APPENDIX 8.II

Bathurst Caribou Herd Winter Resource Selection Function: Development and Application

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8.II.1 INTRODUCTION

The Bathurst barren-ground caribou herd (*Rangifer tarandus groenlandicus*) has been in a state of decline since about 1990 (Adamczewski et al. 2009). A recent workshop incorporating scientific information and Traditional Knowledge identified fire on the winter range, disease, timing of spring, predators, hunter harvest, and human development as factors that likely influence the abundance and distribution of caribou (Adamczewski et al. 2009). The Fortune NICO Project is located in the forested portion of the herd's winter range. The combination of the NICO Project and previous, existing, and reasonably foreseeable developments may result in a loss of habitat for caribou on their winter range.

During winter, caribou generally forage within mature, open conifer forests and treed peatlands (reviewed in Environment Canada 2008). For boreal forest caribou, trends in habitat selection at the regional or seasonal range scale are typically driven by an avoidance of deciduous and early succession forest stands that support high densities of moose and deer (Bergerud et al. 1984; reviewed in Dzus 2001, and in Chowns and Gates 2004). High densities of alternate prey species attract and support greater numbers of wolves, which in turn result in higher levels of predation risk for caribou (Bergerud et al. 1984; Bergerud 1985; Rettie and Messier 2000; Joly et al. 2010). Conifer-dominated and peatland habitats may have lower predation risk than other habitat types (Environment Canada 2008). At a finer scale (e.g., selection of the daily range), habitat selection may be linked to lichen availability and accessibility (Rettie and Messier 2000; Bergerud et al. 2008; Joly et al. 2010). For example, caribou may select coniferous stands for access to arboreal lichens, as an important winter food resource (Chowns and Gates 2004; Bergerud et al. 2008; Environment Canada 2008). In addition, forested areas may act as refugia from either weather or predators, and possibly facilitate winter movements of caribou as trees intercept falling snow and can alter snow depth and density (Thomas et al. 1998; Mysterud and Ostbye 1999).

Natural disturbance such as fire can also alter the movement and distribution of caribou. Caribou from the Bathurst herd do not appear to use burns except as secondary travel routes (Croft et al. 2009). Caribou from the Beverly herd were found to cross burns freely, but spend little time in them, and the main concentration of individuals was away from extensively burned areas (Thomas et al. 1998). This may be due, in part, higher densities of other ungulates near burned areas. Alternately, reduced canopy cover in burns leads to higher snow depths, which appear to increase mobility costs for caribou and slow travel (Thomas et al. 1998). The distribution of caribou from the Beverly herd appeared to be affected by burns that were 50 years old (Thomas 1998). In addition to greater snow depths and ungulate densities, burns are generally poor for supplying forage for caribou. After fire, lichen regeneration has been estimated to take about 40 to 60 years for *Cladonia* species to over 150 years for *Cladina rangiferina* and *Cetraria nivalis* (Thomas et al. 1996). Although researchers typically conclude that fire is not responsible for caribou declines in North America, they agree that caribou avoid burned areas for many decades or longer (reviewed in Nelson et al. 2008). Traditional knowledge also contends that fire frequency and intensity affects caribou numbers and distribution (Kendrick et al. 2005).

Development activities may affect the abundance and distribution of caribou through sensory disturbance (e.g., noise and lights, dust, and presence of humans). For example, in northeastern Alberta, Dyer et al. (2001) studied woodland caribou response to industrial development and found that woodland caribou in open coniferous wetlands (i.e., peatland) avoided areas within about 250 metres (m) of roads during all time periods (i.e., late winter, calving, summer, and rut). Road avoidance was generally less when woodland caribou were in closed coniferous forest that provided effective security cover. Another study found that caribou exposed to sudden loud noises moved faster than non-disturbed animals (Bradshaw et al. 1997). Studies on the movements of woodland caribou in the boreal forest of Newfoundland near resource extraction industries indicated that caribou avoided mining activities, with avoidance distances of up to 4 kilometres (km) during the summer and 6 km during the late winter, pre-calving, and calving seasons (Weir et al. 2007).

Above the treeline, studies of barren-ground caribou have detected behavioural changes extending 5 to 7 km from the Ekati Diamond Mine (BHPB 2004), and avoidance from 10 to 40 km around mines (Boulanger et al. 2004; Johnson et al. 2005; Golder 2008a, b). More recent analysis have suggested that caribou are 4 times more likely to occur in areas greater that 11 to 14 km from the Ekati-Diavik mine complex (Boulanger et al. 2009). For the smaller Snap Lake Mine, caribou tend to prefer areas greater than 6.5 km from the mine, although the measurable avoidance of the mine was weak (Boulanger et al. 2009). Other research indicates that caribou reduce their use of areas within 5 km of development by 50 to 95% (reviewed in Vistnes and Nellemann 2008). Such 'zones of influence' typically do not extend beyond 10 km (reviewed in Vistnes and Nellemann 2008).

Analyzing and predicting the effects of landscape changes (both direct and indirect) for caribou is a key component of the Developer's Assessment Report (DAR) for the NICO Project. A common method for assessing and predicting effects is the development and application of habitat suitability models. These models combine computer technology, scientific knowledge, and field data into numerical values and graphical illustrations of habitat suitability for a specified study area. A RSF is a particular class of habitat suitability model that is defined as any function that estimates relative probabilities of habitat use (Manly et al. 2002). A key element of a sampling design for RSF studies is the use of available locations within a specified area, such that preference is the use of a land cover type less or more than would be proportionally expected based on availability (Manly et al. 2002). Among the benefits of RSFs are that they take advantage of existing field data and robust statistical techniques to estimate relative habitat use by animals. For these reasons, they are frequently used for estimating the habitat preferences of wildlife (Manly et al. 2002; Johnson et al. 2004; Johnson et al. 2005; Lander 2006; Johnson and Gillingham 2008).

