University of Alberta

Planning for woodland caribou winter habitat needs in west-central Alberta

by

Darin W. Stepaniuk ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

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Abstract

Development of planning tools for management of woodland caribou was explored in west-central Alberta.

Caribou use of the major Alberta Phase 3 Timber Inventory variables (crown closure, stand height, age, origin, species) as determined from tracks in the snow, was compared to expected use. The comparisons did not reveal patterns that could form the basis of habitat maps. Use versus expected use of stand age was contrary to prediction based on the assumed relationship between stand age and the main winter forage of these caribou, terrestrial lichens.

Investigation of terrestrial lichen abundance and snow conditions at feeding and non-feeding sites on caribou travel paths showed that feeding locations were chosen based on lichen abundance and not by snow conditions. This investigation also showed that timber stands of a variety of ages can have terrestrial lichens that caribou will use.

Reform of the legal regime governing timber harvest is also discussed.

Acknowledgments

It is with pleasure that I can now write a few lines to thank the people and organizations who made this research possible.

My greatest debt is owed to my wife Shavon. She started dating me in my previous incarnation as a well-paid lawyer and ended up married to a financially insecure graduate student. Her love and support has seen me through challenging times.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

A. RATIONALE

The continued existence of woodland caribou (*Rangifer tarandus caribou*) populations in Alberta is in doubt. Woodland caribou are designated as threatened under the Fish and Wildlife Policy for the Management of Threatened Wildlife in Alberta.[1] They are also prescribed as endangered by regulation[2] made pursuant to the *Wildlife Act*.[3] Government records indicate that Alberta's herd has significantly declined from perhaps 8000 plus animals in 1890 (Edmonds 1986) to as few as 3600 animals[4] (Alberta Woodland Caribou Conservation Strategy Development Committee 1996).

The portion of Alberta's population that is the focus of this thesis, the so-called mountain caribou, lives a migratory existence spending their summers in the mountains and winters in the adjacent foothills in west-central Alberta. These animals represent 400-500 of Alberta's herd (Alberta Woodland Caribou Conservation Strategy Development Committee 1996). It has been speculated that these are the last of a unique ecotype in Alberta and that remnant herds living year-round in the mountains of southern Jasper National Park, northern Banff National Park, Siffleur Wilderness, and White Goat Wilderness, have abandoned such migrations as a result of human activity in the foothills to the east (Edmonds and Bloomfield 1984 : 82-85).

The cause of the decline of caribou in Alberta and even its existence is in dispute. Bradshaw and Hebert (1996) review the possible causes of decline, natural and human, and the information behind the numbers, concluding that it is possible that no decline has occurred. Low population densities may simply space caribou away from predators and reduce predation risk.

Whether present caribou densities in the Province are the result of a mysterious decline or a natural adaptation to predation, their low numbers certainly warrant careful management and the development of planning tools.

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[1]The Policy assigns all indigenous wildlife populations in Alberta to 1 of 6 categories depending on information on their status and their vulnerability to disappearing in Alberta. The policy also provides that populations in the 3 most vulnerable categories be designated as "endangered" under the *Wildlife Act*.
[2]See s. 1(2) of the *General Wildlife Regulation*, Alta. Reg. 50/87 as am.
[3]S.A. 1991, c. W-9.1. For a discussion of the way endangered species are dealt with under the Act see Chapter 5.
[4]Edmond's 1986 estimate of 1890 caribou numbers may not be comparable to the 1996 estimate of present numbers. Since 1986, estimates of present caribou numbers in the Province have been revised upwards because of improved censusing techniques.

Careful caribou management is complicated by the fact that large-scale timber harvest occurs on their range. Timber harvest in Alberta has also intensified in recent years. In 1980/81, 5.4 million m^3 of wood was harvested (Alberta 1983) as compared to 15.1 million m^3 in 1994/95 (Alberta 1996). Logging has been identified as one of the possible causes for woodland caribou declines but logging's role, if any, is poorly understood (Bergerud 1974, Edmonds 1991, Cumming 1992). What is clear is that intensive forest harvest can conflict with managing forests to maintain caribou needs as they are currently known (Racey *et al.* 1991, Stevenson *et al.* 1991, Cumming 1992). In particular, caribou in Alberta depend heavily on terrestrial lichens as food in the winter and these are associated with timber stands greater than 75 years of age (Edmonds and Bloomfield 1984 : 7). To address this conflict, forest and wildlife managers need to be able to predict how timber harvest will affect these animals in the future with a view to avoiding or minimizing timber harvesting regimes that will cause population declines or extirpation from loss of habitat, increased natural predation, increased human caused mortality, or other causes. At the least, the ability to predict effects with different harvesting regimes improves informed decision making. It is important to note that accurate predictions are critical because a timber harvest regime is essentially irreversible; 75 year-old trees cannot be grown overnight.

Scientific research into caribou needs does not offer a complete solution to the development of planning tools. The legal framework governing timber harvest certainly affects the way caribou research is applied. Reform of this regulatory framework has the potential of being extremely beneficial to woodland caribou and other wildlife species.

B. RESEARCH OBJECTIVES

The objective of the thesis research is to further the development of planning tools that can be used in managing Alberta's woodland caribou by specifically addressing the following:

1) evaluation of the use of Alberta Phase 3 Timber Inventory in planning for woodland caribou winter habitat needs;

2) examination of the role terrestrial lichen abundance and snow cover play in caribou winter feeding site selection; and,

3) reform of the regulatory framework surrounding timber harvest to protect wildlife.

Objectives 1 and 2 were approached by gathering data on the ground from caribou tracks. Objective 3 was explored through research of the existing legal framework surrounding timber harvest to arrive at suggestions for improvement.

C. RELATIONSHIP TO OTHER CARIBOU RESEARCH IN WESTERN CANADA

The thesis research complements ongoing research initiatives in western Canada addressing integration of woodland caribou needs into forest harvest planning.

In Alberta the Foothills Model Forest, in addition to supporting the thesis research presented here, has supported an as yet unpublished radio-telemetry helicopter relocation study to monitor caribou response to timber harvest in west-central Alberta using 20-25 radio-collared animals (Smith and Edmonds 1993). It has also supported a study on the effect of forest harvesting on terrestrial lichen availability (Kranrod 1996).

A northern Alberta coordinated woodland caribou research program has resulted from the joining of the Province's Northeast and Northwest Regional Standing Committees on Woodland Caribou (NERSC and NWRSC) in 1996. The program seeks to understand population dynamics, predator-prey interactions, habitat use, and the effect(s) of industrial activity on woodland caribou in northern Alberta (NERSC 1996). Some of the research sponsored by the predecessor committees has been published (see Bradshaw 1994; Bradshaw *et al.* 1995; Bradshaw and Hebert 1996; Bradshaw *et al.* 1997; Stuart-Smith *et al.* 1996; Stuart-Smith *et al.* 1997) but much of it is ongoing.

Forest companies in Alberta, in addition to supporting the research of the Foothills Model Forest and the Northern Alberta Coordinated Woodland Research Program, have their own research programs. Brown (1996) lists research initiatives undertaken by these companies within the past 5 years as follows[5]: Alberta Newsprint Company - HSI model designed to predict the occurrence of lichen on the basis of forest cover and soils; Alberta Pacific Forest Industries - distribution and seasonal movements, including habitat preference and use of recently disturbed sites based on an intensive radio-telemetry program involving 127 collared animals to date; Daishowa-Marubeni International Ltd. - radio-telemetry studies to determine caribou distribution and movements; and Weyerhaeuser Canada Ltd. - detailed habitat assessment and caribou distribution surveys on selected winter ranges.

The Mountain Caribou in Managed Forests (MCMF) program was initiated in British Columbia in 1988 to address the question: can forest stands be managed, through silvicultural systems and habitat management techniques to provide both timber and caribou habitat? (Stevenson *et. al* 1994). This program addresses the specific needs of an ecotype of woodland caribou in British Columbia which relies heavily on arboreal lichens as a winter food source because of snow depths. However, this research may have relevance to Alberta's herd in winters or portions of winters with difficult snow conditions. The program has offered preliminary recommendations for managers and it is expected that those will be refined over the next 5 to 10 years (Stevenson *et. al* 1994).

[5]These initiatives appear to be independent of those of those already described. Brown's paper gives a complete list of forest company initiatives including those involving cooperation with other agencies.

A study to assess critical habitats of woodland caribou in northern Saskatchewan's commercial forests is expected to be completed in 1997 (Rettie and Messier 1993; Rettie 1997). The Canadian Wildlife Service undertook a complementary study specifically addressing the potential effects of logging on woodland caribou in Saskatchewan and 2 progress reports are available (Thomas and Armbruster 1995 and 1996).

The Manitoba Model Forest initiated the Integrated Forestry/Woodland Caribou Management Strategy Project in 1994. A report containing interim strategies is available (Manitoba Model Forest Inc. 1995).

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CHAPTER 2

STUDY AREA AND POPULATION

A. STUDY AREA

The field portion of the thesis research was conducted within the boundaries of the Foothills Model Forest radio-telemetry caribou relocation study (Figure 1). The radio-telemetry study was designed to monitor caribou habitat use and distribution response to timber harvest using 20-25 radio-collared animals (Smith and Edmonds 1993).

The study area is outside the Foothills Model Forest in the Redrock/ Chicken/ Prairie Creeks area in Townships 59-62, Ranges 8-12, west of the 6th meridian. It is located within a Weyerhaeuser Canada Ltd. forest management area (FMA) (Figure 2). The nearest settlement to the study area is Grande Cache, Alberta.

As shown in Figure 1, Smith and Edmonds divided the overall study area into 2 portions or blocks, a portion containing some logged clear-cuts of varying ages, and a portion in which no logging has taken place. The thesis research, because of study design considerations (Chapter 3), only uses selected townships in each of these 2 blocks (hereafter, "**available habitat**").

Logging in the available habitat began in 1981, presumably in accordance with Provincial standards[6]. The 1989 Ground Rules (Forestry, Lands and Wildlife 1989) for the FMA stipulate a basic cutting system of alternate patch clear-cutting with residual patches of merchantable timber between clear-cuts to be harvested at a later date. The Ground Rules have specific provisions that refer to ongoing and future development of strategies to address access management, cutblock design and harvest timing on caribou winter range (pp. 25-26). Hervieux *et al.* (1996) provides a history of the development of these strategies. In the available habitat, as at April 1995, there were 42 clear-cuts ranging in size from 1-166 ha (mean 32 ha) having a total area of 1358 ha all within the logged portion of the study area. This is approximately 3% of the logged portion of available habitat. These clear-cuts range in origin from 1981-1991 (mean 1987.5). If figures provided for the majority of the logged portion of the study area are typical, then, by area, 44.1% of the clear-cuts were summer harvested and 34.8% were scarified (Weyerhaeuser Canada Ltd. 1997).

The study area is in the foothills of the Rocky Mountains with topography dominated by major ridges running northwest - southeast bisected by many small drainages flowing into larger rivers having headwaters in the mountainous regions of Wilmore Wilderness Park and Jasper National Park.

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[6]Chapter 5 of this thesis presents some suggestions for reform of forestry law in Alberta. For the reader unfamiliar with the basics of forestry law, this chapter would also serve as an introduction to the area.

Two major ecoregions occur in the study area: upper boreal cordilleran and subalpine (Corns and Annas 1986). The upper boreal cordilleran ecoregion is characterized by elevations of 900 to 1500 m, rolling topography with deep valleys, Continental and Cordilleran origin geology, with forest communities dominated by lodgepole pine (*Pinus contorta*) with varying intermixtures of white and black spruce (*Picea glauca* and *mariana*) and lesser amounts of aspen (*Populus tremuloides*) (especially at lower elevations, along river valleys, and on south exposures), balsam poplar (*Populus balsamifera*) and balsam fir (*Abies balsamea*). The subalpine ecoregion is characterized by elevations of 1300 to 2000 m, rolling topography with steep slopes, uplifted Mesozoic shale and sandstone geology, with characteristic trees including lodgepole pine, white spruce/Engelmann spruce (*Picea engelmannii*) hybrids, fir, and black spruce. Aspen and balsam poplar may occur on south facing exposures.

The study area contains a diversity of large mammals in addition to caribou including: moose (*Alces alces*), wapiti (*Cervus elaphus*), mule deer (*Odoicoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), bighorn sheep (*Ovis canadensis*), mountain goat (*Oreamnos americanus*), grizzly bear (*Ursus arctos*), black bear (*Ursus americanus*), gray wolf (*Canis lupus*), cougar (*Felis concolor*), and coyote (*Canis latrans*).

B. CARIBOU POPULATION IN THE STUDY AREA

The estimated 3600 - 6700 woodland caribou in Alberta (Alberta Woodland Caribou Conservation Strategy Development Committee 1996) have been divided into 2 ecotypes: a migratory population of 400 - 500 (Alberta Woodland Caribou Conservation Strategy Development Committee 1996) spending their summers in the mountains and winters in the adjacent foothills in west-central Alberta (the "mountain caribou"); and, a more sedentary forest-dwelling population which is found in west-central Alberta and elsewhere in the boreal forest of Alberta (Edmonds and Bloomfield 1984).

The caribou studied in the thesis research are mountain caribou. The study area is located on 2 of the 3 winter ranges that have been identified for these animals (Hervieux *et al.* 1996).

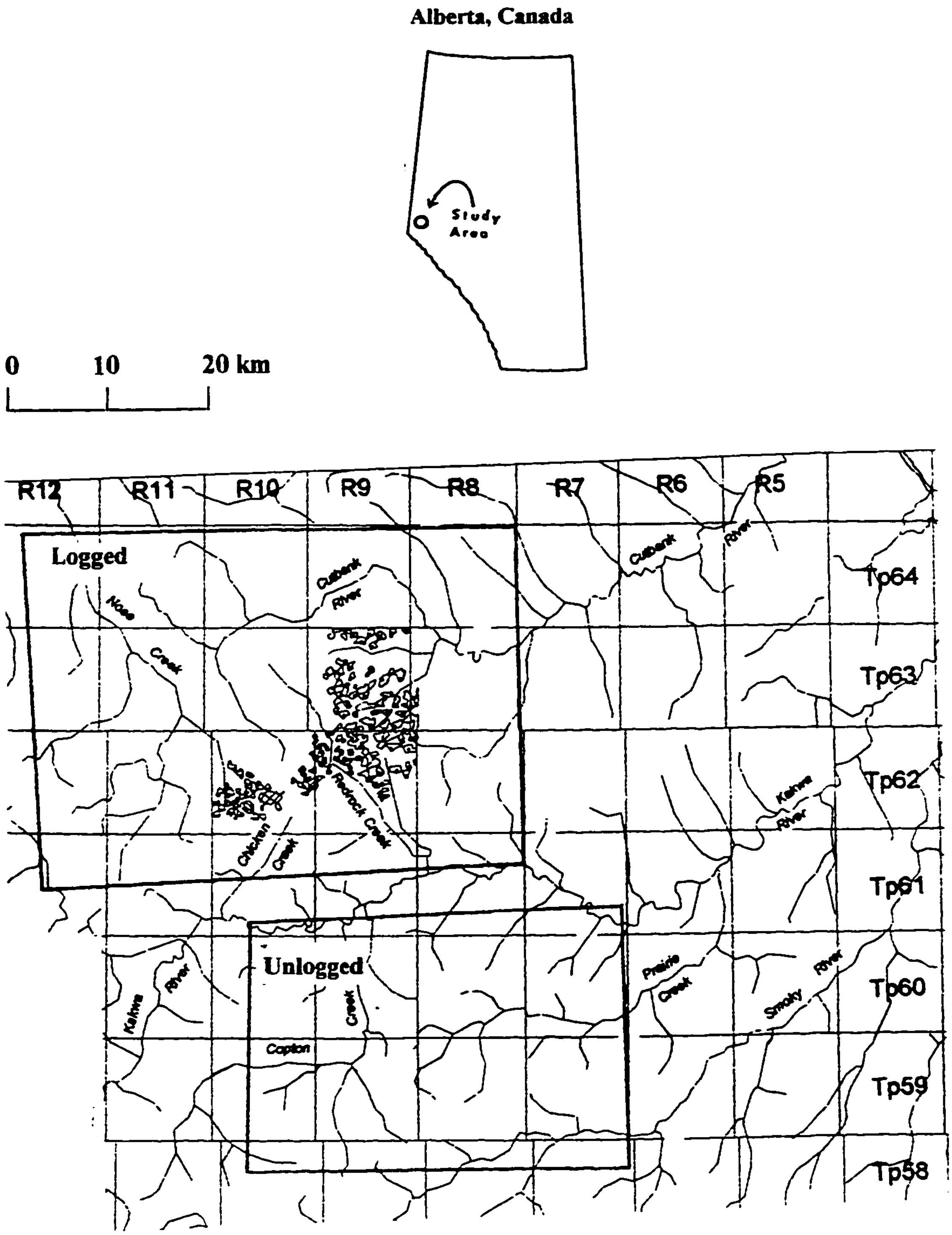

Figure 1. Study area.[7]

[7] Adapted from unpublished February 13, 1996 report prepared by Kirby Smith , Alberta Environmental Protection, Natural Resource Division, Edson, AB. Polygons in townships in "Logged" block are clear-cuts. All clear-cuts are not shown (in particular those in township 62 range 8) because the Weyerhaeuser supplied digital timber inventory upon which the map is based was not complete.

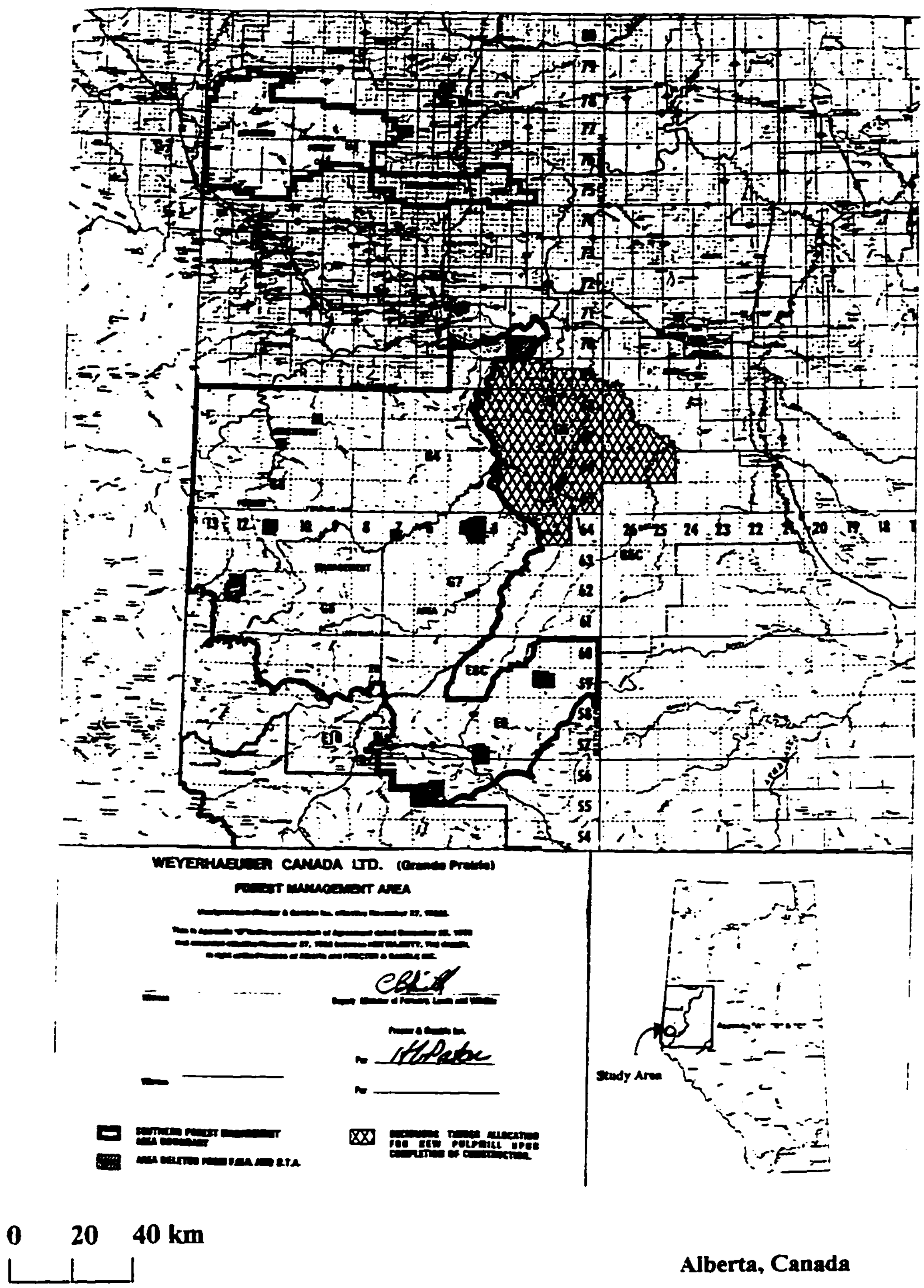

Figure 2. Weyerhaeuser Canada Ltd. forest management area.[8]

[8]Adapted from appendix in December 22, 1988 Forest Management Agreement between Her Majesty the Queen and Proctor and Gamble Inc., assigned in favour of Weyerhaeuser Canada Ltd. on November 27. 1992.

