University of Alberta

PEATLAND HABITAT USE AND SELECTION BY WOODLAND CARIBOU (*RANGIFER TARANDUS CARIBOU*) IN NORTHERN ALBERTA

by

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The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **Peatland Habitat Use and Selection by Woodland Caribou (*Rangifer tarandus caribou*) in Northern Alberta** submitted by Robert B. Anderson in partial fulfilment of the requirements for the degree of Master of Science in Environmental Biology and Ecology.

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ABSTRACT

Woodland caribou (*Rangifer tarandus caribou*) are on Alberta's Blue List of species that may be at risk of declining to non-viable population levels in the province and are designated as Threatened under the provincial Wildlife Act. Habitat loss has been suggested as one factor contributing to an apparent decline in caribou numbers over the last 100 years. Treed-peatland-dominated areas are considered crucial for caribou survival in northeastern Alberta. The purpose of the current study was two-fold: 1) to determine if caribou in northwestern Alberta also select treed-peatland-dominated landscapes over upland-dominated landscapes, and 2) to examine fine-scale patterns of habitat use and selection within peatland complexes. Habitat use and selection were studied for caribou in the Athabasca and Red Earth caribou ranges of northern Alberta using habitat information derived from both coarse-scale (1:250,000 air-photo interpretation) and fine-scale (1:20,000 air-photo interpretation) peatland inventory data. Results indicate that woodland caribou in northern Alberta are not restricted to landscapes dominated by treed peatlands as home ranges of caribou in the southern portion of the Red Earth study area were comprised mostly of upland-dominated habitat at the coarse scale. However, caribou in both upland-dominated and treed-peatland-dominated landscapes used available treed peatland stands extensively at the fine scale and selected this class over all other habitat classes.

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CHAPTER I: GENERAL INTRODUCTION

Woodland caribou (*Rangifer tarandus caribou*) are on Alberta's Blue List of species that may be at risk of declining to non-viable population levels in the province (Alberta Wildlife Management Division 1996) and are designated as Threatened under the provincial Wildlife Act (Alberta Environmental Protection 1998). Concern for this species led to the development of a provincial restoration plan designed to ensure that Alberta caribou populations do not continue to decline. To ensure stable caribou populations in the future, wildlife managers must understand the mechanisms responsible for past population declines and mitigate current human activities that may lead to further declines.

Decline in Alberta's woodland caribou populations may have been influenced by a number of factors including hunting, wolf predation, industrial disturbance, and habitat loss (Alberta Environmental Protection 1998). Although the general hunting season for caribou was discontinued in 1981, poaching may continue to impact caribou populations. Legal harvest by natives also continues in some areas. To address the issue of human-induced mortality, the Boreal Caribou Research Program (BCRP; see http:/www.deer.rr.ualberta.ca/caribou/bcrp.htm) is studying caribou survival in areas with differing levels of control on public access. James (1999) suggested that increases in moose populations in areas surrounding caribou habitat may lead to increased wolf presence in caribou habitat and, ultimately, increased caribou mortality. Bradshaw et al. (1997) examined the potential impact of industrial disturbance on woodland caribou and found that caribou responded to loud noise (blast of a cannon) by increasing movement rates. Bradshaw et al. (1998) suggested that cumulative disturbance from industrial activity may have the potential to negatively affect calf production and survival. Human activity may also affect caribou through either direct or functional habitat loss. Direct habitat loss occurs when habitat undergoes drastic physical alteration, such as during the construction of roads and other industrial infrastructure. Functional habitat loss occurs when animals are displaced from an otherwise suitable area. Dyer (1999) has shown that industrial disturbance can lead to functional habitat loss as caribou avoided industrial infrastructure by up to 1000m. Dyer calculated that industrial activity could result in reduced use of 48% of his study area.

Alberta Government Information Letter (IL) 91-17 states that industrial activity can continue on caribou range, "provided the integrity of the habitat is maintained to support its use by caribou" (Alberta Energy 1991). As current practices appear to reduce caribou use of habitat surrounding industrial disturbances, it is questionable as to whether IL 91-17 is being met. Until the effects of such disturbance on caribou population dynamics and overall distribution can be determined, it is imperative that all steps be taken to reduce the impact that industrial activity has on caribou habitat use. This can be accomplished by avoiding caribou range whenever possible, and by ensuring industrial activity within caribou range coincides with habitat classes that are naturally avoided by caribou.

Bradshaw et al. (1995) found that caribou in northeastern Alberta select landscapes dominated by treed fens and bogs and avoid landscapes dominated by upland stands. These findings were incorporated into a method of mapping caribou range in northeastern Alberta. Though this coarse-scale mapping method was able to identify large peatland complexes used by caribou, the habitat information was not detailed enough to be used in planning industrial activity within these complexes.

The purpose of the current study was two-fold: 1) to determine if Bradshaw et al.'s (1995) conclusions about caribou habitat are applicable to northwestern Alberta, and 2) to examine fine-scale patterns of habitat use and selection within the peatland complexes used by caribou. Bradshaw et al.'s conclusions were tested by comparing coarse-scale habitat use and selection for caribou in the Red Earth and Athabasca study areas. Fine-scale habitat use and selection patterns were examined for subpopulations from the Red Earth and Athabasca study areas.

Two seasonal breakdowns were used in this thesis. As the purpose of Chapter II was to test the applicability of the Bradshaw et al. (1995) habitat conclusions for an area in northwestern Alberta, the dates used in Chapter II (winter season = November to April) were adopted from Bradshaw et al. Chapter III used a more detailed breakdown of seasons. These seasons (Autumn = September 15 – November 14; Early winter =

November 15 – January 15; Late winter = January 16 – March 31; Spring = April 1 – May 15; and Summer = May 16 – September 14) were adopted from a previous habitat selection analysis conducted for caribou in the Red Earth range (Brown et al., unpublished data).

This research was conducted as a component of the Boreal Caribou Research Program (BCRP). The original data used in this thesis is stored on CD-ROM and is available through the BCRP. Requests for original data can be made to the BCRP by contacting Dr. Stan Boutin, Department of Biological Sciences, University of Alberta.

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CHAPTER II: COARSE-SCALE HABITAT SELECTION: TREED PEATLANDS VS. UPLANDS

INTRODUCTION

Woodland caribou (*Rangifer tarandus caribou*) are on Alberta's Blue List of species that may be at risk of declining to non-viable population levels in the province (Alberta Wildlife Management Division 1996) and are designated as Threatened under the provincial Wildlife Act (Alberta Environmental Protection 1998). Concern for this species was caused by a reduction in distribution and an apparent decrease in population numbers over the past one hundred years (Soper 1964, 1970; Edmonds and Bloomfield 1984; Dzus 1999. However, also see Bradshaw and Hebert 1996). To address issues associated with industrial activity on caribou range, the Alberta government drafted Information Letter 91-17 (Alberta Energy 1991)[1]. This *Procedural Guide for Petroleum and Natural Gas Activity on Caribou Range* allows for industrial activity on caribou range, "provided the integrity of the habitat is maintained to support its use by caribou." The wording of IL-91-17 implies a prerequisite ability of wildlife managers to identify caribou habitat.

Woodland caribou select lowland habitats during winter in boreal regions of southeastern Manitoba (Darby and Pruitt 1984, Schaefer and Pruitt 1991), west central Alberta (Edmonds and Bloomfield 1984), and northeastern Alberta (Fuller and Keith 1981, Bradshaw et al. 1995, Stuart-Smith et al. 1997). Bradshaw et al. (1995) used a coarse-scale[2] peatland inventory to study habitat selection in northeastern Alberta. Air-photo-interpreted polygons were classified based on the most common peatland type within the polygon and the percent of that polygon made up by peatlands. Bradshaw et al. (1995) found that caribou in northeastern Alberta (Athabasca caribou range) select habitat polygons dominated by treed fens and bogs during winter and avoid polygons

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[1] See also updates IL 94-29 and IL 96-7 (Alberta Energy 1994, Alberta Energy 1996).

[2] 1:250,000 scale air-photo interpretation

dominated by upland habitat. They suggested that large areas of these treed fen and bog dominated polygons were 'crucial' to the survival of caribou in northeastern Alberta. Upland-dominated areas are not considered suitable habitat as caribou may be exposed to higher risk of predation from wolves in upland areas (Stuart-Smith et al. 1997, James 1999).

If treed fen and bog dominated areas are crucial to caribou survival in northeastern Alberta, similar patterns of habitat use and selection should be evident in other northern Alberta populations. In January 1995, animals from a previously unstudied caribou population were radio-collared (Morton and Wynes 1997) within the same natural subregion (Figure 2.1) as the animals studied by Bradshaw et al. (1995). The addition of the Red Earth study area provided an opportunity to test conclusions drawn by Bradshaw et al. regarding habitat selection. The primary objective of the current study was to determine if winter habitat use and selection patterns reported for caribou in the Athabasca range were also observed for caribou in the Red Earth range. Specifically, habitat use and selection were compared for polygons dominated by treed fens and bogs and polygons dominated by uplands. Selection of polygons dominated by treed fens and bogs over polygons dominated by uplands was expected in all cases.

Habitat selection may be scale dependent (Johnson 1980) as animals often select different environmental features at various spatial scales (Orians and Wittenberger 1991, Ward and Saltz 1994, Henschel and Lubin 1997). Selection patterns may also vary among populations examined at the same scale: Orians and Wittenberger (1991) suggested that differential habitat selection among populations may be due to differences in the scale at which animals respond to influences such as forage availability and predation. As a result, restricting the comparison of Red Earth and Athabasca data to a single scale limits the interpretability of the results. A secondary objective of the current study was to determine if differential habitat use identified at the coarse level was evident at a finer mapping scale. To address this, fine-scale habitat use was compared for a sub-population in the Athabasca range and a sub-population in the Red Earth range. Both sub-populations were expected to use treed peatlands more than any other habitat class.

STUDY AREA

The Athabasca study area has a central co-ordinate of 112.4º W (decimal degrees), 56.1º N (decimal degrees) and covers approximately 23,000 km^2 (Figure 2.1). Elevation in the Athabasca study area ranges from 500 to 700m above sea level. The Red Earth study has a central co-ordinate of 114.7º W (decimal degrees), 57.1º N (decimal degrees), and covers approximately 15,500 km^2 (Figure 2.1). Elevation in the Red Earth study area ranges from 400 to 550m above sea level. Much of the topographic relief found in the two study areas is associated with large river valleys that bisect each area. Little topographic relief exists outside these river valleys. Both areas are part of the central mixedwood natural subregion (Alberta Environmental Protection 1994). The Athabasca study area and the northern portion of the Red Earth study area are dominated by large, treed peatland complexes. The southern portion of the Red Earth study area is a mosaic of wetland and upland habitat. See Bradshaw et al. (1995) for a description of the dominant lowland and upland vegetation.

