FINAL REPORT

Probability of Range Occupancy by Woodland Caribou during Winter in the Muskwa-Kechika Management Area, British Columbia

R.S. MCNAY[1] AND M. SNIVELY[1]
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[1]Wildlife Infometrics Inc., PO Box 308, Mackenzie, BC, V0J 2C0, wild_info@wildlifeinfometrics.com

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ABSTRACT

Occupancy by caribou is not formally known or recorded for some locations within the Muskwa-Kechika Management Area (MKMA) in northern British Columbia even though, anecdotally, caribou are known to occur in those places. To assist execution of population surveys, we applied a habitat model to forecast the relative probability of occupancy by caribou in high-elevation areas during winter in the MKMA. The MKMA is located in north-eastern BC, its' extent ranging approximately from N56^{o}22' to N59^{o}57' and W122^{o}47' to W128^{o}56' encompassing an area of 6.4 million hectares. We determined that more than half of the MKMA was above 1,300m asl (57% or 3.48 M ha) and that 2.48 M ha (71% of the high elevation and 39% of the entire MKMA) was apparently capable of providing winter range for woodland caribou. To assess the model results, we collected 2,388 observations of woodland caribou when they occurred at high-elevations during winter including that from 14 individual radio-collared caribou and 9 different population surveys. Although a disproportionate majority of the observations were for caribou using the best of the high elevation range, use of poor habitat was still 24% of the sample.

We concluded that the model was not able to distinguish high-valued winter range sufficient to greatly raise the efficiency of population surveys in the MKMA. This result was contrary to previous applications of the model in north-central BC where we were successful in formally designating Ungulate Winter Range for woodland caribou. If use of the model in the MKMA is to be investigated further, we suggest focusing on setting new parameters for the snowfall factor in the model which may help refine the prediction of high-elevation winter range to the point where is will be operationally of benefit. Also, more care should be taken to insure test observations from caribou are from behavior types that are relevant to the habitat being predicted.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

This report was developed to document the production of fine resolution (1 ha) maps predicting the probability of occupancy by woodland caribou (*Rangifer tarandus caribou* Linnaeus) in the Muskwa-Kechika Management Area (MKMA). The MKMA is 6.4 million hectares of globally significant wilderness in northern British Columbia (BC) and is occupied, or partially occupied, by eight herds of woodland caribou (i.e., the Rabbit, Muskwa, Pink Mountain, Gataga, Frog, Horseranch, Finlay, and Graham herds). These are herds of woodland caribou that are considered by the Council on the Status of Endangered Wildlife in Canada (Thomas and Gray 2002) to be a species-at-risk and, for the most part, are listed as "special management concern"; the Graham herd has been listed as "threatened". The occupancy by caribou is not formally known or recorded for some locations within the MKMA even though, anecdotally, they are known to occur throughout the area. Most notably, this apparent void of formal information occurs north, west, and south of the Frog herd (Figure 1A). Population surveys can help fill this void of information about caribou but because the MKMA is remote, these surveys are expensive and inefficient without prior information to assist execution of the work. Our specific objectives were to predict the probability of occupancy by caribou in high-elevation range during late winter (High-elevation winter range – Hewr). This is the time period and location where population surveys for caribou are typically conducted. Use of range by caribou in the MKMA was intensively studied for two herds: (1) the Muskwa herd (Tripp[1]) and (2) the Pink Mountain herd (Gustine and Parker 2008). Models of range use by these caribou were produced as a part of these investigations. Core conservation areas for caribou were also modeled for the entire MKMA by Heinemeyer et al. (2004). However, these models, and the map results, were all inductively derived and therefore accuracy is restricted to the spatial and temporal conditions under which data were collected. The Bayesian modelling framework we used was deductive in nature, can therefore be applied more broadly than empirical models; they also offer greater transparency about the ecological principles used to forecast occupancy probability (for more on Bayesian modeling approaches in natural resource management see McCann et al. (2006)). In addition, an inherent flexibility in our approach allows for investigations that address a range of interests beyond this specific application and we considered this may have future benefits (e.g., modeling management scenarios such as hypothetical future conditions or scenarios based on naturally disturbed ecosystems, global climate change, etc.).