Recently, RSFs were developed for the Bathurst caribou herd for the spring migration and calving, post-calving, and autumn-rut seasons (Johnson et al. 2005); however, an RSF or a similar species distribution model is currently unavailable for the winter period for the Bathurst caribou herd. The primary objective of this work was to develop a winter RSF as a predictive model for mapping habitat so that the DAR can reliably assess the effects from the NICO Project and other previous, existing, and reasonably foreseeable developments on caribou. A secondary objective was to provide new ecological information on important habitat features influencing the distribution of barren-ground caribou during the winter. Specifically, a suite of models (or hypotheses) were tested, including the hypothesis that barren-ground caribou avoid human disturbances in their winter range. Habitat preferences were quantified at 2 spatial scales (Rettie and Messier 2000).

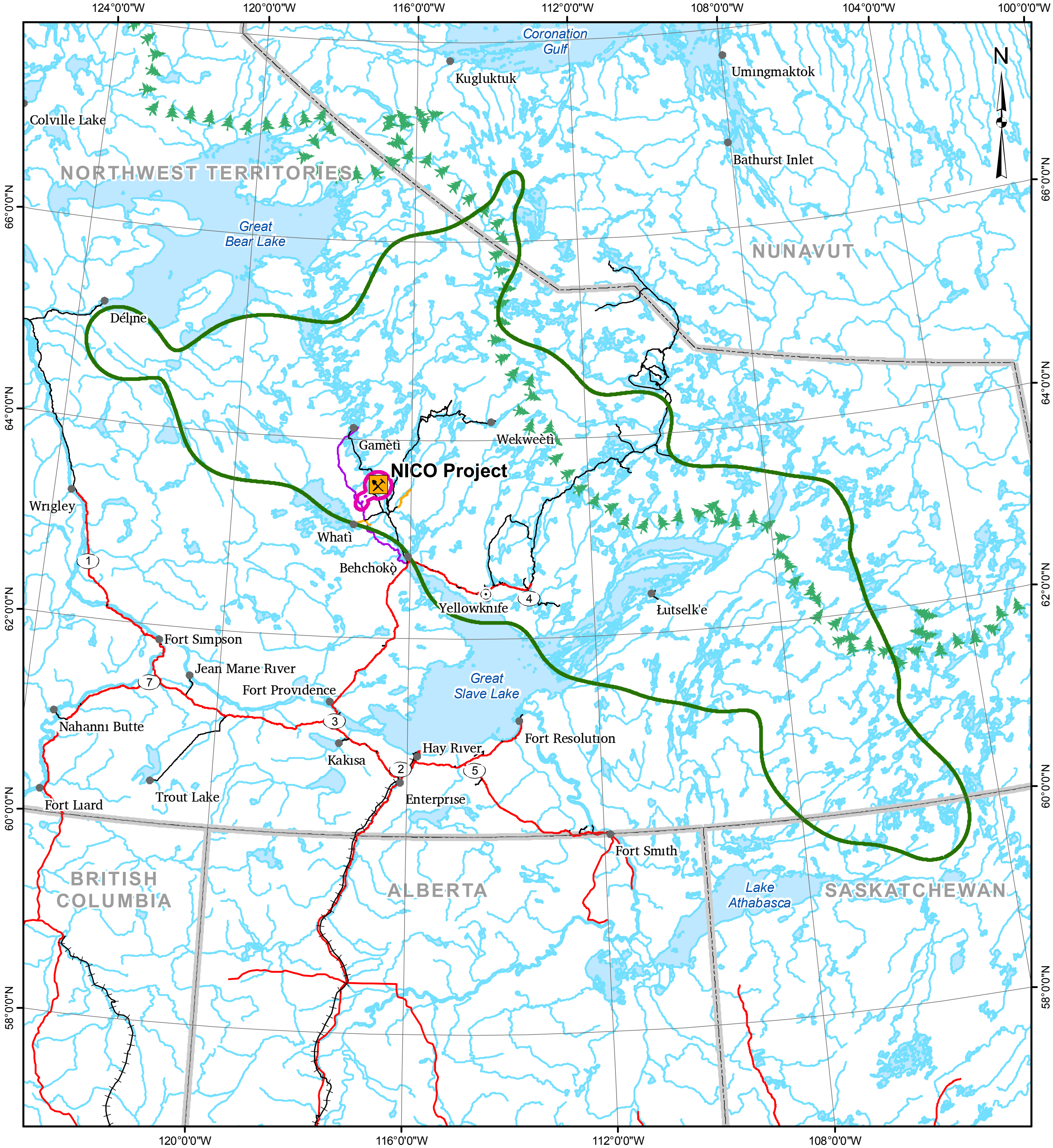
8.II.2 MATERIALS AND METHODS

8.II.2.1 Study Area and Satellite Collar Data

The NICO Project is located within the winter range of the Bathurst herd (Figure 8.II.2-1), which is defined by caribou distributions from 1 November to 30 April (ENR 2007, internet site). A total of 6805 satellite and GPS collar locations from 86 female Bathurst caribou were collected for the winter periods from April 1996 through March 2009 (Table 8.II.2-1). Closer examination of the data indicate that 89% of caribou locations were below the treeline during the winter period. In addition, the influence of human disturbance on caribou distribution suggests that the response of individuals to development is likely different in the forest than on the tundra (Section 8.II.1), which may be related to the function and structure of available habitat types. Therefore, the study area for developing the RSF was defined by the core area of use below the treeline of the Bathurst winter range (Figure 8.II.2-2).