METHODS

Caribou location data -- Location data were collected for caribou fitted with VHF radio collars. Between November 1994 and April 1998, 93 caribou were monitored in the Athabasca range. For the same time period, 36 animals were monitored in the Red Earth range. All animals were captured as per Bradshaw et al. (1995). During the winter time period (November 1 to April 30), monitoring ranged from once per week to once per month, depending on the area and year. Relocation was done with a Cessna fixed-wing aircraft equipped with a Global Positioning System (GPS) receiver, a telemetry receiver and directional, strut-mounted antennae. Latitude and longitude were recorded from the aircraft's GPS for each animal location. Tests of relocation accuracy revealed a mean location error of 116 m (SE = 41 m) (Boreal Caribou Research Program, unpublished data). Telemetry locations were imported into Arc/INFO (Environmental Systems Research Institute, Inc.) geographic information system for analysis. Locations were pooled across winters as Bradshaw et al. (1995) found little variation in habitat use among years. Animals were included in analyses if they had been located more than 10 times during the winter period. Sixty-two caribou from the Athabasca range and 34 caribou from the Red Earth range met this criterion.

Coarse-scale

Habitat data -- Habitat information was derived from a digital copy of the Peatland Inventory of Alberta[3] (Vitt et al., 1998). Habitat polygons were classified to approximate the categories used by Bradshaw et al. (1995). See Table 2.1 for a description of the classes used in this study. A habitat class was assigned to each telemetry location using Arc/INFO.

Habitat selection for the Athabasca and Red Earth populations – Johnson (1980) described habitat selection as a hierarchy: first order selection defines a species' geographical range, second order selection determines home range location for individuals or a social group, and third order selection is defined as the selection of habitat within a home range. Bradshaw et al. (1995) examined both second and third-order habitat selection. Selection of treed peatland areas over upland areas did not differ between second and third order analyses in their study. As a result, the current study only examined second-order selection. Selection of treed-peatland-dominated areas over upland-dominated areas was tested using log-ratio analysis of compositions (Aebischer et al. 1993, Bradshaw et al. 1995). Animals in the Red Earth and Athabasca ranges were treated as two separate populations. Available habitat was considered the same for all animals within a given range and was defined by connecting the outermost telemetry points for each study area. Habitat use composition for each animal was calculated as the proportion of telemetry points located in each habitat class. As proportional use, and not individual telemetry location data, is used in the calculation, the sample unit for this analysis is the individual animal. Selection of polygons dominated by treed fens and bogs over polygons dominated by uplands was calculated for each animal using the following formula:

$$d_{PDU,\ PDTFAB} = \ln(U_{PDTFAB}/U_{PDU}) - \ln(A_{PDTFAB}/A_{PDU})$$

where U_{PDTFAB} and U_{PDU} are the proportional use of polygons dominated by treed fens and bogs, and polygons dominated by uplands, and A_{PDTFAB} and A_{PDU} are the proportional availabilities of polygons dominated by treed fens and bogs, and polygons dominated by uplands. A positive value for $d_{PDU,PDTFAB}$ indicates selection by that animal

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[3] 1:250,000 scale air-photo interpretation

of polygons dominated by treed fens and bogs over polygons dominated by uplands. A negative value for $d_{PDU,PDTFAB}$ indicates selection by that animal of polygons dominated by uplands over polygons dominated by treed fens and bogs. For each study area, the ratio of mean $d_{PDU,PDTFAB}$ to standard error gives a t value (n = number of animals) that measures departure from random. Values for $d_{PDU,PDTFAB}$ were compared for Red Earth and Athabasca using a t-test.

Differential habitat selection by sub-populations -- When habitat selection is analyzed, available habitat must be defined by the researcher. Changing the definition of available habitat can have large impacts on the results of the analysis (White and Garrott 1990). For analysis of habitat selection for the Athabasca and Red Earth populations, study area boundaries were produced by joining the outermost telemetry points from each caribou range. The area within each boundary was considered available to a single population. As radio collared animals are spread over a large area, joining the outermost telemetry points resulted in the inclusion of areas where no animals were collared. Inclusion of these areas in the calculation of available habitat may bias selection analysis results. This method of defining available habitat also precludes identification of unique habitat selection patterns of sub-populations within the larger study area. An alternative method of defining the study area(s) and available habitat is to use a kernel estimation (Worton 1989) of the pooled telemetry data. Kernel estimation provides study area boundaries that more closely follow the distribution of radio collared animals. It can also be used to separate data into core areas or sub-populations. Habitat selection can then be analyzed independently for each of the resulting sub-populations.

Differential habitat selection among sub-populations was tested after applying a 95% adaptive kernel estimation to the pooled telemetry database. Kernel estimation (h = 2.695) was calculated using The Home Ranger software (Hovey, 1998). Eight regions resulted from the kernel estimation (Figure 2.2). Two of the Red Earth regions (Red Earth South, Red Earth North), and one of the Athabasca regions (Athabasca West) met the required number of animals necessary for log-ratio analysis of compositions (Aebischer et al., 1993). Red Earth South, Red Earth North, and Athabasca West analyses used 13, 19, and 47 animals respectively. Selection of polygons dominated by treed fens and bogs over polygons dominated by uplands was tested for each area using the log-ratio analysis of compositions as described above. Differential selection among sub-populations was tested using a one-way ANOVA conducted with $d_{PDU,PDTFAB}$ values.

Fine-scale

Differences among subpopulations were further investigated by comparing caribou locations to finer scale peatland inventory data. The Alberta Wetland Inventory (AWI) provides a methodology for classifying wetland areas from air-photos (Halsey and Vitt 1997). Whereas the 1:250,000 scale Peatland Inventory of Alberta (Vitt et al., 1998) describes the proportion of each AWI class within a large polygon, fine-scale AWI data (air-photos ranged from 1:15,000 to 1:40,000) identifies individual peatland stands. Fine-scale AWI data were available for the Red Earth South (Daishowa-Marubeni International Ltd., unpublished data) and Athabasca West (S. Mauser, unpublished data) study areas. Telemetry locations were assigned one of the following habitat classes: open peatland, treed peatland, non-peat wetland, or upland. As only a simple comparison of the general patterns was desired (more extensive habitat use and selection analyses are presented in Chapter III), loglinear analysis was used to determine if the pattern of fine-scale habitat use was the same for both study areas. To avoid biasing the data toward animals with the most relocations, one location per caribou was randomly chosen for each winter. Animals were only included in the analysis if they had been located two or more times during each of the following winters: 94/95, 95/96, 96/97, 97/98. Seventeen and nine animals were used for Athabasca West and Red Earth South respectively.

RESULTS

Coarse-scale

Habitat selection for the Athabasca and Red Earth populations.— In both study areas, mean use of polygons dominated by treed fens and bogs (U_{PDTFAB}) was greater than availability (A_{PDTFAB}) and mean use of polygons dominated by uplands (U_{PDU}) was less than availability (A_{PDU}) (Table 2.2). The pattern of habitat selection differed between study areas however ($t = 2.27$, $v = 94$, $p = 0.025$). Athabasca caribou selected polygons dominated by treed fens and bogs over polygons dominated by uplands (mean $d_{PDU,PDTFAB} = 5.12$, $t = 5.82$, $v = 61$, $p < 0.001$). Red Earth animals did not select polygons dominated by treed fens and bogs over polygons dominated by uplands (mean $d_{PDU,PDTFAB} = 1.66$, $t = 1.28$, $\nu = 33$, $p = 0.21$).

Differential habitat selection by sub-populations.-- For all subpopulations, mean use of polygons dominated by treed fens and bogs (U_{PDTFAB}) was greater than availability (A_{PDTFAB}) and mean use of polygons dominated by uplands (U_{PDU}) was less than availability (Table 2.3). However, the pattern of habitat selection differed among the three areas ($F = 11.03$, $df = 2$, $p < 0.0001$). Polygons dominated by treed fens and bogs were selected over polygons dominated by uplands for Athabasca West (mean $d_{PDU,PDTFAB} = 5.33$, $t = 5.89$, $\nu = 46$, $p < 0.001$) and Red Earth North (mean $d_{PDU,PDTFAB} = 4.51$, $t = 3.16$, $\nu = 18$, $p < 0.001$). In Red Earth South, polygons dominated by uplands were selected over polygons dominated by treed fens and bogs with marginal significance (mean $d_{PDU,PDTFAB} = -3.74$, $t = 2.12$, $\nu = 12$, $p = 0.056$).

Fine-scale

At the fine-scale, habitat use was independent of study area ($G = 4.15$, $df = 3$, $p = 0.25$). Fine-scale analysis reveals that, although Red Earth South animals spend most of their time in upland-dominated polygons at the coarse-scale, they actually use treed peatlands most commonly at the fine-scale (Figure 2.3). Treed peatland was the most commonly used habitat class in both areas (Table 2.4).

DISCUSSION

The occurrence of woodland caribou in an area with low prevalence of coarse-scale polygons dominated by treed fens and bogs raises questions about the 'crucial' nature of this habitat class. Bradshaw et al. (1995) suggested that areas dominated by treed fens and bogs were crucial to the survival of caribou in northeastern Alberta, yet caribou occur in Red Earth South, where the 'crucial' habitat class makes up only 4% of the area. Although use of polygons dominated by treed fens and bogs was greater than availability for both the Athabasca West and Red Earth South sub-populations, average use of polygons dominated by treed fens and bogs by Red Earth South animals was only 8%. It is important to remember, however, that occupation is not necessarily an indication of habitat quality (Danielson 1992). Although caribou occupy an area dominated by uplands, the Red Earth area may be a population sink. Preliminary findings suggest that survival is lower and more variable for animals in the Red Earth population than for those in the Athabasca population (E. Dzus et al., Boreal Caribou Research Program, unpublished data). Survival analysis was not done separately for Red Earth South and Red Earth North, however. If habitat composition affects survival, survival in Red Earth North should be similar to Athabasca West. Similar population dynamics between Red Earth South and Red Earth North would suggest that differences in landscape pattern are not responsible for differential survival. Other factors such as human disturbance may also affect population dynamics for animals in the Red Earth range.

Even though coarse-scale polygons dominated by treed fens and bogs were not required for caribou presence, treed peatlands were found to be an important habitat component for both the Athabasca West and Red Earth South animals at the fine-scale. Both sub-populations used treed peatlands most commonly, regardless of differential coarse-scale patterns. The identification of this pattern raises some questions in terms of how caribou select peatland habitat from two very different landscapes. This will be addressed in Chapter III of this thesis.