STUDY AREA

The study area of the MKMA is located in north-eastern BC, its' extent ranging approximately from N56°22' to N59°57' and W122°47' to W128°56'. The MKMA is comprised of four biogeoclimatic zones, Boreal Black and White Spruce (BWBS), Spruce Willow Birch (SWB), Boreal Altai Fescue Alpine (BAFA) and Engelmann Spruce – Subalpine Fir (ESSF) (Figure 1B)

[1] See http://a100.gov.bc.ca/pub/siwe/details.do;jsessionid=f2a3b0f234126dfc98b37b6310f562b1a3da5e6559678a8de86377f99c1cbd8e.e3uMah8KbhmLe3iOahySbN8Te6fznA5Pp7ftolbGmkTy?id=4466 (accessed March 16, 2010)

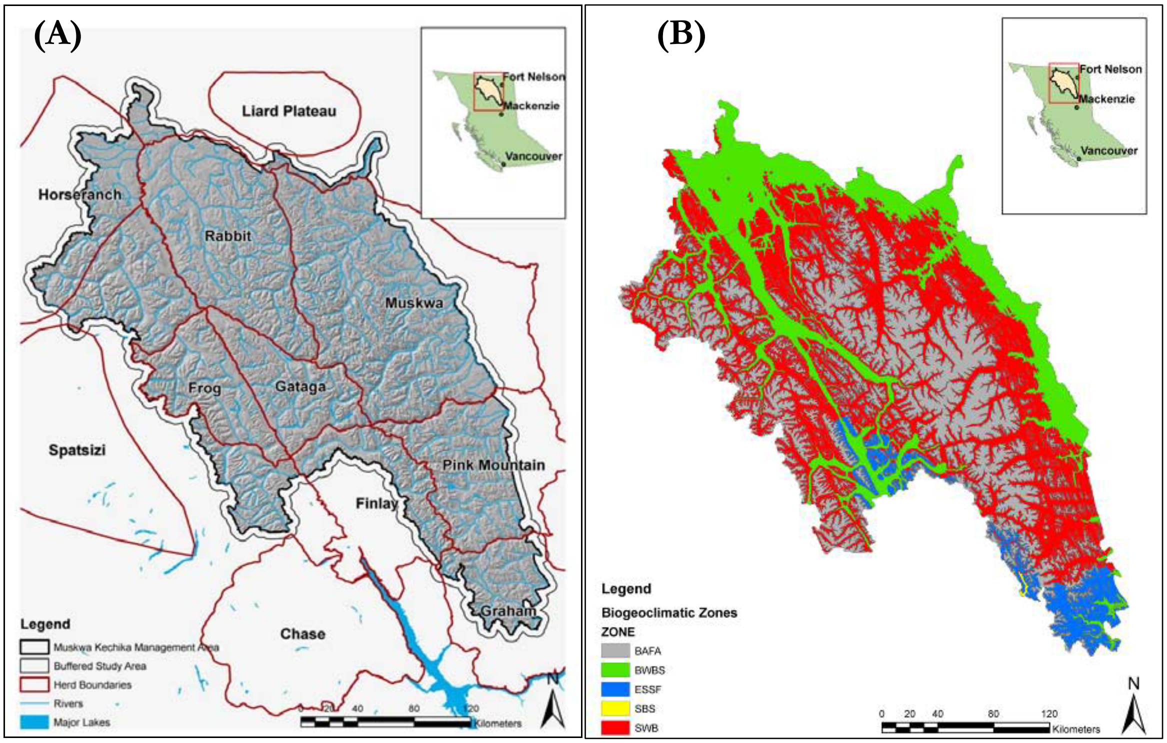

Figure 1. Woodland caribou herds (A) that occupy, or are adjacent to, the Muskwa-Kechika Management Area in northern British Columbia and the Biogeoclimatic zones (B) represented in the area.