Table 8.II.2-1: Satellite Collar Data Attributed to the Bathurst Caribou Herd Below the Treeline During the Winter Period, 1996 to 2009

Month	Total Observations	Collar Observations Below the Treeline	
		Number	Percent of Total Observations
November	965	723	75
December	1 299	1 113	86
January	1 241	1 146	92
February	1 137	1 082	95
March	1 255	1 188	95
April	908	807	89
Total	**6 805**	**6 059**	**89**



LEGEND

- NICO PROJECT
- TERRITORIAL CAPITAL
- POPULATED PLACE
- HIGHWAY
- EXISTING ALL-WEATHER ROAD
- EXISTING WINTER ROAD
- PROPOSED NICO PROJECT ACCESS ROAD
- PROPOSED TŁĮCHǪ ROAD ROUTE
- RAILROAD
- TERRITORIAL/PROVINCIAL BOUNDARY
- WATERCOURSE
- WATERBODY
- TREELINE
- CARIBOU WINTER RANGE
- REGIONAL STUDY AREA

200 0 200

SCALE 1:6,000,000 KILOMETRES

REFERENCE

Base data obtained from Atlas of Canada, DMTI, and ESRI.
Projection: Canada Lambert Conformal Conic

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

WINTER RANGE OF THE BATHURST CARIBOU HERD

Golder Associates
Edmonton, Alberta

FILE No. EA-Wild-004-GIS				
PROJECT No. 09-1373-1004		SCALE AS SHOWN		REV. 0
DESIGN	JV	27 July 2010	FIGURE: 8.II.2-1	
GIS	ANK	14 Mar. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

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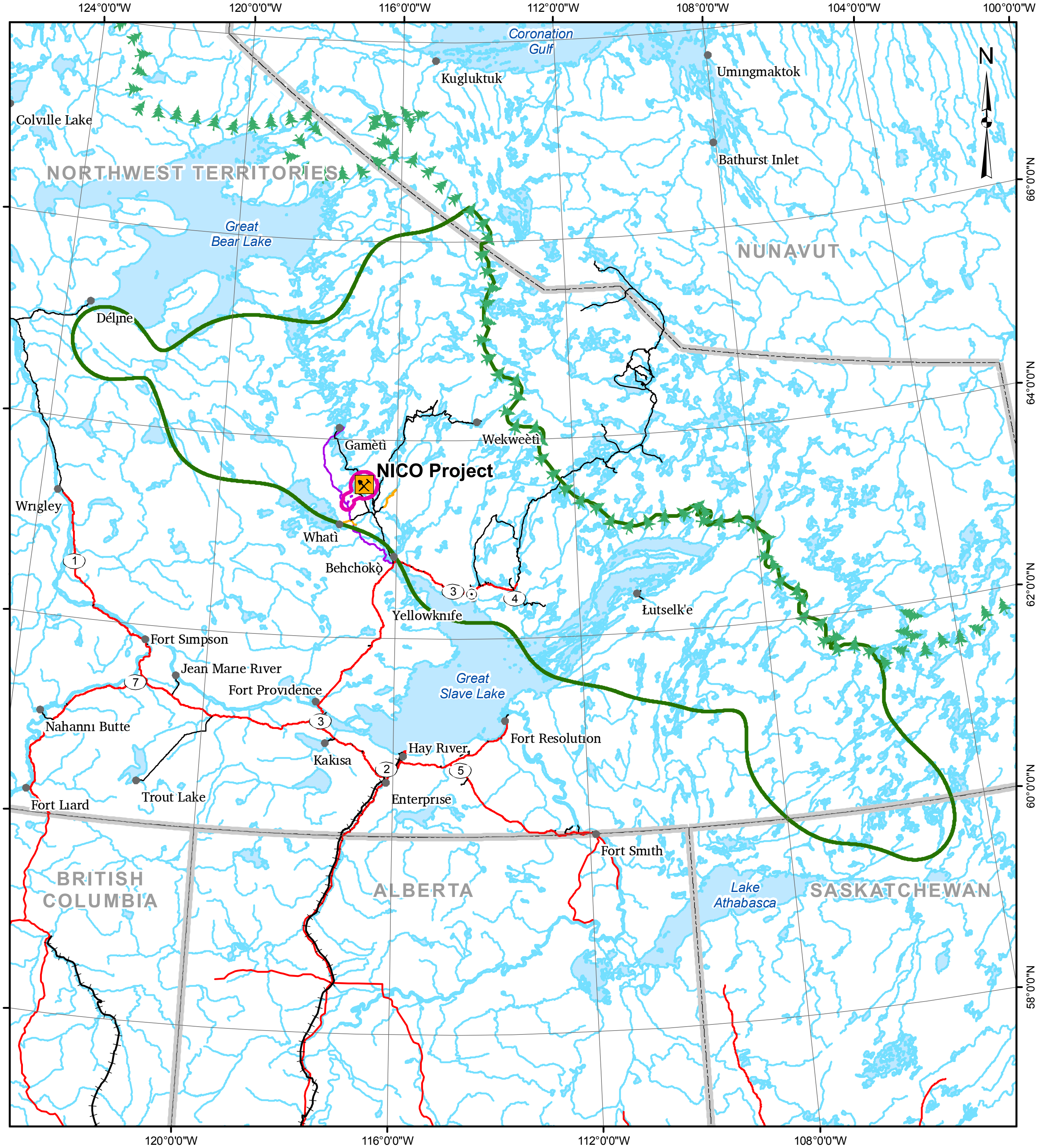

LEGEND

- NICO PROJECT
- TERRITORIAL CAPITAL
- POPULATED PLACE
- HIGHWAY
- EXISTING ALL-WEATHER ROAD
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- WATERCOURSE
- WATERBODY
- TREELINE
- CARIBOU STUDY AREA
- REGIONAL STUDY AREA

200 0 200

SCALE 1:6,000,000 KILOMETRES

REFERENCE

Base data obtained from Atlas of Canada, DMTI, and ESRI.
Projection: Canada Lambert Conformal Conic

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE **STUDY AREA FOR DEVELOPMENT OF WINTER RESOURCE SELECTION FUNCTION FOR THE BATHURST CARIBOU HERD**

Golder Associates
Edmonton, Alberta

FILE No. EA-Wild-005-GIS

PROJECT No. 09-1373-1004		SCALE AS SHOWN	REV. 0
DESIGN	JV	27 July 2010	
GIS	ANK	14 Mar. 2011	
CHECK	GRA	03 Apr. 2011	
REVIEW	GRA	03 Apr. 2011	

FIGURE: 8.II.2-2

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Satellite telemetry collar locations had designated error classes of 3, 2, and 1 (i.e., accurate to within 150 m, 300 m, and 1000 m, respectively; Gunn et al. 2002) (Table 8.II.2-2). Alternately, GPS collar data had been collected in 2008 and 2009, of which 95% were estimated to be accurate within 8 to 10 m (B. Croft, Department of Environment and Natural Resources, 2009, pers. comm.).

