated 17 of the 23 females calved this year and females calving in both years showed apparent fidelity to calving areas and pre-calving migration routes. To evaluate calving habitat selection, we expanded upon our 2011 analyses by using a multi-scale approach that assessed how female caribou selected calving areas within a given herd's range (landscape-scale selection) and what resources females selected within these areas (local-scale selection). In general, females selected calving areas in landscape mosaics comprised of high proportions of poor fens, rich fens and upland conifer, which contrasts with winter ranges dominated by treed bogs. Within calving areas, females selected poor and rich fens relative to treed bogs and avoided most other land cover types. Caribou also avoided anthropogenic features during the calving season with this effect more pronounced for females with calves. These results suggest that caribou move into landscapes with higher forage quality during the spring, perhaps to meet maternal nutritional demands, yet attempt to minimize predation risk within these areas.

Using a combination of aerial surveys and movement analyses, we estimated six of 17 calves survived to four weeks old. Maternal selection of calving habitat influenced the probability of a neonate calf surviving. The risk of calf mortality was generally higher in landscapes with high proportions of hardwood swamp. Calving areas with high linear feature density also weakly increased the probability of calf mortality. At the local scale, increasing selection of rich fens equated to an increasing risk of calf mortality. The increased use of riskier habitats, such as rich fens, by caribou at calving may partially account for the higher reported predation rates of caribou during the spring.

During the past year we initiated efforts to deploy radio-collars on wolves (*Canis lupus*) and black bears (*Ursus americanus*), the two main predators of caribou calves. In March, we deployed 10 collars on wolves in five different packs; however, seven of the collars failed shortly after deployment, leaving only three collars functional through the calving season. In early May, we deployed collars on four bears, but further capturing efforts scheduled for the later in the month were halted due to unforeseen legal issues between government and First Nations. Using these limited data sets and a multi-scale analysis

similar to the approach used for caribou, we found predator habitat selection to be highly variable. Two of the three collared wolves selected landscapes with high proportions of fens and upland conifer while the third wolf selected for landscapes dominated by conifer and mixed-wood swamps. At the local scale, all wolves showed high use of poor fens and selection for rich fens, which suggests wolves spatially overlap with caribou during the spring. Interestingly, wolf response to linear features was also variable with only one wolf selecting for areas with high linear feature density and one wolf avoiding lines in terms of proximity. We further assessed fine-scale factors influencing wolf use of lines. In general, wolf use of linear features increased with increasing sightability and decreased with higher amounts of coarse woody debris.

Black bears showed less overlap with caribou as no individuals selected for fens and overall use of these habitats was low. Three bears had > 30% of their locations in upland habitats while the fourth bear had a third of its locations in treed bogs. The response of bears to anthropogenic features varied among individuals; however, bears were generally closer to roads than random locations.

Boreal caribou populations in northeast BC continue to sustain low rates of calf survival. Effective management of these populations will require prioritizing and conserving calving areas as well as the migration routes used to access these areas. For 2013, the project's final year of data collection, we anticipate completing our analyses of calving habitat selection and neonate calf survival to identify attributes of calving habitat quality. Further, we will be continuing efforts to increase our sample size of radio-collared predators to better understand the potential mechanisms influencing caribou-predator interactions during the calving season.

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2012 YEAR END SUMMARY

INTRODUCTION

Boreal caribou, an ecotype of woodland caribou, are federally listed as *Threatened* due to population declines throughout much of their distribution (Environment Canada 2012). Population declines of boreal caribou are believed to be caused by increased predation rates ultimately facilitated by disturbance of intact boreal forest landscapes (Sorensen *et al.* 2008; Festa-Bianchet *et al.* 2011). In many declining caribou populations, predation rates are particularly high during the spring and summer, resulting in high mortality rates of neonate calves (0-4 weeks old; Adams *et al.* 1995; Stuart-Smith *et al.* 1997) and negatively impacting juvenile recruitment, a key determinant of ungulate population dynamics (Gaillard *et al.* 2000)

Low rates of calf survival are likely a driving factor in suspected population declines of boreal caribou herds in northeast British Columbia (Culling & Cichowski 2010). Although calf recruitment survey data are inconsistent and of relatively short duration for most BC ranges, observed rates of recruitment have been consistently below thresholds associated with population stability (Culling & Cichowski 2010; Environment Canada 2011). Consequently, in 2011, we initiated this project – located near Fort Nelson, BC – to assess the spatial dynamics of caribou and their predators during the calving season and to ultimately identify spatial factors influencing predation risk to neonate calves. The project is a collaborative effort among industry, government, non-governmental organizations, and academia.

For the project's first year, we provided preliminary results on calving habitat selection by caribou and how maternal calving behaviour impacts neonate calf survival (see 2011 Annual Report). For 2012, we expanded these analyses and began preliminary analyses of predator behaviour during the calving season. From the perspective of caribou, we used a multi-scale approach to evaluate calving habitat selection. With this year's analysis, we attempted to answer three key questions:

i. Can calving habitat be identified on the landscape?
ii. How do calving areas differ from areas used in the winter?
iii. Does selection of habitat in the spring depend on whether a female has a calf or not?

Within the context of these questions, we also evaluated whether caribou are selecting calving areas to reduce predation risk (e.g., Bergerud 1985) or to access higher quality forage to meet maternal nutritional demands (Parker *et al.* 2009). If reducing predation risk is important, then females should select calving areas dominated by peatlands (e.g. bogs and nutrient-poor fens), which are thought to provide predator refuge (McLoughlin *et al.* 2005). If forage quality is important, then calving areas should have a higher composition of more productive habitats (e.g. rich fens, uplands) than winter ranges.

In highly altered landscapes, evaluating habitat selection by itself is not sufficient for identifying attributes influencing habitat quality because selection may not reflect environmental conditions positively influencing individual fitness (e.g. maladaptive selection; Hollander *et al.* 2011). We therefore evaluated the relative quality of calving areas by relating maternal selection of habitat to the probability of neonate calf survival. Because habitat selection is a multi-scale process (Johnson 1980), we similarly assessed the impact of selection on neonate survival at multiple scales. Because of the hypothesized negative correlation between range disturbance and caribou population growth rates (Sorensen *et al.* 2008; Environment Canada 2012), we predicted that calving areas with high densities of landscape disturbance would equate to lower probabilities of neonate survival.

From the perspective of predators, recent studies suggest that increased predation rates of caribou during the spring and summer may be due to an increase in predator use of caribou habitat during this time period (Latham *et al.* 2011b; Whittington *et al.* 2011). For the project's second year, one of our primary objectives was to analyze space use patterns and habitat selection of wolves and black bears – the primary predators of boreal caribou calves (Bergerud 2007; Pinard *et al.* 2012) – during the calving season. Because BC boreal caribou herds are sustaining low rates of calf survival and predation is the likely cause of most calf mortality (Adams *et al.* 1995; Gustine *et al.* 2006; Pinard *et al.* 2012), we predicted that at least some proportion of predators should have a high degree of spatial overlap with caribou calving areas.

Developing effective conservation strategies for boreal caribou has become a priority at both regional and national scales (Environment Canada 2012). Inherent in such strategies is integrating an understanding of animal behaviour, its mechanistic effects on resource use (e.g. where they go and why they go there) and subsequent impacts on measures of fitness, particularly during time periods that have high influence on population dynamics (Caro 1999). Using this framework, we present results from the project's second year that detail caribou and predator behaviours during the calving season.

METHODS

Study Area

In British Columbia, boreal caribou occur in six recognized ranges situated within the boreal forest plains that comprise the northeast corner of the province. For 2012, we expanded our study area to include all of the Maxhamish, Parker, Prophet, and Snake-Sahtaneh ranges as well as a portion of the Calendar range (Appendix 1). Although we have no radio-collared caribou currently within the Calendar range, one radio-collared wolf captured this year spent the majority of its time within the east part of Calendar. A full description of the study area is contained in the 2011 Annual Report.

Caribou Capture and Collaring

In 2011, we captured and radio-collared 25 female caribou distributed throughout the study area (see 2011 Annual Report). In late November 2011 to early January 2012, three of these original collars stopped transmitting GPS location data via email [Note: for caribou radio-collars deployed in February 2011, batteries were estimated to remain operational through August 2013.]. We therefore obtained replacement Iridium GPS radio-collars from Advanced Telemetry Systems (model G2110E) for deployment in March 2012 to maintain our target sample size. For capturing caribou, we followed the same capture procedures outlined in the 2011 Annual Report, firing a net gun from a helicopter to physically restrain individual females.

Wolf Capture and Collaring

For 2012, our objective was to deploy 20 Iridium GPS radio-collars on wolves occurring within the study area. We specifically focused capturing efforts within and adjacent to caribou ranges, particularly on areas in close proximity to radio-collared caribou. Prior to actual deployment of the wolf collars, we collaborated with the BC Ministry of Transportation office in Fort Nelson to collect road-killed ungulate carcasses to use for baiting wolves and thereby increase capture efficiency. We also used a fixed-wing aircraft to scout portions of our study area for recent wolf sign. We captured wolves by chemically immobilizing each animal with Telazol delivered by aerial darts fired from a helicopter. For each wolf pack located, we attempted to radio-collar 2-3 individuals. We fitted captured wolves with Iridium GPS radio-collars from Advanced Telemetry Systems (ATS; model #2110E). Collars were programmed for a fix-rate of every 15 minutes from May 1 to June 30 and once per day otherwise, which equates to an estimated battery life of one year. In addition to attaching the radio-collars, we collected blood and hair samples from all captured individuals. After collar attachment, we monitored each wolf until the animal displayed signs of recovering from the effects of anaesthesia (e.g. regaining head control).

Black Bear Capturing and Collaring

Similar to wolves, our objective was to deploy Iridium GPS radio-collars (ATS; model #2110E) on a sample of 20 black bears found within or near caribou range. We scheduled black bear capture efforts for the middle of May, just shortly after bears emerge from denning and near the peak calving period for caribou. We targeted large, mature bears and avoided young animals or females with cubs. Once an appropriate bear was located, we chemically immobilized each animal using Telazol delivered by aerial darts fired from a helicopter. For each captured bear, we estimated the animal's age and collected hair samples prior to attaching the radio-collar. We programmed bear collars for a fix-rate of every 30 minutes from May 1 to June 30 and once per day otherwise. With this fix-rate schedule, the estimated battery life for the collars is 1.5 years which should allow for the collars to be operational through two calving seasons. After collar attachment, we monitored each bear until the animal displayed signs of recovering from the effects of anaesthesia (e.g. regaining head control).

All animals were captured and handled in accordance with approved provincial and institutional animal care protocols (BC RIC 1998; University of Alberta Animal Use protocol # 748/02/13). The capture team consisted of B. Culling (aerial darting and net-gunning), C. Thiessen (aerial darting and net-gunning), C. DeMars, and pilots Z. Dancevic and C. Allen from Qwest Helicopters in Fort Nelson, BC.

Caribou Calf Surveys

As in 2011, we conducted aerial surveys of female caribou in the spring to determine the survival status of neonate calves. We followed a similar survey protocol to last year by first modelling female movement rates to establish a survey priority list (see 2011 Annual Report). Surveys were conducted weekly to biweekly during the neonate period (~ May 1 – July 15). For this year, we concentrated survey efforts to determine calf survival status at 4 weeks of age because ongoing movement analyses suggest that: *i*) calving events can predicted with near certainty; and *ii*) neonate survival can only be confidently inferred from female movement patterns up to 4 weeks of age (DeMars et al. 2012, *in prep*.). We therefore structured the surveys to ensure cows that calved were observed at 4 weeks post-calving to establish calf survival status and thereby corroborate our ongoing neonate survival modelling. Because detection rates of calf presence/absence are estimated to be high (see 2011 Annual Report), we did not repeatedly re-survey cows after 4 weeks post-calving.

Pre-calving Movement Behaviour of Caribou

In 2011, female caribou showed considerable variation in distances travelled just prior to calving. For 2012, we measured the distance travelled by each individual female in the two weeks prior to the estimated calving date. For those females calving both in 2011 and 2012, we assessed the fidelity of females to calving sites by measuring the distance between 2011 and 2012 calving sites.

Caribou Calving and Winter Site Sampling

We continued fine-scale sampling of calving and winter sites used by female caribou to further augment our ongoing analyses to determine whether caribou select calving sites to reduce predation risk or optimize forage quality. We followed the same protocol initiated in 2011 (see 2011 Annual Report for detailed methodology) and sampled all calving sites that could be reasonably reached by foot or helicopter. For each calving site sampled, we sampled a winter site used by the same caribou. Winter sites were randomly selected from GPS locations collected between January 15 and March 15, 2012.