The BWBS zone forms nearly a quarter of the MKMA, dominating the plateau areas to the north east of the study area and valley bottoms of rugged mountainous terrain. The two main ecosystems found in the BWBS are upland forests and muskeg. Stands of trembling aspen (*Populus tremuloides*), balsam poplar (*P. balsamifera*), white spruce (*Picea glauca*), lodgepole pine (*Pinus contorta*), and black spruce (*P. mariana*) can be found in the upland forests, occupying suitable sites dependent on drainage and topography. The muskeg ecosystem supports both black spruce and tamarack (*Larix laricina*) tree species and is primarily a result of a climate which is both long and cold in the winter and warm and short in the summer with the presence of permafrost. Precipitation is relatively low receiving the least amount of snowfall of the four zones found in the MKMA. Long cold winters and short cool summers are characteristic of the SWB zone which generally has a harsh climate. This zone is dominant covering nearly half of the MKMA and occurs between the BWBS and Alpine Tundra zones. Tree species are more limited than the BWBS zone; white spruce, trembling aspen and lodgepole pine can be found at the lower elevations of the SWB shifting to more dominant stands of subalpine fir (*Abies lasiocarpa*) to deciduous shrubs at higher elevations. Many of these forests are relatively old due to infrequent fires; although, large burns have been introduced to create open grassland areas with occurrences of trembling aspen.

The BAFA zone occurs on a quarter of the MKMA landscape. It occurs in the mountainous high elevations in steep rugged terrain. The growing season is relatively short with temperatures rising above 0^{o}C for 1 to 4 months of the year. Ecosystems are a patchy mosaic near the treeline, a combination of krummholz, alpine tundra and alpine meadows. Distribution of plant and tree species is highly dependent on erosion deposition, drainage, precipitation and aspect. The ESSF zone is limited to the southeastern portion of the MKMA and upper portion of the Fox River drainage. It occurs in mountainous terrain typically at mid slope elevations and high elevation valleys. The climate conditions create long cold winters with deep snowpacks to short cool summers. Engelmann spruce (*P. engelmannii*) and subalpine fir are the main tree species in the ESSF. Pure stands of subalpine fir occur at higher elevations forming patchy tree islands in the subalpine parklands. There is only a trace occurrence of the Sub-Boreal Spruce zone in the lower southeastern portion of the MKMA and hence will not be discussed.

METHODS

Model Application and Mapping

We used ArcMap 9.1 (Environmental Systems Research Institute, Redlands, California) and Microsoft Access 2003 (Microsoft Corp., Redmond, Washington) to construct and manage case files of environmental conditions in the study area. Case files are simply a collection of the environmental variables (columns) for each 1-ha cell (rows) in the study area. The correlates of environmental conditions that we used came primarily from the BC Forest Inventory Planning (FIP) attribute database[2], the BC Vegetation Resources Inventory (VRI)[3], and the BC Terrain Resource Information Management program[4]. A Digital Elevation Model (DEM) was obtained from the Integrated Land Management Bureau. It was necessary to use both FIP and VRI data sources to characterize the condition of vegetation in the area since the VRI data proved to have incomplete non-productive forest codes. The FIP data was obtained, processed and combined with the VRI data replacing the portions of inadequate VRI (Figure 2). Albeit, the FIP mapsheet of 94B.044 was not used due to incomplete polygons therefore the VRI data was used regardless of missing non-productive codes. The study area was split into 4 subsets to facilitate the data preparation and processing, the subset area boundaries were determined by landscape unit polygons (Figure 2). Our decision to map results at 1-ha resolution was based on our interests in focusing the management problem and did not imply accuracy of the input data. We used the Bayesian Belief modeling software package Netica, and a previously constructed model of High Elevation Winter Range (Figure 3), to process the case files and determine predicted probability of occupancy.

Final results were modified to restrict and generalize the extent of the modeled HEWR by using: (1) a map query of the output node expected values[5] >-0.333 and (2) a 1-cell circular maximum[6] filter followed by a 2-cell circular majority[7] filter. These generalized

[2] See Ministry of Sustainable Resource Management web site at http://srmwww.gov.bc.ca/gis/Databases/

[3] See Integrated Land Management Bureau GeoBC web site at http://apps.gov.bc.ca/pub/geometadata/home.do

[4] See Ministry of Sustainable Resource Management web site at http://srmwww.gov.bc.ca/bmgs/trim/

[5] Expected values are calculated as the probability of each node state multiplied by the state value and summed across all states. In the case of the seasonal forage usefulness node, state values ranged from 1 to -1 in equidistant intervals hence -0.333 was used to distinguish UWR from non-UWR.

