Habitat use by caribou in northern Alberta, Canada

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Abstract: Habitat mapping and habitat supply assessment have been identified as key elements of the Alberta Woodland Caribou Conservation Strategy. Previous studies from northeastern Alberta have shown that caribou select lowland habitat types and avoid upland. The objectives of our study were to determine whether these selection patterns are consistent across all of northern Alberta and to generate a map of habitat suitability for the entire region. Our database included over 11 000 radiotelemetry locations collected over six years from caribou across northern Alberta. We also had available a recently revised map of peatlands for the entire province. We found that polygons in the peatland map containing greater than 30% bog were selected by caribou. Fens were also selected, but not as strongly as bogs. Habitat polygons containing greater than 50% non-peat were avoided. These findings were consistent among all regions studied, and among years. The proportion of caribou relocations declined exponentially with distance from polygons classified as peatlands. Based on the observed selection patterns, we reclassified the peatland map to reflect the potential suitability of habitat for caribou across northern Alberta.

Key words: conservation, habitat suitability, radiotelemetry, *Rangifer tarandus caribou.*

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Introduction

Woodland caribou (*Rangifer tarandus caribou*) in Alberta are listed an endangered species under the Alberta Wildlife Act (AEP, 1994a). This designation was established in the mid-1980s in response to a general deterioration of caribou range and a perceived decline in population size (AWCCSDC, 1996). Since that time the boreal forest in Alberta has been impacted by a substantial increase in industrial activity, primarily related to forestry operations and petroleum exploration and extraction (AEP, 1998). In an effort to cooperatively address the needs of caribou in areas influenced by industry, multi-stakeholder committees were formed to direct research and conservation initiatives, including the development of the Alberta Woodland Caribou Conservation Strategy (AWCCSDC, 1996; Edey *et al.,* 1998).

Habitat mapping and habitat supply assessment were identified as key elements of the Conservation Strategy (AWCCSDC, 1996). Accurate descriptions of what constitutes suitable habitat for caribou and where these habitats are located are necessary for monitoring changes in habitat supply and for estab-

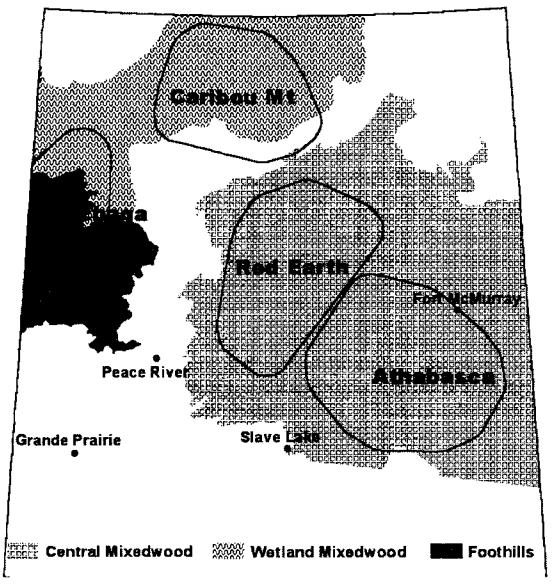

Fig. 1. Location of the four study areas in northern Alberta (open polygons). The boundaries of the three zones used in the Natural Subregion analysis are also shown (shaded polygons; labels indicate the dominate National Subregion in each zone).

lishing zones where special rules for industrial management can be applied (Cumming, 1992). Previous studies of habitat use by caribou in Alberta have determined that caribou select lowland habitats, particularly those dominated by treed fens and bogs (Bradshaw *et al*, 1995; Stuart-Smith *et al*, 1997). The main goals of our study were to determine whether these selection patterns are consistent across all of northern Alberta and to generate a map of habitat suitability across the entire region.

Our ability to investigate habitat selection at the provincial-scale was made possible by two new sources of data. First, through ongoing field efforts of the Boreal Caribou Research Program (Edey *et al*, 1998) we had available a six-year database containing over 11 000 telemetry locations recorded with aircraft Global Positioning System (GPS) receivers. Second, a revised version of the Peatland Inventory of Alberta was released in 1998 in which the composition of the landscape in terms of habitat categories important to caribou could be determined across the province (Vitt *et al.*, 1998). This map was essential for extrapolating patterns of habitat selection derived from radiotelemetry data to a description of habitat suitability at the regional level.