Resource Selection Analyses: General Framework

To assess habitat selection of caribou, wolves, and black bears during the calving season, we developed resource selection functions (RSFs;) of the form

$$\omega(x_i) = \exp(\beta_1 x_1 + \beta_2 x_{2\,+} \ldots \beta_n x_n) \qquad \text{Eqn. 1}$$

where $\omega(x_i)$ is the relative probability of use of a resource unit in category *i* as a function of *a priori* covariates thought to influence selection and their estimated coefficients (β) from logistic regression. In this type of analysis, resource usage, represented by GPS locations of animals during a fixed time period, is compared to resource availability, represented by random locations generated within the area deemed available to the animal during the same time period. To adequately characterize availability for each RSF analysis, we generated random locations equal to twice the number of used locations then subsequently down-weighted the random locations by half during estimation of model coefficients. Prior to final RSF model development, we assessed for collinearity among explanatory variables. For those variables having a correlation coefficient (*r*) of > 0.70, we conducted univariate logistic regression analyses of each variable and retained the variable with the lowest Akaike's Information Criterion (AIC) for further RSF modelling.

While the specific analysis framework varied by species (see below), we developed RSF models at two scales and used the same set of explanatory covariates for each species to facilitate comparisons. At the larger scale, we evaluated the composition of landscapes selected by each species (Table 1). Within this model, hereafter referred to as the landscape model, we quantified the proportion of different land covers at spatial scales ranging from 400-m to 4500-m, the radius of the largest calving range we recorded for cows with calves up to four weeks old. Within this same range of scales, we further quantified the density of natural features (lakes, rivers, and forest fires < 50 years old) and anthropogenic features (forestry cut blocks, linear features and active well sites). For each landscape covariate, we conducted univariate logistic regression analyses at each spatial scale (400-m to 4500-m) and selected the spatial scale with the lowest AIC value as the spatial scale of response. Prior to model formulation, we arcsin transformed all variables measured as proportions then standardized all variables to allow comparison of effect sizes and facilitate model convergence (Zuur *et al.* 2010). For final model development, we retained all uncorrelated land cover variables as a base model then individually added each natural feature or anthropogenic feature variable in a forward step-wise selection procedure. Variables that did not result in a lowering of AIC values by at least 2 units relative to the base model were deemed to be uninformative (i.e., explained little variation in resource selection) and were excluded from the final model (Arnold 2010).

For the second RSF model, hereafter referred to as the local model, we assessed selection of resources within the immediate vicinity of each location, defined at a pixel scale of 30-m. Specifically, we assessed the land cover type, percent canopy cover, slope, and topographic position of locations used by animals compared to random locations. To characterize topographic position, we measured the Euclidean distance of locations to the nearest lake, river, upland, forest fire < 50 years old, cut block, road, seismic line, pipeline and active well site. All distance-measured variables were transformed using an exponential decay function of $e^{-0.002d}$, which erodes the importance of distance measures beyond a few hundred meters (Nielsen *et al.* 2009). Similar to the landscape model, we used a forward step-wise procedure to exclude uninformative variables from the final model.

To model the explanatory covariates used in RSF analyses, we obtained GIS data from a variety of sources (Appendix 2). For characterizing land cover within the study area, we used Enhanced Wetlands Classification (EWC) GIS data developed by Ducks Unlimited Canada (DU 2010; see also 2011 Annual Report), which we collapsed into 10 categories that were biologically meaningful to caribou. In all RSF analyses involving this land cover data, we set Treed Bog as the reference category. For canopy cover, we accessed Vegetation Resource Inventory data available from BC Ministry of Forests, Lands and Natural Resource Operations. We calculated slope in a GIS framework using a digital elevation model obtained from BC Terrain Resources Information Management data (BC ILMB 2011). For rivers, lakes, major roads and forestry data (fires, cut blocks, and forestry roads), we used data sets from the BC Geographic Data Discovery Service (BC GDDS 2012). For well sites, pipelines, seismic lines (1996 to present) and petroleum development roads, we accessed data sets from the BC Oil and Gas Commission (BC OGC 2012). We also used BC Terrain Resources Information Management (BC ILMB 2011) data for modelling linear features, specifically a shapefile representing all linear features visible on the landscape, regardless of type or age, from 1992 aerial photos. To create a parsimonious linear feature data set for the study area, we merged all major roads, forestry roads, petroleum development roads, and seismic lines into one file then integrated the resulting data set at a scale of 10-m to eliminate redundancies among the original data sets.

Table 1: Classification of land cover types used to model resource selection by boreal caribou in northeastern BC. Land cover types were developed from Ducks Unlimited Enhanced Wetlands Classification data clipped to the study area (DU 2010).

Land cover	EWC Class	Description
Treed bog	Treed bog, Open bog, Shrubby bog	Black spruce and *Spaghnum* moss dominated bogs with no hydrodynamic flow. Areal coverage: ~20%
Nutrient poor fen	Graminoid poor fen, Shrubby poor fen, Treed poor fen	Low nutrient peatland soils influenced by groundwater flows. Treed poor fens dominate, comprised of black spruce, tamarack and bog birch (25-60% tree cover). Areal coverage: ~22%
Nutrient rich fen	Graminoid rich fen, Shrubby rich fen, Treed rich fen	Low nutrient peatland soils influenced by groundwater flows. Shrubby fens dominate, comprised of bog birch, willow and alder. Areal coverage: ~4%
Conifer swamp	Conifer swamp	Tree cover >60% dominated by black or white spruce. Occur on peatland or mineral soils. Areal coverage: ~9%
Hardwood swamp	Shrub swamp, Hardwood swamp	Mineral soils with pools of water often present. Dominant tree species : paper birch and balsam poplar. Areal coverage: ~7%
Mixed wood swamp		Mix of conifer and deciduous tree species. Areal coverage: ~7%
Upland conifer	Upland conifer	Mineral soils with tree cover >25%. Dominant tree species: black spruce, white spruce and pine. Areal coverage: ~5%
Upland mixedwood	Upland mixedwood	Mineral soils with tree cover >25%. Mix of conifer and deciduous tree species. Areal coverage: ~7%
Upland deciduous	Upland deciduous	Mineral soils with tree cover >25% and >75% deciduous trees Dominant tree species: aspen and paper birch. Areal coverage: ~13%
Other	Upland other, Cloud shadow, Anthropogenic, Burn, Aquatic	Uplands: mineral soils with tree cover <25%. Anthropogenic: urban areas, houses, roads and cut blocks. Burns: recent burns where vegetation is limited or covered by burn Aquatic: includes a continuum of aquatic classes from low turbidity lakes to emergent marshes where aquatic vegetation is >20% of the cover. Total areal coverage: ~6% (Cloud shadow <0.5%)

Calving Habitat Selection by Caribou

To assess calving habitat selection by female caribou, we considered only those locations where a female was accompanied by a calf less than four weeks old. Because we were interested in how females select calving areas within caribou range, we defined availability for the landscape model as the entire herd range in which a female calved (e.g. for females calving in the Prophet range, availability was the entire Prophet range). To account for those females that calved outside of current range boundaries, we created minimum convex polygons (MCPs) using all GPS locations from individuals travelling outside range boundaries. We buffered these MCPs by the mean daily distance travelled then merged the resultant polygons with existing range boundaries. For the local model, we defined availability as the calving range of each individual. We created individual-based MCPs around all GPS locations from estimated calving date to either the estimated date of calf loss or until the calf reached four weeks of age, whichever came first, and buffered the resultant MCPs by mean step length.

To estimate local and landscape RSFs for caribou, we used a two-stage approach where RSF models were first developed for each individual then population-level coefficients were estimated by averaging across individuals, weighting each individual estimate by the inverse of its variance (Fieberg *et al.* 2010). We calculated 95% confidence intervals of population-level estimates using bootstrap methods. We used this two-stage approach rather than general linear mixed-effects models (Bolker *et al.* 2008) because we wanted to generate individual estimates for each covariate which we then used to evaluate how variation in calving habitat selection impacts survival of neonate calves (see *Calf Survival Analyses* below; Gaillard et al. 2010).

We used the landscape and local RSF models to develop a scale-integrated predictive map of calving areas within the study area (DeCesare *et al.* 2012). We applied model coefficients to raster maps of explanatory variables within a GIS to produce predictive maps at the local and landscape scales. The resultant maps were multiplied together to produce a final map of predicted calving areas. To validate performance of the scale-integrated map, we used GPS locations of nine female caribou with neonate calves from a 2004 study conducted in the Snake-Sahtaneh range (Culling *et al.* 2006). Based on aerial surveys, all nine calves from this sample were known to have survived to 4 weeks of age. We reclassified the scale-integrated map into 10 ordinal bins of equal area and compared the frequency of 2004 calving locations to bin ranks using Spearman rank correlation (r_s). Good model performance should be reflected by increasing frequencies of calving locations in higher bin ranks, thus resulting in a strongly positive r_s.

We further assessed how calving habitats differed from winter ranges and whether female selection of spring habitats depended on whether she had a calf or not. In each instance, we estimated latent resource difference functions (LSDs; Latham *et al*. 2011), a modelling framework similar to RSFs that compares differences in habitat use that result from an underlying selection process. We developed LSD models at the local and landscape scales using the same covariates and spatial scales as in the above RSF models. To assess differences in winter and calving range use, we coded calving locations as one while winter locations by the same animals were coded as zero. For this analysis, we subsampled calving locations at a rate of once per day because GPS locations are generated only once per day outside of the calving season. We then drew a random sample of winter locations (January 1 - March 15) equal to the number of calving locations. We estimated these LSDs using generalized linear mixed-effects models with a logit link, specifying individual caribou as a random effect (Bolker *et al.* 2008). To assess differences in spring habitat selection between cows with calves and barren cows, we coded cows with calves as one and barren cows as zero. For this analysis, we compared GPS locations of barren cows (n = 10) falling between May 15 - June 15 with locations of a subsample of cows with calves surviving to four weeks of age (n = 10). For these LSD models, individual caribou cannot be specified as a random effect therefore we generated general logistic regression models at the population-level and used Newey-West variance estimators to account for autocorrelation among GPS locations (Nielsen *et al.* 2002).

Predator Habitat Selection During the Caribou Calving Season
We assessed predator habitat selection during the calving season in an RSF framework similar to caribou, modelling selection at local and landscape scales with the same suite of covariates. For wolves, we used GPS locations from May 1 to June 30 but rarefied the data to exclude locations falling between 10 a.m. and 6 p.m. because inspection of the data revealed that wolves are essentially inactive (e.g. bedded down) during that period of the day. We further excluded all locations falling within 200-m of suspected den sites. Because wolves are highly territorial, we defined availability for both the local and landscape models as the estimated home range of each wolf pack. To define home ranges, we generated MCPs around all GPS locations for individuals within each pack. We also defined availability for black bears as the individual home range but buffered individual MCPs but mean step length. For black bears, we used all GPS locations from May 1 to June 30 and did not further rarefy the data because obvious daily movement patterns were not apparent. With a limited number of individual data sets for wolves (n = 3) and bears (n = 4), we estimated RSFs for each individual wolf and bear using general logistic regression models and Newey-West variance estimators.

Calf Survival Analyses
To evaluate relative calving habitat quality, we used Cox proportional hazard models to relate individual selection coefficients to the probability of neonate calf survival. Because our data set includes females calving in both years, we used mixed-effects Cox models of the form

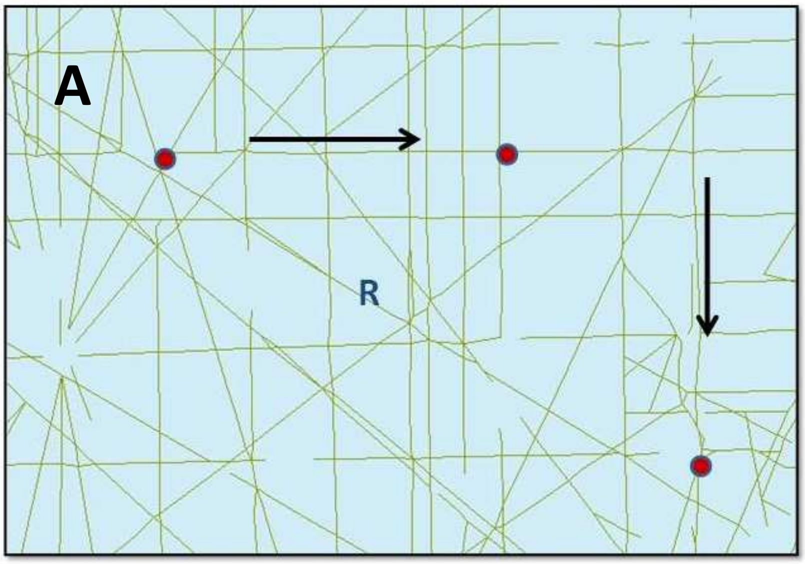
$$h_{ij}(t) = h_0(t)\exp(\beta_1 x_{i1} + \beta_2 x_{i2} + \ldots\ldots + \beta_k x_{ik} + \Upsilon_j) \qquad \text{Eqn. 2}$$

where $h_{ij}(t)$ is the hazard function for individual calf i with female j at time t, $h_0(t)$ is an unspecified baseline hazard function, the x's are explanatory covariates and Υ_j is the random effect attributable to female j. In this model formulation, we coded calf loss as one; thus, a positive coefficient of an explanatory variable equates to an increasing risk of calf mortality. We calculated Cox proportional hazard models at both the local and landscape scales. Because of our small sample size, in this report we present univariate analyses only. For explanatory variables, we used the coefficients of the explanatory variables derived for each individual caribou in the first stage of RSF estimation. To estimate dates of calf loss, we evaluated female movement patterns and assessed for an abrupt change in mean step length distribution post-calving (DeMars et al. 2012, *in prep*.). We corroborated estimated loss dates using information from aerial surveys of calf survival (e.g. the date must fall between the last survey a female was observed with a calf and the first survey the same female was observed without a calf).