Table 8.II.2-2: Error Radius for Bathurst Caribou Global Positioning System and Satellite Collar Observations Below the Treeline in the Winter Range

Collar Error Class				Total
GPS (8-10 m)	3 (150 m)	2 (300 m)	1 (1000 m)	
1668	2213	1135	700	5716

GPS = Global Positioning System; m = metres

8.II.2.2 Land Cover Data

The best available vegetation cover data for the study area was the Earth Observation for Sustainable Development (EOSD) data (Wulder 2002). These data classify the landscape into 23 cover types at a 25 m resolution (Table 8.II.2-3), and were incorporated into a GIS platform. The number of land cover types was reduced to a smaller subset to facilitate the GIS and RSF modeling process, and to focus the analysis on variables anticipated to most strongly influence habitat selection by caribou. In some cases, land cover types were combined because the response by caribou was expected to be similar, thereby reducing redundant variables in models (e.g., open and sparse conifer and broadleaf stands). Expected land cover types that caribou may prefer included wetlands (including bryophytes) and coniferous habitat; whereas habitat types that may be avoided include deciduous forest (including mixedwood and broadleaf forest), human disturbances, and recent burns (e.g., Bergerud et al. 1984; Bergerud et al. 1985; Thomas et al. 1998; Bergerud et al. 2008; Environment Canada 2008; Croft et al. 2009; Boulanger et al. 2009). Water (e.g., frozen lakes and ponds) may be used by caribou for travel and resting while maintaining vigilance for predators. Shrubland cover (shrubs/herbs) was included in the models, and although the influence of this habitat type on caribou distribution was unclear, it was hypothesized that shrubland may be avoided because of low lichen biomass in these habitats (Joly et al. 2010).

Table 8.II.2-3: Land Cover Classes and Associated Re-Classified Superclasses Within the Winter Range of the Bathurst Caribou Herd

EOSD Land Cover Class	Re-Classified Land Cover Superclass	Expected Habitat Value for Caribou
Rock/rubble	Exposed land/rock[a]	nil to negligible
Exposed land	Exposed land/rock[a]	nil to negligible
Shrub tall	Shrub/Herbs	negligible
Shrub low	Shrub/Herbs	negligible
Herbs	Shrub/Herbs	negligible
Bryoids	Wetland	reduced predation risk
Wetland – treed	Wetland	food and reduced predation risk
Wetland – herb	Wetland	reduced predation risk
Wetland – shrub	Wetland	reduced predation risk
Coniferous – dense	Coniferous	food and cover
Coniferous – open	Coniferous	food and cover
Coniferous – sparse	Coniferous	food and cover
Broadleaf – dense	Deciduous	negligible
Broadleaf – open	Deciduous	negligible
Broadleaf – sparse	Deciduous	negligible
Mixedwood – dense	Deciduous	negligible
Mixedwood – open	Deciduous	negligible
Mixedwood – sparse	Deciduous	negligible
Water	Water	travel and reduced predation risk
Not present	Human disturbance[b]	nil
Not present	Burn[b]	nil to negligible

[a] land cover variable excluded from models to minimize multicollinearity and because variable not anticipated to influence distributions;
[b] land cover variables obtained from other data sources than EOSD.

Data describing the spatial distribution of fires over time were also compiled and combined with the EOSD land cover database. Previous research has demonstrated that barren-ground caribou spend little time in burns and do not appear to use burns except as secondary travel routes (Thomas et al. 1998; Croft et al. 2009). Burn data were compiled from 2 separate sources. For years prior to 2005, fire polygons in the NWT were from Mair (Department of Environment and Natural Resources, 2009, pers. comm.). Polygons defining the spatial extent of more recent fires were delineated using 80% volume contours around MODIS thermal anomaly data (USDA 2009, internet site) within a GIS platform using the Hawth’s Tools extension (version 3.27; Beyer 2004) for ESRI ArcGIS 9.2.