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CHAPTER 3

EVALUATION OF USE OF TIMBER INVENTORY (ALBERTA PHASE 3) IN PLANNING FOR WOODLAND CARIBOU WINTER HABITAT NEEDS

A. INTRODUCTION

The primary objective of this portion of the thesis was to investigate the relationship between caribou use and timber inventory variables on traditional winter range of migratory woodland caribou (*Rangifer tarandus caribou*) in west-central Alberta.

In west-central Alberta, the Province inventorys timber for harvest planning using its Phase 3 system. In Phase 3, productive timber stands are primarily characterized by crown or canopy closure (4 classes), stand height (6 classes), stand origin (10 year origin or birth classes), and species composition. Non-productive stands are simply given 1 of several descriptors. For example, tm is treed muskeg.

If there are strong relationships between the occurence of caribou and the presence or absence of Phase 3 Inventory variables, then Phase 3 may be used to map good and bad caribou habitat in the study area. Maintenance or creation of good caribou habitat could also be incorporated into timber harvest plans for the study area. There would also be the potential to perform this exercise for woodland caribou elsewhere in Alberta because all of the Province's forests are covered by Phase 3.

Although caribou depend on their habitat to meet needs other than food requirements (see Manitoba Model Forest Inc. 1995 for a review of these needs), the primary focus here is on lichens as food in the winter. The prediction before investigation was that Phase 3 variables would largely only be meaningful to caribou to the extent that they were correlated with lichen abundance. However, it is important to note that the view that caribou select habitats in the fall and winter primarily on the basis of food is being questioned (Bergerud 1996).

Previous work has shown that the winter diet of caribou of west central Alberta averages 66% terrestrial lichens (Edmonds and Bloomfield 1984 : 8). Caribou that feed on terrestrial lichens in the winter prefer *Cladina* spp. (Russell and Martell 1984; Schafer and Pruitt 1991; Edmonds 1991; Thomas 1994). In the natural boreal forest, it is generally acknowledged that fire governs successional processes (Heinselman 1981). Fire consumes terrestrial lichen mats (Rouse 1976). Studies on lichen regeneration and succession following fire generally show that peak *Cladina* spp. abundance is achieved 50-100 years post-fire and that this represents a successionally mature stage in some boreal forest community types (Viereck 1973; Johnson 1981; Snyder 1987 : 34; Morneau and Payette 1988). Edmonds and Bloomfield (1984 : 7) found good terrestrial lichen abundance in west-central Alberta in timber stands greater than 75 years of age.

Although arboreal lichens only constitute a small proportion of the usual winter diet of caribou in west-central Alberta (Edmonds and Bloomfield 1984: 8), available arboreal lichens may be critical as a food source when snow depth or snow hardness (especially during thaw/freeze cycles in the spring) exceeds some threshold (Edmonds and Bloomfield 1984: 120; Snyder 1987: 35). Edmonds and Bloomfield (1984 : 124) state that substantial quantities of arboreal lichens are not produced in west-central Alberta in stands less than 80 years of age. Armleder and Stevenson (1984) state that arboreal lichens do not become abundant enough in British Columbia to be a significant forage source for caribou until a stand is 100-150 years old.

Bjorge (1984), working in a portion of the present study area, reports preliminary results based on 2 winters of aerial relocation data that caribou avoid timber stands less than 82 years of age and preferred stands 122-141 years old and greater than 161 years old. Snyder (1987) points out that Bjorge's preference results for older stands cannot be completely explained by use for arboreal lichen feeding given Edmonds and Bloomfield (1984) findings on the lack of arboreal lichens in the winter diet. She suggests that snow conditions in the older stands may make them more attractive for cratering for terrestrial lichens as compared to younger stands with larger lichen quantities but less favourable snow conditions.

Cladina spp. are associated with conifer stands (see descriptions of ecoregion communities in Corns and Annas 1986) and seem to prefer an open canopy (Vitt *et al.* 1988 : 209-210). Arboreal lichens commonly used by caribou, *Bryoria* spp. and *Alectoria sarmentosa* (Stevenson *et al.* 1991 but see Rominger *et al.* 1996 on *A. sarmentosa*) are also associated with conifer stands (Vitt *et al.* 1988 : 249-251). Edmonds and Bloomfield (1984 : 6) found that the most commonly used winter habitat for caribou in west central Alberta was pine and pine/spruce forests on flat terrain or on gentle to moderate slopes having SE, S, SW, or W exposures. However, these workers did not compare use with availability and this finding may simply be the result of the predominance of this habitat category.

Clear-cutting detrimentally affects terrestrial lichens. The machinery used in modern timber harvest mechanically destroys lichen mats (Helle *et al.* 1983). Residue from tree felling also kills terrestrial lichens (Helle *et al.* 1983). The damage is exacerbated with summer logging and scarification but even conventional winter logging can reduce terrestrial lichen abundance by up to 50 % (Armleder and Stevenson 1994; but see Kranrod 1996, in 2 of 3 stands sampled very little reduction in abundance in *Cladina mitis* and *C. rangiferina* with winter logging as long as no scarification).[9] Micro-climate changes that occur with timber harvest may also detrimentally affect the growth rates of lichen remaining after logging (Eriksson 1975; but see Helle *et al.* 1983 - no change in

[9]Weyerhaeuser Canada Ltd. supplied information on February 7, 1997, which indicates that 44.1% (by area) of the clear-cuts in the study area were summer harvested and 34.8% were scarified, see Chapter 2.

growth rate in 2 *Cladina* spp. in Finland and Harris 1992 - no die-offs of residual lichens in northern Ontario). Recovery of terrestrial lichen biomass following modern timber harvest has been little investigated and it is unclear whether recovery will be similar to that post-fire.[10] Given that the clear-cuts in the present study were relatively recent (created between 1981 and 1993), it was assumed that they would represent poor habitat because of low terrestrial lichen availability.

Clear-cuts, even if they contain adequate terrestrial lichen biomass of the type preferred by caribou, may be poor winter caribou habitat for other reasons. Wind speed may be 80 % higher in clear-cut areas as compared to adjacent forest (Eriksson 1975, synthesizing other studies) possibly creating difficult snow conditions for caribou to feed and travel and the density of early regenerated stands may make them unsuitable for predator avoidance (Harris 1992 : 17).

Given the above information, the prediction prior to investigation was that the analysis of the relationship between caribou and Phase 3 stand origin would generate some useful results. It was also predicted that caribou would prefer conifer stands, and perhaps open canopies and avoid clear-cuts.

In west central Alberta, caribou distribution and habitat selection prior to timber harvest was studied for 8 years. In the winter of 1993-94, following logging on the northern half of the range, the Foothills Model Forest implemented a radio-telemetry helicopter relocation study to monitor caribou response to timber harvest using 20-25 radio-collared animals (Smith and Edmonds 1993).

The thesis research was developed to complement the Smith and Edmonds study and provide information about caribou habitat use based on activity observed on the ground.

B. METHODS

Identification of Phase 3 Timber Inventory variables potentially important to caribou was accomplished by identifying **preferred** and **avoided** variables. Preferred variables are those used in proportion significantly greater than their occurrence in the environment with avoided variables being the converse (White and Garrot 1990 : 186). In other words, are caribou using Phase 3 variables in the same proportions as they occur in the environment as one would expect if they were wandering randomly? If not, then that is some evidence that caribou are seeking out or avoiding the variable or something associated with the variable (like lichens) for survival reasons. It is only some evidence because preference and avoidance are the result of statistical analysis. Statistical preference for one of a set of habitat variables increases the liklihood that another variable in the set will be avoided. Tests of preferred habitats do not show that a habitat is critical to reproduction and survivial. At most, strong preferences provide a basis for inferring that the habitat benefits fitness (White and Garrot 1990: 198-200).

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[10]Some work has been done in this regard, see for example Abrams and Dickman 1981; Brumelis and Carleton 1989; Harris 1992; Nieppola 1992; Snyder 1987; Snyder and Woodard 1992; and, Woodard 1995.

Analysis of caribou use versus availability of each of the basic Phase 3 variables was performed. For example, which of the 4 crown closure classes did caribou prefer and avoid ? Because combinations of Phase 3 variables might be better predictors of lichen availability, combinations of Phase 3 variables were also analyzed. For example, which combinations of crown closure and height did caribou prefer and avoid ? For the same reason, the analysis was performed for Phase 3 variables combined with aspect.

Stratification of the data by portion of overall study area (logged and non-logged, see Chapter 2) and by winter of data collection allowed qualitative comparisons of the preference/avoidance analysis between these data sub-sets.

1. Winter Field Techniques

Habitat use data based on caribou tracks was gathered over 2 winters. Winter 1 data collection was completed during 48 days in the field (excluding travel) between January 26 and April 15, 1994. Winter 2 data collection was completed during 58 days in the field between January 14 and April 15, 1995. In each winter, approximately equal time was spent in the 2 study area blocks or portions (generally, consecutive weeks spent in each followed by a week's rest).

Data collection employed backtracking. The most recent locations of the radio-collared caribou from the Foothills Model Forest aerial relocation study (relocated weekly) were used as starting places for searches for fresh caribou tracks in the snow. Once found, the fresh tracks were followed opposite to the direction of caribou travel until weather, time of day, fatigue, or track conditions brought tracking to a halt. Backtracking avoids influencing the behaviour of animals. However, forward tracking was occasionally used where it was certain that the animals were no longer in the vicinity. This happened in several cases where tracks were backtracked one day then forward tracked the next from the previous day's start. Fresh tracks are necessary to ensure, to the extent possible, the following: avoiding the use of another ungulate species tracks, which is especially problematic in areas where moose and caribou tracks intersect; using a specific group of caribou tracks during a trailing episode as predicated by the study design; and maximizing the information about activities available from the tracks. "Fresh" in this context means estimated to be 2 days old or less.

Several sources assisted in ensuring that only caribou tracks were used in data collection. The tracks of caribou are distinctive (Burt & Grossenheider 1964 : 217) but can be confused with those of moose in some snow conditions. Fortunately, caribou winter fecal pellets which accompany tracks are easily distinguished by their size, shape, and colour from those of moose (Stelfox 1993 : 7). An understanding of the types of activities caribou engage in and what they may look like in the snow was obtained from Edmonds and Bloomfield (1984). Hair left on the snow as animals brushed vegetation also proved instructive. Moose tend to leave long (up to 7 cm +) very dark brown /near black, coarse hair in the snow whereas caribou seem to leave less hair which is shorter, finer and light brown coloured, white or grey. If there was any doubt as to whether a set of tracks belonged to caribou, they were not used in the study.

Every effort was made to use as many aerial relocations as possible as starting places for track searches. However, any location more than 2 kilometers from snowmobile access was, given the constraints of snowshoe travel in rough terrain and daylight, practically unreachable. Chance observations of caribou provided additional backtracking opportunities on several occasions.

A record was kept of caribou activities as evidenced from the tracks. An estimate of group size was made based on the number of tracks observed. These estimates are difficult to make because of the tendency for a group to use each others tracks (Edmonds and Bloomfield 1984 : 122, observed that caribou use the same trails many times). This information would be used later in developing measures of habitat use.

The path taken during a tracking episode was marked with surveying ribbon approximately every 20 m to assist in mapping the lines later. The starting location was recorded with a Trimble Scout 1 hand-held global positioning system ("GPS") to assist in returning to the path in the summer for mapping purposes. Detailed mapping methods are discussed under sub-heading 4 below. The starting location, a finishing location, and locations in between representing locations where there was a change in activity or obvious change in timber cover were given numbered flags.

Fifty-nine[11] caribou track travel paths were surveyed using these methods over both winters with a total length of 69 020 m.[12] The mean length was 1 170 m (range 49 m to 2 763 m). The number of track paths by winter and portion of study area was 27 v. 32, winter 1 v. 2; 31 v. 28, non-logged v. logged; 13 v.18, non-logged-winter 1 v. non-logged-winter 2; and 14 v. 14, logged-winter 1 v. logged-winter 2.

2. Animal Activities

The activities interpreted from tracks were travel, bedding, feeding by cratering through the snow, feeding on arboreal lichens, feeding in snow well, feeding on exposed ground, use of mineral lick[13] and tree thrashing (rubbing trunks and branches with antlers). The numbers of beds, feeding craters, etc., were recorded. Most of the activity types relate to a point location. For example 3 beds might be recorded at a site marked as flag number 6 along a track travel path. The activity "travel" is different in that it represents the absence of any of the other activities and is measured in terms of distance between 2 point locations.

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[11]Sixty-seven track travel paths were mapped but some of these were a continuation of a previous day's backtracking.
[12]This length would have been slightly larger but for the events described in footnotes 16 and 18 *infra*.
[13]This activity might have also simply been use of surface water.

Feeding craters were divided into 4 categories: small, < 2 m diameter; medium, 2-5 m diameter; large, >5 m diameter: and large crater complex, many craters over a large area.[14] These categories depend on the observer's judgment, for example 2 small craters with well trampled snow between might be classified as 1 medium crater by a different observer. Nonetheless, the categories assist in measuring intensity of cratering activity. Although every feeding crater might have been assigned a numbered flag, this was not done as it would have restricted the amount of backtracking that could be accomplished in a day. In many cases only a record of the number of craters between 2 numbered flags was recorded.

To illustrate the backtracking process Figure 3 shows a typical caribou track travel line overlaid on Phase 3 timber stand polygons. Figure 3 also shows reasons for placement of numbered flags during that backtracking episode. Table 1 shows the activities recorded during this backtracking episode.

Table 1. Caribou activities recorded on track travel path line 45.

Flag #	Activity	Remarks
123a	large crater	
124a	3 small craters	
125a	travel	3 small and 1 medium craters between 124a and 125a in same stand as 124a
126a	travel	1 medium crater between 125a and 126a in same stand as 125a
127a	travel	
128a	use of mineral lick	too many tracks including moose at lick to continue

[14]These categories were not used during the very first tracking episode, line 20, flags 1 -10. For the purpose of analysis the craters encountered then have been assigned to the "small" category.

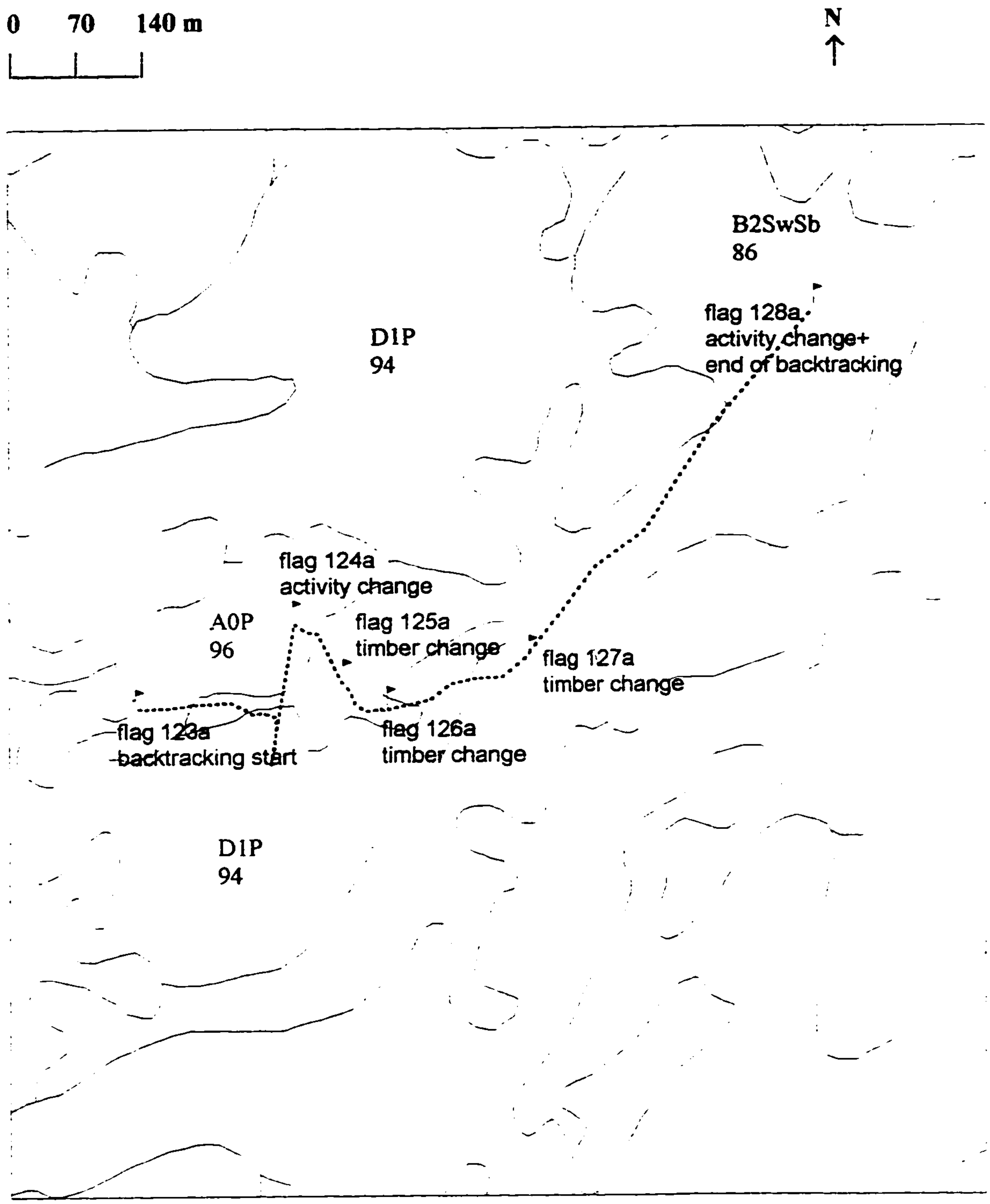

Figure 3. Caribou track travel path line 45.[15]

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[15]Caribou track travel paths (numbered as lines during mapping) were numbered for identification based on the order in which their starting location was recorded in June 1995 rather than on the date backtracking took place. For example, the first backtracking episode, flags 1-10, is line 20. Flag numbers with an "a" subscript indicate that the backtracking took place during the 2nd winter. See pp. 19-20 and Table 2 for forest stand description codes.

3. Measures of Habitat Use

Three measures of habitat use were employed: 1) distance traveled in m, 2) feeding craters per km, and, 3) feeding craters per km per caribou. Habitat measures based on other caribou activities were not used because these activities were not observed during backtracking frequently enough to make analysis meaningful.

Feeding craters per km tallies for each habitat category were calculated using the following formula: 1 small crater = 1; 1 medium crater = 2; 1 large crater = 3; and 1 cratering complex = 12. In many cases, the field record of the numbers of each crater size category only showed the number of craters between 2 numbered flags along the travel path irrespective of the number of timber stands crossed. In those cases, the total number of craters between flags were arbitrarily assigned to each timber stand crossed on the basis of the distance traveled through a stand (greater distance means greater share of the craters). During the second winter, a record was sometimes kept showing that x craters between 2 flags were found in a certain habitat rather than another. However, the winter field record of habitat types entered was restricted to a brief description of species and an estimate of height class and canopy closure.

The final measure of habitat use employed in this study is number of feeding craters per km traveled per caribou. It is the second measure of use adjusted for the estimated caribou group size backtracked.

3. Habitat Categories

(a) Alberta Phase 3 Timber Inventory Specifications

The Phase 3 inventory of Alberta's forests began in the early 1970s and was completed in 1984 (Alberta Forestry Lands & Wildlife 1988). Its main objectives are as follows: to appraise forest resources on the basis of providing a reliable and current data base for the development of forest management plans; to calculate annual allowable cuts; and to identify and schedule timber stands for harvesting (Alberta Forestry Lands & Wildlife 1988). The following is a summary based on the specification report (Alberta Forestry Lands & Wildlife 1988). Phase 3 makes a basic distinction prior to harvest between productive forest and non-productive forest land based on the capability of producing a certain yield of wood within 120 years. Productive forest stands are described by a set of variables. Non-productive stands are simply given 1 of several descriptor designations.

The Phase 3 productive forest land variables used in the creation of habitat categories in this study are crown closure, stand height, stand origin, and tree species composition.

Crown closure is the percentage of ground area covered by the tree canopy of a stand as viewed from above. The crown closure classes are A, 6-30 %; B, 31-50 %; C, 51-70 %; and D, 71-100%.

Stand height is the average height of dominant and codominant trees in a stand. The classes are 0, 0-6m: 1, 6.1-12m: 2, 12.1-18m: 3, 18.1-24m: 4, 24.1-30m; and 5, 30.1m and greater.

Stand origin describes the average dominant or codominant tree's "birth year". In Phase 3, stand origins are recorded as 10 year classes. For example, a designation of 83 describes a stand origin within the years 1830 to 1839.