[6] Used to compute the maximum value in the neighborhood and assign that value to the processing cell.

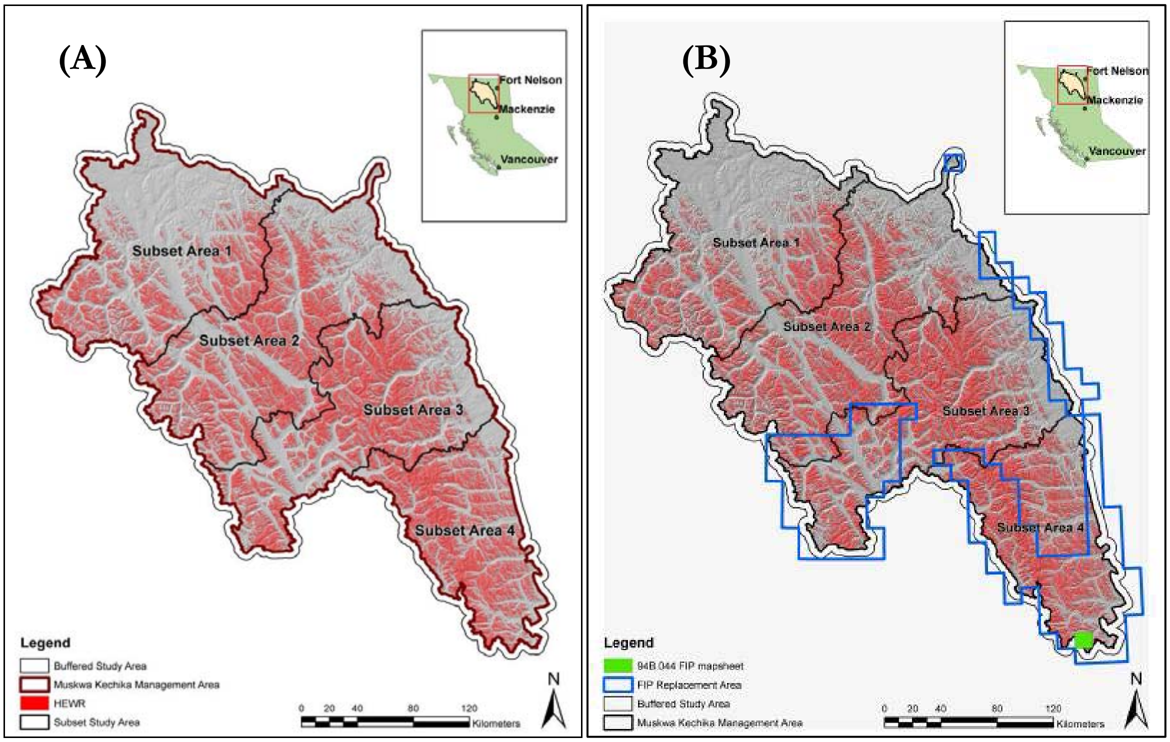

Figure 2. Subset areas (A) and areas of FIP data gathering (B) applicable to the Muskwa-Kechika Management Area where a model of High Elevation Winter Range (HEWR) for woodland caribou was applied.

results were converted to vector (shapefile) format and the resultant cleaned by removing all polygons <10ha. The remaining polygons had their boundaries smoothed and annulus holes filled using the hole_filler.avx extension for ArcView 3.2 to create a less rasterized final HEWR map[8]. Additional cleaning was completed on the resultant after it was clipped to the MKMA boundary to remove all polygons <10 ha.

Assessment of Results

Success of the model application was assessed using two criteria: 1) the amount of high-elevation (i.e., area > 1,300 m asl) that could be eliminated as having potential for use by caribou (calculated as 1 – proportion of high elevation area in Hewr) and 2) the degree of statistically significant preference shown for Hewr by caribou using high-elevations in winter (December through April). The latter calculation was made following methods of Chesson (1983) and using relocations of radio collared caribou and observations of caribou made during population surveys; both types of data were obtained from the Species Inventory database available from the BC Min. of Environment[9]. We understood that the use of population survey data could impart bias on the analysis but the surveys were mostly (or wholly) supported by relocation of radio-

[7] Used to compute the value that occurs most often in the neighborhood and assign that value to the processing cell.
[8] See ESRI Support web site at http://arcscripts.esri.com/details.asp?dbid=13821
[9] See http://www.env.gov.bc.ca/wildlife/wsi/index.html (accessed March 10, 2010).