Study area

Radiotelemetry data were collected from four study areas distributed across northern Alberta, Canada (Fig. 1). Certain features, including key vegetation types, were common to all study areas. The upland vegetation was typified by pure and mixed stands of trembling aspen (*Populus tremuloides*) and white spruce (*Picea glauca*), along with jack pine (*Pinus banksiana*) on drier sites and black spruce (*Picea mariana*) on wetter sites. Lowland habitat, in the form of extensive peatland complexes, was a prominent feature of all areas. These lowland areas were typified by black spruce or black spruce-tamarack (*Larix laricina*) bogs and fens.

The Red Earth (30 276 km^2) and Athabasca (38 413 km^2) study areas had little topographic relief and both were located within the Central Mixedwood Natural Subregion (AEP, 1994b). The Caribou Mountain (25 584 km^2) study area was centered on a large hill mass that straddles the Boreal Subarctic and Wetland Mixedwood Subregions. The Chinchaga study area (21 438 km^2) was located in the Lower Foothills Subregion.

Methods

Data collection

One hundred and seventy-two adult caribou fitted with very high frequency (VHF) radiocollars were tracked from 1993 to 1998 (Table 1). The collared animals did not represent a systematic or random sampling of caribou within the study areas; however, an attempt was made to include individuals from a variety of locations within each area. The period and duration of data collection varied among individual caribou (range = 1-6 years). The total number of relocations was 11 075 and the total number of caribou-years, with greater than 10 relocations/year, was 455.

Table 1. Number of caribou tracked with VHF radiocollars, by study area.

Study Area	Female	Male	Total Caribou	Caribou-years
Caribou Mountain	30	6	36	86
Red Earth	23	13	36	106
Athabasca	84	10	94	249
Chinchaga	5	1	6	14
Total	142	30	172	455

Fixed-wing aircraft equipped with radio antennae and GPS receivers were used to relocate the caribou and establish their geographic coordinates. Tests of relocation accuracy showed an upper 95% confidence limit of 157 m (Boreal Caribou Research Program, unpub. data). Relocation flights were generally conducted every one to two weeks in the winter and spring, and less often during the summer and fall. Annual home ranges were calculated using the minimum convex polygon method (Mohr, 1947). Only animals with greater than 10 relocations in a given year were included in the home range calculations and subsequent analyses.

A digital version of the Peatland Inventory of Alberta (Vitt *et al*, 1998) was used to define the habitat composition of the study areas (Fig. 2). The peatland map uses a hietarchical classification system to define peat types and for our analyses only the highest level of classification was used: Bog, Fen, Marsh, Swamp, and Non-wetland. Fens are distinguished from bogs on the basis of vegetative patterns that result from the presence of surface water. Marshes are distinguished by their lack of tree or shrub cover, and swamps are recognized by their association with water bodies that flood frequently. Subclasses based on peat modifiers were not used because they were generally not represented among all of our study areas, precluding a regional analysis. Because Swamp and Marsh were too uncommon to be analyzed as distinct classes (combined proportion = 0.017) they were combined with Non-wetland to form a new category termed Non-peat (total proportion = 0.656). While the peatland map provides coverage across all of northern Alberta it does so at the expense of resolution. The scale of the map is 1:250 000 and instead of uniquely defining habitat types each polygon in the map describes the percentage of each peat class present in increments of 10%.

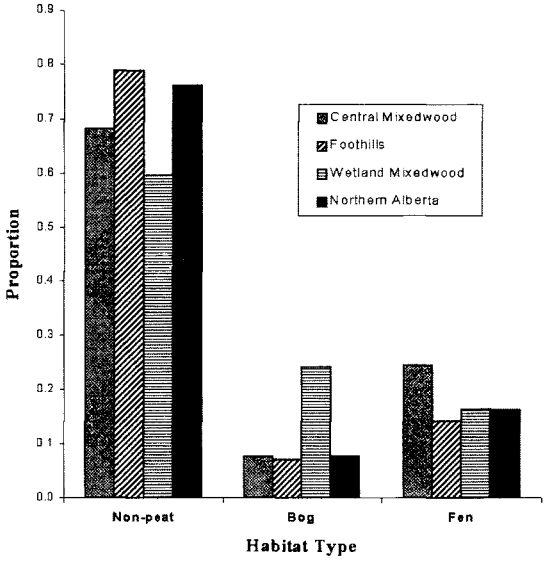

Fig. 2. Comparison of proportional habitat availability for the three Natural Subregions analyzed, along with the values for all of Alberta north of 54 degrees latitude.