Contrary to previous belief, landscapes dominated by uplands may be suitable caribou habitat in some cases. Until the current study, upland-dominated habitat was considered unsuitable for caribou as predation risk was expected to be high (Stuart-Smith et al. 1997, James 1999). Although the results of the current study can not be used to judge the quality of the habitat, one of the sub-populations (Red Earth South) used polygons dominated by uplands extensively and even selected them over areas dominated by treed fens and bogs. However, Red Earth South animals appear to use upland-dominated landscapes that include treed peatland stands. Whereas average use of upland-dominated areas was 61%, 69% of the locations were actually in treed peatlands. As mentioned above, however, it is not known how this habitat configuration affects population dynamics. It is also unknown if there is a minimum peatland patch size or habitat configuration that will support woodland caribou. Future research should examine reproductive success in relation to fine-scale habitat configuration.

Several methodological insights can be taken from the results of the current study. First, the influence of mapping scale must be considered when habitat use and selection are studied. Maps that identify broad habitat patterns only allow for detection of broad habitat use and selection patterns. Although this may seem obvious, it is easy to make the mistake of extrapolating fine-scale habitat use from coarse-scale inventories. It would be just as wrong to conclude that Athabasca West caribou use treed peatlands because they are in polygons dominated by treed fens and bogs as it would be to conclude that Red Earth South animals use uplands because they are in upland-dominated polygons. Only after looking at the fine-scale could it be concluded that both sub-populations use treed peatlands, albeit in two very different landscapes. In many cases a multi-scale assessment of habitat use and selection will provide a better understanding of the ecology of a species in a given area and, therefore, improve range-specific management.

Habitat use and selection alone should not be used to define critical habitat. Population dynamics of animals with and without a selected habitat should be compared if conclusions are to be made about the crucial nature of that habitat class. Use alone can also be misleading. It would be incorrect to conclude from the current study that upland-dominated landscapes are vital to caribou, even though Red Earth South animals used upland-dominated areas extensively. Habitat use and selection can be used to identify patterns and make hypotheses; however, conclusions about the quality of a given habitat should be based on population dynamics with and without that habitat.

Finally, the arbitrary assignment of population and study area boundaries can have a great influence on the conclusions of second-order habitat selection analyses. Population-level analyses in the current study used minimum convex polygon boundaries placed around two arbitrarily assigned populations. Although the two populations differed in their selection between polygons dominated by treed fens and bogs and polygons dominated by uplands, variation among Red Earth animals precluded identification of a single factor that differentiated the Red Earth and Athabasca animals. Separation of the pooled data into sub-populations by kernel estimation resulted in more easily interpretable results. The Red Earth North and Athabasca West study areas had similar habitat compositions at the coarse-scale and the two sub-populations showed similar habitat selection patterns. The Red Earth South study area had a very different habitat composition at the coarse-scale and Red Earth South animals showed a unique habitat selection pattern. Having the ability to compare habitat use by Red Earth South and Athabasca West animals at the fine-scale also allowed for explanation of the differences seen at the coarse-scale. In this case, producing sub-population boundaries by kernel estimation produced valuable additional information about habitat associations of woodland caribou in northern Alberta.

MANAGEMENT IMPLICATIONS

The Peatland Inventory of Alberta (Vitt et al. 1998) is too coarse to be used alone to identify all caribou habitat in northern Alberta. Although this data source can be used to identifying the large peatland complexes that are likely to comprise the core of the caribou range, areas used by woodland caribou in the surrounding upland-dominated polygons may be missed. Because caribou have been shown to use treed peatlands within upland-dominated polygons, finer scale habitat data may provide a more universal predictor of caribou distribution in areas adjacent to large peatland complexes. Both coarse-scale and fine-scale peatland inventory maps should be used in future refinements of caribou range boundaries.

Table 2.1 Coarse-scale habitat classes derived from the Peatland Inventory of Alberta (Vitt et al. 1998) and used to test the applicability of the Bradshaw et al. (1995) conclusions to caribou in the Red Earth area.

Habitat class[a]	Dominant wetland type and percent cover	Approximates Bradshaw et al. (1995) class
Polygons dominated by treed fens and bogs	Treed fens and bogs; >50%	C
Polygons dominated by uplands	Non-wetland (mineral soil); >85%	G

[a]These classes describe the dominant peatland type in air-photo-interpreted polygons, which range in size from 16 to 845,679 ha. (mean = 4277 ha.).

Table 2.2 Mean proportional use of polygons dominated by treed fens and bogs (U_{PDTFAB}) and polygons dominated by uplands (U_{PDU}), and availability of polygons dominated by treed fens and bogs (A_{PDTFAB}) and polygons dominated by uplands (A_{PDU}) for woodland caribou in the Red Earth and Athabasca caribou ranges.

	U_{PDTFAB} (+/- SE)	A_{PDTFAB}	U_{PDU} (+/- SE)	A_{PDU}
Red Earth (n = 34)	0.42 (+/- 0.06)	0.16	0.29 (+/- 0.05)	0.42
Athabasca (n = 62)	0.53 (+/- 0.00)	0.19	0.12 (+/- 0.00)	0.46

Table 2.3 Mean proportional use of polygons dominated by treed fens and bogs (U_{PDTFAB}) and polygons dominated by uplands (U_{PDU}) and, availability of polygons dominated by treed fens and bogs (A_{PDTFAB}) and polygons dominated by uplands (A_{PDU}) for woodland caribou in the Red Earth South, Red Earth North, and Athabasca West study areas.

	U_{PDTFAB} (+/- SE)	A_{PDTFAB}	U_{PDU} (+/- SE)	A_{PDU}
Red Earth South (n = 13)	0.08 (+/- 0.05)	0.04	0.61 (+/- 0.04)	0.75
Red Earth North (n = 19)	0.71 (+/- 0.05)	0.51	0.06 (+/- 0.02)	0.14
Athabasca West (n = 47)	0.60 (+/- 0.03)	0.40	0.07 (+/- 0.01)	0.26

Table 2.4 Proportional use of treed peatland, open peatland, non-peat wetland, and upland habitat by caribou in the Red Earth South and Athabasca West study areas.

	Treed peatland	Open peatland	Non-peat wetland	Upland
Red Earth South (36 locations)	0.69	0.17	0.06	0.08
Athabasca West (68 locations)	0.79	0.04	0.04	0.12

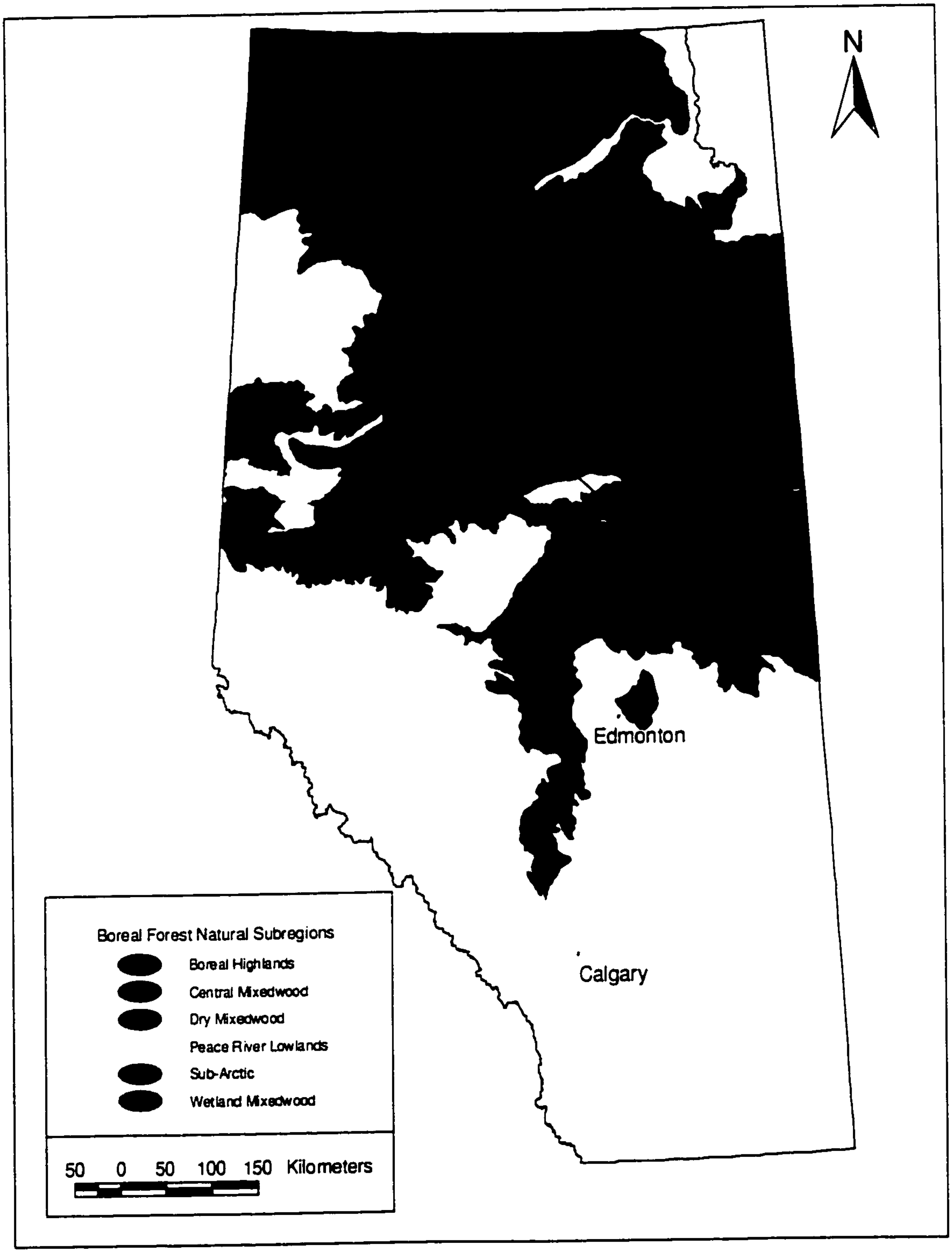

Figure 2.1 Map of Alberta, Canada, with Boreal Forest Natural Subregions and the Red Earth and Athabasca study areas.