Wolf Use of Linear Features

To assess wolf use of linear features, we used GPS data from two wolves in separate packs, one in the Prophet range and one centered within the Kiwigana core area. We used a paired sampling design where each line used by a wolf was matched to a line considered to be unused, at least within the calving season of May 1 to June 30. We considered a line to be used if least two sequential wolf locations were situated on the same line and were within 10 m of the line itself to account for GPS location error. To select an unused line for comparison, we used one of two methods depending on the wolf's movement trajectory. If the wolf's movement trajectory involved a turn onto another line, we selected and sampled an unused line that represented the shortest distance between the start and end points of the trajectory (shortest path lines; Fig. 1a). If this movement pattern was not evident, we randomly selected a line within a 1 km radius of the used line that was perpendicular to the wolf's direction of travel and had no wolf GPS locations during our temporal window of sampling (parallel lines; Fig. 1b).

At each sampled line, we established three plots placed 200-m apart. For lines used by wolves, the center plot was placed at the mid-point between the two GPS locations. For unused lines, the center plot was placed midway along the line for shortest path lines or, for parallel lines, at a similar easting or northing (United Transverse Mercator units) location as the paired used line. For all lines, we noted the habitat type in which the line was located (e.g., bog, fen, upland conifer, upland deciduous), the orientation of the line, whether the line was straight or tortuous, and calculated the average line width from measurements taken at all three plots. For line width, we subsequently assigned lines to one of three types (Latham *et al.* 2011b): low-impact seismic lines (0-5m), traditional seismic lines (6-10m) and pipelines and secondary roads (>10m).



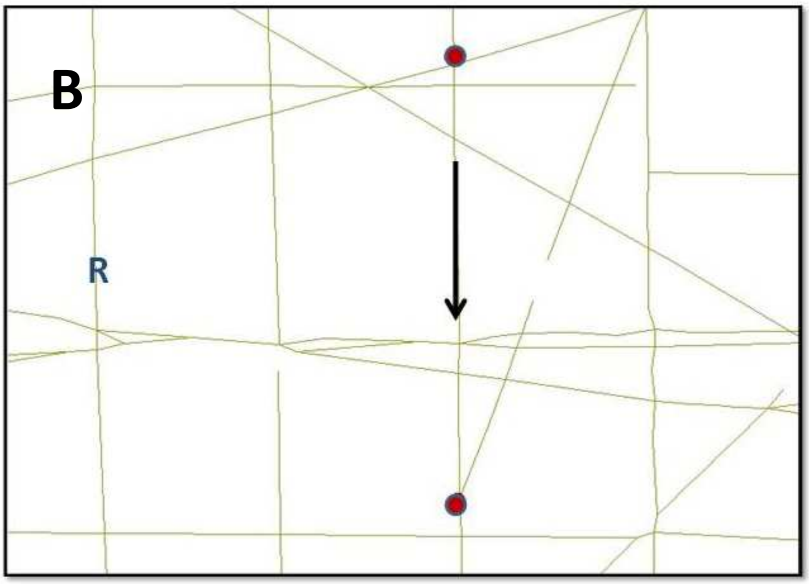


Figure 1: Selection of random lines with respect to wolf movement trajectories. Red circles represent wolf GPS locations, solid arrows represent direction of wolf travel and **R** represents unused lines selected for sampling. In A, the selected unused line represents the shortest path between the initial and final GPS location. In B, the selected unused line is parallel to the direction of travel.

To specifically describe line sightability, we recorded the maximum distance a white 40-cm diameter disk affixed to a 1.5-m pole could be seen way from the center plot in each direction down the line. For line characteristics associated with movement efficiency, we calculated indices of shrub density, substrate hardness and coarse woody debris (CWD). For the shrub density index, we multiplied average shrub height by the averaged percent shrub cover for each line. We calculated average shrub height by measuring shrub height at the center of the line and at 1-m in from each line edge at each plot. Shrub height measures were then grouped into six ordinal bins (1 = lowest shrub height values; 6 = highest shrub height values) based on the distribution of all heights recorded. Similarly, we created a six bin index for average percent cover, based on the methods of Daubenmire (1959), by estimating percent shrub cover in a 1-m wide transect extending from line edge to line edge and oriented through the plot center. For substrate hardness, we used the following index: 3 = dry ground; 2 = squishy (e.g. moss covered); 1 = squishy with water; and 0 = water visible on surface. For coarse woody debris, we recorded the number of downed woody debris with a diameter > 10 cm along a central 400-m transect connecting the end plots then created a five-level index based on the distribution of recorded counts. A score of five indicated little to no CWD while a score of one indicated lines with CWD counts > 30, a threshold selected because it approached the upper limit of the data and accounted for counting error in areas of high densities of CWD. To create an overall mobility score for each line, we summed the scores of the line width, shrub density, substrate hardness and CWD indices.

We used logistic regression to assess the relative effects of line mobility and sightability on the probability of wolf use of linear features. Because the addition of CWD to linear features has previously been considered as a management option for impeding wolf movements (Neufeld 2006), we also evaluated the effects of CWD independent of the overall mobility score. We assessed both multivariate and univariate models and used AIC, corrected for small sizes, to evaluate model performance.

Data Analyses
All statistical analyses were performed in R, version 2.15 (R Development Core Team, 2011). We used the R package ‘lme4’ (Bates *et al*., 2011) for estimating LSDs with generalized linear mixed-effects models. Mixed effects Cox proportional hazards models were implemented using the R package ‘coxme’ (Therneau 2012).

RESULTS

Caribou Collaring
During March 2012, we located two of the three non-functioning collars while conducting demographic surveys of caribou in the Maxhamish and Prophet ranges as part of long-term monitoring by the BC government. One collar was localized to an area in the Kiwigana core but the animal was not seen and no recent caribou sign was observed. We returned to this area during spring calf surveys but we could no longer pick up the collar’s VHF signal, which may indicate that the collar released from the animal due to low batteries. The other collar was still

affixed to a female in the Kiwigana core. We recaptured this animal and replaced its non-functioning GPS collar with a VHF collar. We opportunistically captured and collared two additional female caribou in the Kiwigana core area and deployed two replacement Iridium GPS radio collars (Advanced Telemetry Systems; model G2110E) on these animals. The third non-functioning collar, deployed on an animal in the Prophet range, was not relocated during our recapture efforts in March. Earlier in February, the animal had been located during a fixed-wing survey with the collar still emitting a weak VHF signal. We will continue to try to locate this animal but the collar may no longer be operational and is likely no longer on the animal as the GPS collars deployed in February 2011 were pre-programmed to release on low battery.

During the past six months, we have continued to lose caribou radio-collars due to failing batteries. One collar was lost in April just prior to the initiation of calf surveys. Two others failed at the end of June and another in September. In late October to early November, nine of the remaining 19 collars stopped transmitting GPS location data. As of November 23, 2012, only five caribou collars remain operational, with three of these collars – deployed in February 2011 – transmitting low battery warnings. In December 2012 – January 2013, we will be deploying at least ten replacement Iridium GPS collars in order to retain a sufficient sample size of caribou for calf survival surveys in 2013.

Wolf Collaring

Wolf capturing and collaring efforts occurred in two sessions: March 11-14 and March 23-28, 2012. Surprisingly, we were only able to collect one road-killed carcass in the two months prior to wolf capturing efforts. The lack of bait, combined with the relative lack of snow in the Fort Nelson area this year, made locating wolf packs difficult. In total, we were able to capture and radio-collar 10 wolves distributed among five packs (Appendix 3). During the first capturing session, we located four packs. The first pack was located near the Paradise core area. This pack had ~ 14 individuals and we were able to capture and radio-collar three wolves: two males and one female. The next pack encountered was located in the southern portion of the Kiwigana core. This pack consisted of only two individuals – a male and a female – which were both captured and collared. The third pack was found just to the southeast of the current Prophet range boundary, an area that is currently being used by all six collared caribou in the Prophet herd. This pack consisted of 6 individuals and we placed collars on a male and female. The final pack encountered during the first capturing session was located just outside of the northeast boundary of the Kiwigana core. This pack also consisted of six individuals and we captured and collared a male and a female. During the second capturing session, we were able to locate one further pack of six individuals in an area between the Tsea and Kiwigana cores. We capture and collared what is likely to be the alpha male of this pack.

Shortly after deployment, a significant proportion of wolf collars began to fail. By the end of April 2012, only three of the ten deployed collars were still transmitting GPS location data. These three collars continued to transmit data through June 30 but then all stopped transmitting during the first part of July; thus, we no longer have any active wolf collars in the study area at this time.

Black Bear Collaring

We began black bear capture efforts on May 6, 2012 after Qwest Helicopter pilots had recorded multiple sightings of bears during the prior week. After searching Kiwigana, Parker and Clarke core areas without seeing bears, we delayed capture efforts for a further week to allow for more bears to emerge. We resumed capture efforts on May 11-12, 2012 and captured four bears clustered around the southern edge of the Clarke core (Appendix 4). During this time period, we also searched Kiwigana, Parker, Prophet and Fort Nelson cores and although we encountered at least 10 bears other than the four captured, all of these other bears were judged to be small (e.g. < 3 years old) and unlikely to be significant predators of caribou calves. Because of the lack of large, mature bears – and due to staffing constraints, we scheduled another capture session during the last week of May. However, prior to the start of this next capture session, the ability of government to participate in wildlife capture activities – which is essential to the capture activities associated with this project – became compromised due to legal issues between government and First Nations. These legal issues halted all wildlife capture work in the Peace Region for the next few months, including remaining work associated with this project. Consequently, only four black bear radio-collars were deployed for the 2012 caribou calving season.

Only one of the four black bear collars remained operational through the entire calving season. One bear was struck by a train and killed. Two of the collars prematurely released in June, one due to water leaking into the battery case while the other released for unknown reasons. The one collar that did transmit through June stopped transmitting data in early July. As with wolves, we no longer have active black bears collars in the study area at this time.

Caribou Calf Surveys

Caribou calf surveys commenced on May 19, 2012 and continued on a weekly to bi-weekly basis until July 9, 2012. From these surveys and analyses of female movement patterns, we estimated 17 of the 23 collared females calved in 2012 (Fig. 2). Interestingly, two of the cows that did not calve this year also did not calve last year (one in Fort Nelson core and one in Parker core). Calving dates in 2012 ranged from April 22 to June 21, which is a larger spread than last year; however, similar to 2011, the majority of calving dates in 2012 were clustered around May 15 (Fig. 3).

For 2012, we structured aerial surveys to determine calf survival to 4 weeks of age. Because we could not locate two females due to malfunctioning of the VHF component of the radio-collars, we also used analyses of female movement patterns to infer calf survival status. Using the survey data and the movement analyses, we estimated that six of the 17 calves survived to four weeks old, which equates to a standardized calf-to-cow ratio of 26 calves per 100 cows for the study area by the end of the neonate period. At the range level, four of eight calves survived in Maxhamish, one of three in Parker, one of four in Prophet while neither of the two calves born in Snake-Sahtaneh survived.

Pre-calving Movement Behaviour of Caribou

As in 2011, female caribou showed variation in pre-calving movement behaviour. The average straight-line distance travelled in the 2 weeks prior to calving was 11.2 km (range: 0.5 – 56.6

km; median 6.6 km), which was slightly less than 16.2 km average recorded in 2011. For those females that calved in both years, there was also considerable variation in relative fidelity to calving sites (Fig. 4). The mean distance between 2011 and 2012 calving sites was 7.41 km (range: 0.04 - 43.35 km) while the median distance was 3.32 km. Fidelity was perhaps stronger to pre-calving migratory routes. For those females calving in both years, all travelled in similar directions from winter ranges to calving areas in 2012 as they did in 2011. For example, prior to calving in both years, two Kiwigana females travelled in a northwesterly direction from wintering areas located in the southwest portion of the core to calving areas located north of the newly constructed Windflower Road (Fig. 5). Although cow 30329 did not make it as far northwest to calve in 2012 as in 2011 (distance between calving sites was ~ 43km), the route taken prior to calving was similar in both years.