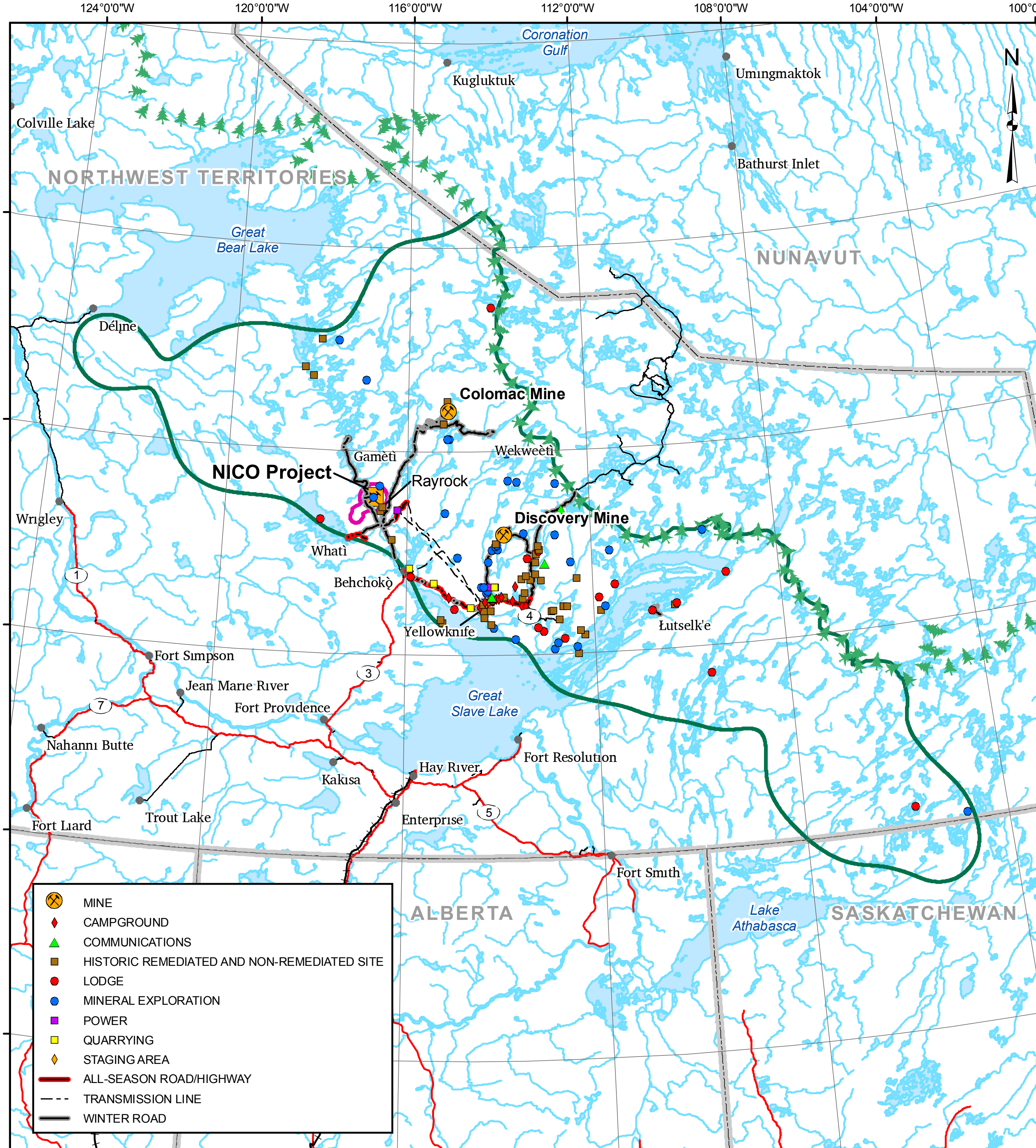
A spatially-explicit dataset describing the location and type of human developments within the study area was incorporated into a GIS layer (Figure 8.II.2-3). Information for the development layer was obtained from the following sources:

- Mackenzie Valley Land and Water Board: permitted and licensed activities within the NWT;
- Indian and Northern Affairs Canada permitted and licensed activities within the NWT (INAC 2009);

- Natural Resources Canada: obtained a GIS file on community locations from GeoGratis website;
- Indian and Northern Affairs Canada contaminated sites database (INAC 2009);
- Individual operators for project-specific information (e.g., component footprints and routes);
- company websites; and
- knowledge of the area and project status.

Initially, data indicating permitted and licensed activities were obtained in spreadsheet format. The file was examined for duplication of information (e.g., a water license and a land use permit for the same development). In cases where 2 or more pieces of location information for the same activity were present, the extra information was deleted from the file so that it contained only one point per development. The location of the footprint for the Snare Hydro to Yellowknife transmission line was obtained from the Northwest Territories Power Corporation.

For communities, the footprint was digitized from Landsat 7 Imagery from Natural Resources Canada (NRC 2007). An estimate of the physical footprint and associated local-scale disturbance was used for all other development types (Table 8.II.2-4). For linear features (i.e., roads and transmission lines), a 100 m buffer was used to define the footprint (i.e., corridor = 200 m). For most point disturbances, a 200 m radius was used to estimate the footprint, except for mineral exploration sites and power generation plants, which were applied a footprint of 500 m radius (78.5 hectares). All historical remediated and non-remediated sites (i.e., low, moderate, and high risk categories) were applied to the study area.



120°0'0"W 116°0'0"W 112°0'0"W 108°0'0"W

LEGEND

- NICO PROJECT
- TERRITORIAL CAPITAL
- POPULATED PLACE
- HIGHWAY
- EXISTING ALL-WEATHER ROAD
- EXISTING WINTER ROAD
- RAILROAD
- TERRITORIAL/PROVINCIAL BOUNDARY
- WATERCOURSE
- WATERBODY
- TREELINE
- CARIBOU STUDY AREA
- REGIONAL STUDY AREA

200 0 200

SCALE 1:6,000,000 KILOMETRES

REFERENCE

Base data obtained from Atlas of Canada, DMTI, and ESRI.
Projection: Canada Lambert Conformal Conic

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

PREVIOUS AND EXISTING DEVELOPMENTS IN THE STUDY AREA, 1996 TO 2009

Golder Associates
Edmonton, Alberta

FILE No. EA-Wild-006-GIS				
PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	JV	27 July 2010	**FIGURE: 8.II.2-3**	
GIS	ANK	03 Apr. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

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Table 8.II.2-4: Number of Developments and Hypothetical Footprints for Previous and Existing Developments in the Study Area, 1996 to 2009

Development Type	Footprint[b] (m)	Number
Campground	200	11
Communications (e.g., microwave tower)	200	3
Community	polygon	7
Historical remediated / non-remediated sites[a]	200	230
Lodge (outfitters, tourism)	200	17
Mineral exploration	500	35
Operating / closed mines	polygon	2
Power	500	2
Quarrying	200	5
Staging area (equipment and material storage)	200	1
Transmission line	200	3
Winter road	200	13
All season road	200	6
Total	n/a	**335**

[a] Includes all low, medium, and high risk sites.

