

WILDLIFE INFOMETRICS INC.

HABITAT ASSESSMENT

**An Assessment of Modeled High-elevation
Winter Range in Woodland Caribou Herd Areas
of North-Central British Columbia**

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MARCH 30, 2007

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Prepared for Canadian Forest Products Ltd., Mackenzie Operations under contract # **C06001**

CITATION: Rankin, L. M. and R. S. McNay. 2007. An assessment of modeled high-elevation winter range in woodland caribou herd areas of north-central British Columbia. Wildlife Infometrics Inc. Report No. 224. Wildlife Infometrics Inc., Mackenzie, British Columbia, Canada.

ABSTRACT

To aid in the recovery of woodland caribou in north-central British Columbia, Bayesian modeling techniques were employed to identify high elevation winter range (HEWR). The model was used to assign values from -1 (low range value), through 0 (medium), to +1 (high) for alpine and high-elevation forested habitats. The resulting spectrum of range values led to the development of seven different habitat types. We assessed the models effectiveness using three independent data sets collected within the Chase, Wolverine, Finlay and Scott caribou herd areas in the Mackenzie forest district of north-central British Columbia. Collected data sources were: telemetry relocations of radio-collared caribou (December through March, 1991-2006); a population survey conducted February through March 2007; and an assessment of arboreal lichen abundance conducted February through March 2007. Results from the model assessment indicated that caribou exhibit greater preference for HEWR during the late- (February and March), rather than early- (January and February) winter. We concluded that the model was successful in predicting HEWR habitat in alpine areas but was less successful predicting forested HEWR. We found no significant difference in observed caribou preferences between HEWR forested high value and HEWR forested low value habitat types; caribou in the Wolverine study area strongly preferred the latter habitat during late winter. Although model results indicated northwest aspects should be best for arboreal forage lichens, caribou preferred southwest aspects. We found that elevation affected lichen abundance more than aspect, and that there was significantly more lichen on trees with half, or more, of the branches dead within the typical caribou foraging height. Application of these results will be used to aid in the refinement of the HEWR model as the fundamental science basis for delineating officially recognized ungulate winter range for caribou in north-central British Columbia. However, prior to using model results for establishment of UWRs, we recommend at least two high priority sampling steps: confirmation of, and extension of, the lichen abundance estimates through summer-season field sampling and evaluation of sites known to be used by caribou (summer- and winter-season field sampling).

ACKNOWLEDGMENTS

The study was funded by the BC Forest Investment Account Land Based Investment Program and completed under contract to Canadian Forest Products, Mackenzie Operations. We appreciate the assistance from Doug Ambedian in his management and administration of project funding. Greg Altoft, Brian Dougherty, and Ryan Kuntz did a great job flying us to sampling sites and putting us in a position to complete our work. Viktor Brumovsky and Robin McKinley conducted the spatial modeling and Viktor drafted the study area graphics. Assistance in the field was provided by: Line Giguere, Travis McIsaac, Tasheena England, Fraser McDonald, and Allen Carson. Data for the preference analyses were collected from collaborative databases housing information from a variety research projects. In general we'd like to thank Chris Johnson and Mari Wood for the use of data that they contributed.

TABLE OF CONTENTS

ABSTRACT.....	I
ACKNOWLEDGMENTS.....	II
LIST OF TABLES.....	III
LIST OF FIGURES.....	IV
INTRODUCTION.....	1
STUDY AREA.....	1
METHODS.....	3
High elevation winter range model.....	3
Preference estimates.....	5
Telemetry data.....	5
Caribou population survey data.....	5
Arboreal lichen abundance estimates.....	5
Data analysis.....	6
RESULTS.....	6
Preference for modeled HEWR (terrestrial and arboreal).....	6
Preference for modeled HEWR (terrestrial).....	7
Preference for aspect within forested high elevations.....	7
Arboreal Lichen Estimates.....	10
DISCUSSION.....	10
High Elevation Winter Range Model.....	10
Arboreal Lichen Habitat Assessment.....	11
MANAGEMENT IMPLICATIONS.....	12
LITERATURE CITED.....	12

LIST OF TABLES

Table 1. Six class system for classifying the estimated abundance of arboreal forage lichens on trees sampled in a study of high-elevation winter range within woodland caribou herd areas, north-central British Columbia.....	6
Table 2. Analysis of variance ($P < 0.0001$, $R^2 = 0.532286$, $n = 968$) of ranked preferences for modeled High Elevation Winter Range (HEWR) interpreted from relocation of radio-collared woodland caribou observed during early- (December and January) and late- (February and March) winter, 1991-2006, in three herd areas of north-central British Columbia.....	9

Table 3. Preference for modeled High Elevation Winter Range (HEWR) interpreted from the location of woodland caribou groups observed during a population survey conducted March 2007 in three herd areas of north-central British Columbia. Ranges assessed were open areas where terrestrial forage lichens were predicted to be either absent or in relatively high or low abundance.	9
Table 4. Analysis of variance ($P < 0.0001$, $R^2 = 0.494720$, $N = 121$) of ranked preferences for forested, high-elevation aspect classes interpreted from relocations of radio-collared woodland caribou observed during early- (December and January) and late- (February and March) winter, 1991-2006, in three herd areas of north-central British Columbia.....	10
Table 5. Analysis of variance ($P < 0.0001$, $R^2 = 0.228154$, $N = 1,533$) of ranked, abundance of arboreal forage lichens (grams/linear meter) measured during a survey of modeled High Elevation Winter Range in four caribou herd areas in north-central British Columbia.	10