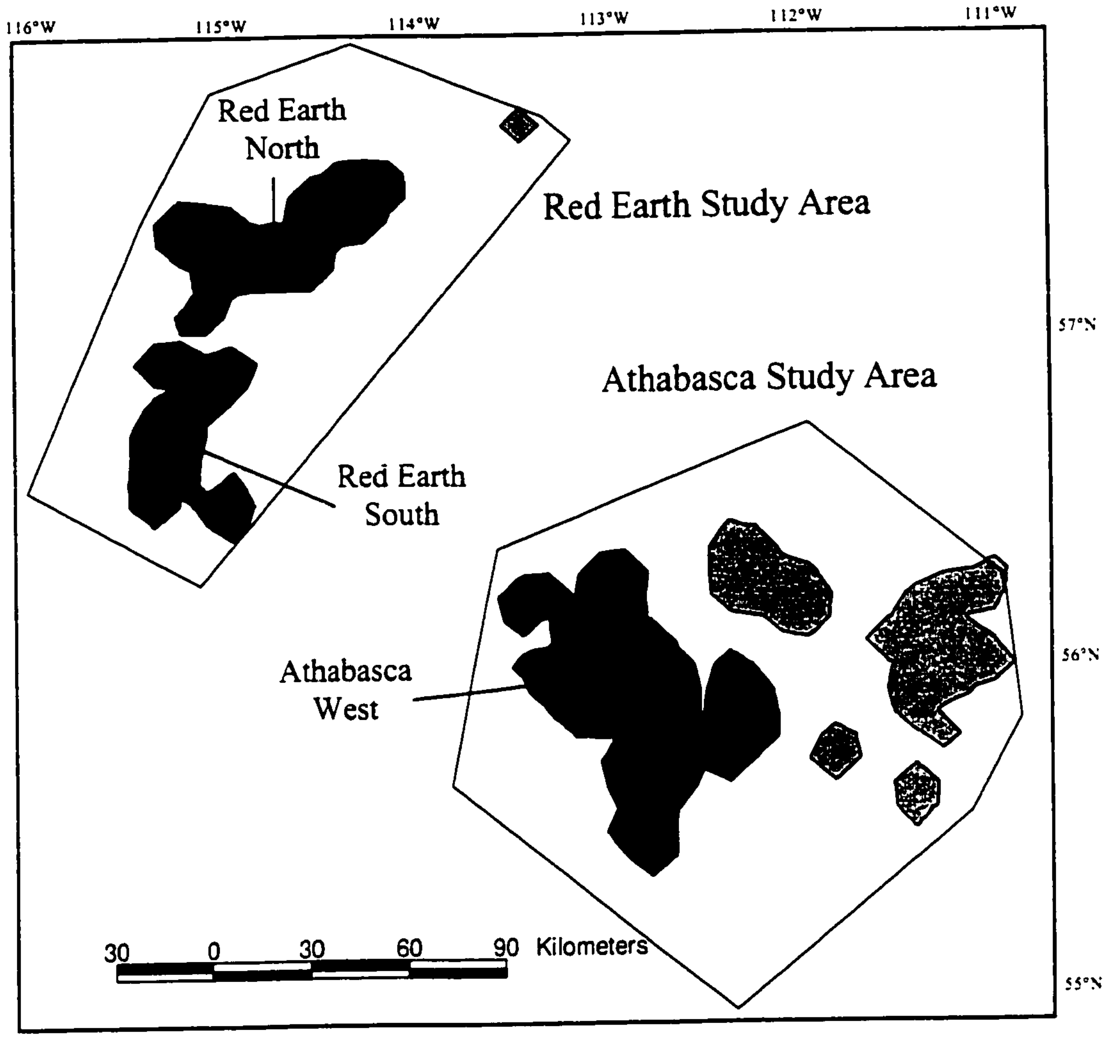

Figure 2.2 Red Earth and Athabasca study area boundaries (solid line) created by connecting the outermost telemetry locations, and sub-population boundaries (shaded) created by a 95% adaptive kernel estimation performed on telemetry location data pooled across caribou ranges. Red Earth North, Red Earth South, and Athabasca West study areas were used to examine differential habitat selection among subpopulations.

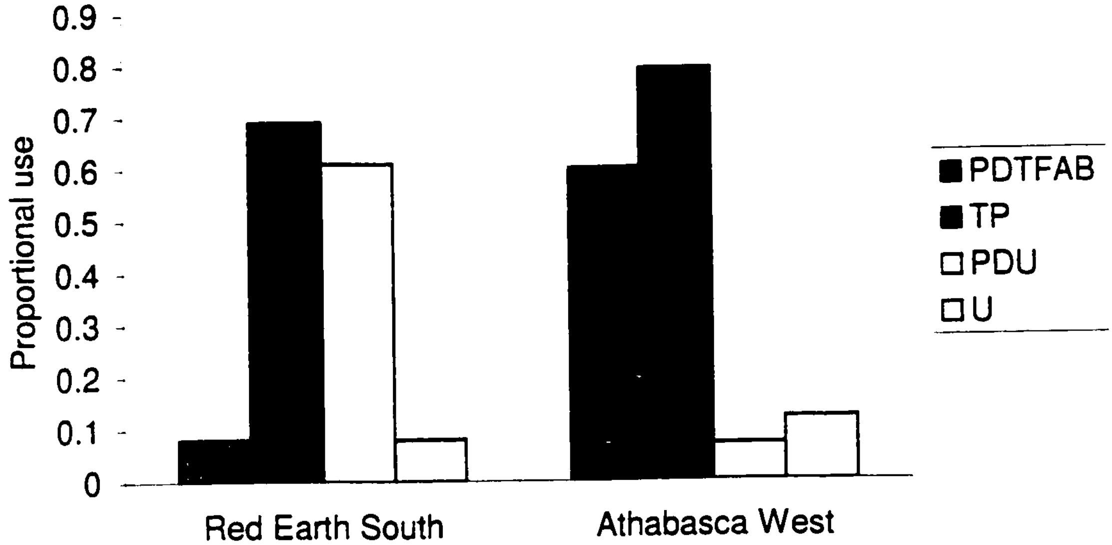

Figure 2.3 Comparison of treed peatland and upland habitat use at two scales for Red Earth South and Athabasca West animals; PDTFAB = Coarse-scale polygons dominated by treed fens and bogs; TP = Fine-scale treed peatland stands; PDU = Coarse-scale polygons dominated by upland; U = Fine-scale upland stands.

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CHAPTER III: FINE-SCALE PEATLAND USE AND SELECTION

INTRODUCTION

Alberta's boreal ecotype woodland caribou (*Rangifer tarandus caribou*; hereafter boreal caribou) are associated primarily with large, treed peatland complexes. Bradshaw et al. (1995) found that caribou in northeastern Alberta select landscapes dominated by treed fens and bogs and avoid upland-dominated landscapes during winter. Similar findings have been reported for boreal caribou in other areas of northern Alberta (Fuller and Keith 1981; Edmonds and Bloomfield 1984; Schneider et al., Boreal Caribou Research Program, unpublished data). Caribou will also use peatland complexes in upland-dominated landscapes (see Chapter II of this thesis).

Understanding habitat associations within the peatland complex is important for caribou management in northern Alberta. Woodland caribou are on Alberta's Blue List of species that may be at risk of declining to non-viable population levels in the province (Alberta Wildlife Management Division 1996) and are designated as Threatened under the provincial Wildlife Act (Alberta Environmental Protection 1998). The *Procedural Guide for Petroleum and Natural Gas Activity on Caribou Range* (Alberta Energy 1991)[4] allows for industrial activity on caribou range, "provided the integrity of the habitat is maintained to support its use by caribou." Caribou range maps identify areas where guidelines for industrial activity must be followed. These guidelines impose some restrictions on the timing of activity, but say very little about the location or amount of activity. Recent work by Dyer (1999) shows that caribou in northeastern Alberta avoid seismic lines, roads, and recently developed well sites. Although negative impacts on population dynamics have yet to be associated with these conditions, avoidance of these features suggests that habitat integrity has been affected in such a way as to reduce use of these areas by caribou. If caribou are not able to habituate to human disturbance, habitat integrity in large portions of the current caribou range may eventually be degraded to the

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[4] See also updates IL 94-29 and IL 96-7 (Alberta Energy 1994, Alberta Energy 1996).

point of no longer supporting a caribou population. As a preventative measure, companies may be able to reduce disturbance by planning activity to coincide with areas that are naturally avoided by caribou.

Habitat use and selection within Alberta's peatland complexes have only been dealt with superficially. In Chapter II of this thesis, winter habitat use was examined to determine if animals in an upland-dominated landscape use the same habitat as animals in a peatland-dominated landscape -- both groups used treed peatlands most commonly during winter. No other seasons were examined and no analysis of habitat selection was conducted. Brown et al. (unpublished data) examined peatland habitat selection for animals in the Red Earth range. They found that caribou select treed bog, treed fen and open fen habitat, and avoid upland areas. The Brown et al. study was conducted for animals in a fragmented landscape. No study has been done on peatland habitat selection in large, continuous peatland complexes.

The primary purpose of the current study was to examine habitat use and selection within peatland complexes by caribou in northern Alberta. Under this objective, four main questions were asked. The first question was: Are certain wetland types both used extensively and consistently selected over all other habitat types? Areas that are both used extensively and consistently selected over alternative habitats should be avoided by industrial activity. The second question was: Do caribou consistently avoid certain areas of the peatland complex? If caribou consistently avoid certain habitat classes, these areas may provide a more suitable location for industrial infrastructure. Thirdly: Do these patterns change among seasons? If the pattern of habitat use and selection changes greatly among seasons, industrial planning should take this into account. Lastly: Do these patterns differ between a fragmented peatland complex (southern portion of the Red Earth range; see Figure 3.1) and a continuous peatland complex (western portion of the Athabasca range; see Figure 3.1).

A second objective was to determine if the patterns of habitat use and selection observed for caribou in the Athabasca and Red Earth ranges support the hypothesis put forward by Bergerud et al. (1990). Bergerud et al. (1990) hypothesized that caribou "forage optimally in a fine-grained sense and reduce [predation] risk in coarse-grain manner." Based on this hypothesis and the suggestion by Orians and Wittenberger

(1991) that populations may respond to influences such as forage availability and predation risk at different scales, two different scenarios were expected for the two study areas examined in the current study.

Caribou in the Athabasca range reduce predation risk by utilizing large peatland complexes and avoiding well drained (upland) areas (James 1999). If Athabasca caribou behave as Bergerud et al. suggest, selection of wetland habitat over upland habitat is expected at a coarse level (selection of a home range), regardless of forage abundance. Such selection would place home ranges in low predation-risk areas. At a fine level (within home range selection), habitat classes with the greatest forage availability should be selected over habitat classes with low forage availability.