Species composition is described with up to 4 species descriptors, depending on their percentage of stand content. Up to 3 species, each comprising at least 20 % of the stand content, and no more than 1 species constituting 11-20 % of stand content can be recorded. Any species comprising less than 10 % of a stand is grouped with similar species in the stand increasing its percentage and possibly, rank. The actual percentages are not recorded in the inventory beyond what can be inferred from the position a species is recorded. In digital form, there are 4 species columns for a stand, s1, s2, s3 and s4. S1 will have a descriptor and the other positions may or may not depending on stand composition. The s1-s3 positions are equal in terms of percentages, at least 20 % of stand composition. The s4 position records a species only comprising 11-20 %. Some of the important species descriptors are set out in Table 2.

Non-productive forest land descriptors used in Phase 3 that are used in habitat categories in this study and their digital form abbreviations are set out in Table 3.

The designation cc refers to an area of clear-cut timber harvest before regeneration. Clear-cuts are dealt with differently. They are not the same as non-productive lands in that they have the potential to produce wood of the volume required for productive forest land. Additionally, unlike non-productive lands, they are also given an origin designation.

Table 2. Important Alberta Phase 3 Timber Inventory tree species.

Scientific name	Common name	Phase 3 species code
Picea glauca	white spruce	Sw
Picea mariana	black spruce	Sb
Pinus contorta var. *latifolia*	lodgepole pine	P
Abies balsamea	balsam fir	Fb
Pseudotsuga menziesii	Douglas fir	Fd
Larix sp.	tamarack, western and alpine larch	Lt
Populus tremuloides	trembling aspen	Aw*
Populus balsamifera	balsam popular	Pb*
Betula papyrifera	white birch	Bw*

* because differentiation of deciduous species is difficult using aerial photographs. Phase 3 inventory often uses "A" as a species descriptor indicating undifferentiated deciduous species

Table 3. Important Alberta Phase 3 Timber Inventory non-productive forest land descriptors.

Class	Description	Phase 3 code
muskeg	lowland and sites of excessive moisture, crown closure 0-10 %	om
treed muskeg	as above with crown closure 11-30 %	tm
coniferous scrub	inferior conifer growth, > 30 % crown closure	cs
deciduous scrub	inferior deciduous growth, > 30 % crown closure	ds

(b) Single Variable Habitat Categories

The single variable Phase 3 based habitat categories used in the thesis are shown in Table 4.

Table 4. Single variable habitat categories based on Alberta Phase 3 Timber Inventory.

Category	Level
crown closure	A, B, C, D, other
height	0, 1, 2, 3, other
origin	<=1830, 1831-1879, 1880-1929, 1930-1985, cc, other
species	p, sb, sw, conifer, decid, mixed, ds, cs, muskeg, cc, other

"Other" as a level in each category describes everything not accounted for by the rest of the levels.

Height level 3 includes Phase 3 height class 4 as 4 alone occurs <1% in the digital inventory used in the study. Phase 3 height class 5 was absent in the timber inventory used in this study.

The origin levels were arrived at in consultation with the workers on the companion aerial relocation study. Of particular concern here was the relationship between stand age and lichen abundance. Reference was made to the findings of Edmonds and Bloomfield (1984) in that regard. The age classes with a year designation are productive timber only.

Conifer = Phase 3 P, Sb or Sw in Phase 3 digital form species 1 (s1) position with no deciduous ("decid", as defined below) in s2 position.

P, Sb, Sw = a breakdown of conifer into its components.

Decid (deciduous)= Phase 3 A, Aw, or Pb in s1 position with no conifer in s2 position.

Mixed = decid (deciduous) in s1 position, conifer in s2 position or vice versa.

Muskeg = Phase 3 om and tm (open and treed muskeg).

"Other" in the species categorization is everything not accounted for by the 4 items listed above and cc including: Fb in the s1 position as it only accounted for 0.02% of the inventory used in the study: and Fd and Lt which were absent.

For each category results in the thesis are presented in 2 basic ways: 1) using all of the levels, 2) using only the levels representing productive forest lands. For example, crown closure is examined in 2 ways; productive forest stands alone (A, B, C, D) and with an "other" class (A, B, C, D, other).

(c) Two Variable Habitat Categories

All productive forest stands in the thesis possess density (4 levels), height (4 levels), age (4 levels) and species (5 levels P, Sb, Sw, decid, and mixed). Two variable habitat categories using all combinations of density, height, age, and species with these levels were also tested. This was done because some variables may only be important in combination with others. Use of categories based on 3 or all of the variables is not practical because it results in a large number of levels. For example density*height involves 16 levels, species *age, 20. The 4 combinations of the variables 3 at a time result in 80 and 100 levels. Using all 4 variables results in 300 levels. Using a large number of category classifications results in proportions close to 0 for both use and availability in some of the levels. This creates statistical problems as discussed in detail under sub-heading 9 below.

(d) Aspect

Edmonds and Bloomfield (1984 : 6) found that certain aspects were commonly used by caribou. As a result, this study tests use of aspect alone and in combination with the Phase 3 based variables. The aspect categories developed by the workers on the aerial relocation study based on Edmonds and Bloomfield's work (Smith 1996) and adopted here are as follows: **n**, north = 300-60 degrees; **s**, south = 120-240 degrees; **o** (for other) = 241-299 degrees, 61- 119 degrees, and no aspect (slope 10% or less).

5. Mapping

(a) Techniques

Caribou track travel paths marked with survey ribbon during winter were revisited during July and August 1994 and July and August 1995.[16]

Locating the paths in the summer was assisted by use of a Trimble Scout 1 hand-held GPS which had been used to record starting locations in the winter. The Trimble unit provided an estimated confidence interval for the locations it recorded which ranged from ± 100 - 1000 m, with most locations ± 300 m.

Slope and aspect were measured and recorded at each numbered flag using a foresters' clinometer and compass.

The ribbon-marked route between numbered flags was recorded by measuring distances and recording compass bearings between ribbons using a foresters' hip chain and compass. This information was used later to map the caribou track travel paths on Phase 3 timber inventory maps.

In June 1995 the starting locations for all paths were revisited and a starting location was recorded with a Corvallis MC-GPS hand-held GPS receiver with GPS C/A code differential correction capability.[17] This capability is absent in the Trimble unit. Aerial Recon Ltd. performed differential correction on the locations.[18] Differential correction involves a second GPS receiver, a base station[19], collecting data at a stationery position on a precisely known point like a surveyed benchmark. Because the physical location of the base station is known, a correction factor can be computed by comparing the known location with the GPS location determined using the satellites (Corvallis Microtechnology, Inc. 1996). Differential correction eliminates most of the errors inherent in locations recorded with a GPS receiver (Corvallis Microtechnology, Inc. 1996.).

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[16]Only 1 numbered flag could not be located, flag 238, which should have started line 4. The rest of the flags for that line were located.
[17]Receiver settings were those suggested by Aerial Recon Ltd. to maximize accuracy in the locations given the forest canopy and topography of the study area while still allowing locations to be recorded within approximately 5 minutes. The settings were as follows: alt control - auto; el mask - 13; vdop - 10; hdop - 5; select constellation - blockage; settle time - 3; logging mode - static; session - 120 seconds; and, interval - 1.
[18]The location for the start of line 6, flag 125, could not be corrected so the location for flag 126 on that line, which fortunately had been recorded, was differentially corrected and used as the start of this tracking episode.
[19]Aerial Recon Ltd.'s base station is located at the Whitecourt, AB airport approximately 225 km east of the study area.

Phase 3 timber inventory maps for the study area in digital form were provided by Weyerhaeuser Canada Ltd.. Aerial Recon Ltd. translated these for use with the geographic information system (GIS) software, MapInfo (Version 3.0, MapInfo Corporation 1985-1994). Aerial Recon Ltd. also created a MapInfo compatible computer program to map the lines using the corrected starting locations and the distance and bearing information describing the route moving away from the starting locations.[20]

MapInfo was used to determine the distances between points on caribou paths involved in the habitat use measures.[21]

One of the aspect categories was assigned to each Phase 3 timber stand based on an average of the field measurements for each numbered flag within a stand. Some stands intersected by the mapped caribou paths did not have any numbered flags. These stands were excluded from the analysis of use of aspect and use of aspect*Phase 3 habitat categories.

(b) Sources of Mapping Error

The major sources of mapping error are as follows: inaccuracy in the measurement of distances inherent in use of a hip chain; inaccuracy in compass bearings caused by declination; physical feature errors in the Phase 3 maps; inaccuracy in the GPS recorded, differentially corrected, starting points; errors in the Phase 3 maps caused by misidentification of stands during creation of those maps; and, loss of distance in the caribou track travel lines caused by MapInfo. Each of these sources of error is discussed below.

The hip chains used in mapping were each tested 10 times over a known distance of 20 m at the conclusion of the 2 summer field seasons. The test of the hip chain used during the first summer resulted in a mean of 19.03 m, standard deviation 0.98. The second summer hip chain test resulted in a mean of 19.3 m, standard deviation 0.78.

The compass bearings used in mapping the caribou travel paths were adjusted for 22 degrees declination based on 1994 and 1995 values for the area provided by L. Newitt, Geomagnetic Supervisor with the Geological Survey of Canada (pers. comm. January 30, 1996). The values provided were for the centres of 1: 50 000 National Topographic System map sheets 83-L-3 and 83-L-6. All caribou track travel path lines in this study were located on these 2 map sheets. The declination values provided were as follows: 83-

[20]One path, line 67, was not properly entered into the program by Aerial Recon and it was mapped on a Phase 3 paper map by hand. The very first tracking episode, line 50, was mapped in Mapinfo by connecting corrected locations for each of its numbered flags as survey flags between were not placed during backtracking.

[21]A Phase 3 digital map was not provided by Weyerhaeuser for Township 62 Range 8, west of the 4th meridian. The distances for the 3 paths in this township were measured by hand overlaying the computer drawn lines on a paper Phase 3 timber inventory map. Digital maps for Township 59 ranges 8 and 9 were not made available until after the mapping was completed so the distances for the 11 lines in these townships were also measured by hand.

L-3, 22 degrees 16 minutes 1994, 22 degrees 7 minutes 1995; 83-L-6, 22 degrees 24 minutes 1994, 22 degrees 15 minutes 1995. These figures are based on sample surveys of the geomagnetic field conducted every 5 years and mathematical models that predict annual changes. The declination used here does not account for the slight declination changes as one moves from the centre of the map. The difference between the figures for sheet 83-L-3 and L-6 illustrates the type of changes that can be expected in this regard. The declination figures also do not account for localized magnetic anomalies caused by iron ore deposits.[22]

Use of a GPS receiver with differential correction capability to map the whole of the lines would probably have improved accuracy but at substantially increased cost. Nonetheless, my impression from traveling the lines and field notes on timber types traversed is that the lines as mapped in this study are close to the accuracy of the Phase 3 maps (see below for a discussion of the accuracy of Phase 3 maps). In terms of actual checks, differentially corrected locations for a few non-start numbered flag locations were taken and compared to location as mapped in MapInfo using the distance bearing measurements (Table 5).[23]

Table 5. Difference between selected GPS differentially corrected locations along caribou track travel paths in comparison to location as mapped in the study.

Line no.	Flags	Distance from start to flag checked	Flag checked	Difference GPS v. mapped
4	239-245	120 m	240	within 14 m
		166 m	241	within 10 m
7	383-390	168 m	384	within 4 m
		200 m	385	within 3 m
		237 m	386	within 14 m
		674 m	390	within 19 m
21	50-63	74 m	51	within 6 m
		165 m	53	within 15 m
		213 m	54	within 9 m
		248 m	55	within 12 m
		280 m	56	within 26 m
		308 m	58	within 39 m
58	94a-102a	193 m	95a	within 17 m

Phase 3 maps are prepared from aerial photographs (Alberta Forestry, Lands and Wildlife 1985a) and therefore have distortions in them in terms of physical placement of timber

[22]Newitt advised that these are not as much of a problem in Alberta as compared to other parts of the Country.

[23]A comparison of lines 31 and 32 is also a check. The end of line 32 as mapped, which was 922 m long, was approximately 30 m from the start of line 31. Physically on the ground the actual distance between these points was 1 m.

stands, roads etc.. The mapping specifications call for map accuracy of within 12 m of actual true ground positioning (Alberta Forestry, Lands and Wildlife 1985b : 29) but this was not checked here.

The GPS differentially corrected starting points are advertised as accurate to within to 1-5 m (Corvallis Microtechnology, Inc. 1993). Deckert and Bolstad (1996) tested differentially corrected locations recorded with a C/A code GPS receiver in Shenandoah National Park in Virginia, U.S.A.. Under conifer canopy the accuracies ranged from 11.4 ft to 22.5 ft depending on the number of fixes[24] and whether the location was ridgetop, midslope or valley. There was no opportunity to verify the accuracy of differentially corrected starting locations in this study except with reference to physical landmarks. If there was a discrepancy then the question was whether the landmark was incorrectly placed on the map because of error in the map or because the differential correction was not as accurate as advertised by Corvallis. Appendix 1 contains comments on the accuracy of the differentially corrected GPS determined starting points. Lines 23 and 24 (only counted as 1 line in analysis, 24 continues 23) were moved approximately 100 m because of an obvious discrepancy between their common GPS differentially corrected start on the appropriate Phase 3 map relative to a road and their known location relative to the road on the ground. Line 30 was moved approximately 100 m straight south of its GPS location to place it in the same position on the digital map as on the ground relative to a road.

The inventory process for Phase 3 involves interpretation of aerial photographs (Alberta Forestry, Lands and Wildlife 1985a) which obviously admits the potential for misclassification of stands.[25] For this reason, the accuracy of the stand designation for stands crossed by the caribou track travel path lines was evaluated during the summer at locations along the lines appearing to be representative of each stand encountered. A 10 x 10 m plot was set up and the following variables were evaluated or measured: number of tree stories; crown closure; height each class; and, species composition. If the stand designation was obviously in error then the following additional information was also collected: diameter at breast height of all trees > 12.4 cm; age of 1 representative tree from each species of each height class and, height of trees aged. In view of the other errors involved in the mapping process as discussed above and in deference to the superior experience of those officials conducting Phase 3 inventory, only the following

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[24]GPS receivers can be set to collect many position fixes for a given point and then averaging them. The mean of the fixes is then differentially corrected. Collecting a large number of fixes improves initial accuracy but increases the amount of time to record a location. Deckert and Bolstad tested differential correction accuracy using 60, 200, and 500 fixes. The receiver used in this study was set to collect fixes for 120 s with the mean differentially corrected. The receiver used here does not maintain a record of the number of fixes recorded during the 120 s session. According to Deckert and Bolstad a typical receiver typically records a maximum of 1 fix a second.

[25]In a study to evaluate the effect of film type on interpretation of aerial photographs (Morton 1981) at 42 sites found that 17 intepreters working on Phase 3 inventory identified height class correctly in 63.7% of the cases and species compostion 75 % when working with black and white infrared 1:15 000 film, the film used in Phase 3. Phase 3 inventory did employ ground-truthing procedures which would improve on initial photo interpretation.

stands were reclassified for the purpose of analysis in this study: stand 78 traversed by line 13 reclassified to b3Sb from b2P and stand 399 traversed by line 1 reclassified to b3P origin 90 from b1SwA origin 93.

Use of MapInfo in segmenting lines to measure the distance traveled through stands resulted in a loss of some of the total distance. This loss was carried through in the analysis. Appendix 1 also shows the total distance for each line and the loss caused by segmenting.

6. Approach To Analysis

This study compares use of habitat categories as described above with expected use based on a habitat category's availability. In other words, are habitats being used in the same proportions as they occur in the environment as one would expect if animals are using them randomly, or are they preferring some and avoiding others? Preferential use may indicate that a habitat attribute is (or is associated with an attribute) beneficial to survival with avoidance possibly indicating the opposite.

7. Habitat Availability

Availability consists of the amount of area of each habitat type that is available to the wildlife population. Unfortunately, what the biologist determines is available habitat and what the animal perceives as available habitat may be different things. Discrepancies here can obviously distort results (see White and Garrot, 1990 : 183-184).

The assumption in this study is that every township where backtracking was conducted represents available habitat.

Availability of Phase 3 based habitat categories was determined from the digital Phase 3 maps provided by Weyerhaeuser Canada Ltd. for the following townships in the study area (township/range(s)): 59 / 8-9, 60 / 8-9, 61 / 8-10, 62 / 9-10, small eastern portion of 62 / 11 , and the large portion of 63 / 10 provided. These are the townships where backtracking took place with one exception. No backtracking took place in 62 / 9. This township was used in substitution for 62 / 8 where there was backtracking because there was no digital inventory for 62 / 8. The substitution seems reasonable given that they are adjacent townships and both contain substantial clear-cuts.

Availability of aspect and aspect*Phase 3-based categories was provided by Forestry Corp., a consulting firm doing work on the companion aerial relocation study, using GIS software ARC/INFO (Environmental Systems Research Institute, Inc. 1990) digital Phase 3 maps for the same townships (except the small portion of 62/11), and provincially supplied digital aspect maps for these townships.

The portions of these townships north of the Kakwa River are logged, those portions south of the River are non-logged (see Chapter 2).

One of the primary difficulties in ascribing differences in use of habitats between the logged and non-logged portions of the available habitat is that the expected use differs for each portion. Table 6 shows the differences in proportions of the single variable habitat categories between the available habitat overall, and the logged and non-logged portions. To overcome this, the test of preference/avoidance was standardized by comparing use of habitats in each portion to availability of those habitats overall rather than the availability in each portion.

Table 6. Habitat categories as proportion of overall available habitat and the 2 study area portions.

Category Level[a]		Overall	Logged	Unlogged
crown closure				
A		0.03	0.03	0.03
B		0.12	0.09	0.14
C		0.58	0.61	0.54
D		0.12	0.16	0.09
other		0.16	0.12	0.20
	total	1.00	1.00	1.00
height				
0		0.12	0.10	0.14
1		0.18	0.17	0.19
2		0.36	0.39	0.33
3		0.19	0.23	0.15
other		0.16	0.12	0.20
	total	1.00	1.00	1.00
origin				
≤1830		0.10	0.07	0.14
1831-1879		0.18	0.28	0.08
1880-1929		0.28	0.29	0.28
1930-1985		0.28	0.24	0.31
cc		0.01	0.03	0.00
other		0.14	0.09	0.20
	total	1.00	1.00	1.00

[a] For those familiar with Phase 3 Inventory, the categories and levels do not require explanation except as follows: height 3 here includes Phase 3 height 3 and 4; conifer = Phase 3 P, Sb, or Sw in s1 position with no decid as defined below in s2 position; P,Sb, and Sw = a breakdown of conifer into its components; decid = Phase 3 A, Aw, or Pb in s1 position with no conifer in s2 position; mixed= decid in s1 position, conifer in s2 position or vice versa; and, muskeg= Phase 3 om and tm. For those unfamiliar with Phase 3 Inventory, a reading of Phase 3 Timber Inventory Specifications, sub-heading 3 above is required.

Table 6 (continued). Habitat categories as proportion of overall available habitat and the 2 study area portions.

Category Level		Overall	Logged	Unlogged
species				
conifer		0.73	0.78	0.69
decid		0.04	0.05	0.03
mixed		0.07	0.06	0.07
ds		0.05	0.03	0.07
cs		0.03	0.02	0.03
muskeg		0.03	0.03	0.03
cc		0.01	0.03	0.00
other		0.04	0.01	0.07
	total	1.00	1.00	1.00
species				
P		0.57	0.61	0.52
Sb		0.08	0.08	0.08
Sw		0.22	0.19	0.26
decid		0.05	0.05	0.04
mixed		0.08	0.07	0.09
	total	1.00	1.00	1.00
aspect[a]				
n		0.18	0.11	0.25
o		0.64	0.67	0.61
s		0.18	0.22	0.15
	total	1.00	1.00	1.00

8. Data Compilation

Habitat use data determined through mapping was stored in the spreadsheet software Excel (Version 5, Microsoft Corporation). Determining proportions of use of habitat categories was greatly assisted by Excel's data filtering capabilities. Proportions of 2 variable timber categories were determined using PROC FREQ in the software SAS (SAS Institute Inc. 1987).

The table portions of digital Phase 3 maps were transferred from MapInfo to an Excel spreadsheet. Again, Excel data filtering and use of SAS assisted in determining the availability of habitat categories.

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[a] Aspect categories are as follows: north (n) = 300-60 dgrees; south (s) = 120-240 dgrees; and, other (o) = 241-299 degrees, 61-119 degrees, and no aspect (slope 10% or less).

9. Statistical Tests

One of the important considerations in choosing a test of preference was consistency with the companion aerial relocation study. A standard approach to testing preference hypotheses is presented by Neu *et al.* (1974). This approach first employs a $\chi 2$ test looking at overall goodness of fit between the number of observations in each habitat category versus the expected number of observations based on availability. If there is a significant difference, then the null hypothesis of no preference is rejected implying that, overall, the habitat categories were not used proportionately to their availability. The second part of the Neu procedure is to determine which of the individual habitat categories are being preferred and avoided constructing Bonferonni confidence intervals.