LIST OF FIGURES

Figure 1. Location of arboreal lichen assessment plots (pink squares), observed groups of caribou (red triangles), and relocations of radio-collared caribou (brown dots) used in an assessment of modeled high-elevation winter range (HWR) within four recovery planning areas (RPA) within the Mackenzie Timber Supply Area (TSA) in north-central British Columbia.	2
Figure 2. A Bayesian belief network used to predict the likely value (high, moderate, low) of high-elevation winter ranges used by woodland caribou in north-central British Columbia.	4
Figure 3. Preference for modeled High Elevation Winter Range (HEWR) interpreted from relocation of radio-collared woodland caribou observed during early- (December and January) and late- (February and March) winter, 1991-2006, in three herd areas of north-central British Columbia. Ranges assessed were those where terrestrial or arboreal forage lichens were predicted to be either absent (Other Low) or in relatively high, moderate (Mod1 and Mod2) or low abundance.	8
Figure 4. Frequency of caribou relocations observed in 45° aspects classes.....	9
Figure 5. Mean percent frequency of trees, with standard error, in each of the lichen classes at high (> 1450 m) and low (1300 m – 1450 m). Grey bars denote low elevation and white bars denote high elevation sites.	11

INTRODUCTION

Under the auspices of the Forest Practices Code of BC Act (Government Actions Regulation), the Government of British Columbia (BC), is authorized to designate areas of land necessary for the over-winter survival of ungulates and to set objectives for the management of those areas as Ungulate Winter Ranges (UWR). In north-central BC, direction has been undertaken to delineate UWRs for northern caribou (Schmidt and McNay 2002) using a Bayesian modeling technique (McNay et al. 2006). The model results were used to form predictions about the quality of Pine-Lichen Winter Range (PLWR) and High-elevation Winter Range (HEWR), located with 1-ha resolution, covering a total area of more than three million hectares in north-central BC. The results were also used to inform decisions about recovery planning (McNay et al. Submitted). Prior to identifying UWRs based on modeled PLWR, predictions were assessed by: comparing modeled range values to observations of habitat preferences (Chesson 1983) obtained from radio-collared caribou (Doucette and McNay 2003, McNay and Doucette 2003). Next the locations of modeled PLWR were confirmed spatially through an aerial reconnaissance technique (McNay and Sulyma 2003). While modeled PLWR values have been assessed for operational use and implemented through policy, those of HEWR have not. Here, we focus on two types of HEWR distinguished by the forage type sought by caribou: terrestrial lichens or arboreal lichens.

Our objective was to assess modeled HEWR for woodland caribou in the Finlay, Scott, Chase, and Wolverine herd areas of north-central BC by considering the following hypotheses:

1. Preference, interpreted from relocations of radio-collared caribou, for modeled HEWR (terrestrial and arboreal) would be consistent with predicted range values;
2. Preference, interpreted from locations of caribou groups observed during a population survey, for HEWR (terrestrial) would be consistent with predicted range values;
3. Preference, interpreted from relocations of radio-collared caribou, for aspect classes in forested high elevations, would be significant with highest preference for northwest aspects and lowest preference for southeast aspects; and
4. Sampled observations of arboreal lichen biomass would be consistent with modeled HEWR (arboreal) predictions of lichen abundance.

Outcomes of the assessment were to provide for enhanced confidence in the aerial extent of HEWR and subsequent delineation of UWRs, recovery actions associated with HEWR, and conservation of caribou range in north-central BC.

STUDY AREA

The study area was essentially the recovery planning area for the Wolverine, Scott, and Chase caribou herds and the management area for the Finlay herd (Figure 1). Our study extended from the town of Mackenzie (N55°18'16", W123°07'56") in north-central British Columbia throughout the Rocky Mountain foothills on the east side of Williston Reservoir north to the Peace Arm and in the Omineca Mountains on the west side of