Caribou in the southern portion of the Red Earth range occur in a much more fragmented landscape (Figure 3.1). Whereas most of the upland habitat in the western portion of the Athabasca range occurs along the Athabasca River valley, upland habitat is spread throughout the southern portion of the Red Earth range. As a result, total avoidance of upland habitat (assumed high predation risk) is more difficult. Caribou in the southern portion of the Red Earth range are thus expected to select wetland habitat (assumed low predation risk) over upland (assumed high predation risk) at both a coarse level (selection of a home range) and a fine level (selection within the home range), even if forage availability is high in upland areas.

STUDY AREA

Data for this research came from two of the large northern Alberta study areas (Figure 3.2) used by the Boreal Caribou Research Program. The Athabasca study area has a central co-ordinate of 112.4º W (decimal degrees), 56.1º N (decimal degrees) and covers approximately 23,000 km^2. Elevation in the Athabasca study area ranges from 500 to 700m above sea level. The Red Earth study area has a central co-ordinate of 114.7º W (decimal degrees), 57.1º N (decimal degrees) and covers approximately 15,500 km^2. Elevation in the Red Earth study area ranges from 400 to 550m above sea level. Much of the relief associated with the two study areas results from deep river valleys that bisect each area. Little topographic relief exists outside these river valleys. Both areas are part of the central mixedwood natural subregion (Alberta Environmental Protection

1994). See Bradshaw et al. (1995) for a description of dominant lowland and upland vegetation.

METHODS

Habitat Inventory Data -- Habitat inventory data was available for the Red Earth South subpopulation (Daishowa-Marubeni International Ltd., unpublished data; Figure 3.2) and the Athabasca West subpopulation (S. Mauser, unpublished data; Figure 3.2). See Chapter II for a description of methods used to identify sub-populations. Habitat inventory polygons were mapped from 1:20,000 scale air-photos for Red Earth South (minimum polygon size = 4 ha.) and 1:40,000 scale air-photos for Athabasca West (minimum polygon size = 16 ha.). Information on wetland vegetation was assigned to these polygons according to the Alberta Wetland Inventory (AWI) Classification Standards (Halsey and Vitt 1997) by Dr. Dale Vitt's lab (Department of Biological Sciences, University of Alberta). The AWI classification provides a four-letter descriptive label. The four modifiers give information on wetland type, vegetation cover, presence or absence of permafrost, and presence or absence of internal lawns and collapse scars (melted out areas). For the current study, only the first two modifiers (wetland type and vegetation cover) were considered as using all four modifiers produced too many habitat classes for meaningful habitat selection analyses. Additionally, the difference in air-photo scales may have produced biased results if all four AWI modifiers had been used. Because polygon boundaries were dissolved on wetland type and vegetation type, habitat classification should not be biased by differences in the original air-photo scale.

Six habitat classes were used in this study. The BT (bog with wooded open canopy, 6% - 70% tree cover), FO (open fen, < 6% tree cover), FT (fen with wooded open canopy, 6% - 70% tree cover), ST (swamp with wooded open canopy, 6% - 70% tree cover), and U (upland) categories were derived directly from the first two AWI modifiers. Due to scarcity, AWI class BF (bog with forested closed canopy, > 70% tree cover) was included with BT. AWI classes MO (open marsh, < 6% tree cover), SO (open swamp, < 6% tree cover), and WO (shallow open water) were placed in a group called non-peat open wetland (NPOW).

Caribou location data -- Location data was collected using caribou fitted with VHF radio collars. Between November 1994 and April 1998, 47 caribou were monitored in Athabasca West. For the same time period, 13 animals were monitored in Red Earth South. All animals were captured as per Bradshaw et al. (1995). Monitoring ranged from once per week to once per month, depending on the area and season. Relocation was conducted with a Cessna fixed-wing aircraft equipped with a Global Positioning System (GPS) receiver, a telemetry receiver and directional, strut-mounted antennae. Latitude and longitude were recorded from the aircraft's GPS for each location. Tests of relocation accuracy revealed a mean location error of 116 m (SE = 41 m) (Boreal Caribou Research Program, unpublished data). Locations were pooled across years for each animal. Data was separated into five seasons: autumn (September 15 – November 14); early winter (November 15 – January 15); late winter (January 16 – March 31); spring (April 1 – May 15); and summer (May 16 – September 14). Animals were included in analyses if they had been located more than 10 times during a multi-year season. As no animals in Athabasca West were located 10 times between September 15 and November 14, no analysis was done for autumn. In Red Earth South, samples sizes for early winter, late winter, spring and summer were 10, 12, 12, and 7 animals respectively. In Athabasca West, sample sizes for the same time periods were 26, 30, 36, and 30 animals.

Second-order habitat use and selection – Habitat selection is hierarchical (Johnson 1980). First order selection defines a species' geographical range, second order selection determines home range location for individuals or a social group, and third order selection is defined as the selection of habitat within a home range. Second-order selection was studied for Red Earth South and Athabasca West using log-ratio analysis of compositions (Aebischer et al. 1993, Bradshaw et al. 1995). The habitat used by an animal during a given season was defined as the habitat composition within the animal's seasonal home range. Fixed kernel home ranges (95%) were created for each animal-season using telemetry data imported into The Home Ranger software (Hovey, 1998). Habitat composition within each of these seasonal home ranges was assigned using Arc/INFO (Environmental Systems Research Institute, Inc.). Habitat composition within the study area (sub-population boundary) comprised the available habitat for animals within a given subpopulation. The habitat composition within each sub-population boundary was calculated using Arc/INFO.

Third-order habitat use and selection – Third-order habitat selection compares the habitat used within a home range to the habitat available within that home range. Third-order habitat selection was examined for Red Earth South and Athabasca West animals by comparing habitat information for telemetry location data to the habitat composition within each animal's seasonal home range. To define use for each animal, telemetry locations were imported into Arc/INFO and assigned a habitat class. Proportional use in each habitat class was calculated for each animal-season. Proportional availability was defined by the habitat composition within each animal's seasonal home range. Habitat classes were ranked according to compositional analysis of habitat use (Aebischer et al. 1993).

The Bergerud et al. Hypothesis – To determine whether the habitat selection patterns observed for Red Earth South and Athabasca West caribou fit the hypothesis put forth by Bergerud et al. (1990), habitat use and selection results needed to be compared to predation risk and forage availability in the different habitat classes. Based on the findings of James (1999), the assumption was made that higher predation risk is associated with the upland habitat class (U) and lower predation risk is associated with all wetland habitat classes. Fecal fragment analysis conducted on pellets collected in northern Alberta suggests that *Cladina* lichen is the main food source for caribou during late winter (Kim Morton, Eco-Tec Environmental Services Ltd., unpublished data). As no data were available on diet throughout the remainder of the year, the Bergerud et al. hypothesis was only tested for late winter.

During the summer of 1997, *Cladina* percent cover was determined for each habitat class except upland (U). Upland habitat in the two study areas is characterized by a mixture of aspen and white spruce. Data from the literature (Beckingham and Archibald 1996) suggest that these upland areas have very little *Cladina* ground cover. Preliminary vegetation sampling supported this conclusion. As a result, habitat class U was assumed to have little *Cladina* ground cover. The following number of sites were sampled in each of the following habitat classes: 48 BT, 10 FO, 38 FT, 10 NPOW, and 10 ST sites. Sampling in FO, NPOW and ST was restricted to 10 sites each due to low variation in *Cladina* percent cover. At each site percent cover data was collected in 20 $4m^2$ plots spaced 50m apart along a transect. These 20 plots were averaged to give a single value for the site. As the data did not meet the normality assumption of the ANOVA design (despite transformation), a Kruskal-Wallis test was used to test for differences in *Cladina* abundance among habitat classes.

Feeding site data – The locations of feeding sites in Red Earth South were also used to study habitat use and selection. This was done to determine whether third-order selection, as calculated from telemetry data, mirrored the actual foraging habits of caribou. It was predicted that high forage habitats would be selected over low forage habitats for feeding. During the late winter period of 1997, feeding sites were located by backtracking caribou trails in the Red Earth South study area. To locate caribou trails, a seismic line was chosen randomly within the study area and followed on snowmobile until caribou tracks crossed the line. If the line became impassable before tracks were found, a new line within the same area was followed. Fresh caribou tracks were backtracked until a feeding site was encountered. A feeding site was defined as an aggregation of 2 or more feeding craters, with none of the craters more than 50m from the next closest crater. At the feeding site, a GPS location was taken. To increase independence of feeding site location data, the next line to be surveyed was a minimum of 1 km from where the preceding caribou trail had been found. Midway through the winter field season, it was observed that all of the feeding sites identified in Red Earth South were within 5km of a collared caribou. Methods were then altered so that only seismic lines within 5km of a collared animal were surveyed. This change was made to increase efficiency. Location data for 59 feeding sites were used to rank habitat classes based on compositional analysis of habitat use (Aebischer et al. 1993) using the habitat composition within the study area as available. Because a feeding site could not be associated with a given caribou, all sites were considered a single sample. As the sample of feeding sites represented $n = 1$, no test for significance could be completed.

RESULTS

Second-order habitat use and selection – Peatland habitat classes (BT, FO, and FT) made up a large proportion of caribou home ranges in both study areas and all seasons (Figure 3.3). Treed bog (BT) was the most common class in all cases, though

Red Earth animals had almost as much treed fen (FT) and open fen (FO) in their home ranges. Open fens (FO) were much less common in the Athabasca West study area and in Athabasca West home ranges. Despite differences in habitat distribution, upland (U) was found in similar proportions in Red Earth South and Athabasca West home ranges.

In both study areas and all seasons, habitat composition in home ranges differed from random (all $p < 0.001$). In all cases, compositional analysis ranked peatland classes above non-peatland classes (Table 3.1). Whereas analysis for Red Earth South consistently ranked treed bogs (BT), open fens (FO), and treed fens (FT) in the same order, Athabasca West results show a more variable pattern.

Save some possible switching between treed bogs (BT) and treed fens (FT) in Athabasca West, variation was low among seasons. Variation was also low among animals within the same sub-population.

Third-order habitat use and selection – Treed peatlands (BT and FT) were the most commonly used habitat classes in caribou home ranges (Figure 3.4). Treed swamps (ST) and non-peat open wetlands (NPOW) were used infrequently by both sub-populations. Red Earth animals used the open fens (FO) within their home ranges more commonly than Athabasca animals.

In both study areas and all seasons, habitat use within an animal's home range differed from random (all $p < 0.001$). For all seasons in Red Earth South and in 3 of 4 seasons in Athabasca West, treed peatlands (BT and FT) were ranked higher than all other classes (Table 3.2). Either treed swamps (ST) or non-peat open wetlands (NPOW) ranked last in all but one case.