[b] Footprint for communities were delineated and digitized from remote sensing imagery. Footprints for point features were based on a hypothetical radius. Footprints for linear features were based on a hypothetical corridor.

n/a = not applicable

In addition to spatial coordinates, dates for permitted and licensed activities were available for most human developments, which allowed them to be temporally linked to the year of caribou collar observations (i.e., annual changes in human developments could be associated with year-to-changes in collar locations). Natural (i.e., burns) and human (e.g., mineral exploration) disturbances that occurred in a given year were maintained on the landscape for each subsequent year of the available collar data. In other words, it was assumed that natural regeneration had not occurred for inactive sites whose permits have expired.

Annual area of burns on the landscape showed modest linear increases over time (i.e., a 12% increase from 1996 to 2000, and a 17% increase from 2000 to 2008). Alternately, the annual number of development footprints and areas in the study area changed little from 1996 to 2009. For example, the number of previous development footprints remained constant at 290 from 1996 through 2000, and represented 87% of the existing total number of human disturbance footprints (n = 335; Table 8.II.2-4) on the landscape. Similarly, the area of human disturbance (excluding roads) in 2001 (939 km^2) accounted for 93% of the total area of developments on the landscape (1013 km^2). From 2001 through 2006, the number of developments increased by 36, and during 2007 through 2009, 9 additional development footprints constituted part of the landscape. Seventy-six percent of the growth in development footprints was related to mineral exploration sites (n = 34). Other incremental human disturbances to the landscape were associated with quarries (n = 5), communications (n = 3), and a power plant, staging area, and lodge.

8.II.2.3 Resource Selection Function Models

Fixed-effects exponential RSFs were used (Manly et al. 2002) with coefficients ($\hat{\beta}_n$) estimated from conditional logistic regression (Hosmer and Lemeshow 2000) in Stata™ 9.2:

$$w(x) = \exp(B_1 x_1 + \ldots B_p x_p)$$

where w(x) is the probability of caribou occurrence in X_p land cover variables, and $ß_1$ to $ß_p$ are the number of unknown parameters to be estimated. The models were based on a total of 5716 satellite and GPS collar locations from 86 female caribou (April 1996 to March 2009).

8.II.2.3.1 Available Locations

As collar data represents locations of caribou presence only (animal use), and random samples of 'available' locations were produced in a GIS environment (Arthur et al. 1996; Johnson et al. 2005). Collar relocation distances and intervals (relocation segments) were first defined for each telemetry location and the subsequent location for that individual below the treeline. Relocation segments were then grouped into similar relocation intervals, and the mean and 95th percentile distances were calculated for each interval grouping (Table 8.II.2-5). The scale of availability for a particular location was defined using 'buffers' around the first point in a relocation segment with a radius equal to the 95th percentile distance for the appropriate relocation interval grouping (Table 8.II.2-5). Each animal location was coupled with a unique identifier number, and 5 'available' locations were placed randomly within each buffer (Johnson et al. 2005; Johnson and Gillingham 2008). Thus, animal locations, which represent the chosen habitat of the individual from it's preceding location, are linked to the random selection of 'available' locations and associated habitats the individual could have chosen but did not.

Table 8.II.2-5: Distance Travelled by Caribou at Different Relocation Intervals for Determining Scale of Availability

Relocation Interval Range (days)	Mean (95th Percentile) Distance [km]	Number of Intervals (% of Total)
0.0 – 0.3	2.5 (4.8)	11 (0.2)
0.4 – 0.7	3.9 (14.8)	5 (0.1)
0.8 – 3.5	4.2 (14.7)	1671 (29.3)
4.6 – 5.5	19.2 (65.3)	3522 (61.8)
6.8 – 7.2	30.7 (94.5)	285 (5.0)
9.8 – 10.3	38.2 (121.7)	134 (2.4)
13.9 – 14.1	39.1 (124.4)	16 (0.3)
14.8 – 15.3	38.6 (96.1)	30 (0.5)
19.6 – 21.1	44.3 (175.2)	14 (0.2)
25.0 – 70.0	122.0 (306.3)	11 (0.2)

km = kilometre; % = percent

8.II.2.3.2 Resource Selection Function Variables

Based on an understanding of caribou habitat associations and the EOSD land cover database, a suite of habitat variables likely to affect caribou habitat selection were defined for the study area (Section 8.II.2.2; Table 8.II.2-3; Table 8.II.2-6). The EOSD super-classes were measured at 2 spatial scales (local and regional). The local-scale analysis considered the positional error of collar location. This approach reduced the potential bias from caribou locations being associated with the most common and largest land cover patches (Samuel and Kenow 1992). Local-scale habitat variables were produced by calculating the percentage of a 300 m buffer around each collar location taken up by each land cover class. This buffer included the error radius of about 90% of the satellite collar observations (Table 8.II.2-5). Further, calculating land cover within 300 m of collar locations is potentially advantageous given that large mammals such as caribou are likely to consider more than a 25 x 25 m area (i.e., the resolution of the land cover data) when selecting forage or refugia.

Table 8.II.2-6: Candidate Models for Predicting Caribou Habitat Selection During Winter

Model	Model Description	Number of Parameters (K)
1	Null[a]	1
2	Global (full)[b]	15
3	Global minus human disturbance	13
4	Regional	8
5	Regional minus human disturbance	7
6	Local	8
7	Local minus human disturbance	7
8	Global minus shrub	13
9	Global minus shrub and human disturbance	11
10	Regional minus shrub	7
11	Regional minus shrub and human disturbance	6
12	Local minus shrub	7
13	Local minus shrub and human disturbance	6

[a] Equal means model (only contains intercept).

[b] Includes local variables (relative abundance of wetland, conifer, deciduous, shrubland, burn, water, and human disturbance) + regional variables (relative abundance of wetland, conifer, deciduous, shrubland, burn, water, and human disturbance).

K = number of parameters.