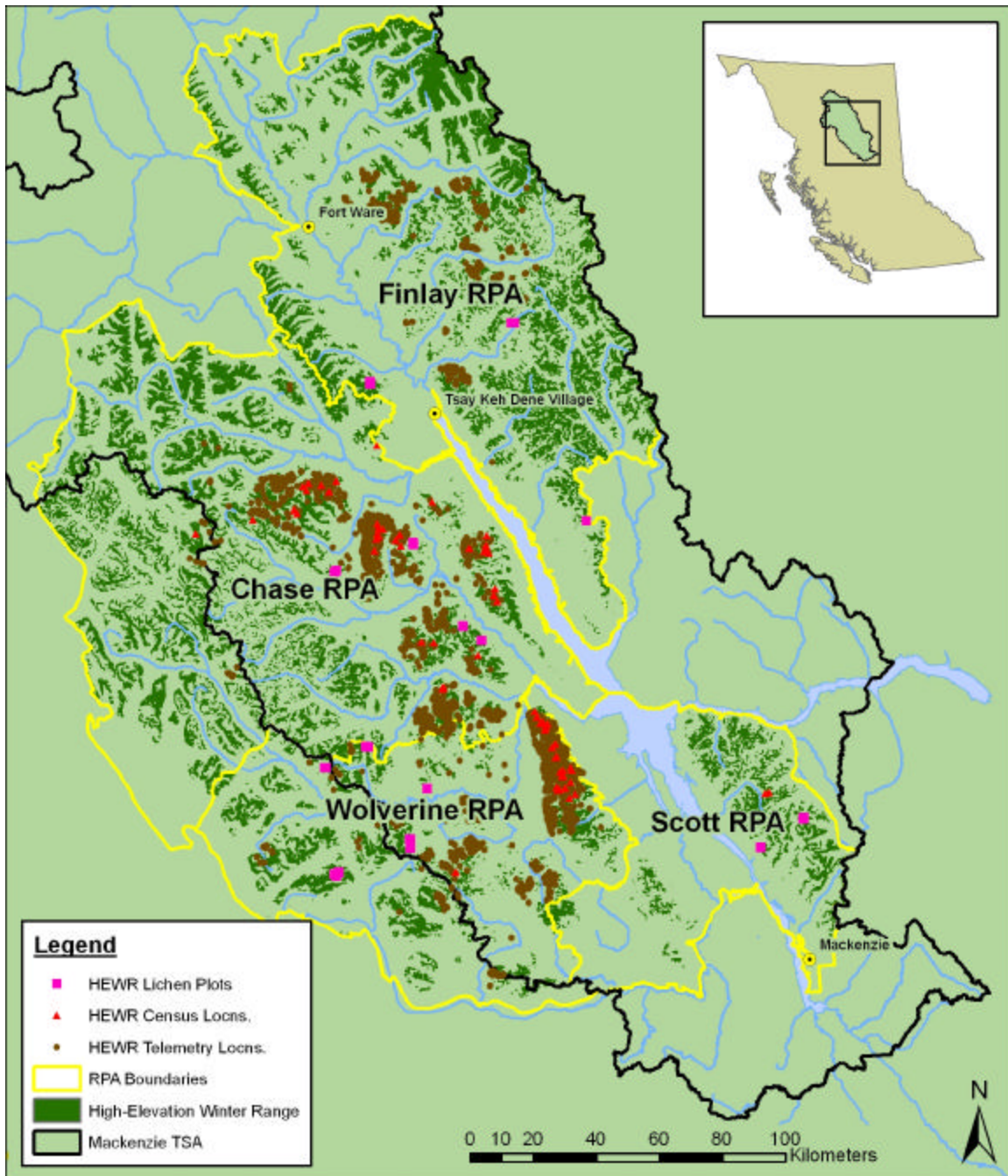


Figure 1. Location of arboreal lichen assessment plots (pink squares), observed groups of caribou (red triangles), and relocations of radio-collared caribou (brown dots) used in an assessment of modeled high-elevation winter range (HWR) within four recovery planning areas (RPA) within the Mackenzie Timber Supply Area (TSA) in north-central British Columbia.

Williston Reservoir north to the Ingenika River. It also included an area north of the Williston Reservoir and east of Fort Ware (N57°30'00", W125°24'00") through the Rocky Mountains to Red Fern Lake. Study areas were partially based on the ranges of three woodland caribou herds described by Heard and Vagt (1998): the Wolverine herd, named after the Wolverine Mountain Range; the Chase herd named after the Chase Mountain; and the Finlay herd which was named after the primary river drainage in the Rocky Mountain trench. A fourth study area, the Scott area, was not identified by Heard and Vagt (1998) but was known locally to have a small herd of caribou originating around Scott Creek north of Mackenzie and seasonally using low-elevation habitats west of the Williston Reservoir. The Wolverine area was 8,443 km² in rolling, high-elevation foothills; the Chase area was 17,330 km² and situated in relatively more steep, mountainous terrain, the Finlay area was 2,483 km² with a range of terrain from steep mountainous areas to the broad U-shaped Finlay River valley; and the Scott area was 5,949 km² with rolling foothills east of the Williston Reservoir and a relatively flat plateau west of the Williston Reservoir. Valley bottoms and mid-slopes of the areas were dominated by relatively cool and dry, or cool and moist, macroclimates of short growing seasons leading to boreal ecosystems of white and black spruce (*Picea glauca* (Moench) Voss) and *P. mariana* (P.Mill) B.S.P (Meidinger and Pojar 1991). Large-scale and frequent wildfires were characteristic prior to fire control policy (DeLong 2002). Common in these ecosystems were large, relatively flat areas of well-drained fluvial deposits, which in combination with frequent fires gave rise to large areas of forest dominated by even-aged lodgepole pine (*Pinus contorta* Dougl). Generally, a cold moist macroclimate with long, cold winters characterized upper slopes where Engelmann spruce (*P. engelmannii* Parry ex Engelm.) and subalpine fir (*A. lasiocarpa* (Hook.) Nutt.) dominated. At the northern extent of the Chase and Finlay areas, deciduous shrubs can dominate the upper slopes. Alpine tundra prevailed above tree line (~1,600 m) throughout all study areas.