Variation in habitat use within home ranges was much higher than variation among home ranges (Figure 3.4). Telemetry data for both areas showed a trend of greater use of treed bogs (BT) in summer than in the winter seasons. Proportional use of treed peatlands (BT and FT combined) was high in all seasons, however.

Vegetation analysis – *Cladina* availability varied among habitat classes ($\chi^2 = 46.57$, $df = 4$, $p < 0.001$). Treed bogs (BT) had the greatest abundance, followed by treed fens (FT), treed swamps (ST), open fens (FO) and non-peat open wetlands (NPOW) (Figure 3.5). Post-hoc comparison revealed that treed bogs (BT) and treed fens (FT) do not differ in *Cladina* abundance ($Q = 0.72$, $p > 0.50$).

Feeding site data – Feeding site data showed a similar pattern to the telemetry data for Red Earth South. The majority of feeding sites were located in tree bogs (BT) (36%) and treed fens (FT) (30%). The third most commonly used habitat for feeding was upland (U) (17%), followed by open fens (FO) (10%) and non-peat open wetlands (NPOW) (7%). No feeding sites were found in treed swamps (ST). Compositional analysis ranked selection of habitat classes for feeding as follows:

BT>FT>NPOW>FO>U>ST

DISCUSSION

Treed peatlands are an important component of woodland caribou habitat in northern Alberta. Treed peatland classes (BT and FT) received high use and were consistently selected over other habitat classes. Home ranges in both Athabasca West and Red Earth South contained more treed peatlands (BT and FT) than any other habitat type. Treed peatlands also contained the majority of the telemetry points and were consistently selected over other habitat classes available within an animal's home range.

Non-peat areas may not be as important a habitat class as treed and open peatlands. Non-peat wetlands (NPOW and ST) received very little use and were consistently ranked below peatland classes, though availability of these classes was low in both study areas. The only habitat class ever ranked lower than treed swamps (ST) or non-peat open wetland (NPOW) was upland (U). Selection of all other habitat classes over upland is noteworthy as upland areas comprise approximately one third of both study areas.

Some seasonal variation in habitat use and selection was seen at the individual level. In both areas, use of treed bogs (BT) was much higher in summer than in early or late winter. Seasonal change in use of treed bogs (BT) was accompanied by the opposite trend in the use of treed and open fens (FT and FO). This shift in habitat use may be due to a number of factors. Two possibilities are: 1) a change in suitable bedding sites, and 2) an avoidance of insects. During summer, when fen areas can be very wet, finding a dry place to bed down in a fen may be difficult. Drier treed bog sites may provide better habitat for bedding during summer. During winter, when all areas are frozen, fens may provide similar bedding habitat to bogs. A second possibility is that insect abundance may be lower in the drier treed bogs. If this is the case, caribou may use treed bogs in greater proportions during summer to reduce insect harassment. However, further work is required to either support or refute these ideas. One concern with these explanations is that they do not explain why caribou switch to fens in early winter. A change in foraging behaviour may partly explain this pattern. During summer, fen areas may be too wet for easy movement by caribou. In early winter, when the ground has begun to freeze, but the plants found in these areas have not yet lost their nutritional value, caribou may shift to foraging in these areas. Information on summer and early winter diet could help to explain this pattern. Regardless of differential use of treed bogs and treed fens among seasons, treed peatlands (as a combined class) remain an important component of boreal woodland caribou habitat throughout the year.

Although some differences were seen between the Red Earth and Athabasca study areas, peatland and upland distribution did not affect general habitat use and selection patterns within the peatland complex. The greatest difference in proportional use between the two areas was in the use of treed vs. open peatland. Red Earth caribou used more open habitat than Athabasca West caribou. This corresponds to a difference in the available habitat in the two areas. Red Earth South has three times as much open fen habitat (FO) as Athabasca West. The basic pattern of high use and selection for treed peatlands over other habitat classes was the same for both areas, however.

At a coarse level (home range selection), caribou behaved as expected from the Bergerud et al. (1990) hypothesis. During late winter, caribou in both areas were expected to select wetland classes over upland, thereby reducing predation risk. In both study areas, peatland classes were selected over upland habitat. In Athabasca West all wetland classes were selected over upland (U). In Red Earth South, where avoidance of upland areas is more difficult due to the fragmented nature of the landscape, compositional analysis ranked upland over non-peat-forming wetlands. Availability of treed swamps (ST) and non-peat open wetlands (NPOW) was minor, however.

Caribou behaviour also followed the Bergerud et al. (1993) predictions at a fine level (use and selection of habitat within an animal's home range). Treed peatlands (BT and FT), which were found to have the greatest *Cladina* abundance, ranked highest in third-order selection analyses for both study areas. As expected, caribou in Athabasca West did not select low *Cladina* habitat classes over uplands within their home ranges;

only high-forage treed peatlands were selected over uplands. Red Earth South animals, however, did select a low forage habitat class (FO) over uplands. This was expected as separation of home ranges from large upland patches (high predation risk) is difficult in Red Earth South.

Although the data appear to support the idea that caribou reduce predation risk at a coarse level and select habitats for foraging at a fine level, the current study does not provide as strong support for the Bergerud et al. (1990) hypothesis as may be possible. Alternative hypotheses have yet to be rejected. If predation risk is lower in treed peatland areas (though there is no evidence that this is so), caribou may select treed peatlands to avoid predation rather than to acquire resources. Alternatively, thermal and snow cover conditions may also influence use of treed peatlands by caribou. The current study was unable to address these issues. The current study also lacked strength in that an important combination of predation risk and forage availability was missing. To adequately address the trade-off between predation risk and forage availability, a habitat class with both high forage availability and the potential for high predation risk was required. Avoidance of the high risk/high forage class at a coarse level and selection for the same at a fine level would have provided stronger support for the Bergerud et al. (1990) hypothesis than the current study was able to do. Such a condition may occur for caribou in the foothills, where home ranges overlap treed peatlands and pine forests. Pine forests may provide both high forage availability and the potential for high predation risk. Future examination of the role of forage availability and predation risk on caribou habitat selection should include a study of habitat use and selection in the foothill region of Alberta.

MANAGEMENT IMPLICATIONS

To reduce caribou disturbance, industrial activity in caribou range should avoid treed peatland areas throughout the year. By avoiding treed peatlands, companies will reduce the risk of encountering caribou and will, therefore, reduce disturbance of caribou. Concentrating disturbance in non-peat wetlands should be done with caution however so as not to influence the hydrology of the peatland complex. Changes in water levels and flow patterns have the potential to affect lichen survival in treed peatlands. Utilizing upland areas within caribou range will likely result in the least amount of direct disturbance to caribou.

Table 3.1 Second-order compositional analysis of habitat use for the Red Earth South and Athabasca West subpopulations. Habitat classes are ranked from most selected to least selected. BT = Treed bog; FO = Open fen; FT = Treed fen; NPOW = Non-peat open wetland; ST = Treed swamp; U = Upland.

	Red Earth South	Athabasca West
Early winter	BT>FO>FT>NPOW>U>ST	FT>FO>>>BT>>>NPOW>ST>>>U
Late winter	BT>FO>FT>>>U>ST>NPOW	FO>>>BT>FT>>>NPOW>ST>U
Spring	BT>FO>FT>>>U>NPOW>ST	FO>BT>FT>>>ST>NPOW>U
Summer	BT>FO>FT>NPOW>U>ST	BT>FO>>>FT>ST>NPOW>U

>>> indicates significant difference between consecutive ranks

Table 3.2 Third-order compositional analysis of habitat use for the Red Earth South and Athabasca West subpopulations. Habitat classes are ranked from most selected to least selected. BT = Treed bog; FO = Open fen; FT = Treed fen; NPOW = Non-peat open wetland; ST = Treed swamp; U = Upland.

	Red Earth South	Athabasca West
Early winter	FT>BT>FO>NPOW>U>>>ST	FT>FO>>>BT>U>ST>NPOW
Late winter	BT>FT>>>FO>>>U>NPOW>ST	BT>FT>U>>>FO>>>NPOW>ST
Spring	FT>BT>FO>ST>U>NPOW	BT>FT>FO>U>ST>NPOW
Summer	BT>FT>>>FO>NPOW>ST>U	BT>>>FT>FO>U>ST>NPOW

>>> indicates significant difference between consecutive ranks

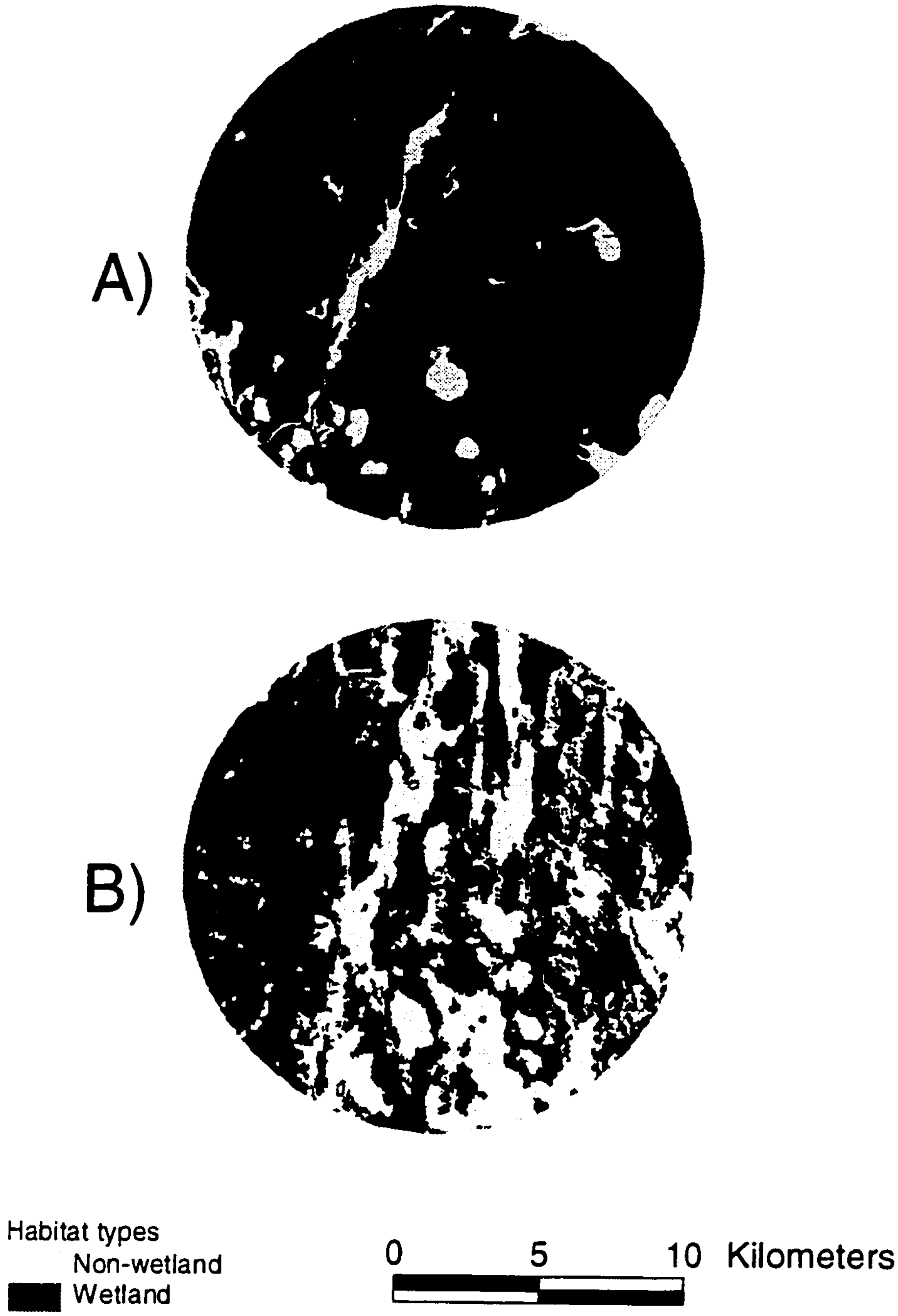


Figure 3.1 Examples of the continuous (A) and fragmented (B) habitat distributions found in the western portion of the Athabasca caribou range and the southern portion of the Red Earth caribou range respectively.