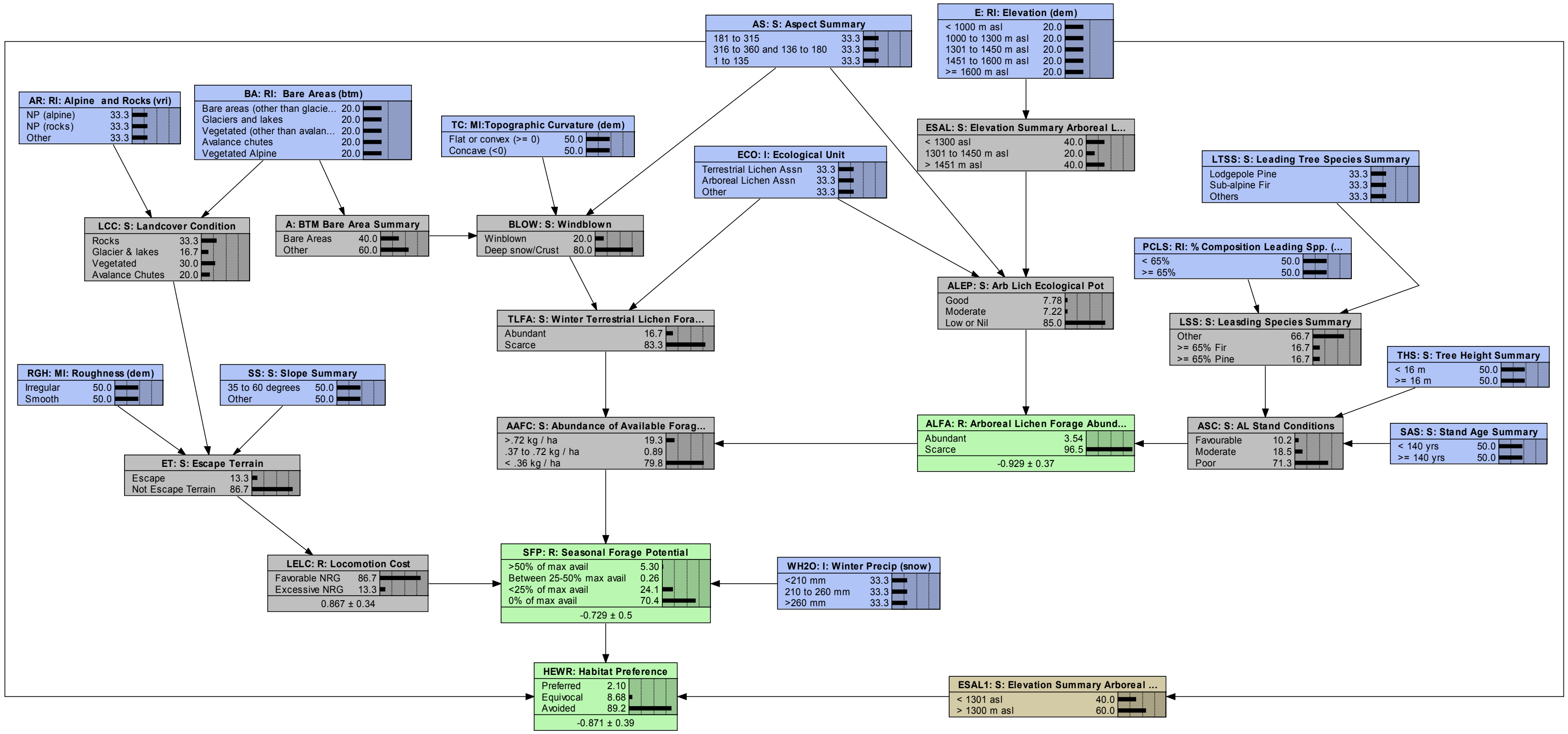

Figure 3. A Bayesian belief network used to predict the likely potential value of high-elevation winter ranges used by woodland caribou (McNay et al. 2009). Model input nodes are represented in blue, output nodes in green, and summary nodes in grey.