METHODS

High elevation winter range model

HEWR was modeled by McNay et al. (2006) through use of a Bayesian belief network (Figure 2). This entailed developing simple influence diagrams, using the modeling shell Netica (version 2.17, Norsys Systems Corp., Vancouver, British Columbia), to depict range value in three discrete states: high, medium, and low. High-valued arboreal lichen range was characterized as: = 1300 m, slopes <45%, aspects = 225°, forests dominated by subalpine fir, sites >120 years old, and trees >15 m in height. High-valued terrestrial lichen range was characterized as: = 1300 m, slopes <45%, open alpine areas, and flat or convex hill shapes. We used unclassified model results to further stratify ranges and to distinguish between forested (arboreal) and non-forested (terrestrial) areas. Our resulting spectrum of range values included the following: Alpine High (AH), Alpine Low (AL), Forest High (FH), Forest Moderate-1 (FM1), Forest Moderate-2 (FM2), Forest Low (FL), and Other Low (OL).

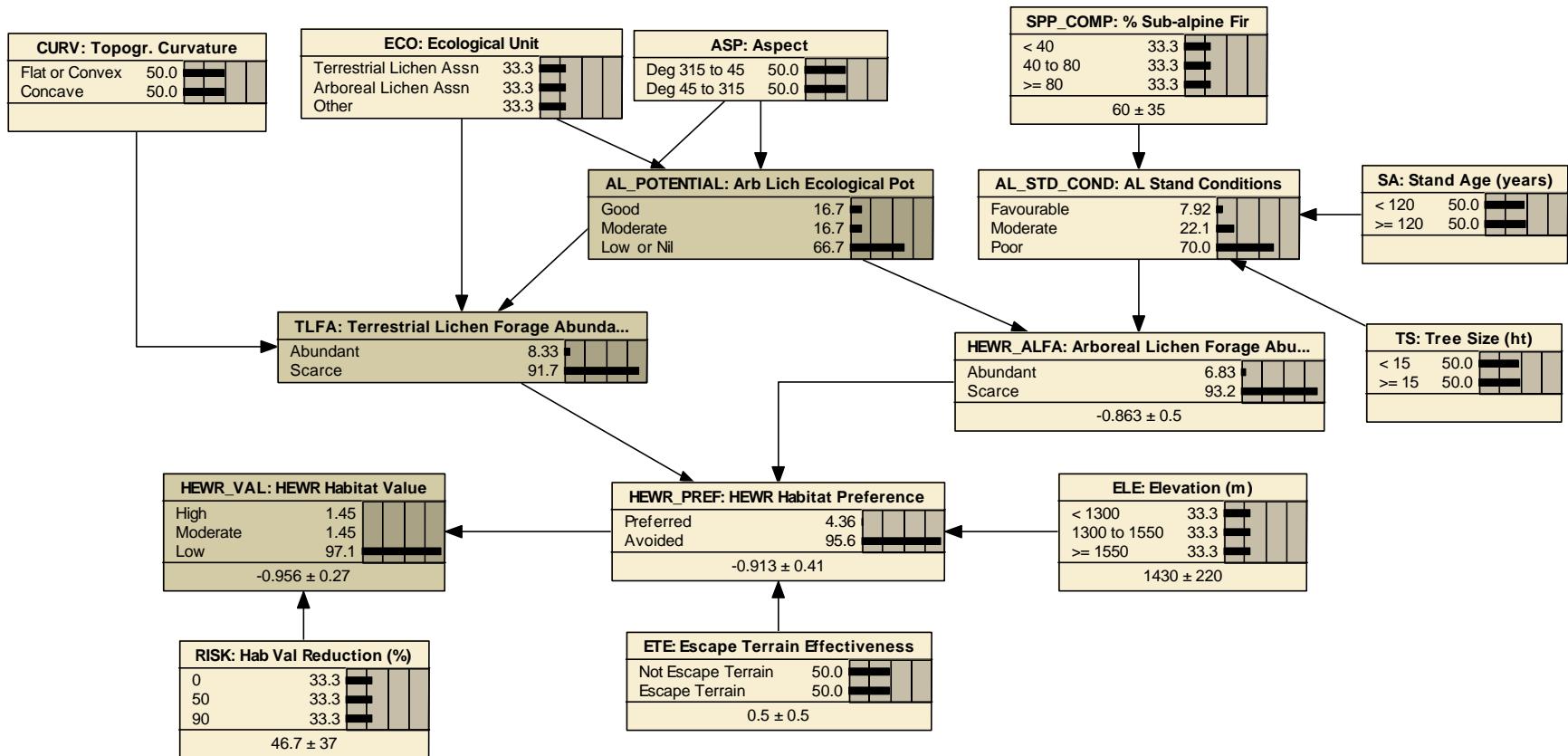


Figure 2. A Bayesian belief network used to predict the likely value (high, moderate, low) of high-elevation winter ranges used by woodland caribou in north-central British Columbia.

Preference estimates

We estimated preference for each of the identified range values using telemetry and population survey data. Range selection by caribou was estimated using Chesson's preference index (Chesson 1983), which was based on the ratio of range-use to range availability corrected for unequal availability of ranges. Relocations of 47 caribou provided range use information as the basis for estimating preference ($\alpha > 0.143$, $P=0.05$) for the seven classes of modeled HEWR (terrestrial and arboreal). Observation of groups of caribou collected during the population survey provided information on preference ($\alpha > 0.333$, $P=0.05$) for the three classes of modeled HEWR (terrestrial). Preference ($\alpha > 0.250$, $P=0.05$) for four classes of forested aspects (northeast - 0 to 90°, southeast - 90 to 180°, southwest - 180 to 270°, and northwest - 270 to 360°) was performed using relocation data from forested areas >1300m in elevation.