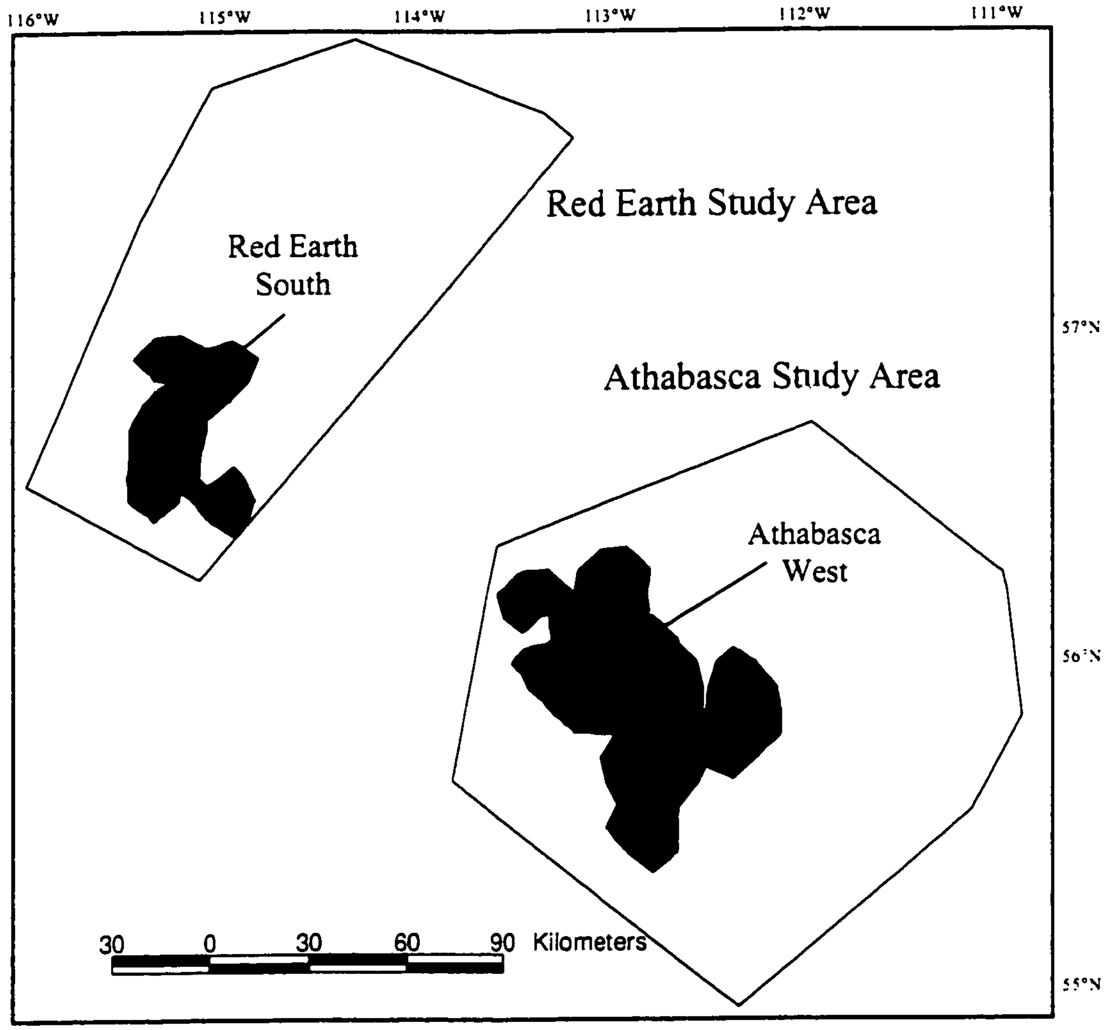
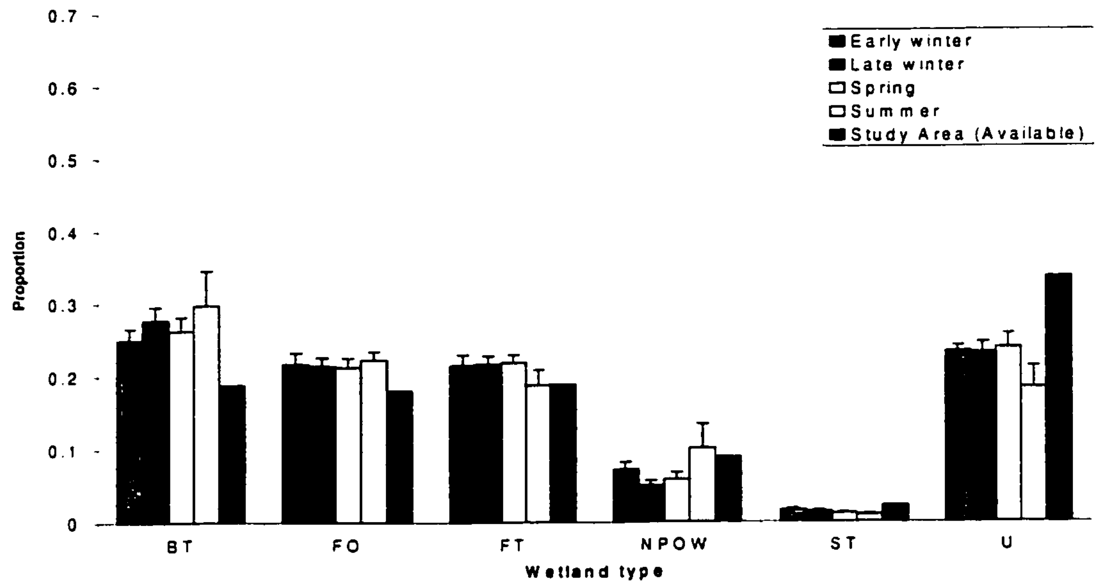


Figure 3.2 Red Earth and Athabasca study areas (solid lines) and boundaries of the two sub-populations (shaded) used in this study (see Chapter II for a description of how sub-populations were defined).

A)



B)

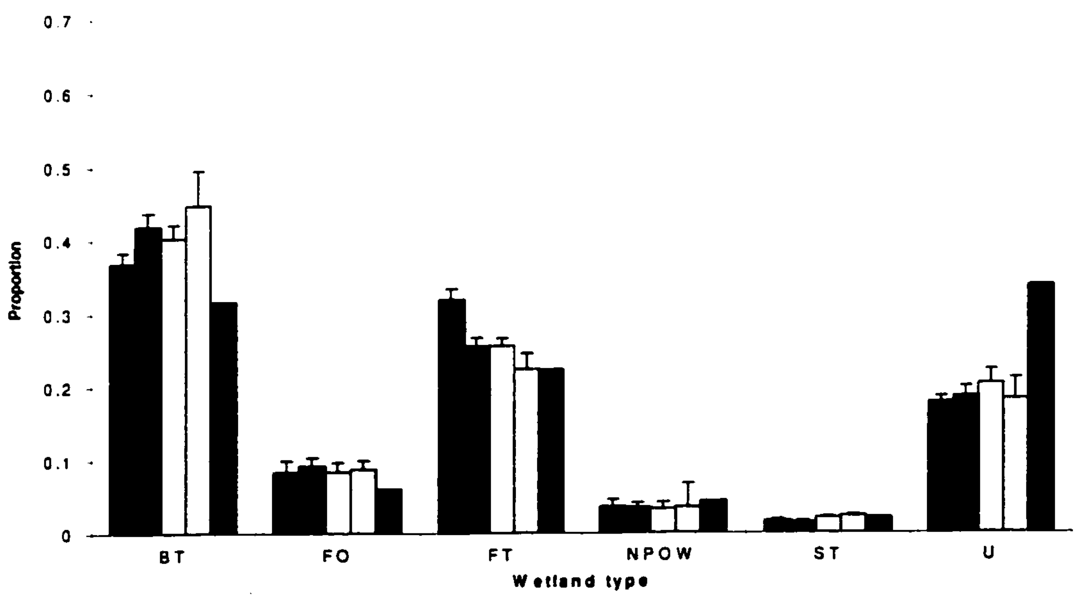
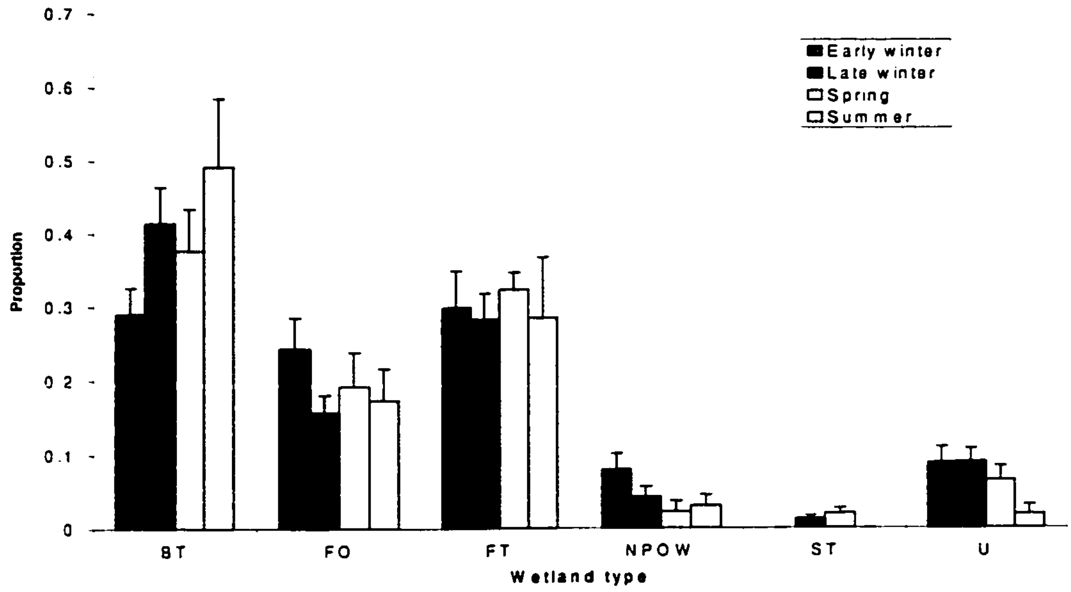


Figure 3.3 Second-order habitat use (mean home range composition + SE) and availability for the Red Earth South (A) and Athabasca West (B) subpopulations. BT = Treed bog; FO = Open fen; FT = Treed fen; NPOW = Non-peat open wetland; ST = Treed swamp; U = Upland.