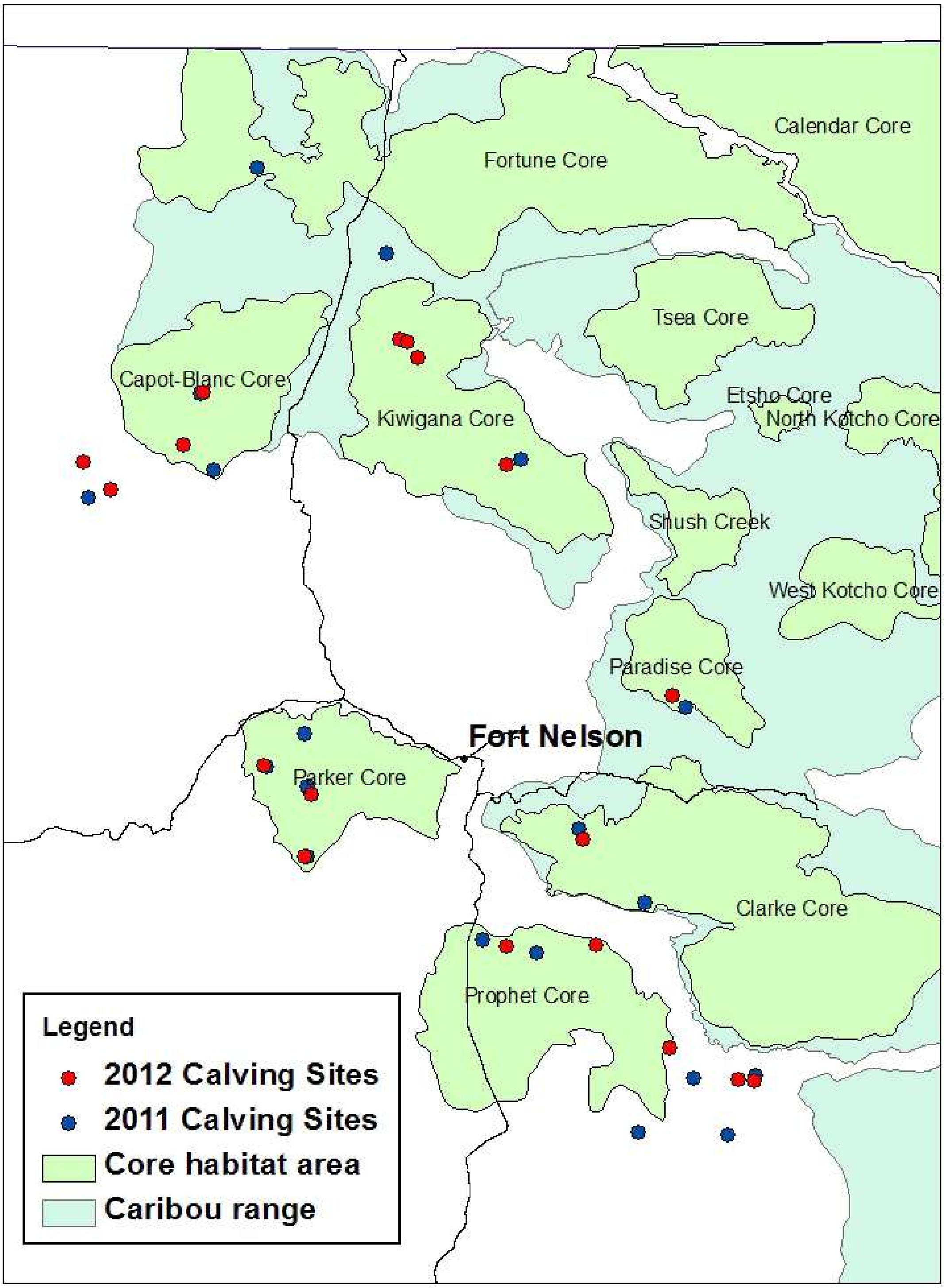


Figure 2: Calving sites used by boreal caribou in northeast BC during 2011 (blue circles) and 2012 (red circles).

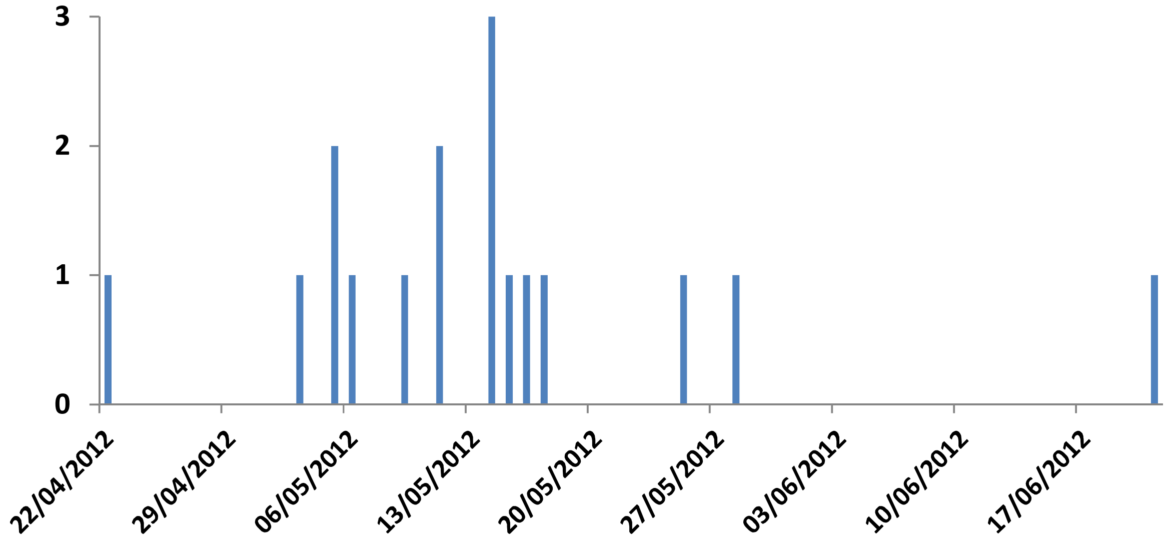


Figure 3: Distribution of 2012 calving dates for 23 female boreal caribou in northeast BC.

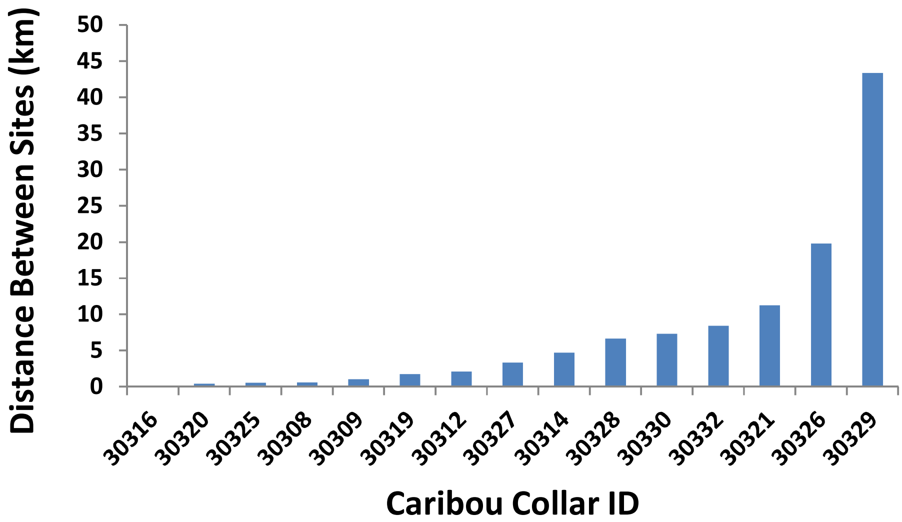


Figure 4: Straight-line distance (km) between 2011 and 2012 calving sites for 15 female boreal caribou in northeast BC.

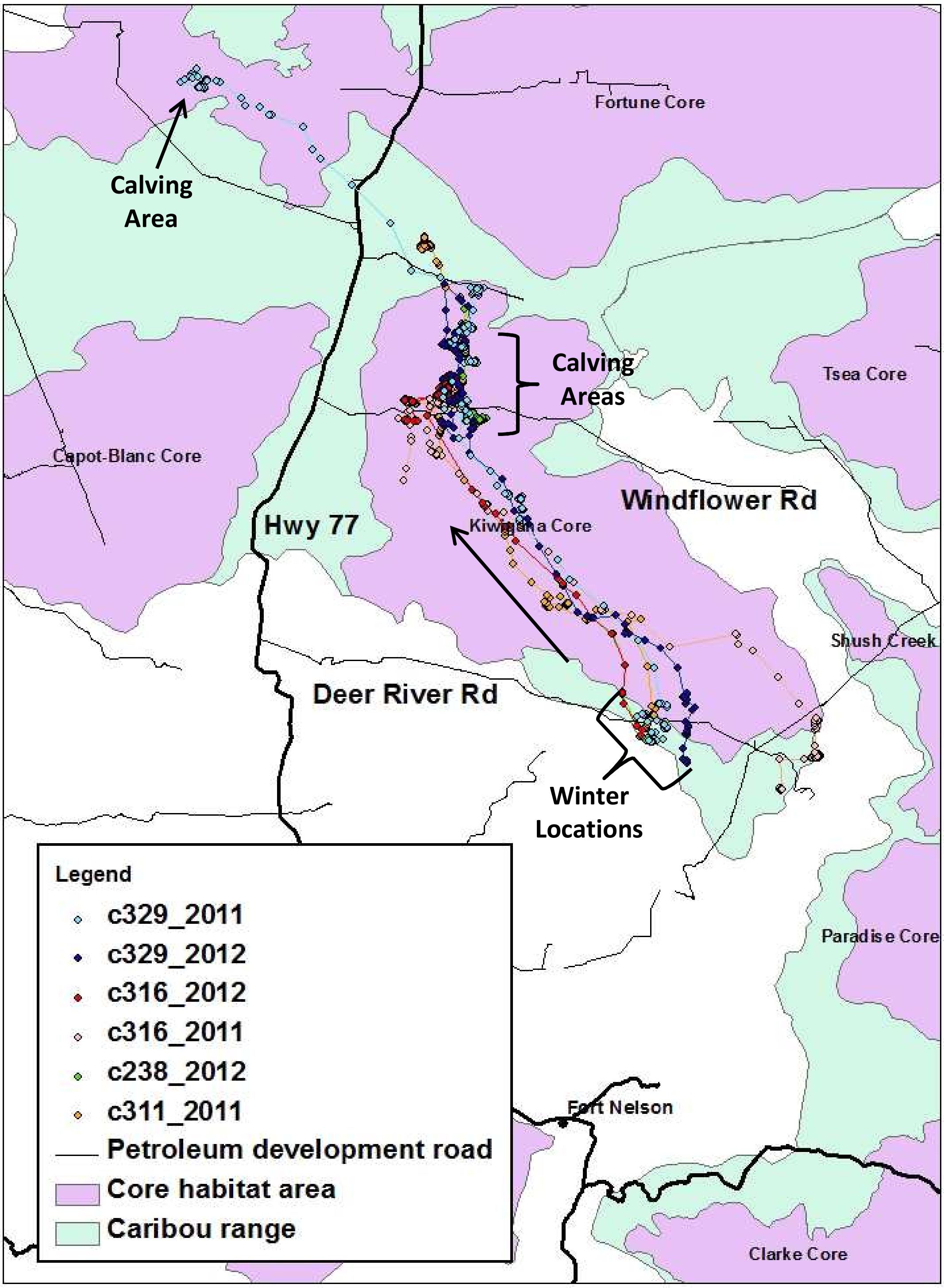


Figure 5: Pre-calving movements of four female boreal caribou in the Kiwigana core habitat area of northeast BC.

Fine-scale Sampling of Caribou Calving and Winter Sites
For 2012, we were able to access and sample 10 calving sites and paired winter locations, which when pooled with the 2011 data, brings the total number of calving sites sampled to 21. Data analyses of fine-scale characteristics of calving sites are currently ongoing and final results will be presented in the 2013 Annual Report.

Calving Habitat Selection by Caribou
Compared to 2011 when the vast majority (19/20) of calving sites were situated in treed bogs or nutrient-poor fens, female caribou in 2012 calved in a variety of vegetation types. Five calving sites were located in treed bog, four in nutrient-poor fen, four in conifer swamp, two in upland conifer and one each in nutrient-rich fen and mixed-wood swamp. As in 2011, five calving sites were situated outside caribou range boundaries last delineated in 2010.

At the landscape scale, caribou selected calving areas with high proportions of poor fens, rich fens and upland conifer (Table 2). They also showed weak selection for areas with fires less than 50 years old. Caribou generally avoided areas with upland hardwoods and swamps as well as areas with high densities of rivers and linear features at a scale of 400-m. Lake density and cut block density did not explain any variation in selection of calving areas (e.g. > 2 AIC unit lowering from the base model) and were therefore excluded from the final model. A similar pattern occurred when comparing landscapes used in the winter versus those used during calving (Table 3). Caribou appeared to move from winter ranges dominated by treed bogs to landscapes mosaics consisting of fens and upland conifer. Avoidance of landscapes with high densities of rivers and linear features increased at calving, although the 400-m scale of line density may be reflective of avoidance in terms of proximity rather than density *per se*. When comparing landscapes used by females with calves versus barren females, females with calves used landscapes with much higher proportions of rich fens and, to a lesser degree, areas with increased river density (Table 4).