Telemetry data

We or researchers previous to us, fit caribou with Very High Frequency (VHF) radio transmitters containing mortality sensors from 1991 to 2004. Some transmitter deployments also contained Global Positioning System (GPS) technology. Animals were captured in the Finlay herd between 1999 and 2003, in the Scott herd in 2002, in the Wolverine herd from 1991 to 2004, and in the Chase herd in 1991 to 1992 and then again from 1997 to 2003. Details of the collaring methods, deployment schedules, relocation schedules, and management of data were reported by McNay and Voller (Submitted). Only relocations observed >1300 m during early- (December and January) and late- (February and March) winter were used for preference tests. To avoid misinterpretation of resource preferences that can sometimes occur with small sample sizes (Johnson 1980, Lechowicz 1982), we chose to arbitrarily eliminate animals with less than 7 relocations. Use of forested versus open habitat was determined by inspecting habitat codes recorded on aerial relocation sample forms. We had no reliable way of determining the cover type used by animals wearing GPS collars so these relocation data were excluded from the analysis of forested aspects.

Caribou population survey data

Population survey data (February-March, 2007) were screened to isolate: 1) location of caribou groups relative to modeled HEWR (terrestrial) and 2) reconnaissance-level comments regarding the quality of modeled HEWR (terrestrial). Survey methods and other details were provided by Giguere and McNay (2007).

Arboreal lichen abundance estimates

Arboreal lichen abundance was estimated in the Englemann Spruce-Subalpine Fir (ESSF) biogeoclimatic zone following modified methods of Stevenson et al. (1998). Modeled HEWR (arboreal) values were used to identify potential sample sites within high-valued forested range. We used a two-factor random block sample design that resulted in four sample domains based on aspect and elevation: 1) northwest, 1300-1450 m; 2) northwest, >1450 m; 3) southeast, 1300-1450 m; and 4) southeast, >1450 m. Lichen abundance was

estimated to an assumed foraging height of 4.5 m above ground on trees =7.5 cm dbh located within circular sample plots. Four to five plots, 5-7 m in radius, were distributed at 40 m intervals along transects. Depictions of 5 g lichen clumps presented by Armleder et al. (1992) were used to aid our visual enumeration of lichen clumps on each tree. Count of lichen clumps was transformed later to grams per linear foot of potential foraging area after accounting for average snow depths measured at each plot. Sampled trees were classified by branch characteristics (A - mostly live, B - mixed living and dead, C - mostly dead, or D - none) and by type of arboreal lichen (A - = 70% *Alectoria*, AB - mixed *Alectoria* and *Bryoria*, and B - = 70% *Bryoria*). Standard classes of lichen abundance (Armleder et al. 1992) were modified due to the generally low abundance of lichen in our study area (Table 1).

Table 1. Six class system for classifying the estimated abundance of arboreal forage lichens on trees sampled in a study of high-elevation winter range within woodland caribou herd areas, north-central British Columbia.

Class	Quantity of lichen (g) Armleder et al. (1992)	Quantity of lichen (g) Modified
0	0	0
1	>0 – 5	1 – 5
2	>5 – 50	5 – 10
3	>50 – 250	10 – 25
4	>250 – 625	25 – 50
5	>625	50 – 100
6	N/A	100 +

Data analysis

We used a Shapiro-Wilk test ($P = 0.05$) to assess normality of preference estimates across our population of radio-collared caribou. If data did not meet the assumptions of normality, we used standard data transformations to achieve normality. Depending on normality and heteroscedasticity, we used either parametric or non-parametric (Kruskal-Wallis) analysis of variance to test the hypothesis that preference was related to modeled range values. Duncan's Multiple Range test was used to make multiple comparisons of preference values among study areas, modeled range values, early- and late-winter, and gender. Management of data, calculations, and test statistics were made using SAS (SAS Institute Inc., Cary, North Carolina).

RESULTS

Preference for modeled HEWR (terrestrial and arboreal)

Preference estimates were based on >10,000 relocations of 47 radio-collared caribou. Caribou generally demonstrated greater preference for HEWR (Figure 3) during the latter part of winter, particularly for high valued HEWR (terrestrial). Preference for HEWR

(arboreal) was generally equivocal (i.e., $P > 0.05$) or absent (i.e., the range was avoided) except perhaps in the Wolverine herd area where, during the latter part of winter, preference was shown by some animals across the entire range of HEWR (arboreal) values (Figure 3). Preference for HEWR (terrestrial and arboreal) was related ($P < 0.05$) to all factors assessed except study area ($P = 0.4622$) with HEWR range value explaining most of the observed variance in ranked preference values (Table 2).

Preference for HEWR range in the Finlay area tended to rank higher ($\bar{X} = 519.79$, $P < 0.05$) than that of the other study areas. No difference ($P > 0.05$) was evident between the Wolverine ($\bar{X} = 483.48$) and the Chase ($\bar{X} = 467.68$) study areas. Preference for HEWR range values was highest for terrestrial high ($\bar{X} = 841.78$) followed by alectoria low ($\bar{X} = 701.91$), and alectoria moderate1 ($\bar{X} = 521.74$). Preferences for alectoria high ($\bar{X} = 358.62$) and alectoria low ($\bar{X} = 320.12$) were not different ($P > 0.05$) from each other, but were different from other classes. Preferences for alectoria low ($\bar{X} = 320.12$) and other low ($\bar{X} = 273.27$) were not different ($P > 0.05$) from each other, but were from each of the other classes. Preferences for HEWR range tended to rank higher ($P < 0.05$) during late ($\bar{X} = 528.02$) winter. Males showed a greater preference for habitat ($\bar{X} = 530.49$) than females ($\bar{X} = 469.75$).