collared animals thereby relieving some of this potential bias. Observations from individual radio-collared caribou or from individual population surveys were included in the analysis only if there were more than 15 observations. Rather than test preference between two classes of habitat (i.e., Hewr compared to non-Hewr), we classified the expected values (ranging from -1 to 1) into four classes of habitat value (best, good, moderate, or poor) where best was established as any result greater than the median expected value (-0.4) and the other classes were equidistant intervals less than the median and the lowest expected value (i.e., < -0.8, -0.8 to -0.6, and -0.6 to -0.4).

RESULTS

We determined that more than half of the MKMA was above 1,300m asl (57% or 3.48 M ha) and that 2.48 M ha (71% of the high elevation and 39% of the entire MKMA) was apparently capable of providing winter range for woodland caribou (Figure 4). The Hewr model resulted in 1.66, 0.33, 0.26, and 1.25 M ha of best, good, moderate, and poor range, respectively. We collected 2,388 observations of woodland caribou (a total sample of 4,808 caribou sightings) that occurred at high-elevations during winter. Fourteen individual radio-collared caribou and 9 different population surveys had sufficient samples (i.e., n > 15) to test habitat preferences among the 4 Hewr classes from best to poor (n = 4,414 caribou sightings). Although a disproportionate majority of these observations were for caribou using the best range, use of poor habitat was still 24% of the sample (Figure 5).

Caribou exhibited statistically significant choices for range in 52 of the potential 92 range tests (i.e., 14 caribou + 9 population surveys multiplied by 4 range classes). The remaining assessments of range preference were either void of information or equivocal (i.e., not significantly different from random choice). Significant range choices were distributed in a manner as to suggest a preference for best habitats (12 preferred while 9 avoided) and avoidance of poor habitats (6 preferred while 11 avoided) (Figure 6). However, preference for good and moderate habitats appeared to be opposite to what would be expected.

DISCUSSION

Our intent in this analysis was focused on the use of high-elevation winter range by woodland caribou (primarily for reasons of making winter population surveys more efficient). However, use of the Hewr model classed only 29% of the high-elevation area as being incapable of providing range for caribou. This result is not expected to greatly improve the efficiency of population surveys. By comparison, the same model performed much better when applied to range used by 4 herds of caribou in north-central BC. In that application, close to 40% of the high-elevation was considered to be poor value for caribou and therefore could be removed from the inventory (McNay et al. 2009).

Although the preference analysis revealed some alignment with modeled Hewr, the trend was not as strong as we anticipated from previous applications of the model in north-central BC (McNay et al. 2009). The reasons for the lack of trend could be due to differences in range use by caribou in the MKMA which would be manifested in either