Statistical analysis

The radiotelemetry data, annual home ranges, and peatland map were all housed and spatially analyzed using the ArcView 3.0 (Environmental Systems Research Institute Inc., 1998) Geographic Information System (GIS). The analysis of habitat selection was conducted at two spatial scales, which we termed local and regional, and followed the approach described by Manly *et al.* (1993). For the local analysis we defined used habitat as a 200 m radius buffer around individual telemetry points (to account for relocation error) and available habitat as the annual home ranges. The habitat values for all telemetry points within a given home range were averaged to provide a single mean for comparison to the available habitat in the home range. This represents the appropriate sample size for this analysis (Aebischer *et al.*, 1993).

For the regional analysis we defined used habitat as the annual home ranges and available habitat on the basis of Natural Subregion boundaries (AEP, 1994b; Fig. 1). To determine the influence of our definitions of used and available habitat on observed patterns of selection we conducted additional analyses using different approaches. In one case we compared annual home ranges to our four study areas (each representing the boundary of the outermost telemetry points for each herd, buffered by the diameter of one caribou home range). In a second case we compared raw telemetry locations to Natural Subregions.

For both the local and regional analyses the initial step was to summarize, by caribou-year, the proportions of each habitat type present in both the used and available categories. This was done using the Spatial Analyst extension of ArcView (Environmental Systems Research Institute Inc.,1998) and the Access 97 database program (Microsoft Corporation, 1997). The proportion used was then divided by the proportion available for each caribou-year to derive selection indices for each habitat type. A Multivariate Analysis of Variance (MANOVA) was

conducted to test for statistical differences in selection indices among habitat types, Natural Subregions, and years (Arthur *et al.*, 1996) using the SAS statistical program (SAS Institute, 1997). Because most caribou had been tracked for multiple years it was necessary to use a mixed model in which Caribou_ID was included as a random effect. The residuals of the analysis were sufficiently normally distributed that transformation of the dependent variables was not required. Given a statistically significant overall model additional contrasts based on error terms from the MANOVA model were constructed to test for pairwise differences between individual variables (Arthur *et al.*, 1996).

There were insufficient degrees of freedom to include sex as a variable in the full MANOVA. Consequently, the effect of sex was investigated in separate univariate ANOVAs for each habitat type.

Given our aim of generating a map of potential habitat suitability across all of northern Alberta, it was also necessary to characterize how selection varied in response to the proportional representation of each habitat type within polygons of the peatland map. We reasoned that if a given habitat type was preferred then polygons containing a large proportion of this habitat type should be used in greater proportion than their availability. Conversely, polygons containing little of the preferred habitat type should be used in proportion to their availability, or even avoided. To investigate these hypotheses we reclassified the habitat polygons in terms of the percentage of Non-peat present in each. We then resummarized the data and conducted a MANOVA analysis as before, but instead of using three different habitat types as the dependent variables we used the proportion of Non-peat present (grouped into three categories). A similar analysis was then conducted for Bog; however, it was not possible to do so for Fen because polygons containing greater than 50% Fen were too uncommon. To test for a linear trend in response to an incteasing proportion of a given habitat type we performed a linear regression using proportion category and Natural Subregion as the independent variables.

Our final analysis was to investigate the spatial distribution of the telemetry points occutting in pure upland. To do this we determined the distance of each of these points from the nearest peat-containing polygon and then plotted the proportion of points as a function of distance. We then fitted the data to lineat and exponential regression curves and tested for statistical significance.

Table 2. Habitat selection indices (used/available) for caribou in northern Alberta from 1993 to 1998.

Natural Subregion	Non-peat[1]	Bog[2]	Fen[3]
Central Mixedwood	0.55	4.63	1.13
Foothills	0.73	2.05	1.96
Wetland Mixedwood	0.71	1.60	1.17

[1] The values for Central Mixedwood and Wetland Mixed- wood are significantly different (P=0.001).

[2] Central Mixedwood is significantly different from the other two regions (P<0.02).

[3] Foorhills is significantly differenr from the other two regions (P<0.001).