Preference for modeled HEWR (terrestrial)

Caribou groups observed during population surveys in the Wolverine and Chase area showed preference for high-valued HEWR (terrestrial) and a lack of preference or avoidance of low-valued sites. Caribou were only observed on low-valued HEWR (terrestrial) in the Scott study area, and as a result they demonstrated preference for this habitat. In all study areas, HEWR (terrestrial) sites with no terrestrial lichen value was typically avoided by caribou (Table 3).

Preference for aspect within forested high elevations

Radio-collared caribou were most frequently observed using southwest through northwest aspects (Figure 4). Preference within forested high elevations interpreted from these relocations was related to aspect across study areas and gender but with a significant interaction among study areas (Table 4). Preferences for southwest aspects tended to be higher ranked ($\bar{X} = 92.457$) than those for northwest aspects ($\bar{X} = 61.939$), both of which were different from the other aspect classes.

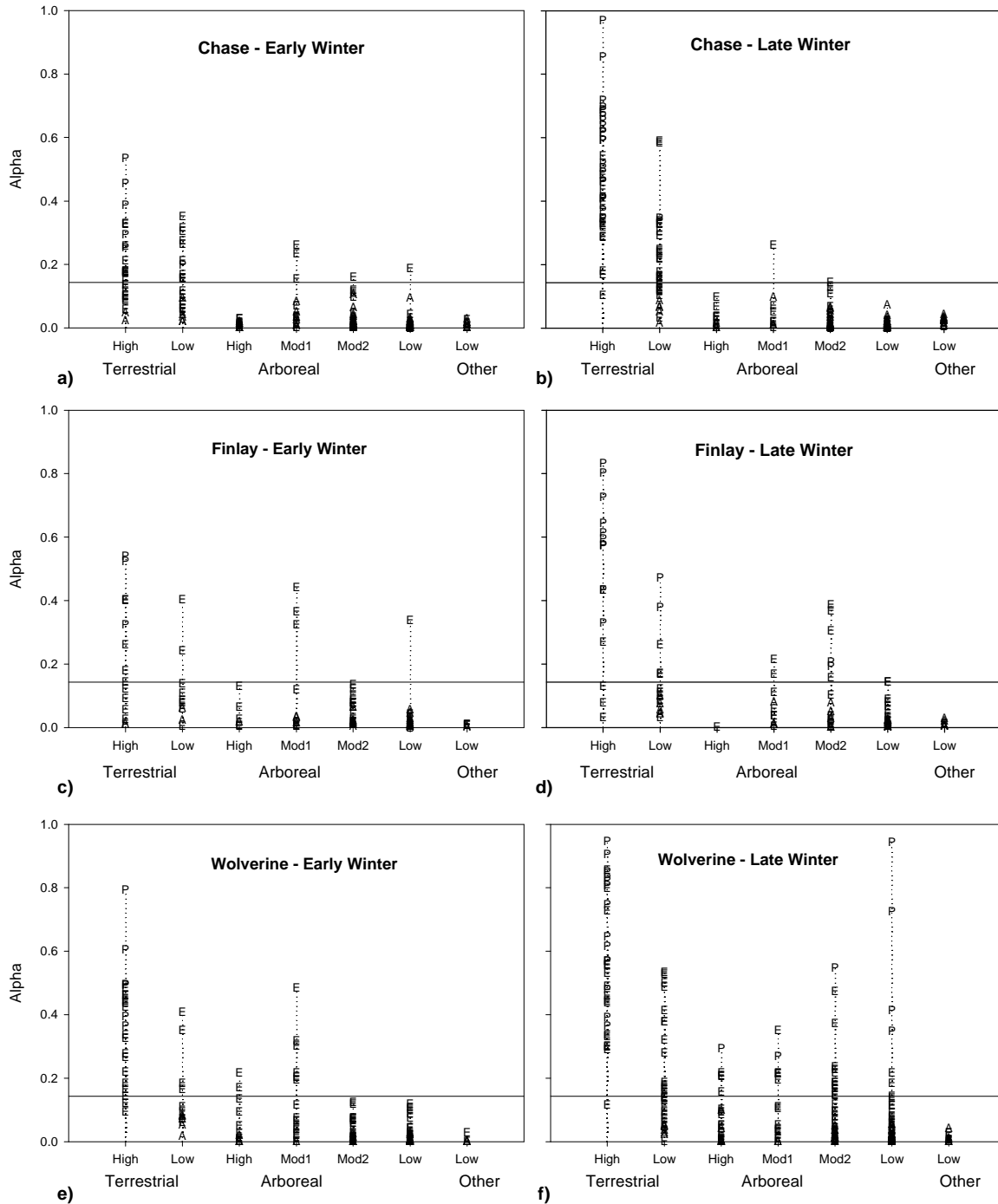


Figure 3. Preference for modeled High Elevation Winter Range (HEWR) interpreted from relocation of radio-collared woodland caribou observed during early- (December and January) and late- (February and March) winter, 1991-2006, in three herd areas of north-central British Columbia. Ranges assessed were those where terrestrial or arboreal forage lichens were predicted to be either absent (Other Low) or in relatively high, moderate (Mod1 and Mod2) or low abundance.