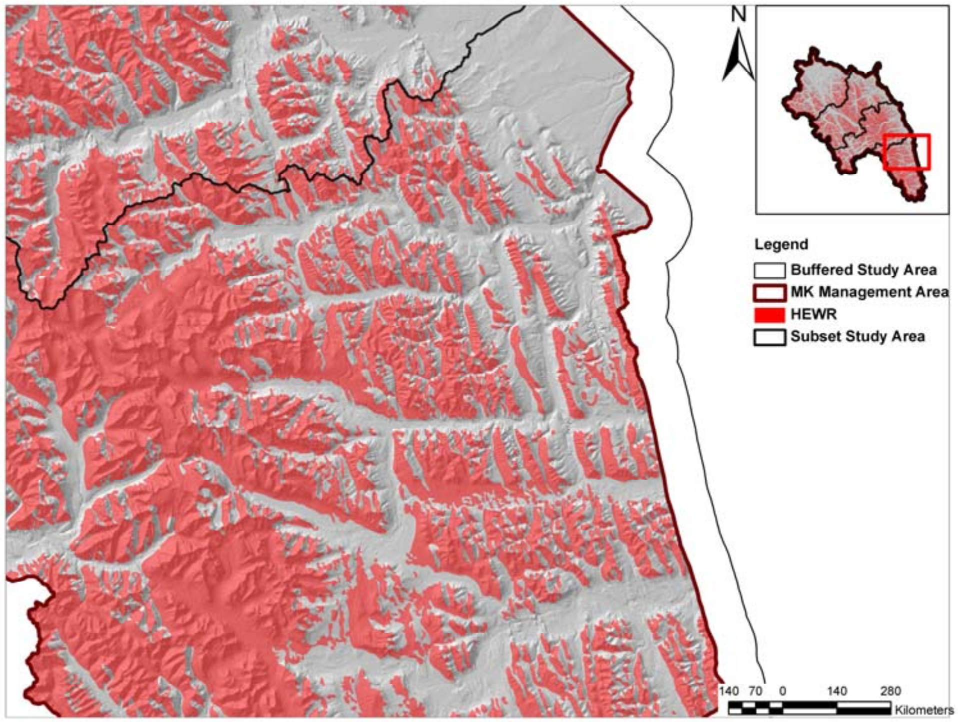

Figure 4. Spatial result of a Bayesian Belief Model depicting High Elevation Winter Range (Hewr) for woodland caribou in the Muskwa-Kechika Management Area in northern British Columbia.

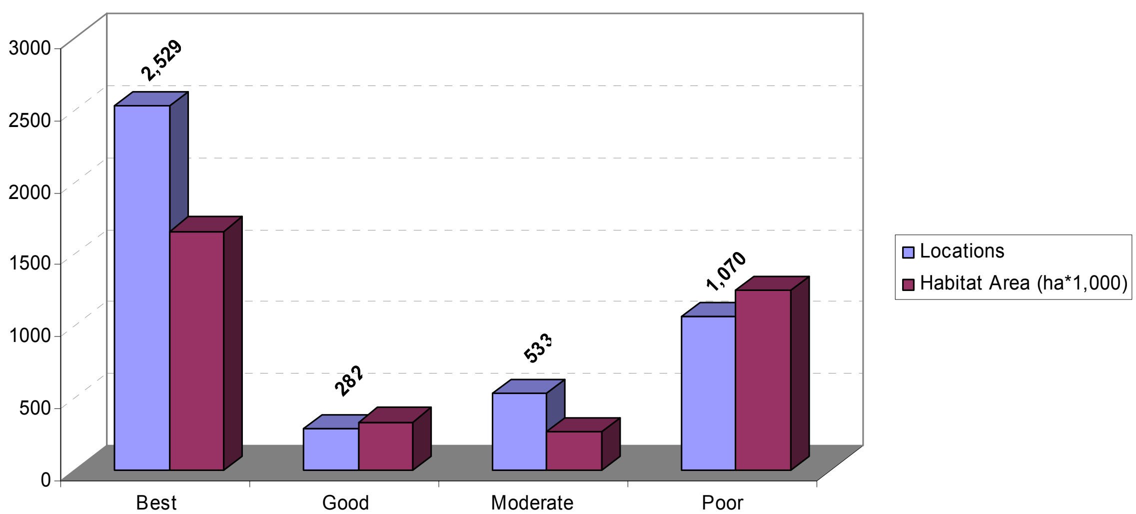

Figure 5. Number of relocations of woodland caribou observed to have occurred in classes (Best, Good, Moderate, and Poor) of modeled high-elevation winter range in the Muskwa-Kechika Management Area in northern British Columbia.