Use of the $\chi 2$ test is not possible with the data in this study because, although it is categorical data, all 3 measures of use of habitat categories contain units. Arbitrary changes in unit size, for example m to km, influences the result of a $\chi 2$ test. As a result, only the Bonferonni procedure is used in analysis of the data here. This procedure does not depend on a $\chi 2$ test having been conducted first: it is independent and the results are valid by themselves (Byers *et al.* 1984).

The Bonferonni procedure, as used in this study, results in ± confidence intervals for use proportions for each habitat category. If the confidence interval embraces the expected proportion based on the category's proportion in the environment, then there is no statistically significant difference (null in the results tables). If the confidence interval does not include the expected proportion, then there is a statistically significant difference; preference or avoidance depending on the difference between the used proportion and the expected proportion.

The calculation of the Bonferonni confidence interval is:

$$p_i - z\left(\sqrt{\frac{p_i(1-p_i)}{n}}\right) \quad \text{to} \quad p_i + z\left(\sqrt{\frac{p_i(1-p_i)}{n}}\right)$$

where p_i is the proportion of use for a habitat category, z is a certain value of the z statistic and n is the total of use observations for all habitat categories (Byers *et al.* 1984).

The value of z is the upper standard normal value for a probability of α (the chosen statistical significance level) divided by 2 times the number of habitat categories. The adjustment in α for the number of categories is apparently necessary because preference and avoidance for all categories is of interest. In statistical parlance, one is calculating simultaneous confidence intervals (Byers *et al.* 1984). This adjustment is only appropriate when the number of parameters is small (Neu *et al.* 1974) but no rule is given for determining when there are too many categories. It is assumed in this study that this adjustment in α is appropriate.

An important assumption with the Bonferonni procedure is that all observations are independent (Alldredge and Ratti 1992). For that reason it is recommended that if animals are observed in groups, the group is the observation and not the number of individuals in the group (Thomas and Taylor 1990). In an aerial relocation study, short time periods between relocations results in an unacceptable violation of the assumption as well (Thomas and Taylor 1990). In recognition of this assumption, trailing episodes, rather than the numbers of meters traveled or craters, are treated here as the observations in determining *n*. Any trailing episode continued over more than one day was only counted as one observation.

Another assumption in using the Bonferonni procedure to compare one proportion to another is that a binomial distribution approximating a normal distribution is involved (Neu *et al.* 1974). According to Neu et al., if the observed proportion is close to 1 or 0 then *n* needs to be fairly large to maintain the normal approximation. A conservative rule of thumb cited by Neu *et al.* is that *n* is large enough if $n \times p_i$ and $n(1- p_i)$ are > = 5. This rule of thumb was occasionally breached in analysis of the single variable habitat categories where some of the observed proportions approached 0. In those few instances, the result was checked by comparing the square root transformation of the used and expected proportions employing the Bonferonni procedure. Square root transformation is a common procedure to get a better approximation to a normal distribution and it is the recommended transformation for count data where the range in percentage terms is 0 to 20 or 80-100 but not both (Montgomery 1984 : 234-235).

Two variable habitat categories spread the data over large numbers of categories resulting in a lot of proportions approaching 0. All 2 variable results were analyzed solely by using the Bonferonni procedure on square root transformed values. Even then, the $n \times p_i$ and $n(1- p_i)$ are > = 5 rule was often violated. Additionally, the conditions Montgomery (1984 : 234-235) places on the recommendation for use of the square root transformation may not exist in the case of the 2 variable categories; the percentage ranges for the proportions include both extremes and values in the middle. For those reasons, the 2 variable habitat category results should be viewed with caution. As the object of this analysis is to find combinations of variables that might be meaningful to caribou and useful for planning purposes, results where the expected use is very small should be ignored.

In all cases where the observed proportion was 0, the value was changed to 0.0001, an arbitrary value close to 0, but which still allows calculation of a Bonferonni ± value.

Alpha here is 0.1, the value chosen for the companion aerial relocation study (Smith and Edmonds 1993). This relatively large alpha level was chosen to minimize Type II error.

C. RESULTS AND DISCUSSION

1. Can Alberta Phase 3 Timber Inventory Variables be Used to Characterize Woodland Caribou Habitat Use?

From a qualitative perspective, the impression gained from observing caribou tracks was that Phase 3 Timber Inventory variables would not work well in mapping caribou habitat. Little in the way of obvious caribou "preference" in the behavioral sense (as opposed to statistical preference) for certain timber characteristics was observed.

The analysis of the data accords with this impression. Phase 3 variables examined alone or in combination with each other or aspect did not prove to be that useful in planning for caribou habitat needs. The results certainly do not support an ability to map good and bad caribou habitat simply using Phase 3 maps.

Table 7 shows the results of the analysis of caribou preference and avoidance of single variable habitat categories pooling all of the data. Results for data subsets stratified by winter of collection and portion of study area are shown in Appendix 2. These also do not reveal any patterns of use of timber variables that could be used in mapping caribou habitat in a useful way.

Table 7. Caribou use of single variable habitat categories based on Alberta Phase 3 Timber Inventory - all track travel paths.

Pooled n=59

Category Level[a]		Proportion of use as measured by... distance (m)	crts/km[b]	adj crts/km[c]	Expected use	Significance[d] distance	crts/km	adj crts/km
crown closure								
A (6-30%)		0.02	0.04	0.04	0.03	null	null	null
B (31-50%)		0.12	0.05	0.08	0.12	null	**avoided**	null
C (51-70%)		0.65	0.56	0.54	0.58	null	null	null
D (>70%)		0.08	0.13	0.14	0.12	null	null	null
other		0.13	0.22	0.20	0.16	null	null	null
	total	1.00	1.00	1.00	1.00			

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[a] For those familiar with Phase 3 Inventory, the variables other than aspect do not require explanation except as follows: height 3 here includes Phase 3 height 3 and 4; conifer = Phase 3 P, Sb, or Sw in s1 position with no decid (as defined below) in s2 position; P, Sb, and Sw = a breakdown of conifer into its components; decid = Phase 3 A, Aw, or Pb in s1 position with no conifer in s2 position; mixed= decid in s1 position, conifer in s2 position or vice versa; and, muskeg= Phase 3 om and tm. For those unfamiliar with Phase 3 Inventory, a reading of Phase 3 Timber Inventory Specifications, heading B. 4. (a) above is required.

[b] Caribou feeding craters/km.

[c] As note b but adjusted for estimated caribou group sizes during tracking.

[d] Significance involves a comparison of observed use proportions with expected. The comparison is based on calculation of simultaneous Bonferonni confidence intervals for use proportions with α 0.1. A "*" following the significance description indicates that the Bonferonni calculation was performed with square root transformed proportions because the use proportion was too close to 0 or 1 given n.

Table 7 (continued). Caribou use of single variable habitat categories - all track travel paths.

Pooled n=59

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
crown closure								
A (6-30%)		0.02	0.05	0.06	0.03	null	null	null
B (31-50%)		0.14	0.06	0.10	0.14	null	**avoided**	null
C (51-70%)		0.75	0.72	0.67	0.68	null	null	null
D (>70%)		0.09	0.17	0.17	0.15	null	null	null
	total	1.00	1.00	1.00	1.00			
height								
0 (0-6m)		0.13	0.07	0.07	0.12	null	null	null
1 (6.1-12m)		0.14	0.23	0.24	0.18	null	null	null
2 (12.1-18m)		0.38	0.25	0.25	0.36	null	null	null
3 (>18m)		0.22	0.22	0.24	0.19	null	null	null
other		0.13	0.22	0.20	0.16	null	null	null
	total	1.00	1.00	1.00	1.00			
0 (0-6m)		0.15	0.09	0.09	0.14	null	null	null
1 (6.1-12m)		0.16	0.30	0.30	0.21	null	null	null
2 (12.1-18m)		0.44	0.33	0.32	0.42	null	null	null
3 (>18m)		0.25	0.28	0.30	0.23	null	null	null
	total	1.00	1.00	1.00	1.00			
origin[c]								
≤1830 (≥164 yrs.)		0.26	0.22	0.24	0.10	**preferred**	null	null
1831-1879 (115-163 yrs.)		0.20	0.13	0.12	0.18	null	null	null
1880-1929 (65-114 yrs.)		0.16	0.16	0.17	0.28	**avoided**	**avoided**	**avoided**
1930-1985 (9-64 yrs)		0.25	0.27	0.29	0.28	null	null	null
cc (clear-cuts)		0.00	0.00	0.00	0.01	**avoided**	**avoided**	**avoided**
other		0.13	0.22	0.20	0.14	null	null	null
	total	1.00	1.00	1.00	1.00			
≤1830 (≥164 yrs.)		0.26	0.22	0.24	0.10	**preferred**	null	**preferred**
1831-1879 (115-163 yrs.)		0.20	0.13	0.12	0.18	null	null	null
1880-1929 (65-114 yrs.)		0.16	0.16	0.17	0.28	**avoided**	**avoided**	**avoided**
1930-1985 (9-64 yrs)		0.25	0.27	0.29	0.28	null	null	null
other & cc		0.13	0.22	0.20	0.16	null	null	null
	total	1.00	1.00	1.00	1.00			
≤1830 (≥164 yrs.)		0.30	0.28	0.29	0.12	**preferred**	**preferred**	**preferred**
1831-1879 (115-163 yrs.)		0.23	0.16	0.15	0.21	null	null	null
1880-1929 (65-114 yrs.)		0.18	0.21	0.21	0.34	**avoided**	**avoided**	**avoided**
1930-1985 (9-64 yrs)		0.29	0.35	0.36	0.33	null	null	null
	total	1.00	1.00	1.00	1.00			

[c] Parenthetical values are tree ages in 1994

Table 7 (continued). Caribou use of single variable habitat categories - all track travel paths.

Pooled n=59

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
species								
conifer		0.80	0.76	0.79	0.73	null	null	null
decid		0.03	0.00	0.00	0.04	null	**avoided**	**avoided**
mixed		0.04	0.01	0.01	0.07	null	**avoided**	**avoided**
ds (decid. scrub)		0.04	0.18	0.15	0.05	null	**preferred**	**preferred***
cs (conifer scrub)		0.02	0.03	0.03	0.03	null	null	null
muskeg		0.05	0.01	0.01	0.03	null	**avoided***	**avoided***
cc (clear-cuts)		0.00	0.00	0.00	0.01	**avoided**	**avoided**	**avoided**
other		0.01	0.01	0.01	0.04	null	**avoided**	**avoided**
	total	1.00	1.00	1.00	1.00			
P (pine)		0.48	0.58	0.57	0.57	null	null	null
Sb (black spruce)		0.13	0.14	0.16	0.08	null	null	null
Sw (white spruce)		0.31	0.26	0.25	0.22	null	null	null
decid		0.04	0.01	0.01	0.05	null	**avoided**	**avoided**
mixed		0.04	0.02	0.02	0.08	null	**avoided**	**avoided**
	total	1.00	1.00	1.00	1.00			
aspect[f]								
n		0.06	0.22	0.23	0.18	**avoided**	null	null
o		0.79	0.66	0.65	0.64	**preferred**	null	null
s		0.15	0.13	0.12	0.18	null	null	null
	total	1.00	1.00	1.00	1.00			

Table 7 shows that for the most part, crown closure and height were not disproportionately used. This is not surprising if one assumes that there is no strong relationship between terrestrial lichen abundance and these variables. However, as discussed in the introduction to this chapter, caribou prefer *Cladina* spp. (Russell and Martell 1984; Schafer and Pruitt 1991; Edmonds 1991; Thomas 1994) which favour open forests (Vitt et al. 1988 : 209-210). Differences in optimum growing conditions for *Cladina* spp. and other terrestrial lichens that caribou eat could explain these results. An alternative explanation, which is discussed in some detail below in the context of the stand origin results, is that the factors that favour lichen growth operate at smaller scale than timber stand variables like crown closure.

The pooled data shows that caribou prefered the oldest origin level, <=1830 (age 164 years or older in 1994), shown by 1, 2, or all 3 use measures, depending on the inclusion of other and clear-cuts as levels, and the class, 1880-1929 (age 65 - 114 years in 1994), was avoided. Preliminary analysis of the data collected in the companion aerial

[f] Aspect categories are as follows: north (n) = 300 - 60 deg.; south (s) = 120 - 240 deg; and, other (o) = 241 - 299 deg., 61 - 119 deg., and no aspect (slope 10% or less).

relocation study agrees (Smith 1997). These 2 results with use measured by craters/km adjusted for caribou group size are shown in Figure 4.

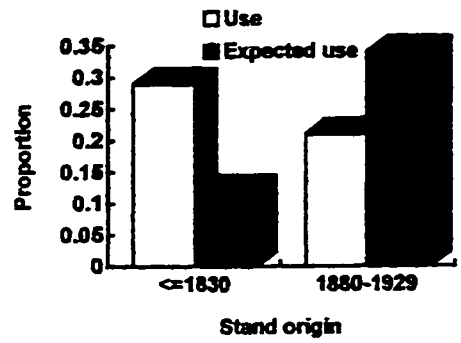

Figure 4. Important stand origin results - caribou use (measured by feeding craters/km adjusted for group size) v. expected use.

The preference for the oldest origin class does not accord with a prediction based on terrestrial lichen abundance. As already discussed caribou prefer *Cladina* spp. and peak abundance is expected in stands aged 50-100 years (Viereck 1973; Johnson 1981; Snyder 1987 : 34; Morneau and Payette 1988). However, this result accords with previous work in the study area and in the Northwest Territories (Bjorge 1984 working in west-central Alberta found that caribou prefer stands > 161 years old; Thomas *et al.* 1996 found that caribou in the Northwest Territories used stands 151-250 years after fire more than other age classes).

Older stands may allow caribou better access to terrestrial lichens because of denser canopy and less snow on the ground (Snyder 1987). However, the results of the analysis of caribou preference/avoidance for crown closure in Table 7 do not support this as an explanation for caribou preference of the very oldest stands.

Caribou avoidance of timber with an origin 1880-1929 is also difficult to explain given the supposed relationship between stand age and terrestrial lichen abundance. One possibility is that inclusion of trees less than 75 years of age in the class meant that it included too many stands of low lichen abundance. However, approximately 90 % of this class was trees 75 years or older.[26] A more plausible explanation is that stand origin is only a rough indicator of terrestrial lichen abundance. Site characteristics ultimately determine lichen growth rates and the growth rates of their competitors. Ground level light intensity, temperature, and moisture regime (Canters *et al.* 1991) and soil/substrate characteristics (Topham 1977) are all thought to influence growth rates of lichens and their competitors. These factors appear to operate at a smaller scale for lichens as

[26]The class 1880-1929=26 425 ha , 23 844 of which had an origin of 1880-1918.

compared to higher plants (Canters *et al.* 1991). This means that there can be great variability in lichen abundance even within an individual timber stand. At many feeding crater sites observed during data collection there would be lichen mats while only a few meters away the ground cover was moss. Micro-site variabilty in lichen abundance could explain both results shown in Figure 4.

Another possible explanation is that the intensity of fires creating these stands may not have been enough to start the normal successional process leading to peak *Cladina* spp. at 50-100 years post-fire (Smith 1997).

Avoidance of stands with origins 1880-1929, even if the result of poor terrestrial lichen abundance in some of those stands, does not necessarily make them bad caribou habitat. Indeed, it may mean that stands of that origin that have good terrestrial lichen abundance represent prime caribou habitat.

Another possible explanation for caribou avoiding stands with this origin is that optimum *Cladina* spp. availability for caribou may not coincide with maximum biomass. Much of the biomass in older patches can be old or dead lichen (Bergerud 1971, Morneau and Payette 1989) and caribou find this less palatable than young lichen (Skunke 1969).

Finally, factors other than lichen abundance may be driving choice of habitats by caribou. Bergerud (1996) argues that predation risk avoidance and snow cover gradients describe habitat selection by caribou better than food and cover needs.

The lack of caribou preference for conifer species individually or as a group is also somewhat surprising assuming that these stands are associated with good terrestrial lichen abundance. The species categories may not predict lichen availability with sufficient accuracy. For example, stands designated pine and treated the same in this study may have good or poor lichen availabilities depending on variables ignored in the analysis.

The crater use measures in Table 7 show deciduous (decid), mixed, and muskeg species categories to be avoided which accords with expectations in terms of probable lichen abundance, but the same measures show deciduous scrub (ds) to be preferred. Preference for deciduous scrub may reflect that winter diet for woodland caribou may be as much as 6% shrubs (Thomas *et al.* 1996).

Clear-cuts (cc), as expected, were avoided. This is one of the few results that was clearly observed qualitatively during data collection. Caribou were never observed to use clear-cuts. Figure 5 shows the caribou track paths coming closest to clear-cuts.

Combining Phase 3 variables with each other did not reveal caribou preferences and avoidances that could be used in planning (Appendix 3). Appendix 4 shows that the same is true for combinations of Phase 3 variables with aspect.

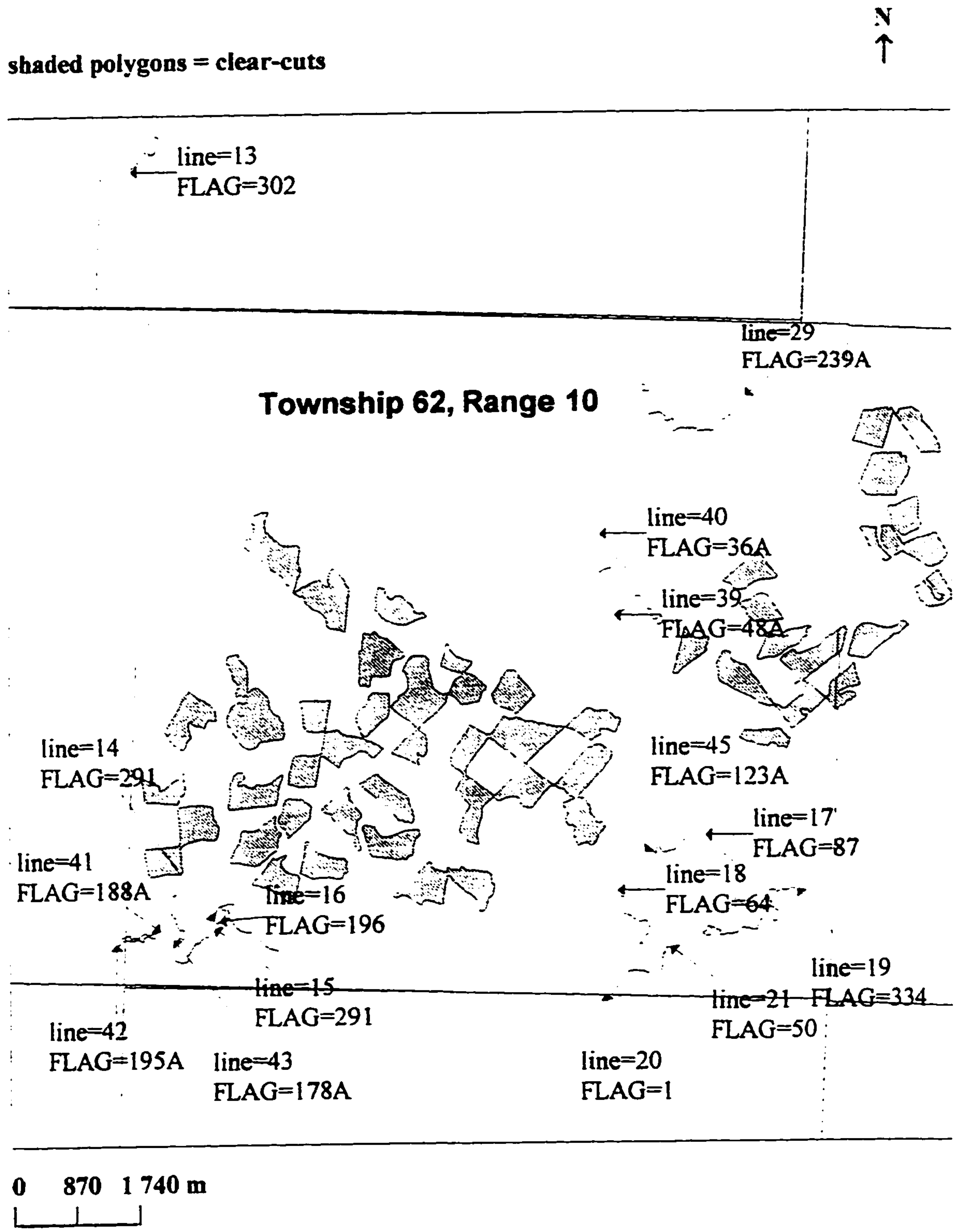

Figure 5. Caribou track paths closest to clear-cuts.[27]

[27] Line 26, flags 172-195, which was within 400 m of a clear-cut is not shown because it is located in township 62 range 8. No digital map was available for this township, see B. METHODS, 7. Habitat Availability, above.