At the regional scale, the density of each vegetation class was measured within a 15 km radius, which was based on the estimated zones of influence from mine sites on the distribution of woodland and barren-ground caribou (Weir et al. 2007; Boulanger et al. 2009). Further, the perceptual abilities of caribou may extend up to 15 km when selecting habitat on the landscape (Mayor et al. 2009).

Due to the computing demands of calculating the amount of each vegetation type within a 15 km radius buffer around each collar location, calculations were performed on a landscape re-sampled to a 300 x 300 m raster cell size (rather than the 25 m raster cell size); however, even at this resolution processing times were constraining. Therefore, regional vegetation density was calculated only for the year 2000 land cover data set. The year 2000 dataset was selected because this year was the most accurate source for vegetation cover of all study years (Wulder 2002).

Thus, local-scale land cover types were based on the year 2000 EOSD habitat variables, and the temporal changes in burn and human developments from 1996 to 2009. At the regional scale, land cover variables included the 2000 EOSD database and all burned areas up to the year 2000. Annual changes in human developments from 1996 to 2009 were also incorporated into the regional analysis.

8.II.2.3.3 Model Selection

Thirteen candidate models (including a null or equal means model) were examined under the objective of identifying a reliable RSF predictive model for mapping caribou habitat and distribution (Table 8.II.2-3; Table 8.II.2-6). A secondary objective was to better understand: 1) the relative influences of local and regional variables on habitat selection during winter; 2) the potential avoidance of human disturbance; and 3) the importance of shrubland and whether its addition improves model performance.

Candidate models were scored and ranked according to how well they fit the data while taking model size and complexity into account (Burnham and Anderson 2002). This approach, most commonly known as the information-theoretic approach (Burnham and Anderson 2002), was based on Chamberlin's (1890) theory of multiple working hypotheses and Akaike's Information Criterion (AIC; Akaike 1973). Primary inferences were drawn from the best model (AIC_{min}) and others within 2 units of AIC_{min} (Burnham and Anderson 2002). Akaike weights (w_i) were also calculated to assess evidence supporting each model and to calculate model-averaged coefficients. Model averaging is best used to deal with model-selection uncertainty (e.g., more than one model with substantial support) and when the primary goal is prediction, rather than variable selection (Arnold et al. 2010). Inferences on the relative importance of predictor variables were assessed by examining the strength (or size) of the coefficient (Manly et al. 2002), and the 95% confidence interval (CI) of the coefficient (Stephens et al. 2005). Preference or avoidance was statistically significant when the 95% confidence interval of the coefficient excluded zero.

Post-regression tests included an assessment of the predictive performance of the top model using K-fold cross validation methods (Boyce et al. 2002; Johnson et al. 2006). For each data fold (there were 5 in total), the withheld dataset was assessed against the model predictions of the training data set using Spearman correlation tests between ordinal ranks of predictive RSF values (10 habitat bins or categories) and the frequency of independent and withheld (i.e., validation) observations in the same bin rank standardized for sample size (Boyce et al. 2002; Johnson et al. 2006). Models that performed well were those having successively more validation observations in higher-value habitat bins. A model was determined to be reliably predictive if r_s was positive (>0.7) and significant at an alpha level of 0.05.

8.II.3 RESULTS

Based on the 5716 animal locations, the dominant land cover types available to caribou at both local and regional scales were coniferous forest and water (Figure 8.II.3-1). At the local scale, the relative abundance of coniferous forest was about 39% and the relative abundance of water was 17%. At the regional scale, the relative abundance of coniferous forest and water was approximately 31% and 22%, respectively. The least abundant habitat type surrounding used locations was human disturbance, which represented less than 1% of the available cover at both the local and regional-scales (Figure 8.II.3-1). Habitat variables were not highly correlated with one another as all Pearson correlation coefficients were less than 0.7 (Tabachnick and Fidell 2001). Thus, it is unlikely that a habitat variable would contribute to multi-collinearity in a regression model.