At the local scale, we further collapsed our land cover GIS data into seven categories because some of the original categories were rarely used by females (e.g. <1% of used locations at the population level) or rare land cover types were not represented within all caribou calving areas. We also excluded canopy cover and slope from our final models as these variables were uninformative in explaining resource selection by female caribou during calving. Using the revised land cover classification, females selected poor and rich fens relative to treed bogs and avoided most other habitats (Table 5). They also avoided linear features and spaced themselves away from uplands but were closer to rivers and cut blocks than random locations, though this latter response may have been driven by a small subset of individuals. Interestingly, fens, swamps and uplands were all used at a higher rate during the calving season compared to winter (Table 6), perhaps reflective of the more mosaic-like pattern of calving areas. Local scale response of females to linear features varied, showing increased avoidance of seismic lines in the spring but being closer in proximity to roads, which indicates that some calving areas were likely situated in areas of higher road density compared to winter ranges. Compared to barren cows, females with calves used a higher proportion of poor fens and hardwood swamps, were closer to cut blocks and spaced themselves further away from roads and uplands (Table 7).

Table 2: Landscape-level selection of calving areas by female boreal caribou in northeast British Columbia during the 2011 -12 calving seasons. Treed bog was used as the reference category for land cover variables. Characteristic scales of response for each variable were determined by previous univariate analyses.

Variable	Scale (m)	Estimate	95% CI
Intercept	900	-0.42	-0.43, -0.40
Poor fen	900	0.34	0.31, 0.37
Rich fen	900	0.41	0.37, 0.44
Conifer swamp	900	-0.18	-0.20, -0.16
Hardwood swamp	900	-0.14	-0.18, -0.11
Mixed wood swamp	900	-0.37	-0.40, -0.35
Upland conifer	900	0.45	0.42, 0.48
Upland hardwood	900	-0.99	-1.02, -0.96
Other	900	-0.55	-0.58, -0.53
River density (km / km^2)	900	-0.35	-0.37, -0.33
Fire < 50 years old	2500	0.13	0.11, 0.16
Line density (km / km^2)	400	-0.23	-0.24, -0.21

Table 3: Comparison of the landscape composition of areas used by female caribou during calving and winter (January 1 – March 15) seasons of 2011 and 2012 in northeast British Columbia. Treed bog was used as the reference category for land cover variables.

Variable	Estimate	95% CI
Intercept	-0.12	-1.03, 0.79
Poor fen	2.70	2.34, 3.07
Rich fen	0.26	0.03, 0.49
Conifer swamp	-0.24	-0.45, -0.03
Hardwood swamp	0.12	-0.08, 0.31
Upland conifer	1.63	1.37, 1.90
Upland hardwood	-0.03	-0.20, 0.14
Other	-0.06	-0.20, 0.09
River density (km / km^2)	-0.16	-0.32, 0.01
Fire	0.56	0.38, 0.74
Line density (km / km^2)	-0.58	-0.77, -0.38

Table 4: Comparison of landscapes selected by female caribou with calves versus barren females during the calving season in northeast British Columbia. Treed bog was used as the reference category for land cover variables.

Variable	Estimate	95% CI
Intercept	-0.31	-1.41, 0.78
Poor fen	1.60	0.77, 2.42
Rich fen	-0.30	-1.55, 0.95
Conifer swamp	-1.03	-2.27, 0.21
Hardwood swamp	0.91	-0.25, 2.07
Mixed wood swamp	0.02	-0.37, 0.42
Upland conifer	0.01	-1.26, 1.27
Upland hardwood	-1.50	-2.34, -0.66
Other	-0.99	-1.59, -0.39
River density (km / km^2)	0.56	0.14, 0.98
Fire	0.24	-0.39, 0.87
Line density (km / km^2)	-0.14	-0.99, 0.72

Table 5: Calving habitat selection by female caribou in northeast British Columbia during 2011-12. Availability was delineated at the calving range scale and treed bog was used as the reference category for land cover variables.

Variable	Estimate	95% CI
Intercept	0.03	0.00, 0.07
Poor fen	0.13	0.08, 0.19
Rich fen	0.16	0.05, 0.28
Conifer swamp	-0.34	-0.41, -0.26
Hardwood swamp	-0.29	-0.40, -0.18
Upland conifer	-0.08	-0.16, 0.01
Upland hardwood	-0.94	-1.08, -0.80
Distance to river	-0.32	-0.38, -0.25
Distance to upland	0.33	0.27, 0.39
Distance to cut block	-1.55	-1.80, -1.29
Distance to seismic line	0.79	0.72, 0.85
Distance to road	1.20	1.09, 1.32

Table 6: Comparison of resources used within the calving area versus resources used within the winter range by female caribou in northeast British Columbia during 2011-12. Treed bog was used as the reference category for land cover variables.

Variable	Estimate	95% CI
Intercept	-4.38	-8.09, -0.66
Poor fen	1.16	0.89, 1.42
Rich fen	1.20	0.70, 1.70
Conifer swamp	1.19	0.68, 1.69
Hardwood swamp	0.72	0.16, 1.28
Upland conifer	1.50	0.83, 2.17
Upland hardwood	1.58	0.39, 2.77
Distance to river	0.12	-0.33, 0.56
Distance to upland	-0.38	-0.82, 0.07
Distance to cut block	5.52	1.84, 9.21
Distance to seismic line	1.21	0.74, 1.68
Distance to road	-2.19	-3.28, -1.10

Table 7: Comparison of resources used by female caribou with calves versus barren cows during the 2011-12 calving seasons in northeast British Columbia. Treed bog was used as the reference category for land cover variables.

Variable	Estimate	95% CI
Intercept	-0.07	-1.25, 1.11
Poor fen	0.87	0.00, 1.74
Rich fen	0.50	-0.82, 1.82
Conifer swamp	-0.59	-2.48, 1.31
Hardwood swamp	1.02	0.33, 1.70
Upland conifer	-3.41	-5.65, -1.17
Upland hardwood	0.67	-0.37, 1.71
Distance to river	-0.08	-2.35, 2.19
Distance to upland	3.64	1.25, 6.04
Distance to cut block	-5.02	-7.91, -2.14
Distance to seismic line	-0.66	-3.98, 2.66
Distance to road	3.12	0.82, 5.43

Because lakeshore habitats have previously been suggested as calving habitat for boreal caribou (Bergerud 1985; Culling *et al.* 2006), we *post hoc* assessed caribou use of lakes and lake clusters, defined as lakes > 2 ha in size within 500-m of each other. When all lakes were considered, < 4% (323/ 8669) of locations used by females with neonate calves fell within 250-m of a lake and only 20% were within 1-km. When considering only lake clusters, only 1% (100 / 8669) of locations fell within 1-km of a lake cluster.

Integrating the landscape and local RSF models for caribou, we developed a predictive map of calving areas within the extent of the study (Figure 6). The map showed strong predictive performance using the nine females from 2004 as validation (r_s = 0.96).

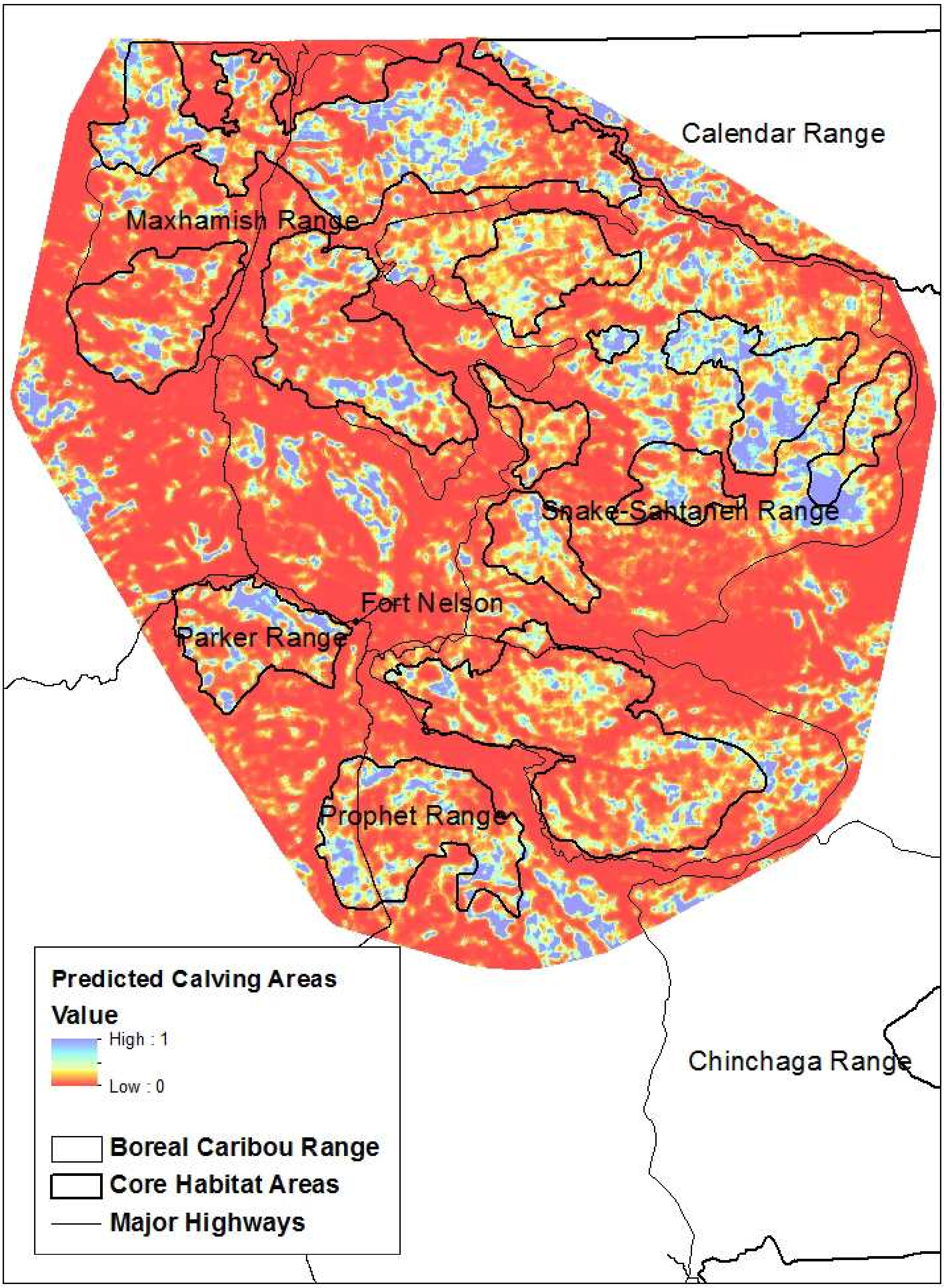


Figure 6: Predicted calving areas (blue) of boreal caribou within northeast British Columbia.

Predator Habitat Selection During the Caribou Calving Season

Predator habitat selection during the spring calving season was highly variable not only between species but also among individuals. Two of the three radio-collared wolves selected for landscapes with higher proportions of fens and upland conifer (Table 8). The other wolf showed higher selection for landscapes dominated by conifer and mixed wood swamps. Surprisingly, two wolves showed avoidance of landscapes with high proportions of upland hardwoods. In general, wolves selected for areas with high lake and river densities. Only one wolf selected landscapes with high densities of linear features. At a local scale, all wolves showed selection for fens (Table 9) and poor fens were the most highly used land cover type by two wolves (Table 10). Similar to the landscape scale, wolves demonstrated no strong selection for upland hardwoods with one wolf showing strong avoidance. Two wolves were generally closer to seismic lines than random locations while the third wolf showed avoidance of these lines. Only one wolf showed selection for roads.

Black bears showed no consistent patterns of selection across individuals at the landscape scale except for weak selection for areas of high linear feature density (Table 11). Two bears showed strong avoidance of poor fens. Variability in selection behaviour was particularly evident in response to upland conifer with two bears showing selection of landscapes with high proportions of upland conifer while two bears avoided these areas. Variability in selection was also evident at the local scale (Table 12). One individual showed consistent selection for swampy areas as well as uplands. No individual demonstrated selection for fens, which is also shown by the low overall use of these land cover types (e.g. < 13%; Table 13). In general, bears seemed to be closer to roads than random locations.

Table 8: Composition of landscapes selected by three wolves during the 2012 calving season (May 1 – June 30) of boreal caribou in northeast British Columbia. Selection coefficients for each wolf are presented with 95% confidence intervals in parentheses. Numbers in bold indicate 95% confidence intervals that do not overlap zero. Treed bog is the reference category for land cover variables.