One might expect that differences between habitat use during each winter of the study as shown in Appendices 2 and 3 might relate to snow cover. Snow cover was greater during winter 1. As a rough indication, Environment Canada indicates total precipitation in Grande Cache for December '93 to April '94 as 165.2 cm and for December '94 to April '95 (April total from Grande Prairie as Grande Cache climate station closed) as 69.1 cm (Environment Canada 1996).[28] However, there is no pattern to the differences between the results of the 2 winters that can easily be attributed to snowfall. The differences between winters could possibly be a reflection of the fact that caribou rotate use of winter range by using one area for several winters and then shifting to another (Thomas *et al.* 1994).

Timber harvest can result in tremendous loss of terrestrial lichens in cut-over areas. Regeneration, if it is the same as recovery post-fire, would be slow. Assuming that clear-cuts in the study area represent poor caribou habitat because of a lack of terrestrial lichens (clear-cuts were consistently avoided), it might be expected that preferences for any variables associated with good lichen abundance would be more pronounced in the logged portion of the available habitat as compared to the unlogged because of concentration of use in the non-harvested areas of the logged portion.

The results do not accord with this possible expectation (Appendix 4). There is no pattern to the differences between the caribou preference/avoidance results for the logged and unlogged portions of the available habitat that might be attributable to logging. Possible explanations include problems inherent in the variables in predicting lichen abundance, and, that the expected is not occurring (perhaps because of the low percentage of clear-cuts, 1% of available habitat, 3 % of logged portion).

Finally, it is worth noting the sample size influence over the comparisons of use and expected use. Larger sample size reduces Bonferonni confidence intervals resulting in smaller differences between use and expected use being statistically significant. A larger sample size will result in more habitat preferences and avoidances and less null comparisons, all other things being equal. A calculation of the sample size necessary to detect a difference between habitat use and expected use proportions of 0.09 (with a habitat use proportion of 0.50) was performed using the Bonferonni formula presented in the methods. With 4 habitat categories, the necessary sample size is 156. Increasing the number of habitat categories to 5 increases the necessary sample size to 167.

2. Conclusion

Phase 3 Timber Inventory is probably inadequate for mapping caribou habitat. The reason for this may be that the variables do not predict terrestrial lichen abundance with sufficient accuracy. The somewhat surprising results of the caribou preferences and avoidances of stand origin are intriguing. They suggest that stand age is inadequate as a

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[28] As an additional measure of the differences in snowfall between winters, cratering site snow depths were compared. The mean crater depth in winter 1 was 43.4 cm, SD 14.6 (n=153) and in winter 2 it was 37.0 cm, SD 11.4 (n=116). An ANOVA with alpha 0.05 showed this to be significantly different (f=15.3).

predictor of terrestrial lichen abundance for caribou habitat planning purposes. The origin results could also suggest that caribou choose habitats for reasons other than forage availability. Bergerud (1996) argues that predation risk avoidance and snow cover gradients describe habitat selection by caribou better than food and cover needs. The avoidance of clear-cuts by caribou may suggest that forest planners and caribou managers find ways to turn them into caribou habitat.

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CHAPTER 4

THE ROLE OF LICHEN AND SNOW IN WINTER FEEDING SITE SELECTION

A. INTRODUCTION

Caribou in west- central Alberta depend on terrestrial lichens as winter forage. Their winter diet averages 66 % terrestrial lichens (Edmonds and Bloomfield 1984 : 8). Snowcover depth and hardness affect the ability of caribou to smell forage below the snow (Bergerud and Nolan 1970) and the amount of energy caribou must expend to reach forage (Thing 1977; Fancy and White 1985). This chapter examines terrestrial lichen abundance and snow characteristics at caribou feeding sites in comparison to that at non-feeding sites along caribou track travel paths.

A second objective to this portion of the thesis was added following analysis of caribou preference/avoidance of Alberta Phase 3 Timber Inventory variables as discussed in Chapter 3. Chapter 3 was in many respects a search for timber stand variables that could predict terrestrial lichen abundance. One of the assumed best predictors before analysis was stand age. The analysis in Chapter 3 investigates the relationship between stand age and lichen abundance indirectly. The second objective of this chapter is to test this relationship more directly by using the feeding site lichen abundance data and determining which stand ages have the highest lichen abundance.

B. METHODS

1. Lichen Abundance, Feeding Sites v. Non-feeding Sites

Abundance of certain terrestrial lichen types was measured at the numbered flags placed during backtracking (see Chapter 3). The numbered flags were revisited in the summer and 5, 20 x 50 cm "over the shoulder coin toss" random microplot measurements of abundance by percent ground cover, were taken within 10 x 10 m plots around each numbered flag. Percent cover of terrestrial lichen is highly correlated with biomass (Snyder and Woodard 1992 : 66-67). Mean abundance at flags where feeding by cratering was recorded was compared for difference to that at flags where there was no feeding. This comparison was performed on the data pooled over both winters and both portions of the study area and on data sub-sets stratified by winter and portion of study area, alone and in combination.

As almost all of the data values ranged between 0 and 20 percent, they were square root transformed to better approximate the normal distribution for statistical analysis. This is the recommended transformation for this type of data (Steel and Torrie 1980 : 235). The square root transformation also provided closer to normal probability plots in SAS (SAS Institute Inc. 1987) as compared to untransformed, arcsine transformed, and log data +1 transformations generated from the data for the logged portion of the study area in winter 1, which was used as a test to compare transformations. Statistically significant differences between means were determined by analysis of variance of the square root transformed data using the General Linear Modeling Procedure in SAS or analysis of variance in Excel (Version 5, Microsoft Corporation) with alpha 0.05.

Two factors led to the choice of lichen types chosen for measurement: importance to caribou based on previous research and recognition that identification of some species within a genera is difficult in the field. The previous research relied on was the analysis of lichen abundance in feeding craters and in fecal pellets by Edmonds and Bloomfield (1984). The lichen types measured and abbreviated in the results tables are as follows: *Cladina mitis*, *Cladina rangifernia*, *Cladina stellaris*, *Cladonia* spp. (other than *uncialis*), *Cetraria* spp., *Peltigera* spp., *Stereocaulon* spp., *Cladonia uncialis*, and "other".

Field identification was assisted by use of a sample kit supplied by the Canadian Wildlife Service; Mosses Lichens & Ferns of Northwest North America (Vitt *et al.* 1988); and a few days of field instruction in May 1994 provided by consultants doing caribou research in the study area for Weyerhaeuser Canada Ltd., Terrestrial & Aquatic Environmental Managers Ltd..

2. Lichen Abundance at Feeding Sites and Stand Age

Feeding sites were plotted on digital or paper Alberta Phase 3 Timber Inventory maps using the mapping techniques discussed in Chapter 3. Stand ages at those sites were tabulated from the maps and added to the spreadsheet containing the lichen abundance data. Feeding sites located in non-productive forest land, which does not have an origin designation in Phase 3, were excluded from analysis. Comparisons between mean lichen abundance at feeding sites of various stand ages were then made using the same techniques as used in the comparison of feeding sites with non-feeding sites. This analyis was only performed for the most important terrestrial lichens for caribou, the *Cladina* spp. and *Cetraria* spp., which have been identified as the second most favoured of caribou in west-central Alberta (Woodard 1995). This analysis was not performed on data sub-sets stratified by winter and portion of study area.

3. Snow Characteristics, Feeding Sites v. Non-feeding Sites

The average snow depth at numbered flags placed during backtracking was measured with a meter stick (average of 4 measurements within 1 m of tracks, 2 on either side). Snow penetrability at the numbered flags was added as an additional measurement during the 2nd winter of the study. To measure snow penetrability, the sinking depth of a 1 kg weight dropped from 1 m was measured (average of 4 measurements within 1 m of tracks, 2 on either side). The weight, an iron disk, had a 90 mm diameter and was 25 mm thick. It was dropped so that the 25 mm edge penetrated the snow rather than either of the 90 mm faces. Mean snow depth and penetrability at flags where feeding by cratering was recorded was compared for difference to that at flags where there was no feeding.

For snow depth, this comparison was performed on the data pooled over both winters and both portions of the study area and on data sub-sets stratified by winter and portion of study area, alone and in combination. For snow penetrability, the comparison was performed for the winter 2 data pooled over both portions of the study area and stratified by portion of study area. Statistically significant differences were determined by analysis of variance using the General Linear Modeling Procedure in SAS (SAS Institute Inc. 1987) or analysis of variance in Excel (Version 5, Microsoft Corporation) with alpha 0.05.

C. RESULTS AND DISCUSSION

1. Lichen Abundance, Feeding Sites v. Non-feeding Sites

The results of the analysis of the comparison of terrestrial lichen abundance between caribou feeding and non-feeding sites are found in Table 8 (pooled) and Appendix 5 (stratified by winter and portion of study area).

Table 8. Mean lichen abundance (% cover) at feeding v. non-feeding sites - pooled ($P \leq 0.05$).[29]

Lichen type	Feeding (n= 271)	SD	Non-feeding (n=461)	SD	F	Prob.	Sig. diff.?
Cladina mitis	3.84	7.10	1.29	4.48	91.70	0.00	yes
C. rangifernia	0.43	2.17	0.05	0.32	33.11	0.00	yes
C. stellaris	0.05	0.85	0.00	0.01	1.60	0.20	no
Cladonia spp.	0.79	1.73	0.22	0.69	92.40	0.00	yes
Certraria spp.	0.05	0.55	0.00	0.03	4.00	0.05	yes
Peltigera spp.	1.94	4.48	0.92	2.20	27.10	0.00	yes
Stereocaulon spp.	2.08	6.21	0.46	3.70	52.68	0.00	yes
Cladonia uncialis	0.52	2.49	0.20	1.51	16.44	0.00	yes
Other	0.34	2.00	0.04	0.48	17.68	0.00	yes

For almost all of the terrestrial lichen types abundance was consistently higher at caribou feeding sites compared to non-feeding sites along caribou travel paths no matter what data set was involved (pooled - Table 8, winter and portion of study area sub-sets - Appendix 5). There were some exceptions to this finding, depending on the data set, but almost all involved *Cladina stellaris, Cetraria* spp., *Cladonia uncialis*, and "other". These were less commonly observed lichen types and abundance of the more common lichen types may have had more of an influence over feeding site selection.

These results lend support to previous work demonstrating that caribou have an excellent ability to detect terrestrial lichens through snow. Edmonds and Bloomfield (1984 : 124 - 125) showed that caribou winter feeding sites had higher terrestrial lichen abundance than adjacent areas that had not been traversed by the caribou within the same habitat. Cichowski (1985 : 62), working with a caribou population in B.C. which made heavy use

[29] Actual means are shown but the table F values, probabilities, and significance of the difference between feeding and non-feeding sites are based on analysis of variance using square root transformed data.

of terrestrial lichens, had similar results comparing winter feeding sites with non-feeding sites within habitat types along routes traversed by caribou.

2. Lichen Abundance at Feeding Sites and Stand Age

Terrestrial lichen abundance at feeding sites between different stand ages is compared in Table 9.

Table 9. Mean lichen abundance (% cover) at feeding sites grouped by stand origin - pooled ($P \leq 0.05$).[30]

≥ 150 years v. <150 years

Lichen type	<1845 (n=67)	SD	>=1845 (n=171)	SD	F	Prob.	Sig. diff.?
Cladina mitis	1.80	3.58	4.30	7.34	5.68	0.02	yes
Cladina rangifernia	0.35	1.33	0.50	2.56	0.01	0.93	no
Cladina stellaris	0.00	0.00	0.08	1.07	0.46	0.50	no
Certraria spp.	0.13	1.04	0.03	0.25	0.14	0.71	no

≥ 98 years v. < 98 years

Lichen type	<1895 (n=116)	SD	>=1895 (n=122)	SD	F	Prob.	Sig. diff.?
Cladina mitis	1.88	4.37	5.40	7.94	27.42	0.00	yes
Cladina rangifernia	0.24	1.01	0.69	3.08	1.47	0.23	no
Cladina stellaris	0.00	0.00	0.12	1.30	1.23	0.27	no
Certraria spp.	0.07	0.77	0.04	0.30	0.10	0.76	no

≥ 73 years v. < 73 years

Lichen type	<1920 (n=177)	SD	>= 1920 (n=61)	SD	F	Prob.	Sig. diff.?
Cladina mitis	2.79	5.99	5.92	7.69	19.68	0.00	yes
Cladina rangifernia	0.48	2.46	0.40	1.64	0.01	0.90	no
Cladina stellaris	0.08	1.05	0.00	0.00	0.40	0.53	no
Certraria spp.	0.08	0.68	0.00	0.02	0.79	0.38	no

≥ 48 years v. < 48 years

Lichen type	<1945 (n=180)	SD	>= 1945 (n=58)	SD	F	Prob.	Sig. diff.?
Cladina mitis	2.77	5.95	6.16	7.80	21.69	0.00	yes
Cladina rangifernia	0.47	2.44	0.42	1.68	0.08	0.78	no
Cladina stellaris	0.08	1.04	0.00	0.00	0.38	0.54	no
Certraria spp.	0.08	0.68	0.01	0.02	0.68	0.41	no

≥ 38 years v. < 38 years

Lichen type	<1955 (n=222)	SD	>= 1955 (n=16)	SD	F	Prob.	Sig. diff.?
Cladina mitis	3.37	6.35	6.69	9.03	3.75	0.05	yes
Cladina rangifernia	0.49	2.36	0.00	0.00	2.23	0.14	no
Cladina stellaris	0.06	0.94	0.00	0.00	0.08	0.77	no
Certraria spp.	0.06	0.61	0.01	0.03	0.11	0.74	no

[30] Actual means are shown but the table F values, probabilities, and significance of the difference between feeding and non-feeding sites are based on analysis of variance using square root transformed data. Site ages in years are given as at 1994.

Only the comparison of *Cladina mitis* abundance at feeding sites of varying stand origins shows significant differences. This result is important as *Cladina mitis* was the dominant lichen at feeding sites (Table 8). In all of the comparisons in Table 9, save one, younger stands had higher *Cladina mitis* abundance. The comparison between stands of trees > 150 years of age (in 1994) versus those 150 years or less as shown at the top of Table 9 shows a mean abundance of *Cladina mitis* in the older stands of 1.8 % cover and 4.3 % in the younger stands. This can be easily explained by what is known of the relationship between peak *Cladina* spp. abundance and stand age; stands 50 - 100 years old should have peak abundance and stands > 150 years old could be expected to have declining abundances. However, as one reviews the rest of Table 9, the results become progressively more difficult to explain. For example, there is more *Cladina mitis* in sites 50 years old or less (in 1994) as compared to those > 50 years old. This latter result seems counter-intuitive. However, it is important to realize that feeding sites are being compared. In all cases there was clearly enough lichen to get caribou to crater through the snow to feed. The best explanation for these results is that some stands less than 50 years old can contain terrestrial lichen crops that can be used by caribou. These results do not tell us anything about how often that can occur nor anything about site characteristics that might favour early lichen development.

3. Snow Characteristics, Feeding Sites v. Non-feeding Sites

There was no significant difference in snow depths between feeding and non-feeding sites (Table 10). For snow penetrability, the only significant difference occurred in the case of the non-stratified data set with the penetration figure being < 3 cm greater for feeding sites as compared to non-feeding sites (Table 11).[31]

Table 10. Mean snow depths (cm) at feeding and non-feeding sites ($P \leq 0.05$).

Data set	Feeding	n	SD	Non-Feeding	n	SD	F	Prob.	Sig. diff.?
pooled	40.6	269	13.7	40.1	464	17.7	0.2	0.7	no
winter 1 (w1)	43.4	153	14.6	42.7	239	17.4	0.2	0.7	no
winter 2 (w2)	37.0	116	11.5	37.4	225	17.7	0.1	0.8	no
non-logged	39.1	128	11.3	37.7	193	17.1	0.7	0.4	no
logged	41.9	141	15.4	41.8	271	17.9	0.0	1.0	no
w1, non-logged	39.3	67	12.6	36.5	84	19.1	1.1	0.3	no
w1, logged	46.6	86	15.2	46.1	155	15.4	0.1	0.8	no
w2, non-logged	38.9	61	9.7	38.6	109	15.4	0.0	0.9	no
w2, logged	34.7	55	12.8	36.2	116	19.6	0.2	0.6	no

[31] There is some discrepancy in the number of feeding and non-feeding sites between the lichen data and the snow data. This is the result of snow measurements not being taken at all of the feeding sites during the first backtracking episode and because a few sites were not revisited in the summer to take lichen measurements (1 flag could not be located and 3 others inadvertently missed).

Table 11. Mean snow penetration (cm) at feeding and non-feeding sites (P ≤ 0.05).

Data set	Feeding	n	SD	Non-Feeding	n	SD	F	Prob.	Sig. diff.?
winter 2 (w2)	33.2	116	10.2	29.6	225	15.2	5.3	0.0	yes
w2, logged	31.6	55	10.7	27.5	116	17.0	2.7	0.1	no
w2, non-logged	34.5	61	9.6	31.7	109	12.7	2.2	0.1	no

The results were somewhat surprising in that it was expected that there would be significantly lesser snow depths and greater snow penetration at caribou feeding sites as compared to non-feeding sites. This expectation was based on the reasoning that caribou would feed at locations involving less snow removal effort to reach terrestrial lichens.

However, the results are not that surprising when viewed in the light of caribou adaptation to snow. Previous work has shown that caribou will crater through snow depths exceeding 1 m (Brown and Theberge 1990) and Edmonds and Bloomfield (1984 : 131) found no limiting snow depths for woodland caribou in west-central Alberta over 4 winters. The results here, for the most part, suggest that factors other than snow characteristics (like lichen abundance, discussed in Chapter 4) influence selection of feeding sites along caribou travel paths. This accords with previous research indicating that caribou select feeding sites primarily for abundance of forage and secondarily on suitability of snow conditions (Pruitt 1959; Bergerud 1974).

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CHAPTER 5

REFORM OF FORESTRY LAW[32]

A. INTRODUCTION

The regulatory framework surrounding timber harvest on Crown land directly shapes forest ecosystems covering large areas of Alberta. The Green Area[33] of the Province is primarily unsettled Crown owned land (Figure 5). It accounts for 53 % (351 381 km^2) of the Province.[34] This area of Alberta provides the land base for the Province to make timber dispositions.

The character of forests presents problems in arriving at appropriate legal mechanisms for management. On the one hand, forests are renewable wood resources, capable of being managed and developed. On the other, forests are integral to the environment and need protection from human activities that would damage them.

The theme of this section of the thesis is that the present regulatory framework for timber harvest could be improved in favour of protecting forest ecosystems and the wildlife species in them while still allowing some large-scale timber harvest to take place. This theme is developed by examining several weaknesses (from the bias of a wildlife management perspective) in the present regulatory framework and making suggestions for reform.

B. THE PERPETUAL SUSTAINED YIELD PROBLEM

One of the major ways in which the Alberta Crown makes dispositions of timber is through forest management agreements (FMAs). A FMA involves the Crown granting a large tract of timber on a long-term basis (typically 20 years with renewal rights) to a person in exchange for that person developing a large wood processing facility such as a pulp and paper plant, chipboard plant, plywood mill, or sawmill.[35] The FMA provides economic benefit to the Province while assuring the wood processor of wood supply for its facility. Figure 6 shows existing FMAs.

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[32]Citation in this part of the thesis is in legal format following C. Tang, *Guide to Legal Citation* (1984).
[33]The Green Area is designated by Ministerial order pursuant to s.10 of the *Public Lands Act*, R.S.A. 1980, c. P-30.
[34]Alberta Environmental Protection, *The Status Of Alberta's Timber Supply* (1996), at p. 4.
[35]Alberta Public Lands Publication No. I/201, at p. 22.