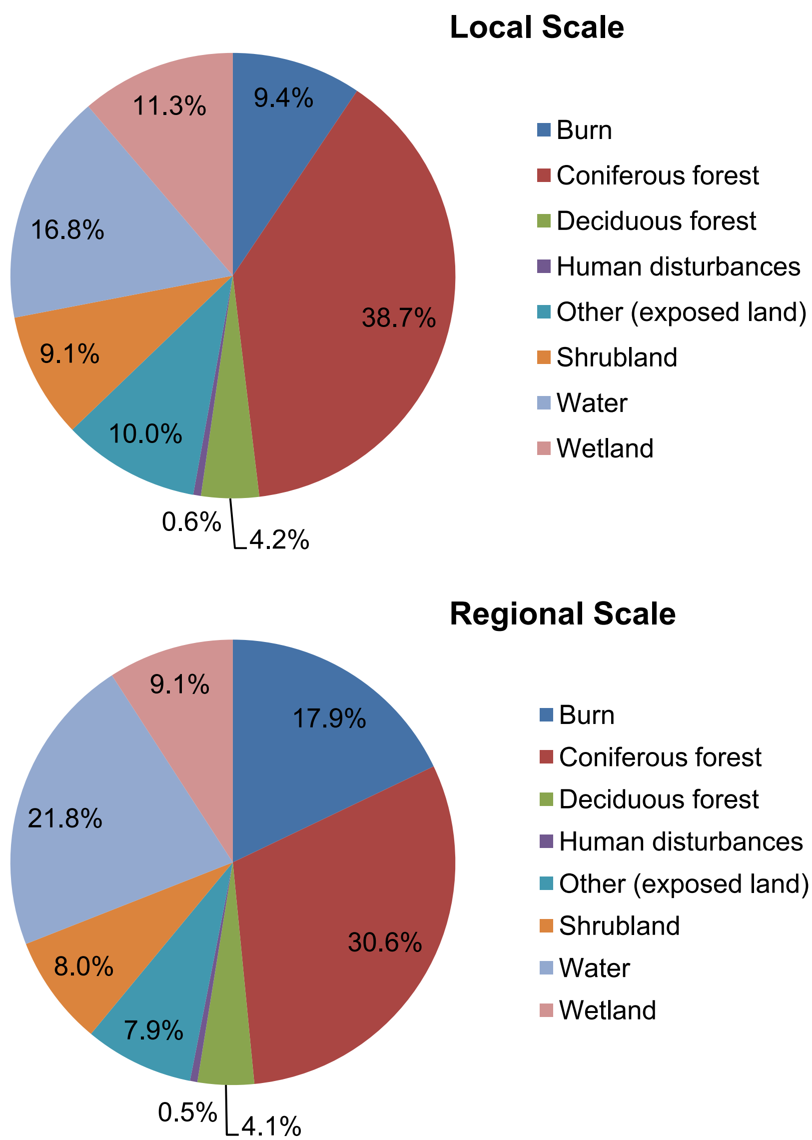

Figure 8.II.3-1: Mean Percentage of Land Cover Types Surrounding Bathurst Caribou Collar Locations in the Study Area

The AIC value for the top model was 1247 units lower than the null model. Of the 13 models, there was support for 2 models. In other words, 2 models were within 2 units of AIC_{min} (Table 8.II.3-1). There was generally more support for local versus regional models. For example, the AIC score for the local model was 731.5 units lower than the score for the regional model.

The top model was the global model without shrubland and human disturbance variables (model 9). Shrubland and human disturbance variables were identified as being uninformative (Table 8.II.3-1). The addition of human developments failed to lower AIC scores by more than 2 units for any of the comparisons (e.g., global versus ‘global minus human disturbance’, ‘local minus shrub’ versus ‘local minus shrub and human disturbance’).

Table 8.II.3-1: Rankings for the Bathurst Caribou Winter Range Resource Selection Function Models

Model	Description	K	LL	AIC	ΔAIC_{min}	w_i
1	Null	1	-9946.0	19892.0	1247.2	0.000
2	Global	14	-9310.1	18648.2	3.5	0.093
3	Global minus human disturbance	13	-9312.3	18648.3	3.5	0.090
4	Regional	7	-9742.4	19498.8	854.0	0.000
5	Regional minus human disturbance	6	-9742.5	19496.9	852.2	0.000
6	Local	8	-9376.6	18767.3	122.5	0.000
7	Local minus human disturbance	7	-9377.8	18767.7	122.9	0.000
8	Global minus shrub	13	-9311.0	18646.0	1.2	0.291
9	**Global minus shrub and human disturbance**	**10**	**-9312.4**	**18644.8**	**0.0**	**0.525**
10	Regional minus shrub	6	-9742.4	19496.8	852.0	0.000
11	Regional minus shrub and human disturbance	5	-9742.5	19494.9	850.2	0.000
12	Local minus shrub	7	-9377.0	18766.0	121.3	0.000
13	Local minus shrub and human disturbance	6	-9377.9	18765.8	121.1	0.000

Note: top model is bolded.

K = number of parameters; LL = Log-likelihood; AIC = Akaikes Information Criterion; ΔAIC_{min} = the difference between the AIC scores of a given model and the model with the lowest score; lower AIC values indicate more parsimonious models; w_i = Akaike weight interpreted as the probability that the model is the best of the candidate set of models.

Based on a 5-fold cross validation procedure, the top model (model 9) appeared to perform very well in predicting high-quality habitats (Table 8.II.3-2). The mean Spearman correlation coefficient was 0.95 and the mean P-value was statistical significant ($P < 0.05$).

Table 8.II.3-2: Spearman-Rank Correlations between Bin and Associated Area-Adjusted Observation Ranks for the Top Resource Selection Function Model

Validation Model (Fold)	Correlation Coefficient	P-value
1	0.952	<0.0001
2	0.915	0.0002
3	0.988	<0.0001
4	0.988	<0.0001
5	0.927	<0.0001

For habitat mapping, model-averaged coefficients were calculated for local abundance of burn and abundance of wetland, conifer, deciduous, and water at local and regional scales. All coefficients were statistical significant (i.e., 95% confidence intervals excluded zero) with the exception of regional water, regional burn, and regional coniferous forest (Table 8.II.3-3). The regional burn coefficient was the smallest in terms of magnitude ($\beta = 2.78$); whereas the largest coefficient was the regional deciduous cover coefficient ($\beta = -50.8$). During winter, Bathurst caribou showed strong avoidance of landscapes with abundant deciduous cover. Caribou also showed strong avoidance of deciduous cover at the local scale ($\beta = -18.2$), burn cover at the local scale ($\beta = -11.8$), and avoidance of wetland cover at the regional scale ($\beta = -22.5$).

Table 8.II.3-3: Model-Averaged Coefficients for the Bathurst Caribou Winter Range Resource Selection Function

Variable (super-classes)	Coefficient	Lower 95% CI	Upper 95% CI	Preference (P) / Avoidance (A)
Local-scale[a]				
Wetland	8.95	5.82	12.08	P
Conifer	3.36	1.12	5.60	P
Deciduous	-18.25	-23.86	-12.64	A
Water	-8.62	-10.72	-6.52	A
Burn	-11.84	-13.91	-9.77	A
Regional-scale[b]				
Wetland	-22.48	-31.59	-13.37	A
Conifer[c]	5.22	-0.92	11.36	--
Deciduous	-50.79	-66.93	-34.66	A
Water[c]	-4.68	-10.89	1.53	--
Burn[c]	2.79	-14.85	20.43	--

Note: coefficients were multiplied by 1000 for illustration purposes.

[a] Local-scale variables were measured as the relative abundance of a given land cover class within a 300-m radius around a collar location, expressed on a 0 to 100% scale.

[b] Regional scale variables were expressed as the relative abundance of a given land cover class within a 15-km radius around a collar location, expressed on a 0 to 100% scale.

[c] 95% confidence interval (CI) included zero suggesting that variable was potentially uninformative, and could be omitted from habitat mapping.

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