Results

The mean size of the annual home ranges was 571 km^2 (standard error of the mean is 29.3). There was no evidence of habitat selection when use was compared to availability at the local level (i.e., telemetry points vs. home ranges). At the regional level (annual home ranges vs. Natural Subregion) the use of all three habitat types was significantly different from availability (P<0.001). Peatlands were selected, with Bog ranking higher than Fen, and Non-peat was avoided (Table 2). Statistically significant differences among Subregions were apparent in the selection indices; however, the ranking of habitat types remained constant (Table 2). Changing the criteria for defining used and available habitat did

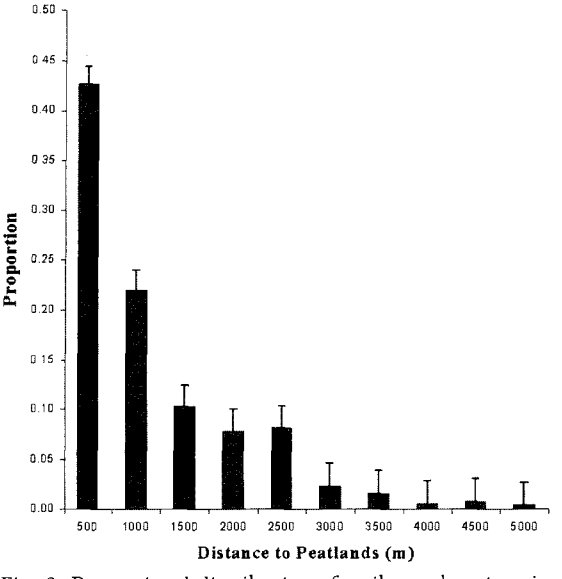

Fig. 3. Proportional distribution of caribou relocations in upland habitat as a function of distance from peat-containing polygons.

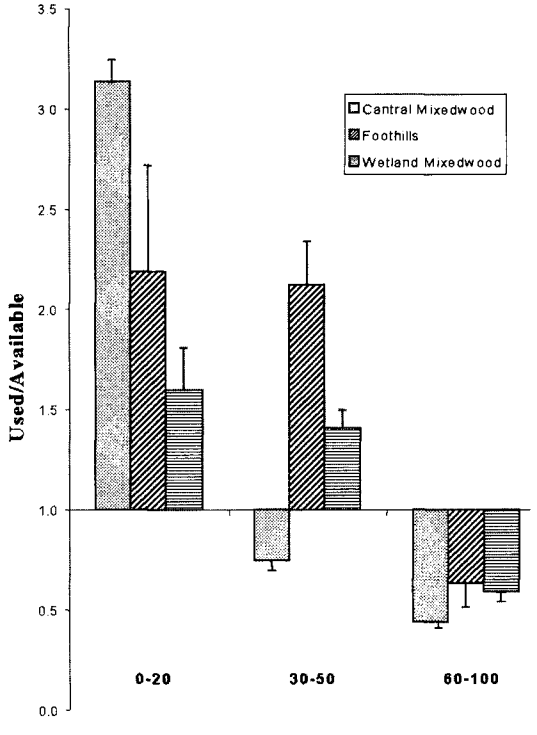

Fig. 4. Selection indices (used/available) for habitat categories representing the percentage of Non-peat present within polygons of the peatland map. Values greater than 1.0 imply selection and values less than 1.0 imply avoidance.

not change the ranking of habitat types, though selection was strongest when telemetry points were compared to Natural Subregions, and weakest when home ranges were compared to study areas.

No significant differences in the selection indices were observed among years. The selection indices did differ significantly between sexes ($P<0.007$); however, the ranking of habitat types remained constant (Table 3).

Even though Non-peat habitat was avoided by caribou it comprised 35% of home ranges on average. The majority of this use of upland habitat was in patches of upland existing within large peat complexes. The proportion of telemetry points in pure upland habitat decreased exponentially with distance from polygons containing peat ($P<0.001$; Fig. 3).

Although Non-peat habitat was avoided as a general category, individual habitat polygons containing Non-peat were not avoided unless the proportion was greater than 50% (Fig. 4). Similarly, while Bog as a general category was selected, individual polygons were only selected if the proportion of Bog was greater than 30% (Fig. 5). Rather than demonstrating an abrupt threshold, the relationship between proportion present and selection index was linear for both habitat types ($P<0.05$; Figs. 4 and 5). Thresholds for Fen could not be investigated because habitat polygons containing greater than 50% Fen were too rare.

Based on the habitat relationships demonstrated in Figures 4 and 5 the Peatland Inventory of Alberta was reclassified to reflect the potential suitability of habitat across northern Alberta for caribou

Table 3. Habitat selection indices (used/available) by sex for caribou in northern Alberta from 1993 to 1998.