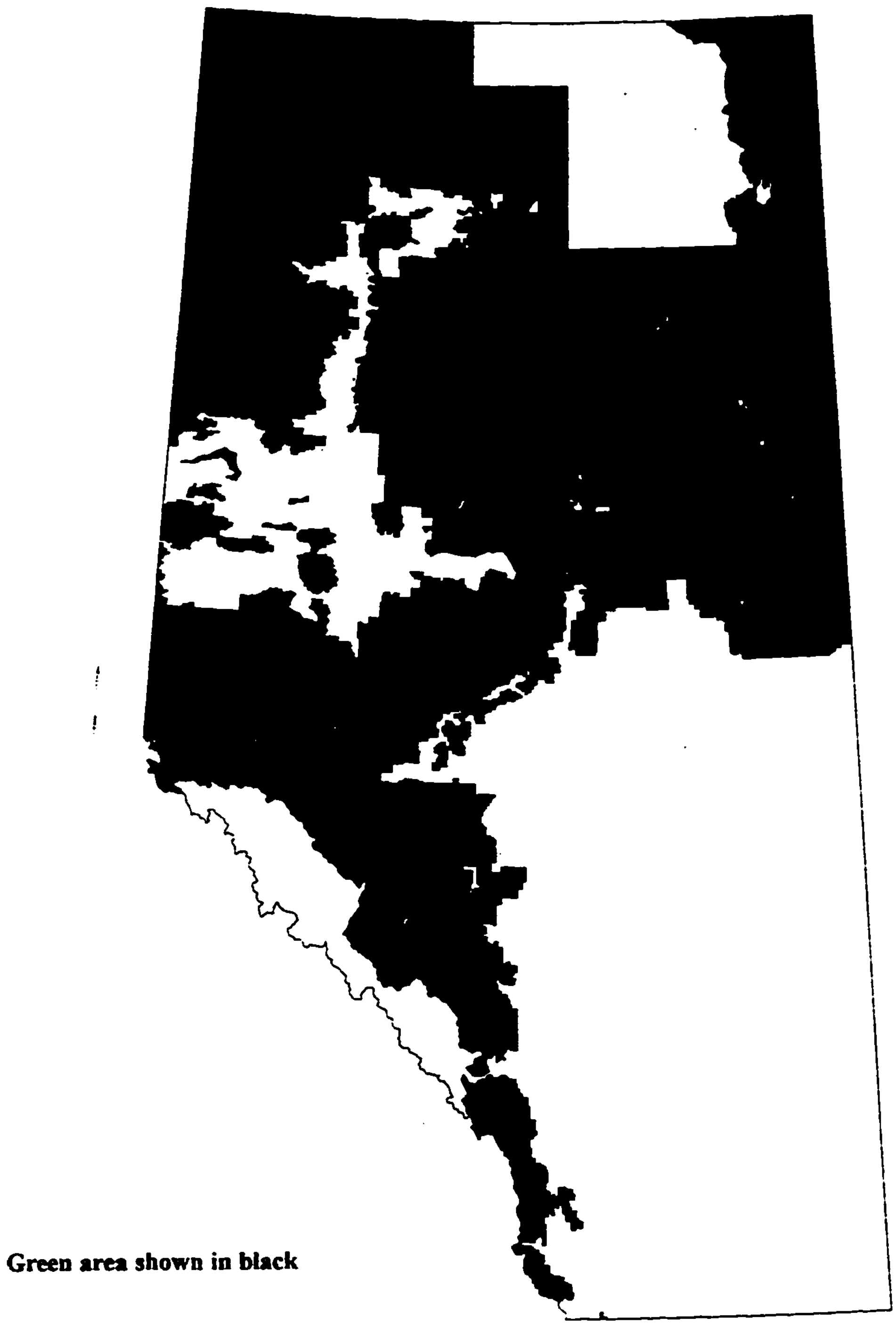

Figure 5. Green area of Alberta.[36]

[36]Adapted from Alberta Environmental Protection, *The Status Of Alberta's Timber Supply* (1996), appendix map # 1.

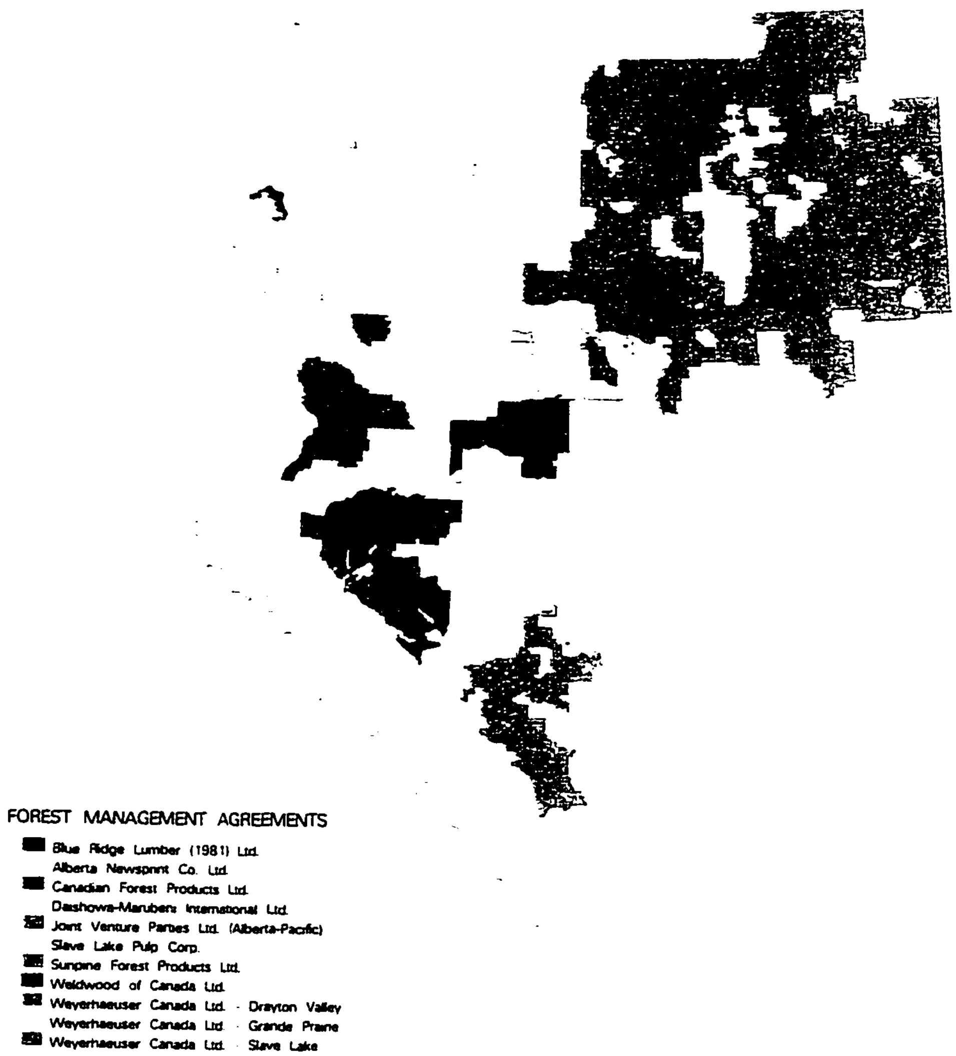

Figure 6. Forest management agreements in Alberta.[37]

[37]Adapted from Alberta Environmental Protection, *The Status Of Alberta's Timber Supply* (1996), appendix map # 2.

The legislative basis for FMAs is s. 16(1) of the *Forests Act*[38] which provides:

> The Minister, with the approval of the Lieutenant Governor in Council, may enter into a forest management agreement with any person to enable that person to enter on forest land for the purpose of establishing, growing and harvesting timber in a manner designed to provide a perpetual sustained yield (emphasis added).

Thus, the *Forests Act* requires that the forested area of the FMA be managed by the wood processor so that it provides a perpetual sustained yield. The concept of perpetual sustained yield was developed in Europe over a century ago. It means that harvest of wood fibre in a forested area must not exceed the growth so that a certain yield can be sustained forever.[39]

The problem with the requirement of perpetual sustained yield is that a forest need only be managed as a long-term supplier of wood fibre. As a concept it does not require management of forests to ensure maintenance of other forest values such as species diversity, watershed protection, recreational value, trapping and hunting potential and visual quality of the landscape.

At present many of these values are addressed by FMA holders because either the FMA specifically requires it (in more recent FMAs) or because harvest plans that must be submitted to the Minister for approval in accordance with FMA provisions will not be approved unless these values are addressed.[40] However, inclusion of such provisions in FMAs or as conditions for harvest plan approval does not ensure protection of these interests in the same way as amendment of s. 16 of the *Forests Act* would. The distinction is between policy versus a legislated requirement that could only be changed after debate in the Legislature. In addition, the present protection of other forest values in FMAs is usually made subordinate to the growing and harvesting of timber[41]. A change in the *Forests Act* is needed to ensure that the corner-stone of FMA forest management is allowance of timber harvest only to the extent that long-term maintenance of forest ecosystems is not impaired. At the least, the *Forests Act* should be amended to reflect current Government policy.

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[38] R.S.A. 1980, c. F-16.

[39] A. Moen, *Demystifying Forestry Law: An Alberta Analysis* (1990), at p. 35.

[40] The specific terms of FMA's are not set out in any statute or regulation but they typically follow a standard form which calls for the parties to negotiate ground rules that govern harvest planning requirements. FMAs also typically call for the ground rules to be reviewed periodically.

[41] For example, the ground rules for Weyerhaeuser's FMA in the study area provide that " The prime use of the Forest Management Area is the growing and harvest of timber; however, in preparation of these Ground Rules, other land uses and resource values have been considered." The text of most FMAs (including Weyerhaeuser's - s. 8(1)) have similar provisions, see Moen, supra note 39 at p. 52.

C. WITHDRAWAL PROVISIONS IN FMAs

A typical FMA has provisions allowing withdrawal of lands from the agreement for certain purposes. For example Weyerhaeuser's FMA[42] in the study area provides as follows:

> 6.(1) The Minister may, at any time in his discretion, after consultation with the Company, either permanently or for a specified term, withdraw from the forest management area:
>
> (b) any lands required for rights-of- way, water resource development or for any other purposes deemed by the Minister to be required for the human or physical resource development of the Province (emphasis added).

Other provisions in the Weyerhaeuser FMA provide for compensation to the Company in the event of withdrawals for use by the Crown. If the withdrawal is 1% or less of the agreement area, then compensation is payable only for loss or damage to improvements caused by the withdrawal (s. 6. (3)(b)). If the withdrawal involves a greater area, then the Company is to be reimbursed (respecting the excess above 1%) for costs reasonably incurred in replacing lost timber volume and for damage to timber, improvements, regeneration, forest growth, or to operations (s. 6 (3)(c)).[43]

From a wildlife management perspective such withdrawal provisions appear to be inadequate. The wording may not be sufficient to authorize withdrawal for maintenance of wildlife habitat. More importantly, there is a question as to whether compensation should be paid at all (and if so, at what level?). There are many inter-related issues that have to be addressed to answer the compensation question. Some of the key issues are discussed below.

First, there is the issue as to when a withdrawal is truly warranted. One can argue that a withdrawal is only warranted when conversion to public use from private use results in an increase in societal welfare. For example, does withdrawal to maintain caribou habitat, especially given scientific uncertainty about whether it will benefit caribou, increase societal welfare?

Second, in deciding whether to award compensation and at what level one must balance possible damage to future investment in the Province (from under-compensation) against ensuring that the Province is not unduly restrained (by the costs of required compensation) from acting in the public good. An appropriate compensation level should

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[42]December 22, 1988 Forest Management Agreement between Her Majesty the Queen and Proctor and Gamble Inc. and assigned in favour of Weyerhaeuser Canada Ltd. on November 27, 1992.

[43]Other FMAs may have different percentage cut-offs and different compensation terms when the withdrawal exceeds the cut-off.

also discourage investment in forest resource development that may not be really worthwhile.[44]

Third, there are largely unresolved technical issues about whether compensation is required as a matter of law should the Province choose to proceed with a large withdrawal via new legislation rather than through renogiatation of specific FMA clauses.[45]

Fourth, there is the issue as to the size of withdrawal a FMA holder can afford without compensation. This depends on the efficiency of the company's operations and market conditions. Unfortunately, the profit margins upon which individual companies operate is unknown. There has been no study in Alberta of the economics of individual mills, probably because this is viewed as competitive information.

Fifth, the question of compensation raises issues about ensuring that FMA holders are on an equal competitive playing field. Should FMA holders who at present have endangered species in their areas and who might potentially face a more immediate prospect of withdrawals be treated differently from those that do not?

Finally, withdrawal decisions potentially affect livelihoods and communities and there is an issue as to how and whether compensation should address this.

D. ENDANGERED SPECIES LEGISLATION

Alberta does not have any separate legislation devoted to protection of endangered species. Instead, endangered species are dealt with in the *Wildlife Act*[46], which primarily regulates hunting, trapping and possession of wildlife. Amendments to the Act[47] when proclaimed in force[48] will strengthen the existing provisions but only to a limited degree. At present, only non-fish vertebrates can be prescribed as endangered.[49] The amendments will allow fish, invertebrates, plants, algae, and fungi to also be prescribed as endangered. The amendments will add to the very limited protection of endangered species[50] by requiring the Minister to establish a committee to make recommendations

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[44]The issues of social welfare and investment effects of resource compensation levels are thoroughly discussed in, British Columbia, *Report of the Commission of Inquiry Into Compensation for the Taking of Resource Interests* (Victoria: Queen's Printer, 21 August 1992), Richard Schwindt, Commissioner.

[45]See Part Four of the Schwindt report for a review of the leading cases; the discussion in Andrew R. Thompson, "Legal Characteristics of Dispositions: An Overview" and Sheila L. Martin, "Land Withdrawals: Government Needs Versus Vested Rights" both in N.D. Bankes and J. Owen Saunders, eds., *Public Disposition of Natural Resources* (Calgary: Canadian Institute of Resources law, 1984); and H. Ian Rounthwaite, " The Impact of Wilderness Preservation on Resource Development Rights: Expropriation and Compensation Issues" in Monique Ross and J. Owen Saunders, eds., *Growing Demands on a Shrinking Heritage: Managing Resource-Use Conflicts* (Calgary: Canadian Institute of Resources Law, 1992).

[46]S.A. 1991, c. W-9.1.

[47]Sections 2(d) and 10 *Wildlife Amendment Act*, 1996, which received Royal Assent on May 24, 1996.

[48]As of August 11, 1997, these amendments had yet to be proclaimed in force.

[49]See definitions of endangered animal and animal in s. 1 of the *Wildlife Act*.

respecting the Minister's preparation and adoption of recovery plans, the organisms that should be prescribed as endangered, endangered species and biodiversity conservation, and any other endangered species matter for which the Minister seeks advice. The amendments provide that recovery plans may (not shall) include population goals, identification of critical habitats and recovery strategies. The amendments also call for recovery plans to undergo an unspecified public review process.

What is clearly missing from Alberta's legislation from the perspective of improved wildlife management is a strongly worded prohibition against killing or disturbing endangered species and a prohibition against any activities that would adversely modify their habitat.[51] Protection of habitat, when it conflicts with private interests, gives rise to many of the same issues as discussed in the context of FMA withdrawals.

Strong endangered species legislation is certainly no panacea[52] but from a wildlife management perspective it is worth having.

E. ENVIRONMENTAL ASSESSMENTS AND PUBLIC PARTICIPATION

Given the potential environmental consequences of unregulated air emissions and effluent discharge into water from wood product plants, it is not surprising that large wood product plants require approvals[53] and must undergo an environmental assessment[54] under the *Environmental Protection and Enhancement Act*[55] (EPEA).

The approval process under EPEA provides an opportunity for the public to voice concerns in connection with the approval; "directly affected" persons have the opportunity to file statements of concerns which are considered by Environmental

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[50]More stringent hunting license suspension for hunting endangered animals as compared to hunting without a license (s. 94), prohibition against willfully disturbing their nests or dens (s. 38 in conjunction with s. 23 of *General Wildlife (Ministerial) Regulation*, Alta. Reg. 95/87, and no permit to possess dead wildlife possible for endangered animals (s. 8(1) *General Wildlife(Ministerial) Regulation*).

[51]Manitoba and the United States are two of the jurisdictions with such provisions. For a short introduction to Manitoba's legislation see D. Stepaniuk, "Endangered Species Protection - Alberta v. Manitoba" (1996), Sept./Oct. *Environment Network News* 19 .

[52]The United States experience with its *Endangered Species Act* (ESA) is instructive. It has a long history and has suffered criticism from many quarters. Appendix 6 is a short article out-lining the ESA's key features and the criticisms made of it.

[53]Section 5, Schedule 1, Part 11, and the definitions for Schedule 1 of the *Activities Designation Regulation*, Alta. Reg. 211/96, result in pulp manufacturing, pulp and paper manufacturing, and wood chemical treatment plants requiring EPEA approvals regardless of capacity. Lumber production plants with a capacity greater than 20 million foot board per year and panel board plants with a capacity greater than 30 million square feet of 3/8 inch panel also require approvals.

[54]Pulp, paper, newsprint or recycled fiber mills with a capacity of more than 100 tonnes per day are mandatory activities in the *Environmental Assessment (Mandatory & Exempted Activities) Regulation*. Alta. Reg. 111/93, requiring assessment under EPEA.

[55]S.A. 1992, c. E-13.3..

Protection in deciding on an approval application.[56] Directly affected persons also have the right to appeal the granting of an approval to the Environmental Appeal Board.[57]

The EPEA environmental assessment process has stated purposes which include predicting the environmental, social, economic, and cultural consequences of a proposed activity, assessing mitigation plans, and providing for the involvement of the public in the review.[58]

The *Natural Resources Conservation Board Act*[59]provides for an additional review by the Natural Resources Conservation Board (NRCB) of pulp, paper, newsprint and, recycled fibre facility projects and of lumber, veneer, panel board, or treated wood facility projects for which an environmental assessment has been ordered.[60] A NRCB review determines if a project is in the public interest having regard to its social, economic and environmental effects.[61] The public can participate in a NRCB review. "Directly affected" persons are eligible to receive funding to assist in their participation in the review[62] and the NRCB can provide opportunities to persons who may not be directly affected to participate (without funding).[63]

Surprisingly, the woodlands operations supporting these plants are not subject to any of these processes notwithstanding that timber harvest has the potential for profound environmental consequences.[64] From the perspective of wildlife management, there is no reason why large-scale timber harvest should not be subject to public scrutiny and environmental assessment processes that are the same as those for the plant the timber harvest supports. Conducting a review before a forest management agreement is concluded will afford an opportunity for all concerned to identify wildlife management problems and have plans in place to mitigate or avoid them before a single tree is cut. Problems like the potential for withdrawals for habitat maintenance are easier to address before a costly plant is built and before people are employed rather than after. For the forest management agreements already in place, these processes could be incorporated into the decision to renew the agreements at the conclusion of their terms.

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[56]EPEA s. 70.
[57]EPEA s. 84.
[58]EPEA s. 38.
[59]S.A. 1990, c. N-5.5.
[60]See s. 4 and s. 1 definitions.
[61]See s. 2.
[62]See s. 10.
[63]See s. 8.
[64]Saskatchewan appears to be a leader in this regard. Section 100 of the *Forest Resources Management Act*, S.S. 1996, c. F-19.1, when proclaimed (expected in late 1997), will amend the Province's environmental assessment legislation to require an assessment of forest management activities under management licenses with 20 year forest management plans not yet having ministerial approval.

F. CONCLUSION

The regulatory framework in which large-scale timber harvest operates directly affects forest ecosystems. Improvements in the regulatory framework can benefit forest ecosystems and the wildlife species that are part of them.

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CHAPTER 6

SYNTHESIS

A. SUMMARY

The objective of this thesis was to further the development of planning tools that could be used in managing Alberta's woodland caribou during large-scale timber harvest on their range. Clearly, the research presented has not resulted in specific planning tools that could be used immediately by forest and wildlife managers. However, it should aid future development of such tools.

Chapter 3 shows that Alberta Phase 3 Timber Inventory is probably inadequate for mapping caribou habitat. Phase 3 's usefulness as a tool to map caribou habitat was predicated on its ability to predict the abundance of terrestrial lichens, the main winter food source for caribou in west-central Alberta. Phase 3 does not seem to be able to do this with sufficient precision. The results in Chapter 3, in particular caribou preferences and avoidances of timber stand origin, may also lend support to the theory that caribou choose habitats for reasons other than forage availability. The avoidance of clear-cuts by caribou may suggest that forest planners and caribou managers find ways to turn them into caribou habitat.

Chapter 4 supports previous research showing that caribou choose feeding locations in their winter travels based on terrestrial lichen abundance. The chapter also showed that timber stands of a variety of ages can have terrestrial lichens that caribou will use. In the 2 winters measured in this study, snow characteristics did not influence where caribou chose to feed as they traveled. This does not mean that snow is of no consequence to caribou. One can envision snow conditions being important. Snow conditions may explain caribou avoiding clear-cuts and, as discussed in Chapter 3, rare extreme snow conditions could force caribou to heavily rely on arboreal lichens as a substitute food source.

Finally, Chapter 5 examines reform of the law regulating timber harvest in Alberta to improve the balance between extraction of wood fibre and protection of the long-term viability of forest ecosystems.

B. RECOMMENDATIONS FOR FURTHER RESEARCH AND PLANNING

1. Comparison with Aerial Relocation Study

The results here should be compared to those of the companion aerial relocation study. This will perhaps provide a clearer picture of caribou habitat needs and whether it is useful to characterize them in terms of Alberta Phase 3 Timber Inventory.

Having the ability to compare the 3 measures of habitat use employed in this study (distance traveled, feeding craters/km, and feeding craters/km adjusted for caribou group size) with aerial relocation by helicopter may help to define their respective reliabilities.[65]

The problem with distance as a measure of habitat use is that the greatest distance traveled in a habitat category is equated to greatest use. In terms of a habitat category's contribution to providing survival benefits, traveling distance might actually indicate unsuitability. Caribou may travel large distances through unsuitable habitats to get to more suitable ones.

The number of feeding craters per km traveled for each habitat category is probably a better measure than distance traveled because it contains an intensity component.

Adjusting feeding craters/km for caribou group size may not necessarily give a more precise measure of use because, although one would expect a larger group of caribou to make more feeding craters all other things being equal, there is considerable difficulty in estimating group size from tracks. Caribou tend to walk in each other's tracks, a single caribou can make tracks like several by circling and meandering through its own tracks, and heavily used cratering areas may have the tracks of several groups' visits over the period of a few days.