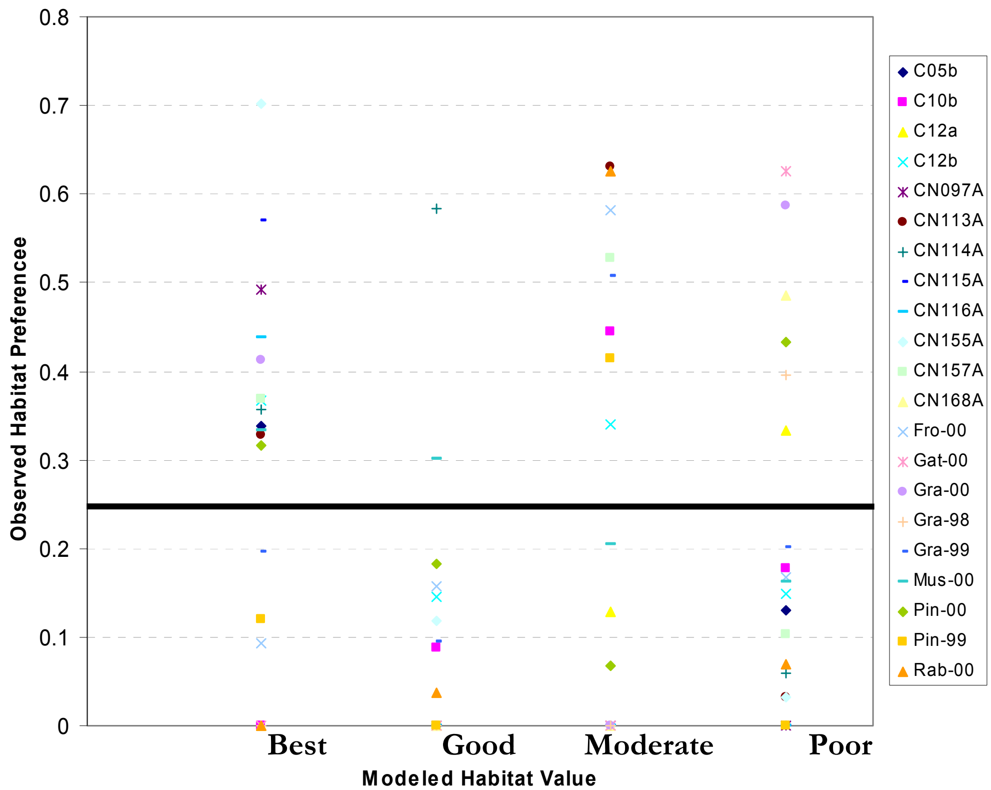

Figure 6. Observed preference by woodland caribou for modeled classes of high-elevation winter range (Best, Good, Moderate, Poor) in the Muskwa-Kechika Management area of northern British Columbia. Points above the bar represent preference and points below the bar represent avoidance – all points are significantly different ($P < 0.05$) from random.

the nature of the test data used, the inadequacy of the model, or both. We know that use of range by caribou varies but the variance is somewhat predictable depending on the type of habitat available during winter. In BC for example, this predictability has led to the classification of caribou ecotypes (Heard and Vagt 1998): boreal caribou which feed predominately on terrestrial forage lichens found in low-land muskeg areas in northeastern BC (Goddard 2009), mountain caribou which feed predominately on arboreal forage lichens found on old conifers in the wet-belt, heavy snowfall region of south-eastern BC (Stevenson and Hatler 1985), and northern caribou which feed predominately on terrestrial forage lichens found either in low-elevation pine forests or high-elevation, rounded convex alpine ridges (Cichowski 2008). While this classification is generally accurate, a mixture of the behaviors is possible depending on habitat availability at a finer resolution (e.g., within an individual herd area; Gustine and Parker 2008) and such behavior could account for the incomplete fit of the Hewr model to the MKMA. Gustine and Parker (2008) recognized this behavioral difference among caribou and chose to fit different models to each behavior type. Our pursuit was focused only on one behavior type but was tested with caribou that may have had varying behaviors. A careful classification of animals or even a classification based on herd area may have led to different and more supportive results. Also, we assumed that the deductive nature of the model would allow for relative robustness and a wide range of application. However, we failed to recognize the difference in climate between the east and west side of the Rocky Mountains. The Hewr model is parameterized using snowfall as a factor to reduce range occupancy in areas where alpine is likely to accumulate large amounts of snow. If the parameters for the snowfall factor were not set properly for the east side of the Rockies it would likely lead to false positive error and the prediction of more range than is really available.

Future work with the Hewr model should focus on setting new parameters for the snowfall factor when being applied to areas of differing climate. More effort is required to investigate the ecological basis for range use in the MKMA (e.g., based on results of Gustine and Parker (2008)) to determine if there is rationale for modifying the underlying structure of the Hewr model. Finally, the caribou relocation data used to test the results in the MKMA should be scrutinized for the possibility of screening out behaviors that are not relevant to the model application.

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