Variable	Wolf 918	Wolf 919	Wolf 920
Intercept	-0.77 (-1.12, -0.42)	-0.75 (-1.10, -0.41)	-0.78 (-1.17, -0.39)
Poor fen	-0.14 (-0.41, 0.12)	**0.35** (0.00, 0.69)	**-1.01** (-1.34, -0.68)
Rich fen	**0.25** (0.02, 0.48)	**-0.33** (-0.65, -0.02)	-0.16 (-0.44, 0.12)
Conifer swamp	**-0.39** (-0.69, -0.1)	-0.29 (-0.70, 0.11)	0.41 (-0.03, 0.85)
Hardwood swamp	-0.22 (-0.52, 0.07)	**0.57** 0.24, 0.90)	-0.18 (-0.45, 0.1)
Mixed wood swamp	**0.39** (0.13, 0.65)	-0.17 (-0.39, 0.05)	**0.56** (0.11, 1.00)
Upland conifer	**0.53** (0.27, 0.79)	**0.46** (0.04, 0.89)	-0.22 (-0.6, 0.16)
Upland hardwood	**-0.65** (-0.96, -0.34)	**0.34** (0.08, 0.60)	**-0.63** (-1.02, -0.23)
Other	-0.14 (-0.48, 0.20)	**-0.46** (-0.74, -0.18)	**0.25** (0.01, 0.49)
Lake density	0.16 (-0.14, 0.45)	**0.21** (0.11, 0.32)	n/a
River density (km / km2)	**0.51** (0.35, 0.66)	n/a	n/a
Line density (km / km2)	0.12 (-0.05, 0.28)	**0.25** (0.07, 0.43)	-0.29 (-0.67, 0.10)

Table 9: Resource selection by three wolves at the local scale during the 2012 calving season of boreal caribou in northeast British Columbia. Selection coefficients for each wolf are presented with 95% confidence intervals in parentheses. Numbers in bold indicate 95% confidence intervals that do not overlap zero. Treed bog is the reference category for land cover variables.

Variable	Wolf 918	Wolf 919	Wolf 920
Intercept	-2.38	-1.41	-2.13
	(-5.34, 0.58)	(-2.20, -0.62)	(-3.31, -0.96)
Poor fen	**0.43**	**0.49**	-0.03
	(0.09, 0.76)	(0.15, 0.82)	(-0.48, 0.42)
Rich fen	**1.63**	0.09	**0.64**
	(1.00, 2.27)	(-0.42, 0.60)	(0.01, 1.28)
Conifer swamp	**1.35**	-0.28	-0.02
	(0.89, 1.82)	(-0.82, 0.25)	(-0.61, 0.57)
Mixedwood swamp	**1.05**	-0.20	-0.69
	(0.47, 1.64)	(-0.64, 0.24)	(-1.37, 0.00)
Hardwood swamp	**0.82**	0.37	**0.76**
	(0.32, 1.31)	(-0.02, 0.77)	(0.28, 1.23)
Upland conifer	**1.61**	**-0.70**	**-1.46**
	(1.06, 2.17)	(-1.38, -0.03)	(-2.34, -0.57)
Upland mixedwood	-0.39	-0.45	-0.70
	(-0.91, 0.12)	(-1.04, 0.13)	(-1.67, 0.27)
Upland hardwood	0.12	-0.36	**-1.11**
	(-0.76, 1.00)	(-0.92, 0.2)	(-1.73, -0.49)
Other	**2.04**	**0.77**	0.45
	(1.41, 2.66)	(0.23, 1.31)	(-0.33, 1.23)
Distance to river	-**0.93**	-0.42	0.59
	(-1.47, -0.39)	(-1.04, 0.21)	(-0.11, 1.30)
Distance to fire	-**0.74**	-**0.68**	0.38
	(-1.37, -0.12)	(-1.25, -0.11)	(-0.66, 1.41)
Distance to lake	**3.20**	**2.06**	0.55
	(0.39, 6.00)	(0.91, 3.22)	(-0.12, 1.22)
Distance to upland	0.00	**-1.26**	-0.47
	(-0.64, 0.64)	(-2.22, -0.31)	(-1.23, 0.29)
Distance to cut block	**-0.73**	**0.76**	**1.02**
	(-1.32, -0.14)	(0.12, 1.40)	(0.08, 1.95)
Distance to seismic line	**0.99**	**-1.66**	**-2.13**
	(0.05, 1.93)	(-2.57, -0.74)	(-3.31, -0.96)
Distance to road	-1.35	**-0.59**	-0.03
	(-2.8, 0.09)	(-1.15, -0.02)	(-0.48, 0.42)
Distance to pipeline	-2.38	-0.31	**0.64**
	(-5.34, 0.58)	(-1.38, 0.76)	(0.01, 1.28)

Table 10: Percent use of land cover types by individual wolf during the 2012 calving season (May 1 – June 30) of boreal caribou in northeast BC.

Land Cover	Wolf 918	Wolf 919	Wolf 920
Treed bog	0.07	0.14	0.29
Open bog	0.04	0.02	0.33
Poor fen	0.29	0.26	0.11
Rich fen	0.04	0.05	0.06
Conifer swamp	0.16	0.05	0.03
Mixed-wood swamp	0.06	0.05	0.03
Hardwood swamp	0.07	0.10	0.10
Upland conifer	0.12	0.07	0.00
Upland mixed-wood	0.03	0.04	0.01
Upland deciduous	0.03	0.09	0.02
Other	0.10	0.12	0.02

Table 11: Composition of landscapes selected by four black bears during the 2012 calving season (May 1 – June 30) of boreal caribou in northeast British Columbia. Selection coefficients for each bear are presented with 95% confidence intervals in parentheses. Numbers in bold indicate 95% confidence intervals that do not overlap zero. Treed bog is the reference category for land cover variables.

Variable	Bear 352	Bear 367	Bear 368	Bear 412
Intercept	-0.48	1.71	0.16,	-0.83
	(-1.31, 0.35)	(0.24, 3.18)	(-0.52, 0.83)	(-2.92, 1.26)
Poor fen	-0.13	**-0.52**	-0.05,	**-0.77**
	(-0.39, 0.13)	(-0.88, -0.15)	(-0.38, 0.28)	(-1.19, -0.35)
Rich fen	**-0.34**	-0.42	0.16,	0.17
	(-0.59, -0.09)	(-1.41, 0.56)	(-0.16, 0.48)	(-0.19, 0.54)
Conifer swamp	**0.44**	-0.25	-0.21,	0.09
	(0.15, 0.74)	(-0.94, 0.43)	(-0.47, 0.05)	(-0.11, 0.30)
Hardwood swamp	**0.60**	**-1.05**	**-0.53**	-0.32
	(0.21, 0.98)	(-2.05, -0.05)	(-0.95, -0.10)	(-0.73, 0.09)
Mixedwood swamp	-0.36	-0.49	**0.55**	0.19
	(-0.75, 0.03)	(-0.98, 0.00)	(0.23, 0.86)	(-0.10, 0.48)
Upland conifer	**-1.08**	**-1.20**	**0.55**	**0.64**
	(-1.96, -0.20)	(-2.27, -0.13)	(0.27, 0.83)	(0.14, 1.14)
Upland hardwood	0.13	**-0.98**	0.26	0.29
	(-0.17, 0.42)	(-1.86, -0.11)	(-0.16, 0.69)	(-0.70, 1.27)
Other	**0.36**	**1.77**	0.01	-0.5
	(0.10, 0.62)	(0.76, 2.77)	(-0.17, 0.20)	(-1.19, 0.18)
Lake density	**0.42**	-0.60	**-0.39**	0.55
	(0.19, 0.64)	(-1.59, 0.38)	(-0.69, -0.08)	(-0.18, 1.29)
Fire	-0.15	**-0.24**	0.05	-0.21
	(-0.72, 0.41)	(-0.46, -0.03)	(-0.32, 0.42)	(-0.64, 0.22)
River density (km / km2)	-0.17	0.10	n/a	n/a
	(-0.55, 0.20)	(-0.25, 0.45)		
Line density (km / km^2)	0.17	**1.13**	0.06	0.15
	(-0.06, 0.40)	(0.37, 1.89)	(-0.2, 0.33)	(-0.21, 0.52)

Table 12: Resource selection by four black bears at the local scale during the 2012 calving season of boreal caribou in northeast British Columbia. Selection coefficients for each bear are presented with 95% confidence intervals in parentheses. Numbers in bold indicate 95% confidence intervals that do not overlap zero. Treed bog is the reference category for land cover variables.

Variable	Bear 352	Bear 367	Bear 368	Bear 412
Intercept	2.20	-1.43	-0.21	0.47
	(0.42, 3.98)	(-3.30, 0.44)	(-1.30, 0.88)	(-1.08, 2.03)
Poor fen	0.20	**-1.68**	0.36	-0.22
	(-0.48, 0.87)	(-3.13, -0.23)	(-0.17, 0.89)	(-1.39, 0.95)
Rich fen	0.35	-0.76	0.46	0.57
	(-0.22, 0.92)	(-2.61, 1.09)	(-0.23, 1.14)	(-0.25, 1.39)
Conifer swamp	-0.01	-1.59	**1.19**	-0.12
	(-1.25, 1.22)	(-3.34, 0.15)	(0.06, 2.32)	(-1.00, 0.75)
Mixedwood swamp	-0.09	-0.91	**0.85**	**0.94**
	(-0.62, 0.44)	(-2.21, 0.39)	(0.27, 1.43)	(0.04, 1.83)
Hardwood swamp	**0.90**	-0.41	**0.82**	-0.78
	(0.47, 1.34)	(-1.78, 0.95)	(0.30, 1.34)	(-1.63, 0.06)
Upland conifer	-1.22	**-1.87**	**2.06**	0.27
	(-2.78, 0.34)	(-3.25, -0.49)	(1.43, 2.69)	(-0.48, 1.01)
Upland mixedwood	-0.26	**-1.41**	**1.68**	0.35
	(-1.32, 0.80)	(-2.79, -0.02)	(0.84, 2.52)	(-0.40, 1.09)
Upland hardwood	-0.31	-0.80	**1.03**	-0.41
	(-0.82, 0.20)	(-2.03, 0.43)	(0.51, 1.55)	(-1.24, 0.41)
Other	-0.52	-0.36	0.26	-0.21
	(-1.41, 0.37)	(-1.64, 0.93)	(-0.39, 0.91)	(-1.37, 0.95)
Distance to river	0.25	-0.31	**-1.33**	-0.15
	(-0.68, 1.17)	(-1.49, 0.86)	(-2.41, -0.24)	(-1.34, 1.05)
Distance to fire	n/a	0.19	n/a	n/a
		(-1.76, 2.14)		
Distance to lake	**-3.09**	**1.76**	**1.08**	-0.93,
	(-3.88, -2.30)	(0.13, 3.40)	(0.17, 2.00)	(-2.27, 0.41)
Distance to upland	**-0.72**	1.17	0.38	**-5.75**
	(-1.44, 0.00)	(-0.99, 3.34)	(-0.70, 1.46)	(-8.58, -2.91)
Distance to cut block	0.74	-0.34	-0.33	0.32
	(-0.73, 2.21)	(-1.96, 1.27)	(-1.17, 0.51)	(-0.70, 1.33)
Distance to seismic line	-0.63	**2.27**	**-1.62**	0.53
	(-1.91, 0.65)	(0.14, 4.39)	(-3.16, -0.08)	(-1.04, 2.10)
Distance to road	**-1.49**	-1.07	-0.65	-0.94,
	(-2.23, -0.76)	(-2.59, 0.45)	(-1.56, 0.27)	(-2.09, 0.21)
Distance to pipeline	0.57	1.24	**0.90**	0.71
	(-0.47, 1.61)	(-1.36, 3.84)	(0.04, 1.76)	(-1.05, 2.46)

Table 13: Percent use of land cover types by individual black bear during the 2012 calving season (May 1 – June 30) of boreal caribou in northeast BC.

Land Cover	Bear 352	Bear 367	Bear 368	Bear 412
Treed bog	0.13	0.03	0.08	0.01
Open bog	0.20	0.02	0.07	0.00
Poor fen	0.04	0.03	0.04	0.01
Rich fen	0.09	0.03	0.04	0.05
Conifer swamp	0.02	0.01	0.01	0.02
Mixed-wood swamp	0.05	0.05	0.04	0.14
Hardwood swamp	0.24	0.14	0.11	0.05
Upland conifer	0.00	0.03	0.13	0.18
Upland mixed-wood	0.00	0.09	0.05	0.41
Upland deciduous	0.18	0.24	0.36	0.12
Other	0.04	0.33	0.06	0.01

Caribou Calf Survival

Maternal selection of calving areas appeared to have some effect on the probability of neonate calf survival (Table 14). An increasing proportion of hardwood swamp in the landscape, at a scale of 900-m, increased the probability of calf mortality ($\beta = 8.42$, 95% CI: 3.54, 13.31). An increase in linear feature density, at a scale of 400-m, also weakly increased the probability of calf mortality ($\beta = 2.03$, 95% CI: -0.01, 4.06). At the local scale, an increasing risk of calf mortality was weakly associated with increasing selection of rich fens ($\beta = 1.37$, 95% CI: -0.01, 2.74; Table 15).

Table 14: Effects of maternal selection of landscapes on the probability of neonate calf survival for boreal caribou during the 2011-12 calving seasons in northeast British Columbia.

Variable	Estimate	95% CI
Intercept	-11.08	-20.18, -1.97
Poor fen	2.21	-0.28, 4.71
Rich fen	1.9	-2.27, 6.08
Conifer swamp	4.29	-2.07, 10.65
Hardwood swamp	**8.42**	3.54, 13.31
Mixed wood swamp	2.82	-3.17, 8.81
Upland conifer	1.75	-0.04, 3.53
Upland hardwood	-2.47	-5.53, 0.58
Other	2.31	-3.23, 7.86
River density	2.6	-0.56, 5.76
Fire	-4.01	-8.05, 0.04
Line density	2.03	-0.01, 4.06

Table 15: Effects of maternal selection of resources within the calving area on the probability of neonate calf survival for boreal caribou during the 2011-12 calving seasons in northeast British Columbia.