Aerial relocation may not be a reliable method of determining habitat preferences because it is possible that, but for a helicopter being in the area, a given caribou would have been in a habitat different from that recorded. Additionally, aerial relocation data may be biased because relocation flights can only be conducted during daylight and during good weather and caribou habitat use may differ at night or during inclement weather.

To the extent that all of these measures of habitat use agree, it may confirm the results of this study showing that Phase 3 Timber Inventory is largely inadequate in planning for caribou habitat needs. Alternatively, it could also suggest ways Phase 3 might be modified and usefully employed in caribou management planning.

2. Analysis of Caribou Track Travel Paths using AVI

Management of forests addressing forest values beyond simple timber supply has created a need for a more comprehensive vegetation inventory incorporating things like ecosystem types for timber stands based on plant associations similar to Corns and Annas (1986). The result is that Phase 3 inventory is to be replaced with Alberta Vegetation Inventory (Alberta Environmental Protection Resource Data Division 1991).

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[65]The 3 habitat use measures in this study largely agreed in terms of results. The most important difference occurred in the case of the timber species categories. Table 7 shows a null result for caribou use of the species levels decid (deciduous), mixed, ds (deciduous scrub), and other as measured by distance traveled but the 2 crater measures show these levels to be avoided.

Unfortunately, Alberta Vegetation Inventory maps were not available for the study area whereas Phase 3 maps were available for all of the Province's forests where large-scale harvest is to take place. When Alberta Vegetation Inventory (AVI) is completed in the study area, an analysis of the caribou track travel paths should be performed using categories based on AVI. AVI may better differentiate timber stands based on terrestrial lichen abundance because it includes understory vegetation. The caribou track paths in MapInfo and in DBF[66] form have been provided to the Department of Environmental Protection, Natural Resource Services, Edson, AB.

3. Predicting Effects of Timber Harvest on Arboreal Lichens

Evaluating the true importance of arboreal lichens to woodland caribou in west-central Alberta is difficult. Arboreal feeding was only observed during tracking in this study a few times.[67] However, as previously discussed, although arboreal lichens only constitute a small proportion of the usual winter diet of caribou in west central Alberta, it is speculated that available arboreal lichens may be critical as a food source when snow depth or snow hardness (especially during thaw/freeze cycles in the spring) exceeds some threshold. Further work is needed to evaluate the present and future capacity of the range to support the herd solely on arboreal lichens for extended periods which could be necessitated by an unusual "bottle-neck" winter. Edmonds and Bloomfield (1984 : 124) found available arboreal lichen production in west-central Alberta to be 119 kg/ha and that this was not less than that reported elsewhere. However, an evaluation is still required of how that has changed and will change with logging and what it may mean for caribou numbers in a critical winter based on estimated consumption rates. Based on the work of Rominger *et al.* (1996), evaluation of arboreal lichen production should keep species separate because some arboreal lichens may essentially not be caribou food. In particular, this work questions previous research identifying *Alectoria sarmentosa* as a caribou food source.

4. Monitoring Clear-Cuts

The methodology used in this study clearly showed that clear-cuts were avoided by caribou. However, caribou may use the clear-cuts in the future. Clear-cuts in the study area should be monitored for future use by caribou and data should be collected (with appropriate adjacent control sites) to show changes in terrestrial lichen availability, stand density, snow conditions, and wind speed over time. This could help clarify the reasons why recent clear-cuts are avoided and possibly lead to improved harvest techniques to speed the development of clear-cuts into useful caribou habitat.

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[66]The DBF file would have to be run through a computer program to draw the lines.

[67]During winter 1 (flag#, line#, township#, stand#, Phase 3 description, date): **1)** 63, 21, 62/10, 3, C3SwP 83, 10/2/94; **2)** 284, 28, 60/8, 160, tm, 24/3/94; **3)** 302, 13, 63/10, 79, A2P 89, 27/3/94; **4)** 305-306 + 313, 13, 63/10, 75, C0Sw 94, 27/3/94; **5)** 339, 19, 62/10, 7, C2P(Sw) 86, 30/3/94; and, **6)** 343, 19, 62/10, 130, C3SwFbP 83, 30/3/94. During winter 2: **1)** 115a, 44, 62/8, 103, D2P 90, 17/2/95; and, **2)** 275a, 57, 60/8, 163, C3PSwSb 82, 29/3/95.

5. Investigation of Natural Forest Mosaic on Traditional Caribou Range

Morrison *et al.* (1992 : 28) suggests that one must study the relationships between an animal and its environment in the context of past events that initially shaped the adaptation of the animal to its environment. It may therefore be worthwhile to explore the natural forest mosaic on traditional caribou range in Alberta before human settlement with a view to attempting to recreate it.

As already discussed, natural boreal forest successional processes are governed by fire. Can logging in conjunction with imperfect fire suppression be used to recreate the natural fire successional processes to which woodland caribou adapted?

There are of course difficulties in such an exercise.

First, one must determine the natural fire history. There is a model that provides the composition of a forested area in terms of age classes based on a given fire-cycle, the time it takes to burn over an area equal to the whole area of the forest (Van Wagner 1978). The same model based on certain assumptions can also be used to deduce the fire history of a forested area based on present composition of age-classes in the forest. However, there is an extremely limited ability to test this model against a known fire cycle because reconstructing past fire events in stands older than 300-350 years is imprecise (Rogeau 1996). How can one assume a consistent fire cycle over time based on only the most recent physical evidence. In addition, the assumptions in the model do not necessarily apply to every area regardless of terrain (Rogeau 1996).

A second problem has to do with the landbase upon which woodland caribou may now be restricted. Even if we can perfectly determine the natural mosaic of boreal forest to which woodland caribou are adapted, will recreating it on a smaller landbase be enough? In other words, we may have to improve upon nature to maintain caribou on a smaller landbase. This may also be necessitated by the fact that even if logging can largely duplicate fire successional patterns, it still has effects (like increased human access) beyond those of fire.

Finally, can logging duplicate fire as a succesional mechanism over the long-term, given that logging essentially removes the biomass of trees whereas fire returns it to the soil?

6. Policy Considerations

What is the present foundation for woodland caribou research in Alberta? Is the present foundation the right one? Such policy questions are not easily answered. For example, one might persuasively argue that it is presently assumed that large-scale timber harvest and woodland caribou can co-exist. This approach is fraught with risk for caribou. Science might eventually conclude that large-scale timber harvest and woodland caribou cannot coexist and, while science slowly arrived at the conclusion, the opportunity to preserve woodland caribou was lost. Should we perhaps adopt a precautionary approach and forego the obvious substantial economic benefits of timber harvest on caribou range until such time as science tells us that logging will not be detrimental to the long-term survival of caribou. Perhaps it is already too late for caribou and therefore we may as well reap the benefits of timber harvest.

The point is that these types of questions are worthy of open debate. Because decisions in forest and wildlife management have important environmental and economic consequences, perhaps Albertans should have improved opportunities to be aware of the issues and participate in the decision-making process.

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APPENDICES

Appendix 1. Accuracy of starting locations of caribou track travel path lines, line length, and length lost through MapInfo segmenting.[68]

Line No.	Starting Flag No.	Comments	Length	Loss
1	270	GPS start 300 m n relative to landmarks not on digital map	2741 m	3 m
2	136	substituted corrected GPS location for end flag 140 as start because 136 GPS data corrupted, GPS 140 within 30 m of landmark not on digital map	321 m	0 m
3	19	no good landmark to compare	1004 m	2 m
4	239	no good landmark to compare	360 m	1 m
5	246	relative to line 4 appears wrong as on ground 11 m away but as mapped 60 m away	1962 m	5 m
6	126	GPS start 85 m nw relative to seismic line landmark not on digital map	494 m	1 m
7	383	GPS start 50 m in error relative to seismic line landmark not on digital map	675 m	1 m
8	391	no good landmark to compare	98 m	0 m

68 "*" indicates line distances through polygons measured by hand and not in Mapinfo.

Appendix 1 (continued). Accuracy of starting locations of caribou track travel path lines, line length, and length lost through MapInfo segmenting.

Line No.	Starting Flag No.	Comments	Length	Loss
9	256	GPS start accords with placement based on landmark	2570 m	+1 m
10	145	GPS start accords with placement based on landmark	1531 m	2 m*
11	9	GPS start accords with placement based on landmark	168 m	0 m*
12	40	relative to line 10 on the ground GPS start appears to be 140 m too far west	351 m	1 m*
13	302	GPS start accords with placement based on landmark	1292 m	2 m
14	291	GPS start accords with placement based on landmark	858 m	1m
15	291	GPS start accords with placement based on landmark	1127m	3 m
16	196	GPS start accords with placement based on landmark	1454 m	3 m
17	87	GPS start accords with placement based on landmark	2258 m	4 m
18	64	no good landmark to compare	1312 m	4 m

Appendix 1 (continued). Accuracy of starting locations of caribou track travel path lines, line length, and length lost through MapInfo segmenting.

Line No.	Starting Flag No.	Comments	Length	Loss
19	334	GPS start 100 m nw relative to road landmark not on digital map	2417 m	5 m
20	1	no GPS start for 1 but location determined by extrapolating distance and bearing information and using GPS location for Flag 2	778 m	18 m
21	50	no good landmark to compare	502 m	1 m
22	121	no good landmark to compare	85 m	0 m
23	316	see text under sources of mapping error c. 3	1090 m	2 m
24	331	see text under sources of mapping error c. 3	90 m	1 m
25	365	relative to lines 32 and 33 GPS start 35 m e	1108 m	3 m
26	172	GPS start accords with placement based on landmark	1406 m	3 m*
27	213	GPS start 20 m in error relative to landmark not on digital map	1848 m	0 m*
28	283	no good landmark to compare	1209 m	3 m
29	239a	GPS start accords with placement based on landmark	2763 m	6 m

Appendix 1 (continued). Accuracy of starting locations of caribou track travel path lines, line length, and length lost through MapInfo segmenting.

Line No.	Starting Flag No.	Comments	Length	Loss
30	309a	see text under sources of mapping error c. 3	1034 m	3 m
31	213a	GPS start within 10 m of landmark	1385 m	2 m
32	203a	GPS start within 30 m of landmark	920 m	2 m
33	117a	GPS start 60 m in error relative to landmark not on digital map	875 m	1 m
34 and 35	335a	no good landmark to compare	435 m	1 m
36	317a	GPS start 50 m in error relative to landmark not on digital map	967 m	2 m
37	103a	GPS start accords with placement based on landmark	1760 m	0 m*
38	104a	GPS start accords with placement based on landmark	710 m	0 m*
39	48a	no good landmark to compare	1331 m	2 m
40	36a	GPS start 50 m in error relative to landmark not on digital map	1358 m	2 m
41	188a	GPS start 100 m in error relative to landmark not on digital map	718 m	3 m

Appendix 1 (continued). Accuracy of starting locations of caribou track travel path lines, line length, and length lost through MapInfo segmenting.

Line No.	Starting Flag No.	Comments	Length	Loss
42	195a	no good landmark to compare	662 m	1 m
43	178a	GPS start 100 m in error relative to landmark not on digital map	1328 m	2 m
44	113a	no good landmark to compare	375 m	1 m*
45	123a	GPS start 80 m in error relative to landmark not on digital map	1176 m	2 m
46	326a	see comments re line 36	1694 m	3 m
47	203a	see comments re line 32	1736 m	3 m
48	173a	no good landmark to compare	447 m	0 m
49	262a	no good landmark to compare	217 m	0 m
50	265a	no good landmark to compare	797 m	1 m
51	163a	no good landmark to compare	1087 m	2 m
52	154a	no good landmark to compare	619 m	1 m
53 and 54	295a	no good landmark to compare	1922 m	4 m
55	23a	GPS start accords with placement based on landmark	865 m	1 m*

Appendix 1 (continued). Accuracy of starting locations of caribou track travel path lines, line length, and length lost through MapInfo segmenting.

Line No.	Starting Flag No.	Comments	Length	Loss
56	147a	GPS start 100 m in error relative to landmark	958 m	2 m*
57	271a	no good landmark to compare	1270 m	3 m
58	94a	GPS start 100 m in error relative to landmark not on digital map	1520 m	4 m
59 and 60	129a	GPS start 85 m w from relative to landmark	1834 m	5 m*
61	16a	GPS start 85 m nw relative to landmark	458 m	1 m*
62	65a	GPS start 100 m nw relative to landmark	1969 m	3 m*
63	82a	GPS start 50 m sw relative to landmark	437 m	1 m*
64	1a	GPS start 140 m sw relative to landmark	1018 m	3 m*
65	11a	GPS start 100 m nw relative to landmark	238 m	0 m*
66	306a	GPS start accords with placement based on landmark	190 m	0 m
67	334	GPS start 100 m nw relative to landmark not on digital map	1055 m	0 m*

Appendix 2. Caribou use of single variable habitat categories - data subsets.[69]

Winter 1 n=27

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
crown closure								
A (6-30%)		0.01	0.06	0.06	0.03	null	null	null
B (31-50%)		0.12	0.05	0.12	0.12	null	null	null
C (51-70%)		0.66	0.68	0.60	0.58	null	null	null
D (>70%)		0.07	0.11	0.13	0.12	null	null	null
other		0.15	0.10	0.09	0.16	null	null	null
	total	1.00	1.00	1.00	1.00			
A (6-30%)		0.01	0.06	0.06	0.03	null	null	null
B (31-50%)		0.14	0.06	0.13	0.14	null	null	null
C (51-70%)		0.77	0.75	0.66	0.68	null	null	null
D (>70%)		0.08	0.13	0.15	0.15	null	null	null
	total	1.00	1.00	1.00	1.00			
height								
0 (0-6m)		0.20	0.07	0.05	0.12	null	null	null
1 (6.1-12m)		0.11	0.21	0.22	0.18	null	null	null
2 (12.1-18m)		0.34	0.26	0.25	0.36	null	null	null
3 (>18m)		0.20	0.37	0.38	0.19	null	null	null
other		0.15	0.10	0.09	0.16	null	null	null
	total	1.00	1.00	1.00	1.00			
0 (0-6m)		0.23	0.07	0.06	0.14	null	null	null
1 (6.1-12m)		0.13	0.24	0.25	0.21	null	null	null
2 (12.1-18m)		0.40	0.29	0.28	0.42	null	null	null
3 (>18m)		0.24	0.41	0.42	0.23	null	null	null
	total	1.00	1.00	1.00	1.00			
origin								
≤1830 (≥164 yrs.)		0.20	0.37	0.38	0.10	null	preferred	preferred
1831-1879 (115-163 yrs.)		0.23	0.13	0.11	0.18	null	null	null
1880-1929 (65-114 yrs.)		0.11	0.08	0.10	0.28	avoided	avoided	avoided
1930-1985 (9-64 yrs)		0.31	0.32	0.31	0.28	null	null	null
cc (clear-cuts)		0.00	0.00	0.00	0.01	avoided	avoided	avoided
other		0.15	0.10	0.09	0.14	null	null	null
	total	1.00	1.00	1.00	1.00			
≤1830 (≥164 yrs.)		0.20	0.37	0.38	0.10	null	preferred	preferred
1831-1879 (115-163 yrs.)		0.23	0.13	0.11	0.18	null	null	null
1880-1929 (65-114 yrs.)		0.11	0.08	0.10	0.28	avoided	avoided	avoided
1930-1985 (9-64 yrs)		0.31	0.32	0.31	0.28	null	null	null
other & cc		0.15	0.10	0.09	0.16	null	null	null
	total	1.00	1.00	1.00	1.00			

[69]For explanatory notes see Table 7.

Appendix 2 (continued). Caribou use of single variable habitat categories - data subsets.

Winter 1 n=27

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
≤1830 (≥164 yrs.)		0.24	0.41	0.42	0.12	null	preferred	preferred
1831-1879 (115-163 yrs.)		0.27	0.14	0.13	0.21	null	null	null
1880-1929 (65-114 yrs.)		0.13	0.09	0.11	0.34	avoided	avoided	avoided
1930-1985 (9-64 yrs)		0.36	0.36	0.34	0.33	null	null	null
	total	1.00	1.00	1.00	1.00			
species								
conifer		0.80	0.88	0.88	0.73	null	null	null
decid		0.03	0.00	0.00	0.04	null	avoided	avoided
mixed		0.04	0.02	0.02	0.07	null	null	null
ds (decid. scrub)		0.04	0.05	0.06	0.05	null	null	null
cs (conifer scrub)		0.02	0.03	0.03	0.03	null	null	null
muskeg		0.05	0.01	0.01	0.03	null	null	null
cc (clear-cuts)		0.00	0.00	0.00	0.01	avoided	avoided	avoided
other		0.01	0.01	0.01	0.04	avoided	null	null
	total	1.00	1.00	1.00	1.00			
P (pine)		0.48	0.45	0.45	0.57	null	null	null
Sb (black spruce)		0.13	0.13	0.16	0.08	null	null	null
Sw (white spruce)		0.31	0.40	0.36	0.22	null	null	null
decid		0.04	0.00	0.00	0.05	null	avoided	avoided
mixed		0.04	0.03	0.03	0.08	null	null	null
	total	1.00	1.00	1.00	1.00			
aspect								
n		0.09	0.34	0.35	0.18	null	null	null
o		0.77	0.52	0.52	0.64	null	null	null
s		0.14	0.14	0.13	0.18	null	null	null
	total	1.00	1.00	1.00	1.00			

Appendix 2 (continued). Caribou use of single variable habitat categories - data subsets.[70]

Winter 2 n=32

Category Level	Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
crown closure							
A (6-30%)	0.02	0.02	0.03	0.03	null	null	null
B (31-50%)	0.13	0.04	0.04	0.12	null	null	null
C (51-70%)	0.64	0.44	0.46	0.58	null	null	null
D (>70%)	0.09	0.14	0.15	0.12	null	null	null
other	0.11	0.35	0.32	0.16	null	null	null
total	1.00	1.00	1.00	1.00			
A (6-30%)	0.03	0.04	0.05	0.03	null	null	null
B (31-50%)	0.14	0.06	0.06	0.14	null	null	null
C (51-70%)	0.73	0.68	0.67	0.68	null	null	null
D (>70%)	0.10	0.22	0.22	0.15	null	null	null
total	1.00	1.00	1.00	1.00			
height							
0 (0-6m)	0.08	0.07	0.09	0.12	null	null	null
1 (6.1-12m)	0.16	0.25	0.26	0.18	null	null	null
2 (12.1-18m)	0.42	0.25	0.26	0.36	null	null	null
3 (>18m)	0.23	0.07	0.08	0.19	null	avoided	avoided
other	0.11	0.35	0.32	0.16	null	null	null
total	1.00	1.00	1.00	1.00			
0 (0-6m)	0.09	0.11	0.13	0.14	null	null	null
1 (6.1-12m)	0.19	0.39	0.38	0.21	null	null	null
2 (12.1-18m)	0.47	0.39	0.38	0.42	null	null	null
3 (>18m)	0.26	0.11	0.11	0.23	null	null	null
total	1.00	1.00	1.00	1.00			
origin							
≤1830 (≥164 yrs.)	0.32	0.07	0.07	0.10	preferred	null	null
1831-1879 (115-163 yrs.)	0.17	0.13	0.12	0.18	null	null	null
1880-1929 (65-114 yrs.)	0.20	0.24	0.24	0.28	null	null	null
1930-1985 (9-64 yrs)	0.20	0.21	0.25	0.28	null	null	null
cc (clear-cuts)	0.00	0.00	0.00	0.01	avoided	avoided	avoided
other	0.11	0.35	0.32	0.14	null	preferred	null
total	1.00	1.00	1.00	1.00			
≤1830 (≥164 yrs.)	0.32	0.07	0.07	0.10	preferred	null	null
1831-1879 (115-163 yrs.)	0.17	0.13	0.12	0.18	null	null	null
1880-1929 (65-114 yrs.)	0.20	0.24	0.24	0.28	null	null	null
1930-1985 (9-64 yrs)	0.20	0.21	0.25	0.28	null	null	null
other & cc	0.11	0.35	0.32	0.16	null	null	null
total	1.00	1.00	1.00	1.00			

[70]For explanatory notes see Table 7.

Appendix 2 (continued). Caribou use of single variable habitat categories - data subsets.