Table 2. Analysis of variance ($P < 0.0001$, $R^2 = 0.532286$, $n = 968$) of ranked preferences for modeled High Elevation Winter Range (HEWR) interpreted from relocation of radio-collared woodland caribou observed during early- (December and January) and late- (February and March) winter, 1991-2006, in three herd areas of north-central British Columbia.

Source	DF	F	Probability
Study Area	2	0.77	0.4622
HEWR Range Value	6	133.70	<0.0001
Study Area X Range Value	12	3.38	<0.0001
Winter Period (early or late)	1	30.89	<0.0001
Gender	1	16.72	<0.0001

Table 3. Preference for modeled High Elevation Winter Range (HEWR) interpreted from the location of woodland caribou groups observed during a population survey conducted March 2007 in three herd areas of north-central British Columbia. Ranges assessed were open areas where terrestrial forage lichens were predicted to be either absent or in relatively high or low abundance.

HEWR Terrestrial Lichen Abundance	Herd Area		
	Chase	Scott	Wolverine
High	Prefered	N/A	Prefered
Low	Avoided	Prefered	Avoided
Absent	Avoided	N/A	N/A

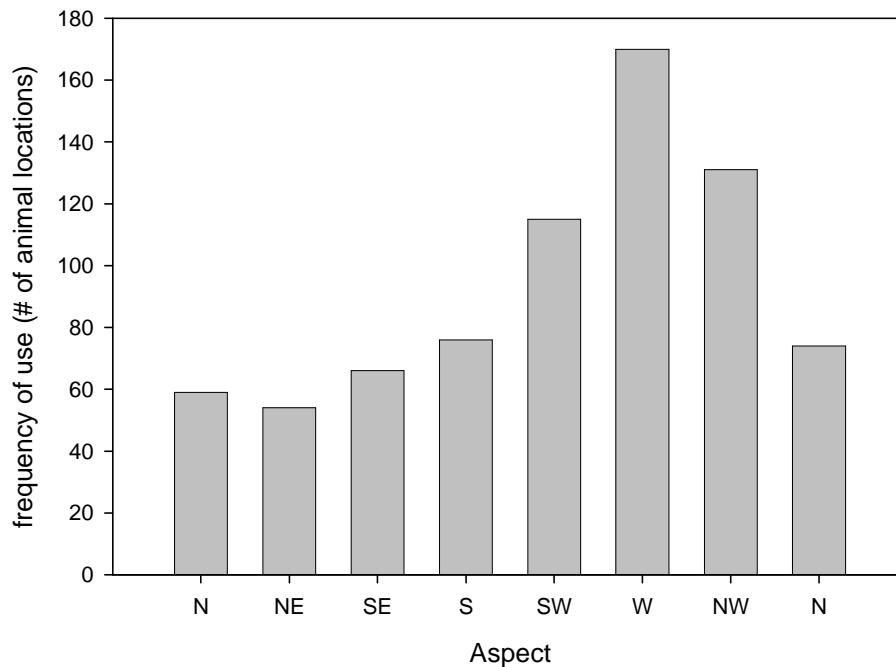


Figure 4. Frequency of caribou relocations observed in 45° aspects classes.

Table 4. Analysis of variance ($P < 0.0001$, $R^2 = 0.494720$, $N = 121$) of ranked preferences for forested, high-elevation aspect classes interpreted from relocations of radio-collared woodland caribou observed during early- (December and January) and late- (February and March) winter, 1991-2006, in three herd areas of north-central British Columbia.

Source	DF	F-Value	Probability
Study Area	2	0.61	0.5462
Aspect	3	28.19	<0.0001
Study Area X Aspect	6	3.10	0.0077
Gender	1	0.04	0.8333

Arboreal Lichen Estimates

Estimates of arboreal lichen abundance ($n = 1,534$ trees) were derived mostly from sub-alpine fir (83%), followed by lodgepole pine (10%), white spruce (6%) and black spruce (2%). All assessed factors (i.e., elevation, aspect, tree species, and branch class) contributed ($P < .05$) to the variance in estimated abundance of arboreal forage lichens ($P < 0.0001$, $R^2 = 0.228154$, $N = 1,533$) with elevational differences being the most important factor (Table 5). There was a greater frequency of trees with a low abundance of arboreal lichens at low-, rather than high-elevations, with the opposite trend occurring at higher elevations (Figure 5).

Table 5. Analysis of variance ($P < 0.0001$, $R^2 = 0.228154$, $N = 1,533$) of ranked, abundance of arboreal forage lichens (grams/linear meter) measured during a survey of modeled High Elevation Winter Range in four caribou herd areas in north-central British Columbia.