Variable	Estimate	95% CI
Poor fen	-0.72	-2.63, 1.19
Rich fen	1.37	-0.01, 2.74
Conifer swamp	0.94	-0.66, 2.55
Hardwood swamp	0.65	-0.22, 1.52
Upland conifer	0.57	-0.48, 1.61
Upland hardwood	0.38	-0.66, 1.42
Distance to river	0.96	-0.15, 2.07
Distance to upland	-1.39	-3.67, 0.9
Distance to cut block	0.16	-0.39, 0.7
Distance to seismic line	-0.68	-1.51, 0.15
Distance to road	0.12	-1.35, 1.59

Wolf Use of Linear Features

The probability of wolves using linear features increased with increasing sightability ($p = 0.01$) and decreased with higher amounts of coarse woody debris ($p = 0.05$; Figs. 7-8). The univariate model containing CWD was the top-ranked model though models with sightability included as a variable were all within one AICc unit (Table 16). CWD seemed to more parsimoniously explain the relative ease of movement on a given line rather than our overall mobility index.

Table 16: Model selection results assessing the relative influence of sightability, coarse woody debris (CWD) and the overall mobility index score on the probability of wolf use of linear features.

Model	AICc	Log-Likelihood	df
Line use ~ CWD	64.17	-29.95	2
Line use ~ CWD + sightability	64.21	-28.83	3
Line use ~ Sightability	64.72	-30.24	2
Line use ~ Mobility	65.79	-30.76	2
Line use ~ Mobility + sightability	66.41	-29.93	3

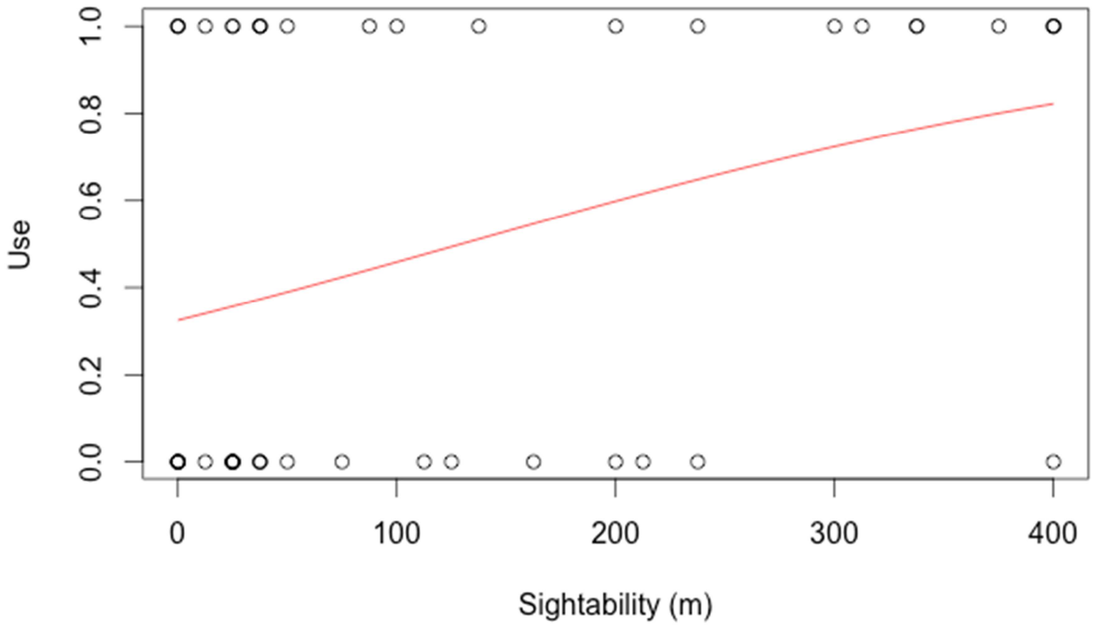


Figure 7: The effect of sightability on probability of line use by wolves. Line use significantly increases with sightability (p = 0.01).

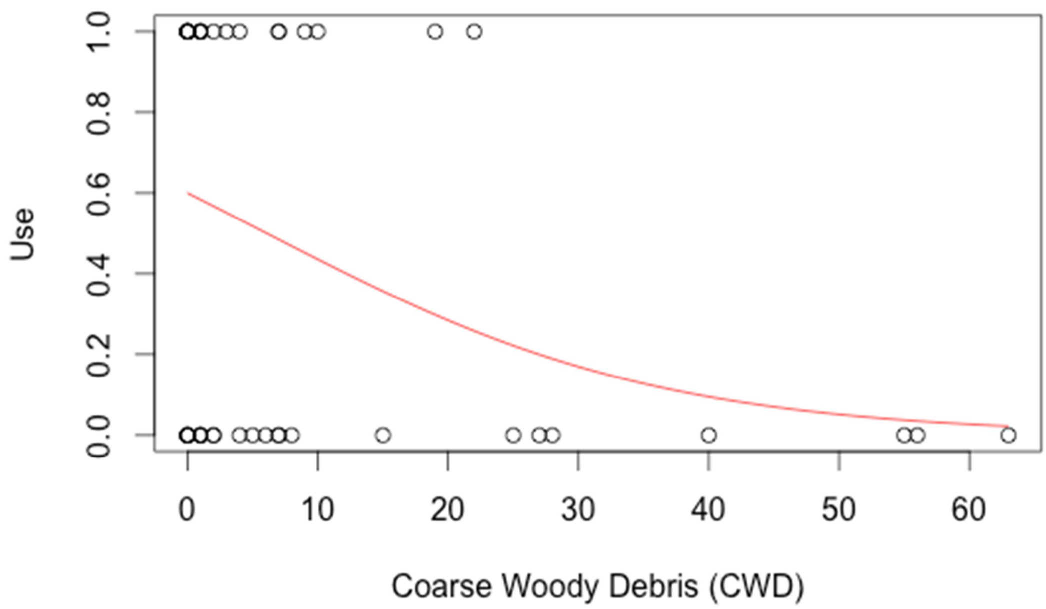


Figure 8: The effect of increasing coarse woody debris (CWD) on probability of line use by wolves. Line use significantly decreases with increasing CWD (p = 0.05).

DISCUSSION

The overarching objective of this project is to assess the spatial dynamics of caribou and their primary predators during the calving season and to evaluate how these dynamics ultimately influence predation risk to caribou calves. In 2011, we mainly focused on the perspective of caribou, performing initial analyses of calving habitat selection and its impact on neonate calf survival. For 2012, we continued these analyses and further attempted to gain insight on predator behaviours during the calving season, an important time period in the population dynamics of many ungulates (Gaillard *et al.* 2000; Raithel *et al.* 2007). Our sample sizes for predators are currently below our initial targets but preliminary analyses based on the data collected this year provide insight into potential mechanisms of caribou-predator interactions during the calving season.

Rates of neonate calf survival in 2012 (26 calves:100 cows) were similar to those recorded in 2011 (28 calves:100 cows). Both rates are below annual recruitment levels associated with population stability (~29 calves: 100 cows; Environment Canada 2011), suggesting that low rates of calf survival continue to be a factor in suspected population declines of caribou herds in BC. However, the lower calf-to-cow ratio in 2012 may be influenced by a lower pregnancy rate compared to 2011. Pregnancy rates for the last two years have been lower than those reported elsewhere (Stuart-Smith *et al.* 1997; Wittmer *et al.* 2005; Culling *et al.* 2006) and could be indicative of Allee effects (Allee & Bowen 1932) in areas with small numbers of caribou.

Calving sites in 2012 were situated in geographic locations similar to those used in 2011. Interestingly, for caribou calving in both years, females seemed to use similar pre-calving migration routes to travel from winter ranges to these areas. Though we have not explicitly assessed fidelity to pre-calving migration routes, fidelity to these routes could be as strong as or stronger than fidelity to specific calving areas. Consequently, the identification and prioritization of calving areas for potential conservation at a landscape-level will also require identifying highly used pre-calving migration routes. We will be conducting further analyses into the relative fidelity of caribou to calving areas and the pre-calving migration routes in 2013.

For this year, we used a multi-scale approach for evaluating calving habitat selection by female caribou. Our results suggest that prior to calving, females move out of winter ranges characterized by high proportions of treed bogs – a land cover associated with higher abundances of terrestrial lichen – and migrate into calving areas that are a mosaic of fens, upland conifers, and secondarily, upland hardwoods. Rettie and Messier (2000) observed a similar phenomenon in Saskatchewan, with female boreal caribou predominantly found in landscape mosaics shortly after calving. Within such mosaics, females may be able to optimize the trade-off between reducing predation risk and accessing high quality forage by primarily using habitat patches that provide lower predation risk (e.g. poor fens) while opportunistically feeding in nearby patches that have higher quality forage (e.g. rich fens). However, this strategy may not be optimal in landscapes with high predator abundances. In mature and unaltered boreal forest landscapes, the shift of female caribou into more productive areas at calving may not substantially increase overall predation risk because predator abundances are low (i.e. the overall rate of caribou-predator encounter is low). With increasing predator abundances, these landscape mosaics may become significantly riskier to caribou, particularly if wolves also increase use of fens in the spring to hunt beaver (Culling *et al.* 2006; Latham 2009). In caribou ranges where predator abundances are high, this seasonal shift of both caribou and predators into similar landscapes could be a major factor in the elevated predation rates observed during the spring and early summer in other caribou populations (Stuart-Smith *et al.* 1997; McLoughlin *et al.* 2003). Our preliminary results support this hypothesis with both caribou and wolves selecting for fens during the spring and increasing selection of rich fens by caribou equating to an increased risk of calf mortality.

Increasing linear feature density also correlated to an increasing risk of calf mortality. Linear features have previously been suggested as increasing predation risk to caribou, both in terms of proximity at a local scale (James & Stuart-Smith 2000) and density at a range scale (Boutin & Arienti 2008; Sorensen *et al.* 2008). Our results suggest that variation in linear feature density creates variation in predation risk below the range scale. It is uncertain, however, whether caribou can perceive variation in predation risk as it relates to linear feature density. Although caribou in our current analysis avoided areas of increased linear feature density during calving, the spatial scale used in this analysis (400-m) is likely confounded by caribou avoidance of lines in terms of proximity. Previous analyses conducted at larger spatial scales (e.g. 1.5-km) found that a substantial portion of caribou moved into landscapes of higher linear feature density at calving (see 2011 Annual Report; C. DeMars, unpublished data). These findings present a number of management problems. First, if areas are set aside within caribou ranges as protected calving areas, it is uncertain whether caribou will perceive such areas and, if so, whether they will alter previously established calving behaviours (e.g. fidelity to a particular calving area) to calve in these protected areas with presumably lower predation risk. A second problem arises in determining the level of intactness an area has to have in order for predation risk to be lowered. Simulations of wolf and caribou movements suggest that the density of linear features needs to be very low (e.g. < 1 km/km^2) to negatively affect wolf movement and hunting efficiency (McCutchen 2007; McKenzie *et al.* 2012). Although our preliminary analyses on wolf line use suggests that decreasing sightability or ease of mobility on lines could deter wolf use, this type of reclamation would need to be done at a relatively large scale (Neufeld 2006; McCutchen 2007). The spatial scale of intactness represents a third problem. Nagy (2011) suggests that population growth rates are higher in caribou ranges comprised of unaltered patches of > 500-km^2, but the relationship between patch size and predation risk has not been fully assessed, particularly during the calving season when predation rates are highest. While the lack of intact patches and the relatively high degree of landscape alteration in our study area limits our ability to directly assess these relationships, our preliminary results suggest reducing predation risk to caribou will require relatively large calving areas that have minimal to no disturbance and, importantly, have low abundances of predators.

The relative influence of black bears on predation risk to caribou calves is unclear from our preliminary analyses. The four bears collared in 2012 did not select for habitats associated with caribou calving areas. Patterns of use are perhaps more informative for bears, with three of the four individuals spending > 30% of their time in upland habitats. While other studies have suggested that some bears may specialize in peatland habitats (Latham *et al.* 2011a), we have observed little to no bear sign within caribou calving areas during the past two calving seasons and the lack of green vegetation at this time period indicates that these areas are likely marginal bear habitat. In other systems where black bears have been identified as significant predator of ungulate neonate calves (Zager & Beecham 2006; White *et al.* 2010), bears and ungulates co-occur in areas of relatively high productivity (e.g. abundant green vegetation). In the boreal forest, caribou-bear encounter rates are more likely to be driven by the number of bears and the frequency of their movements on the landscape (Bastille-Rousseau *et al.* 2011). The abundance of black bears in our study area is currently unknown. Moreover, it is unknown whether black bear abundances are historically high enough to play an important role in the current low rates of calf survival and, if so, whether black bears are also responding numerically to landscape alteration occurring with caribou range.