A)



B)

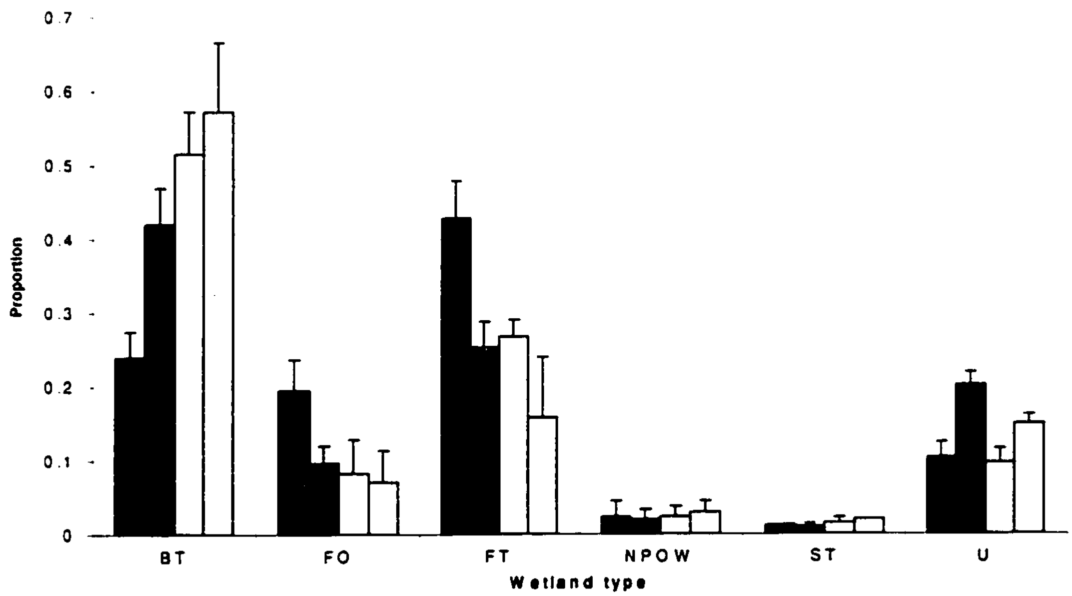


Figure 3.4 Third-order habitat use (mean composition from telemetry data + SE) for the Red Earth South (A) and Athabasca West (B) subpopulations. BT = Treed bog; FO = Open fen; FT = Treed fen; NPOW = Non-peat open wetland; ST = Treed swamp; U = Upland.

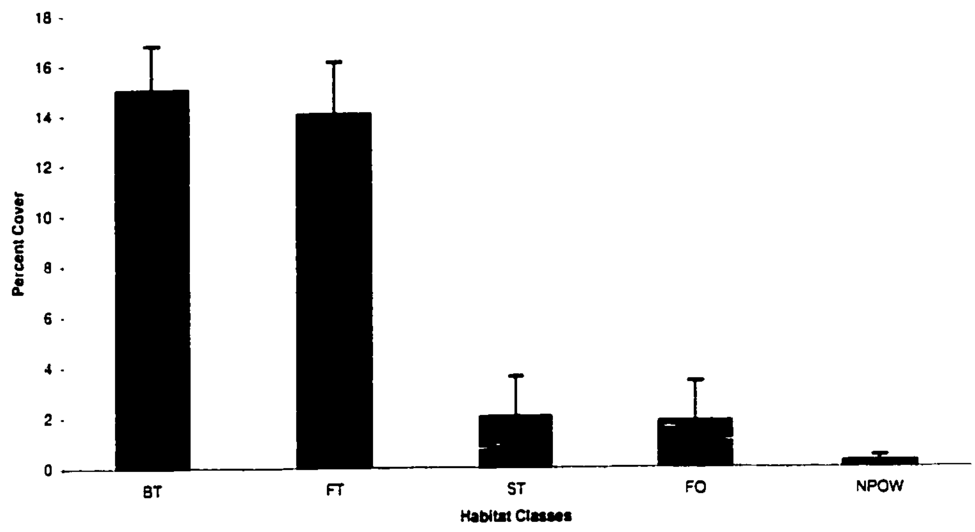


Figure 3.5 *Cladina* percent cover (+ SE) in treed bogs (BT), treed fens (FT), treed swamps (ST), open fens (FO), and non-peat open wetlands (NPOW)

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CHAPTER IV: GENERAL CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

The two-fold purpose of this thesis was to: 1) determine if Bradshaw et al.'s (1995) coarse-scale conclusions about caribou habitat are applicable to northwestern Alberta, and 2) to examine fine-scale patterns of habitat use and selection within peatland complexes. Coarse-scale analyses were conducted to determine if coarse-scale peatland inventory data could be used to map caribou habitat throughout northern Alberta. Examination of fine-scale habitat use and selection patterns was done with the objective of producing recommendations as to where industrial activity could best be placed in order to reduce impacts on Alberta's boreal woodland caribou.

Analysis of coarse-scale data revealed that boreal woodland caribou are not restricted to landscapes dominated by treed fens and bogs. Caribou in the southern portion of the Red Earth range are found in an upland-dominated landscape. As a result, using only coarse-scale peatland maps to identify caribou habitat may result in the omission of some areas used by caribou. However, coarse-scale peatland maps can be used to identify large areas of potential caribou habitat such as that found on the west side of the Athabasca River (Athabasca range) and that found in the northern portion of the Red Earth range.

Fine-scale data such as Alberta Wetland Inventory or Alberta Vegetation Inventory may provide a useful tool for identifying potential caribou habitat in upland-dominated areas. Caribou in both an upland-dominated landscape (southern portion of the Red Earth range) and a treed-peatland-dominated landscape (western portion of the Athabasca range) use treed peatlands extensively and select treed peatlands over all other habitat classes. The combination of coarse-scale and fine-scale peatland data may provide a valuable tool for verifying current caribou range boundaries. Coarse-scale peatland data can be used to identify landscapes dominated by treed peatlands. This habitat class will likely comprise the core area of a given caribou range. Fine-scale peatland inventory data can be used to identify potential caribou habitat in areas adjacent to these large peatland complexes.

Although the current study was unable to determine how factors such as predation risk and forage availability influence habitat selection decisions in caribou, there are a couple of points worth noting. First, previous work has shown that predator presence in a large peatland complex was lower than the surrounding upland area (James 1999). This may suggest that caribou use peatlands to reduce predation risk. However, it is just as plausible that caribou use peatlands in boreal regions as a source of terrestrial lichens (a major winter food source for caribou) as *Cladina* was found in relatively great abundance in treed peatland areas. Information from the literature and observations from the field show that the aspen/white spruce forests which make up most of the upland areas in the Athabasca and Red Earth study areas have very little *Cladina* ground cover. It is, therefore, plausible that caribou select peatlands as a source of forage, and not as a refuge from predation.

Due to an imperfect design, the current study was unable to rigorously test the hypothesis put forward by Bergerud et al. (1990). Future research should examine habitat use and selection in an area where caribou have access to habitat classes representing all four of the following scenarios: 1) high predation risk, high forage; 2) high predation risk, low forage; 3) low predation risk, high forage; and 4) low predation risk, low forage. Such a study design would facilitate examination of the trade-offs that caribou make in terms of selecting habitat for forage abundance and predation risk.

Habitat configuration and the relationship to population dynamics should also receive more research. Although caribou were found using treed peatlands within an upland-dominated landscape, the current study did not examine population parameters for this group of animals. If the fragmented habitat is acting as a population sink, unique management strategies may be required. Information on habitat configuration and population dynamics may also influence how cumulative effects are dealt with. As more and more habitat is functionally lost due to industrial disturbance, it is necessary to have an understanding of how fragmented an area can be before the caribou population will no longer be viable. Future research should also examine gene flow among peatland complexes. A lack of gene flow may become a distinct problem if caribou populations become isolated due to disturbance. Natural disturbance must also be examined in relation to its effects on caribou. At this point, little is known about the influence that natural disturbance has had on boreal woodland caribou. As industrial disturbance is cumulative with natural disturbance, it is very important to be able to predict how natural disturbance will affect caribou in the future.

MANAGEMENT RECOMMENDATIONS:

Any future changes to caribou range maps should be conducted using both coarse-scale and fine-scale peatland inventory data. Coarse-scale data should be used to identify large areas of treed-peatland-dominated polygons. These areas will consist of large patches of treed fens and bogs, which are an important component of boreal woodland caribou habitat. Fine-scale data should be used to aid in the placing of boundaries at the periphery of such peatland complexes. By using fine-scale data to aid in boundary placement, treed peatlands within upland-dominated polygons (such as those found in the southern portion of the Red Earth range) will be included. Any future changes to caribou range boundaries should also include consideration of local knowledge of caribou distribution.

All attempts should be made to reduce human disturbance in peatland complexes that lie within caribou range. Both open and treed peatland areas are an important component of caribou home ranges. If human disturbance can be reduced in peatland areas, the potential for conflict between humans and caribou will be reduced.

In cases where industrial activity must take place in areas of known caribou use, all attempts should be made to avoid treed peatland areas. Restricting activity to upland patches is the most desirable, followed by use of swampy and marshy areas, and finally open fen areas. Activity in treed peatland areas should be kept to a minimum if at all possible.

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