Sex	Non-peat[1]	Bog[1]	Fen[1]
Female	0.54	4.24	1.22
Male	0.82	2.48	1.00

[1] The values for each habitat type are significantly different between females and males ($P<0.007$).

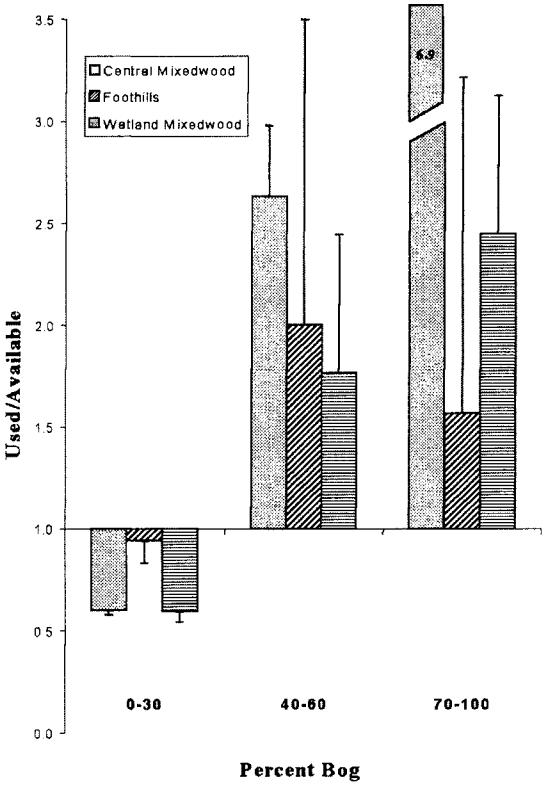

Fig. 5. Selection indices (used/available) for habitat categories representing the percentage of Bog present within polygons of the peatland map.

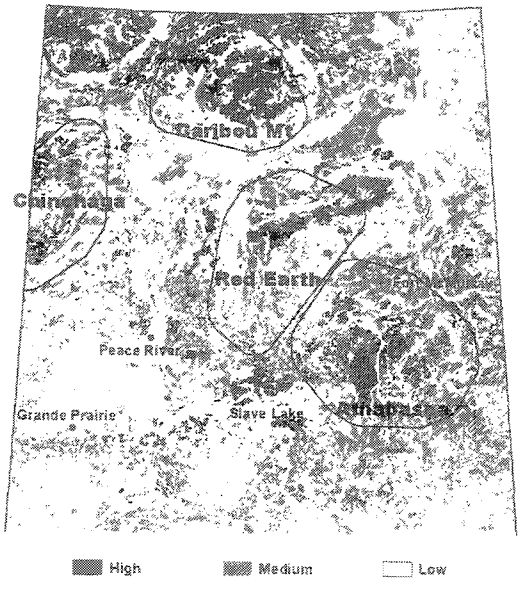

Fig. 6. Potential suitability of habitat across northern Alberta for caribou. See text for definitions of the three classes of suitability.

(Fig. 6). The classification system used was: polygons with greatet than 30% Bog were classified as "high" quality, polygons with greater than 50% Non-peat were classified as "low" quality, and all othet polygons were classified as "medium" quality.

Discussion

As with all studies of habitat selection, decisions made regarding the definition of used and available habitat are pertinent to the interpretation and validity of the results (Aebischer *et al.,* 1993; Johnson, 1980). We followed the common practice of stratifying the analysis into two levels which we termed local and regional, corresponding to Johnson' s (1980) third and second-order selection, respectively. Annual home ranges were used to define available habitat in the local analysis, and used habitat in the regional analysis. The mean size of the home ranges in our study (571 km^2) was comparable to the mean annual home tange for caribou in Alberta reported by Fuller & Keith (539 km^2; 1981), Bradshaw *et al.* (614 km^2; 1995), and Stuart-Smith *et al.* (711 km^2; 1997).

The boundaries of Natural Subregions, representing broad landscape patterns based on vegetation, geology, and landforms (AEP, 1994b), were used to delineate available habitat in the regional analysis. This choice reflects a compromise between our desire to assess selection at the provincial scale and an appreciation that substantial differences in habitat composition (and hence availability) could be expected across such a large area. We assumed that over ecological time the caribou that were studied had access to all habitat types within the Subregion in which they occurred. To address concerns that our delineation of used and available habitat could unduly influence our results we repeated the analyses using more conservative and more extreme criteria.