Management Implications:
Effective management of endangered species requires identifying key attributes of habitat critical to population persistence (Caro 1999; Heinrichs *et al.* 2010). For boreal caribou, critical habitat has been designated as the range of individual populations (Environment Canada 2012). Caribou ranges, however, have a wide geographic extent and typically encompass lands designated for multiple uses; consequently, complementary management strategies must also be developed at scales below the range. Our predictive RSF modelling can be used to identify calving areas within caribou range. Importantly, by relating attributes of calving habitat to neonate survival, our results can be used to assess habitat quality and therefore can inform the prioritization and conservation of calving habitats within caribou range.

The recent release of the federal recovery strategy suggests that a broad suite of management actions may be required to stabilize declining populations of boreal caribou (Environment Canada 2012). To that end, other management recommendations based on our results thus far include the following:

1. Caribou in the Prophet and Maxhamish ranges continue to use areas outside of current range boundaries, both for calving and during the winter, indicating that expansion of these range boundaries is warranted.
2. Because pre-calving movement is an important aspect of calving behaviour, landscape-level planning will be required to ensure functional connectivity between winter ranges and calving areas.
3. Reducing predation risk to caribou in calving areas will require comprehensive management strategies that include potentially reducing predator numbers, temporally diverting predators away from calving areas, and reclamation strategies aimed at reducing predator use of linear features.
4. Because caribou seem to show fidelity to calving areas, management strategies may need to be focused on areas caribou currently use rather than on mitigating other areas within caribou range and relying on caribou to shift their calving behaviours accordingly.

PROJECT YEAR 3 (2013) OUTLOOK

This coming year, the project's third, is our last scheduled year of field work. Because we were unable to fully achieve two of our primary objectives for 2012 – the radio-collaring of 20 wolves and 20 black bears – we anticipate continuing predator capturing efforts in 2013, pending approval of permits submitted in June 2012. We have recently purchased 15 replacement Iridium GPS radio-collars for wolves from Lotek using funds reimbursed by ATS. Similar Lotek collars were deployed on a sample of 19 wolves near Fort MacMurray in February 2012 and after seven months, 17 of the collars were still operational (one collar was chewed off; the other was a mortality; H. Spaedke, *pers. comm.*). Black bear collaring will take place in May 2013 after bears start emerging from their dens. By increasing the sample sizes of both wolves and bears, we will be able to better assess predator movement patterns and habitat use during the 2013 calving season.

We will also be conducting our last year of spring calf survival surveys in 2013. It is unlikely that any of the caribou collars deployed in February 2011 will last until next spring. Because of these collar failures, we will be deploying ten replacement Iridium GPS collars in December 2012 – January 2013 and we anticipate that a portion of the 25 Iridium GPS collars scheduled to be deployed by the Research Effectiveness and Monitoring Board in the winter of 2013 will also be available for calf survival surveys. With the deployment of these additional caribou collars, our sample size for calf survival analyses should increase substantially, thereby improving our statistical power to detect potential effects.

Other project objectives for 2013 include:

1. Continuation of fine-scale sampling of calving and winter sites.
2. Continued data analyses of calving habitat selection and neonate calf survival to determine attributes of calving habitat quality.
3. Analyses of fidelity of caribou to calving areas and the pre-calving migration routes used to travel to these areas from winter ranges.
4. Begin preparation of the project's final report (due in 2014).

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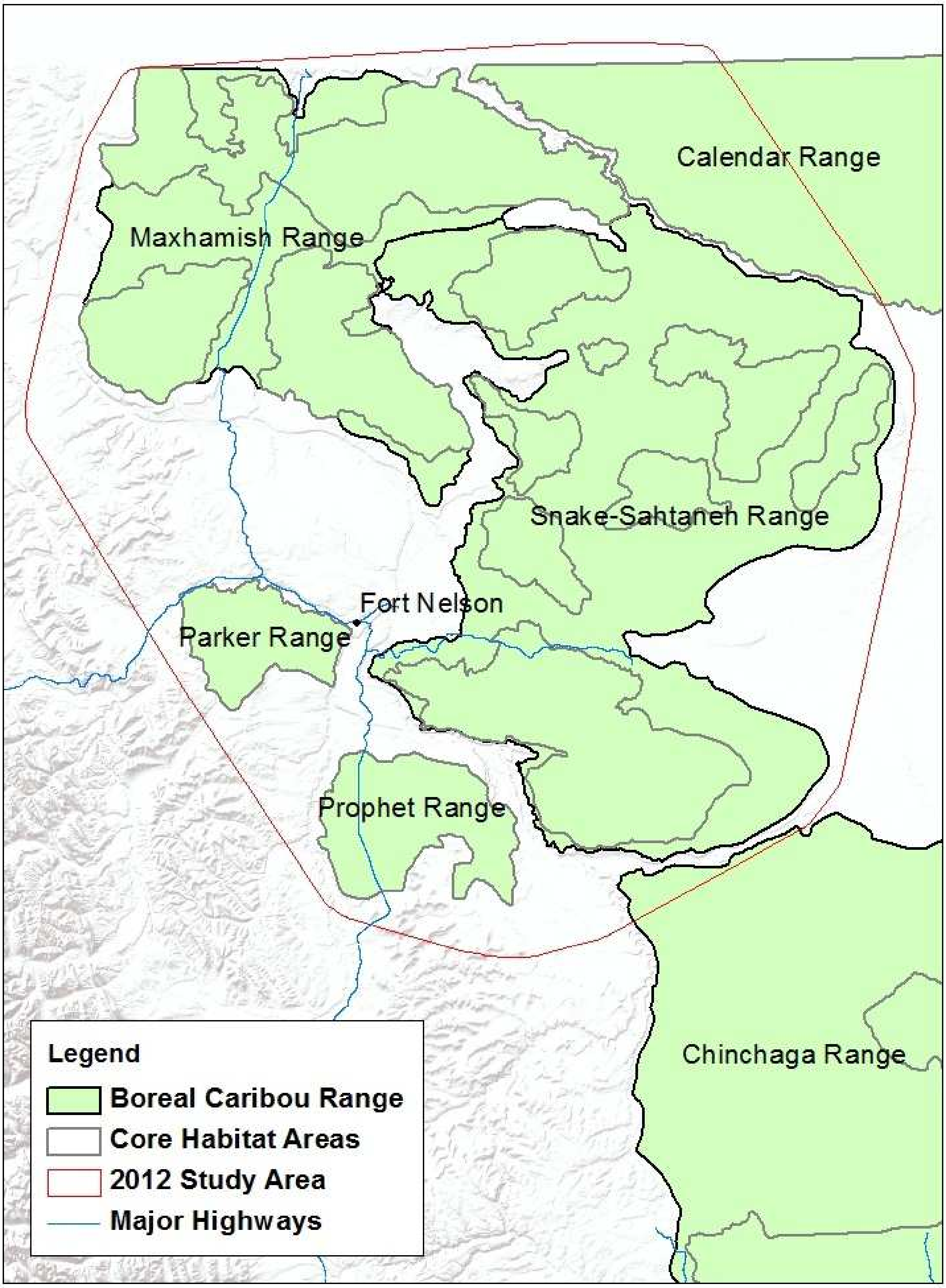
APPENDICES

APPENDIX 1:
Approximate study area for 2012. The study area now encompasses the entirety of four boreal caribou ranges in northeast British Columbia.



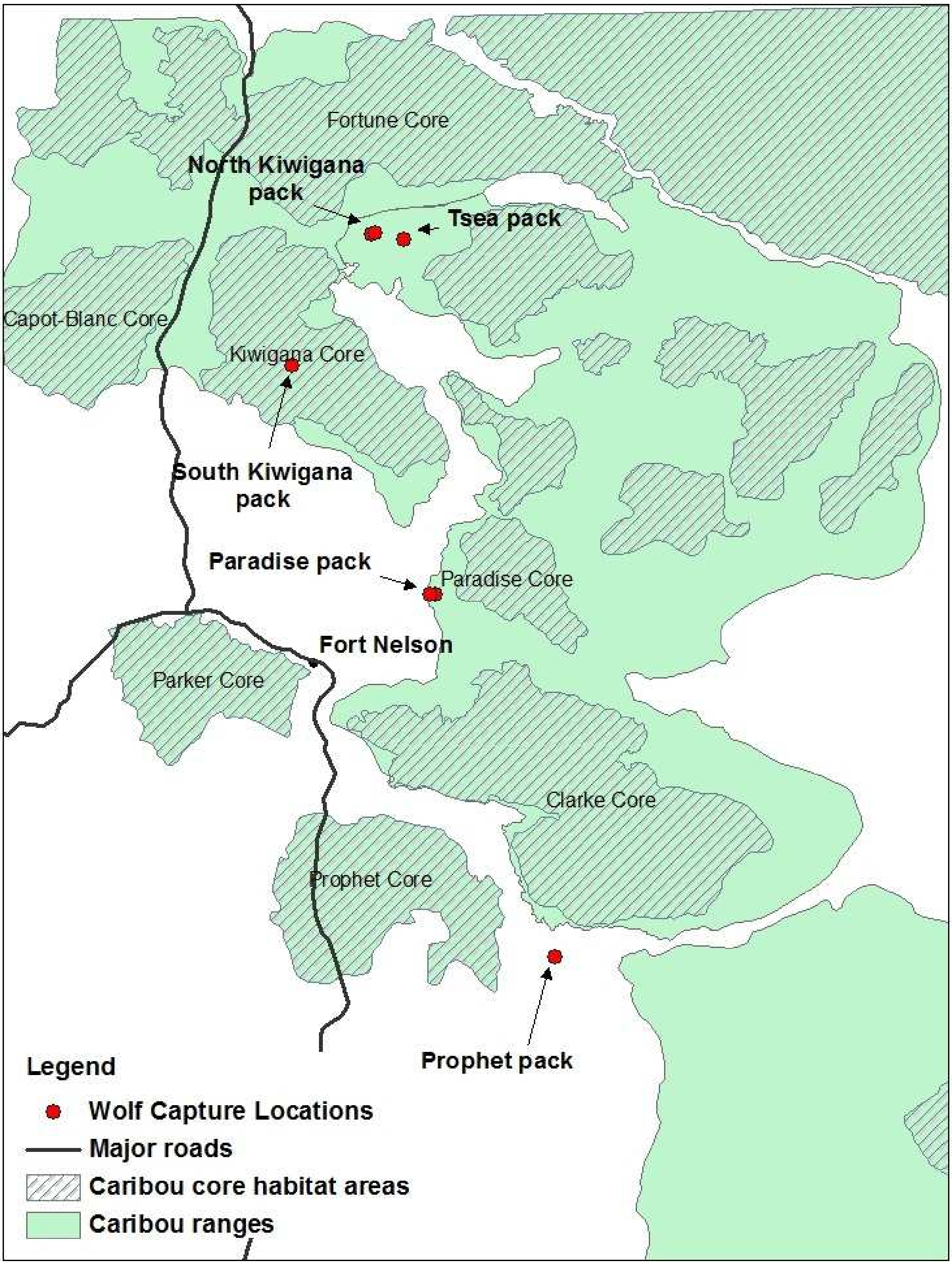
APPENDIX 2:

GIS data sources accessed to model resource selection of boreal caribou, wolves and black bears in northeast British Columbia during 2012.

Variable	Source	Access Information
Land Cover	Ducks Unlimited Canada	Ducks Unlimited Canada 100, 17958 106 Ave, Edmonton, AB T5S 1V4
Forest Structure	Vegetation Resource Inventory, BC Ministry of Forests, Lands and Natural Resource Operations	https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=47574&recordSet=ISO19115
Rivers, Lakes	Digital Baseline Mapping, BC Integrated Land Management Bureau, Geographic Data Discovery Service	https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=3679&recordSet=ISO19115
Forest Fire History	Fire Perimeters – Historical, , BC Integrated Land Management Bureau, Geographic Data Discovery Service	http://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=57060&recordSet=ISO19115
Cut Blocks	Forest Tenure Cut Block Polygons, BC Ministry of Forests, Lands and Natural Resource Operations	https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=50580&recordSet=ISO19115
Pipelines	BC Oil and Gas Commission	ftp://www.bcogc.ca/outgoing/OGC_Data/Pipelines/
OGC Seismic Lines	BC Oil and Gas Commission	ftp://www.bcogc.ca/outgoing/OGC_Data/Geophysical/
Major Roads	Digital Baseline Mapping, BC Integrated Land Management Bureau, Geographic Data Discovery Service	https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=3679&recordSet=ISO19115
Forestry Roads	Forest Tenure As-Built Roads, BCGOV FOR Resource Tenures and Engineering	https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=45694&recordSet=ISO19115
Other Secondary Roads	BC Oil and Gas Commission	ftp://www.bcogc.ca/outgoing/OGC_Data/Roads/
Well Sites	BC Oil and Gas Commission	ftp://www.bcogc.ca/outgoing/OGC_Data/Wells/
TRIM Lines	TRIM miscellaneous annotation, BC Integrated Land Management Bureau, Geographic Data Discovery Service	https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=4105&recordSet=ISO19115

APPENDIX 3:

Capture locations for 10 wolves from 5 packs in northeastern BC. Capturing efforts took place from March 11-14 and 23-28, 2012.



APPENDIX 4:
Capture locations for four black bears in northeastern BC. Three bears were captured on May 11 with the other captured on May 12, 2012.