Source	DF	F-Value	Probability
Aspect	1	14.01	0.0002
Elevation	1	306.54	<0.0001
Aspect X Elevation	1	4.83	0.0281
Tree species	5	18.98	<0.0001
Branch class	3	17.13	<0.0001

DISCUSSION

High Elevation Winter Range Model

Results from the preference analyses indicated that caribou in this study displayed strongest preference for modeled HEWR during late winter and that this preference tended to be for sites predicted to have abundant terrestrial rather than arboreal forage lichens. This observation is consistent with the general tendency for caribou of a northern ecotype to move away from winter ranges at low elevations in late winter as snow at those locations builds to an unfavorable height for cratering (Johnson et al. 2004). During this time in late

winter, alpine habitat provides caribou with additional benefits through protection from predatory wolves (*Canis lupis*). However, the tradeoff for reduced energy expenditure cratering and less risk of predation comes in the form of lower quality and less abundant

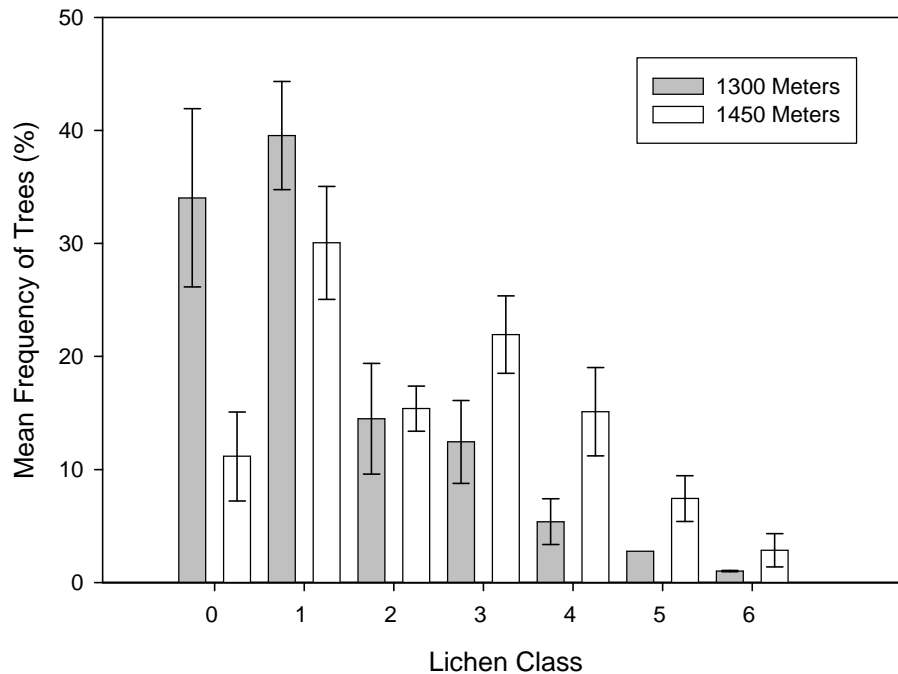


Figure 5. Mean percent frequency of trees, with standard error, in each of the lichen classes at high (> 1450 m) and low (1300 m – 1450 m). Grey bars denote low elevation and white bars denote high elevation sites.

forage (Johnson et al. 2004). The results of the preference analyses (both from telemetry and from the population survey observations) were also consistent with modeled HEWR (terrestrial) values (i.e., high-valued range was preferred and low-valued range was avoided). Although we assumed this consistency would also hold between preferences and HEWR (arboreal) values, this was not the case. Significant avoidance for modeled high-value arboreal sites indicated that there are problems with either the input data or the relationships for that portion of the HEWR model. We expect the problem is more the latter than the former. We built the HEWR model to value stands with ≈80% sub-alpine fir highest for caribou. However, our lichen abundance estimates and other research (Johnson et al. 2004) suggested that forest stands with a greater percent of lodgepole pine are better for lichen growth and therefore likely to be better HEWR.

Arboreal Lichen Habitat Assessment

Generally, the HEWR (arboreal) model predictions were consistent with our observation of lichen abundance. We expected both elevation and aspect to play a role in lichen abundance but did not expect elevation to be as strongly related as it was. We assessed a zone between 1300 m and 1450 m because we considered that forest development

operations are likely to move beyond the current lower limit to HEWR. This is especially likely to happen given the extent and intensity of the Mountain Pine Beetle epidemic which has and continues to occur in lower elevation forests within north-central BC. Our results indicate that southeast, 1300 m sites generally had the lowest abundance (sometimes very little to nil) arboreal forage lichens. By comparison, some highly productive (from a timber perspective) northwest aspects, even at 1450 m, were also very productive for arboreal forage lichens.

It was obvious during data collection, and supported by the analytical results, that branch characteristics, tree species, and tree density play an important role in allowing for the dispersal and subsequent growth of arboreal forage lichens. These results will be helpful in our future attempts to turn the HEWR model into a more precise estimate of values for caribou.

MANAGEMENT IMPLICATIONS

We think the results of our analyses can support refinement of the HEWR model and thereby allow for better predictions about the spatial location and extent of high-valued arboreal foraging sites for caribou. Results from the preference tests could be used with Netica to update conditional probability tables while results from the arboreal sampling could be used to refine or gain precision on the overall spatial predictions. Furthermore, results from the arboreal lichen sampling could be used to direct at least some aspects of general wildlife measures eventually applied to UWRs for a more integrated management of forested HEWR. We recommend at least two high priority sampling steps prior to using model results for establishment of UWRs: confirmation of, and extension of, the lichen abundance estimates through summer-season field sampling and evaluation of sites known to be used by caribou (summer- and winter-season field sampling).

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