At the regional scale we found a pattern of habitat selection that was consistent across all three Subregions studied: peatlands were uniformly selected, with bogs ranking higher than fens, and non-peatlands were uniformly avoided. Selection of peatlands and avoidance of uplands has also been documented in other studies of habitat use by caribou (Bradshaw *et al.,* 1995; Stuart-Smith *et al.,* 1997). The basic pattern of selection was robust with respect to the criteria defining used and available habitat. However, while the ranking of habitat types remained constant, the strength of selection and avoidance was greatest when individual telemetry points wete compared to Natural Subregions and weakest when annual home ranges were compared to the cutrent ranges of the fout herds studied. Our interpretation of these findings is that caribou actively seek large peat complexes, particularly those containing bog, when establishing home ranges. Selection is most obvious when examined at the largest spatial scales because the contrast between the large peat complexes and the remaining landscape is greatest at this scale.

We found no evidence of habitat selection at the local level. This may indicate that once a peat complex has been selected for the establishment of a home range little further selection may be necessary for caribou to meet their habitat-associated needs (Stuart-Smith *et al.,* 1997; Thomas *et al.,* 1996). Howevet, we caution that out study had limited power for detecting habitat selection at the local level. To draw strong conclusions regarding selection patterns at this scale it would have been necessary to use a map of finer scale in which polygons represent unique peat types and to employ a more refined system of habitat classification. Such a map has been generated for the southern end of the Red Earth caribou range and a fine-scale investigation of habitat use by caribou in this region is currently being conducted (R. Anderson, pers. comm.).

While at the regional scale Non-peat was used consistently less than its availability it still comprised, on average, 35% of home ranges. However, virtually all of the Non-peat within home ranges occurred within or adjacent to large peat complexes. Furthermore, the use of uplands declined exponentially with distance from peatlands. Given that peat complexes in Alberta are generally interspersed with islands of uplands (Vitt *et al.,* 1998) the observed use of upland may be incidental to the selection of peat complexes by caribou. However, the possibility that upland islands within peat complexes ate actively exploited by caribou cannot be discounted (Thomas & Armbruster, 1996; Rettie & Messier, 2000) and requires further investigation.

Minot differences in the selection indices among regions were apparent in the regional analysis and some of these differences were statistically significant. Minor differences were also observed among years. In part, we attribute these differences to regional and temporal variations in climatic patterns. For example, differences in snow depth could influence the mobility of caribou and availability of forage, thereby altering habitat use (Cumming, 1992). Regional variations in habitat composition beyond the resolution of the coarse system of habitat classification used in this study were also likely to have been conttibutory factors to the differences observed among regions.

While the aforementioned differences in selection indices suggest that local factors can influence habitat selection, the consistency in the ranking of habitat types, both spatially and temporally, implies that the main drivers of habitat selection are relatively fixed. It may be that peatlands, and bogs in particular, contain the types of forage pteferred by caribou (Stuart-Smith *et al.,* 1997; Thomas *et al.,* 1996). It has also been hypothesized that peatlands offer a relative sanctuary from wolf predation because the overall biomass of large mammals is generally lower in these areas than in the surrounding uplands (Cumming *et al.,* 1996; Rettie & Messier, 2000).

The consistency of the basic pattern of habitat selection by caribou provided the basis for our assessment of the potential suitability of habitat across northern Alberta. The map we generated is intended to aid resource managers in identifying broad regions of suitable habitat. This tegional perspective is critical for the management of caribou given their combined requirements for specialized habitat and large home ranges (Cumming, 1992). A regional approach is also necessary for managing the tisk of habitat loss due to fire (Schaefer, 1991). The potential role of upland habitat within and adjacent to peat complexes should also be considered when regional planning for caribou is undertaken (Thomas & Armbruster, 1996). For example, buffers of forest should be maintained around peat complexes, along with travel corridors between large peat complexes (Thomas & Atmbrustet, 1996).

In order to study selection patterns at the provincial scale it was necessary to limit the level of detail of the analysis. For example, the system used to categorize habitat and the criteria used to designate habitat quality were both relatively coarse. However, it should also be noted that all of telemetry data were collected in areas containing sizeable quantities of high-quality habitat. The suitability of large aggregations of medium-quality habitat when isolated from high-quality habitat remains open to question. Because of these limitations our map of habitat suitability should be considered a broad guide, and not a prescription. Further local analysis of potential sites is warranted before special management regimes are implemented.

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