Winter 2 n=32

Category		Proportion of use as measured by...			Expected	Significance		
Level		distance (m)	crts/km	adj crts/km	use	distance	crts/km	adj crts/km
≤1830 (≥164 yrs.)		0.36	0.10	0.10	0.12	preferred	null	null
1831-1879 (115-163 yrs.)		0.19	0.19	0.18	0.21	null	null	null
1880-1929 (65-114 yrs.)		0.22	0.37	0.35	0.34	null	null	null
1930-1985 (9-64 yrs)		0.23	0.33	0.37	0.33	null	null	null
	total	1.00	1.00	1.00	1.00			
species								
conifer		0.83	0.64	0.67	0.73	null	null	null
decid		0.03	0.01	0.01	0.04	null	null	null
mixed		0.03	0.00	0.00	0.07	null	avoided	avoided
ds (decid. scrub)		0.01	0.30	0.27	0.05	null	preferred	preferred
cs (conifer scrub)		0.02	0.03	0.04	0.03	null	null	null
muskeg		0.06	0.01	0.01	0.03	null	null	null
cc (clear-cuts)		0.00	0.00	0.00	0.01	avoided	avoided	avoided
other		0.02	0.01	0.01	0.04	null	null	null
	total	1.00	1.00	1.00	1.00			
P (pine)		0.54	0.76	0.76	0.57	null	preferred	preferred
Sb (black spruce)		0.11	0.15	0.15	0.08	null	null	null
Sw (white spruce)		0.28	0.08	0.08	0.22	null	avoided	avoided
decid		0.04	0.01	0.01	0.05	null	null	null
mixed		0.03	0.00	0.00	0.08	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
aspect								
n		0.04	0.04	0.03	0.18	avoided	avoided	avoided
o		0.80	0.86	0.86	0.64	preferred	preferred	preferred
s		0.16	0.10	0.10	0.18	null	null	null
	total	1.00	1.00	1.00	1.00			

Appendix 2 (continued). Caribou use of single variable habitat categories - data subsets.[71]

Unlogged n=31

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
crown closure								
A (6-30%)		0.01	0.02	0.03	0.03	null	null	null
B (31-50%)		0.13	0.03	0.08	0.12	null	avoided	null
C (51-70%)		0.61	0.54	0.51	0.58	null	null	null
D (>70%)		0.06	0.00	0.00	0.12	null	avoided	avoided
other		0.18	0.42	0.38	0.16	null	preferred	preferred
	total	1.00	1.00	1.00	1.00			
A (6-30%)		0.02	0.03	0.04	0.03	null	null	null
B (31-50%)		0.16	0.05	0.13	0.14	null	null*	null
C (51-70%)		0.74	0.92	0.82	0.68	null	preferred	null
D (>70%)		0.08	0.00	0.00	0.15	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
height								
0 (0-6m)		0.13	0.05	0.06	0.12	null	null	null
1 (6.1-12m)		0.09	0.15	0.14	0.18	null	null	null
2 (12.1-18m)		0.30	0.30	0.33	0.36	null	null	null
3 (>18m)		0.30	0.08	0.09	0.19	null	avoided	null
other		0.18	0.42	0.38	0.16	null	preferred	preferred
	total	1.00	1.00	1.00	1.00			
0 (0-6m)		0.16	0.09	0.10	0.14	null	null	null
1 (6.1-12m)		0.10	0.26	0.23	0.21	null	null	null
2 (12.1-18m)		0.36	0.52	0.53	0.42	null	null	null
3 (>18m)		0.37	0.13	0.14	0.23	null	null	null
	total	1.00	1.00	1.00	1.00			
origin								
≤1830 (≥164 yrs.)		0.38	0.13	0.13	0.10	preferred	null	null
1831-1879 (115-163 yrs.)		0.02	0.06	0.05	0.18	avoided	avoided	avoided
1880-1929 (65-114 yrs.)		0.23	0.20	0.24	0.28	null	null	null
1930-1985 (9-64 yrs)		0.19	0.19	0.19	0.28	null	null	null
cc (clear-cuts)		0.00	0.00	0.00	0.01	avoided	avoided	avoided
other		0.18	0.42	0.38	0.14	null	preferred	preferred
	total	1.00	1.00	1.00	1.00			
≤1830 (≥164 yrs.)		0.46	0.22	0.22	0.12	preferred	null	null
1831-1879 (115-163 yrs.)		0.03	0.10	0.08	0.21	avoided	null	avoided
1880-1929 (65-114 yrs.)		0.28	0.35	0.39	0.34	null	null	null
1930-1985 (9-64 yrs)		0.23	0.33	0.31	0.33	null	null	null
	total	1.00	1.00	1.00	1.00			

[71]For explanatory notes see Table 7.

Appendix 2 (continued). Caribou use of single variable habitat categories - data subsets.

Unlogged n=31

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
species								
conifer		0.77	0.58	0.61	0.73	null	null	null
decid		0.04	0.00	0.00	0.04	avoided*	avoided	avoided
mixed		0.01	0.00	0.00	0.07	null*	avoided	avoided
ds (decid. scrub)		0.09	0.41	0.37	0.05	null	preferred	preferred
cs (conifer scrub)		0.02	0.01	0.01	0.03	null	avoided*	avoided*
muskeg		0.06	0.01	0.01	0.03	null	null	null
cc (clear-cuts)		0.00	0.00	0.00	0.01	avoided	avoided	avoided
other		0.00	0.00	0.00	0.04	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			
P (pine)		0.48	0.73	0.75	0.57	null	null	preferred
Sb (black spruce)		0.12	0.17	0.14	0.08	preferred*	preferred*	preferred*
Sw (white spruce)		0.34	0.10	0.11	0.22	null	avoided	null
decid		0.05	0.00	0.00	0.05	null	avoided	avoided
mixed		0.01	0.00	0.00	0.08	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			
aspect								
n		0.08	0.11	0.19	0.18	avoided	null	null
o		0.73	0.74	0.68	0.64	null	null	null
s		0.19	0.15	0.13	0.18	null	null	null
	total	1.00	1.00	1.00	1.00			

Appendix 2 (continued). Caribou use of single variable habitat categories - data subsets.[72]

Logged n=28

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
crown closure								
A (6-30%)		0.02	0.06	0.06	0.03	null	null	null
B (31-50%)		0.12	0.06	0.08	0.12	null	null	null
C (51-70%)		0.68	0.58	0.56	0.58	null	null	null
D (>70%)		0.09	0.22	0.23	0.12	null	null	null
other		0.09	0.08	0.07	0.16	null	null	null
	total	1.00	1.00	1.00	1.00			
A (6-30%)		0.02	0.06	0.06	0.03	null	null	null
B (31-50%)		0.13	0.06	0.09	0.14	null	null	null
C (51-70%)		0.75	0.63	0.60	0.68	null	null	null
D (>70%)		0.10	0.24	0.25	0.15	null	null	null
	total	1.00	1.00	1.00	1.00			
height								
0 (0-6m)		0.13	0.08	0.08	0.12	null	null	null
1 (6.1-12m)		0.18	0.29	0.30	0.18	null	null	null
2 (12.1-18m)		0.45	0.22	0.21	0.36	null	null	null
3 (>18m)		0.15	0.33	0.34	0.19	null	null	null
other		0.09	0.08	0.07	0.16	null	null	null
	total	1.00	1.00	1.00	1.00			
0 (0-6m)		0.15	0.09	0.08	0.14	null	null	null
1 (6.1-12m)		0.20	0.32	0.33	0.21	null	null	null
2 (12.1-18m)		0.49	0.24	0.22	0.42	null	avoided	avoided
3 (>18m)		0.17	0.35	0.37	0.23	null	null	null
	total	1.00	1.00	1.00	1.00			
origin								
≤1830 (≥164 yrs.)		0.18	0.28	0.30	0.10	null	null	null
1831-1879 (115-163 yrs.)		0.32	0.18	0.16	0.18	null	null	null
1880-1929 (65-114 yrs.)		0.11	0.13	0.12	0.28	avoided	null	avoided
1930-1985 (9-64 yrs)		0.30	0.33	0.35	0.28	null	null	null
cc (clear-cuts)		0.00	0.00	0.00	0.01	avoided	avoided	avoided
other		0.09	0.08	0.07	0.14	null	null	null
	total	1.00	1.00	1.00	1.00			
≤1830 (≥164 yrs.)		0.20	0.31	0.33	0.12	null	null	preferred
1831-1879 (115-163 yrs.)		0.36	0.19	0.17	0.21	null	null	null
1880-1929 (65-114 yrs.)		0.12	0.14	0.12	0.34	avoided	avoided	avoided
1930-1985 (9-64 yrs)		0.33	0.36	0.38	0.33	null	null	null
	total	1.00	1.00	1.00	1.00			

[72]For explanatory notes see Table 7

Appendix 2 (continued). Caribou use of single variable habitat categories - data subsets.

Logged n=28

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
species								
conifer		0.83	0.90	0.90	0.73	null	preferred	preferred
decid		0.03	0.01	0.01	0.04	null	null	null
mixed		0.05	0.02	0.02	0.07	null	null	null
ds (decid. scrub)		0.01	0.01	0.01	0.05	avoided	null	null
cs (conifer scrub)		0.03	0.05	0.05	0.03	null	null	null
muskeg		0.03	0.00	0.00	0.03	null	null	null
cc (clear-cuts)		0.00	0.00	0.00	0.01	avoided	avoided	avoided
other		0.02	0.02	0.01	0.04	null	null	null
	total	1.00	1.00	1.00	1.00			
P (pine)		0.48	0.50	0.49	0.57	null	null	null
Sb (black spruce)		0.14	0.13	0.16	0.08	null	null	null
Sw (white spruce)		0.29	0.34	0.31	0.22	null	null	null
decid		0.04	0.01	0.01	0.05	null	avoided*	avoided*
mixed		0.06	0.02	0.02	0.08	null	null	null
	total	1.00	1.00	1.00	1.00			
aspect								
n		0.05	0.27	0.26	0.18	avoided	null	null
o		0.83	0.62	0.63	0.64	preferred	null	null
s		0.12	0.11	0.11	0.18	null	null	null
	total	1.00	1.00	1.00	1.00			

Appendix 3. Caribou use of 2 timber variable habitat categories.

Pooled n=59

Category Level[a]		Proportion[b] of use as measured by... distance (m)	crts/km[c]	adj crts/km[d]	Expected use	Significance[e] distance	crts/km	adj crts/km
closure*height								
A*0		0.01	0.02	0.02	0.01	null	null	null
A*1		0.00	0.03	0.03	0.01	null	null	null
A*2		0.01	0.01	0.01	0.01	null	null	null
A*3		0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*0		0.04	0.00	0.00	0.03	null	avoided	avoided
B*1		0.01	0.00	0.00	0.03	null	avoided	avoided
B*2		0.07	0.02	0.04	0.06	null	null	null
B*3		0.03	0.04	0.06	0.03	null	null	null
C*0		0.08	0.07	0.07	0.09	null	null	null
C*1		0.11	0.19	0.18	0.14	null	null	null
C*2		0.33	0.22	0.18	0.28	null	null	null
C*3		0.22	0.25	0.24	0.17	null	null	null
D*0		0.02	0.00	0.00	0.01	null	avoided	avoided
D*1		0.03	0.08	0.08	0.03	null	null	null
D*2		0.04	0.09	0.09	0.08	null	null	null
D*3		0.00	0.00	0.00	0.02	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			
closure*species								
A*p		0.01	0.05	0.05	0.01	null	null	null
A*Sb		0.00	0.00	0.00	0.00	avoided	avoided	avoided
A*Sw		0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*decid		0.00	0.00	0.00	0.00	avoided	avoided	avoided
A*mixed		0.01	0.01	0.01	0.01	null	null	null
B*P		0.05	0.04	0.06	0.06	null	null	null
B*Sb		0.02	0.01	0.04	0.01	null	null	null
B*Sw		0.05	0.01	0.01	0.04	null	null	avoided
B*decid		0.02	0.00	0.00	0.01	null	avoided	avoided

[a] For those familiar with Phase 3 Inventory, the combination variables do not require explanation except as follows: height 3 here includes Phase 3 height 3 and 4; conifer = Phase 3 P, Sb, or Sw in s1 position with no decid (as defined below) in s2 position; P, Sb, and Sw = a breakdown of conifer into its components; decid = Phase 3 A, Aw, or Pb in s1 position with no conifer in s2 position; mixed= decid in s1 position, conifer in s2 position or vice versa; and, muskeg= Phase 3 om and tm. For those unfamiliar with Phase 3 Inventory, a reading of Phase 3 Timber Inventory Specifications, Chapter 3 B. 3. (a) above is required.

[b] Both use and expected proportions are shown to 2 decimal places but calculations were made with 4 decimal places.

[c] Caribou feeding craters/km.

[d] As note c but adjusted for estimated caribou group sizes during tracking.

e Significance involves comparison of observed use proportions with expected. The comparison is based on calculation of simultaneous Bonferonni confidence intervals with α 0.1. The calculation was performed with square root transformed proportions.

Appendix 3 (continued). Caribou use of 2 timber variable habitat categories.

Pooled n=59

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
B*mixed		0.00	0.00	0.00	0.02	avoided	avoided	avoided
C*P		0.34	0.37	0.33	0.37	null	null	null
C*Sb		0.09	0.09	0.08	0.06	null	null	null
C*Sw		0.26	0.25	0.24	0.17	null	null	null
C*decid		0.02	0.00	0.00	0.04	null	avoided	avoided
C*mixed		0.03	0.01	0.01	0.05	null	avoided	avoided
D*P		0.07	0.13	0.13	0.13	null	null	null
D*Sb		0.02	0.03	0.04	0.01	null	null	null
D*Sw		0.00	0.00	0.00	0.00	avoided	avoided	avoided
D*decid		0.00	0.00	0.01	0.00	null	null	null
D*mixed		0.00	0.00	0.00	0.00	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			
closure*origin								
A*<=1830		0.00	0.00	0.00	0.00	avoided	avoided	avoided
A*1831-1879		0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*1880-1929		0.01	0.01	0.01	0.01	null	null	null
A*1930-1985		0.01	0.05	0.05	0.01	null	null	null
B*<=1830		0.03	0.02	0.04	0.01	null	null	null
B*1831-1879		0.04	0.02	0.02	0.02	null	null	null
B*1880-1929		0.02	0.01	0.04	0.05	null	avoided	null
B*1930-1985		0.05	0.00	0.00	0.05	null	avoided	avoided
C*<=1830		0.27	0.26	0.25	0.10	preferred	preferred	preferred
C*1831-1879		0.18	0.10	0.09	0.16	null	null	null
C*1880-1929		0.11	0.10	0.08	0.20	null	null	avoided
C*1930-1985		0.18	0.26	0.25	0.22	null	null	null
D*<=1830		0.00	0.00	0.00	0.01	avoided	avoided	avoided
D*1831-1879		0.00	0.04	0.04	0.03	avoided	null	null
D*1880-1929		0.05	0.09	0.08	0.07	null	null	null
D*1930-1985		0.04	0.04	0.06	0.04	null	null	null
	total	1.00	1.00	1.00	1.00			
height*species								
0*P		0.06	0.03	0.04	0.06	null	null	null
0*Sb		0.04	0.04	0.04	0.02	null	null	null
0*Sw		0.05	0.01	0.01	0.03	null	null	null
0*decid		0.01	0.00	0.00	0.01	null	avoided	avoided
0*mixed		0.00	0.00	0.00	0.03	avoided	avoided	avoided
1*P		0.10	0.25	0.26	0.12	null	null	null
1*Sb		0.00	0.03	0.02	0.02	null	null	null
1*Sw		0.01	0.00	0.00	0.02	null	avoided	avoided
1*decid		0.03	0.01	0.01	0.02	null	null	null
1*mixed		0.02	0.01	0.01	0.04	null	null	null
2*P		0.26	0.26	0.25	0.29	null	null	null
2*Sb		0.06	0.06	0.06	0.04	null	null	null

Appendix 3 (continued). Caribou use of 2 timber variable habitat categories.

Pooled n=59

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
2*Sw		0.08	0.01	0.01	0.06	null	avoided	avoided
2*decid		0.00	0.00	0.00	0.02	null	avoided	avoided
2*mixed		0.02	0.01	0.01	0.01	null	null	null
3*P		0.06	0.03	0.03	0.10	null	null	null
3*Sb		0.02	0.00	0.04	0.01	null	null	null
3*Sw		0.17	0.24	0.23	0.12	null	null	null
3*decid		0.00	0.00	0.00	0.00	avoided	avoided	avoided
3*mixed		0.00	0.00	0.00	0.00	avoided	avoided	avoided
	total	1.00	0.99	1.00	1.00			
height*origin								
0*<=1830		0.00	0.00	0.00	0.00	null	null	null
0*1831-1879		0.00	0.00	0.00	0.00	null	null	null
0*1880-1929		0.01	0.02	0.02	0.00	null	null	null
0*1930-1985		0.14	0.07	0.07	0.13	null	null	null
1*<=1830		0.00	0.00	0.00	0.00	avoided	avoided	avoided
1*1831-1879		0.00	0.03	0.02	0.00	null	null	null
1*1880-1929		0.02	0.04	0.03	0.02	null	null	null
1*1930-1985		0.14	0.23	0.25	0.19	null	null	null
2*<=1830		0.09	0.03	0.02	0.04	null	null	null
2*1831-1879		0.19	0.10	0.09	0.12	null	null	null
2*1880-1929		0.13	0.15	0.16	0.27	null	null	null
2*1930-1985		0.01	0.05	0.04	0.00	null	preferred	preferred
3*<=1830		0.21	0.25	0.27	0.09	null	preferred	preferred
3*1831-1879		0.03	0.03	0.03	0.09	null	null	null
3*1880-1929		0.01	0.00	0.00	0.05	avoided	avoided	avoided
3*1930-1985		0.00	0.00	0.00	0.00	null	null	null
	total	1.00	1.00	1.00	1.00			
species*origin								
P*<=1830		0.07	0.04	0.03	0.03	null	null	null
P*1831-1879		0.13	0.06	0.05	0.12	null	null	null
P*1880-1929		0.13	0.18	0.18	0.25	null	null	null
P*1930-1985		0.15	0.30	0.30	0.17	null	null	null
Sb*<=1830		0.03	0.01	0.04	0.02	null	null	null
Sb*1831-1879		0.04	0.09	0.08	0.03	null	null	null
Sb*1880-1929		0.03	0.02	0.02	0.01	null	null	null
Sb*1930-1985		0.03	0.02	0.02	0.02	null	null	null
Sw*<=1830		0.20	0.23	0.22	0.08	null	preferred	preferred
Sw*1831-1879		0.05	0.02	0.01	0.06	null	null	avoided
Sw*1880-1929		0.01	0.00	0.00	0.04	avoided	avoided	avoided
Sw*1930-1985		0.06	0.02	0.01	0.04	null	null	null
decid*<=1830		0.00	0.00	0.00	0.00	null	null	null
decid*1831-1879		0.00	0.00	0.00	0.00	avoided	avoided	avoided

Appendix 3 (continued). Caribou use of 2 timber variable habitat categories.

Pooled n=59

Category Level	Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
decid*1880-1929	0.00	0.00	0.00	0.02	avoided	avoided	avoided
decid*1930-1985	0.04	0.01	0.01	0.03	null	null	null
mixed*<=1830	0.01	0.00	0.00	0.00	null	avoided	avoided
mixed*1831-1879	0.00	0.00	0.00	0.00	avoided	avoided	avoided
mixed*1880-1929	0.01	0.01	0.01	0.01	null	null	null
mixed*1930-1985	0.02	0.01	0.01	0.07	null	avoided	avoided
total	1.00	1.00	1.00	1.00			

Appendix 3 (continued). Caribou use of 2 timber variable habitat categories.[73]

Winter 1 n=27

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
closure*height								
A*0		0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*1		0.01	0.05	0.05	0.01	null	null	null
A*2		0.00	0.01	0.01	0.01	null	null	null
A*3		0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*0		0.04	0.00	0.00	0.03	null	avoided	avoided
B*1		0.03	0.00	0.00	0.03	null	avoided	avoided
B*2		0.03	0.02	0.06	0.06	null	null	null
B*3		0.04	0.03	0.07	0.03	null	null	null
C*0		0.15	0.07	0.06	0.09	null	null	null
C*1		0.07	0.12	0.11	0.14	null	null	null
C*2		0.36	0.19	0.15	0.28	null	null	null
C*3		0.20	0.37	0.35	0.17	null	null	null
D*0		0.04	0.00	0.00	0.01	null	null	null
D*1		0.02	0.06	0.08	0.03	null	null	null
D*2		0.01	0.07	0.06	0.08	null	null	null
D*3		0.00	0.00	0.00	0.02	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			
closure*species								
A*p		0.01	0.05	0.05	0.01	null	null	null
A*Sb		0.00	0.00	0.00	0.00	null	null	null
A*Sw		0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*decid		0.00	0.00	0.00	0.00	avoided	avoided	avoided
A*mixed		0.00	0.01	0.01	0.01	null	null	null
B*P		0.04	0.02	0.06	0.06	null	null	null
B*Sb		0.01	0.02	0.06	0.01	null	null	null
B*Sw		0.05	0.01	0.01	0.04	null	null	null
B*decid		0.03	0.00	0.00	0.01	null	avoided	avoided
B*mixed		0.00	0.00	0.00	0.02	null	null	null
C*P		0.32	0.31	0.25	0.37	null	null	null
C*Sb		0.09	0.05	0.04	0.06	null	null	null
C*Sw		0.31	0.38	0.35	0.17	null	null	null
C*decid		0.01	0.00	0.00	0.04	null	avoided	avoided
C*mixed		0.05	0.01	0.01	0.05	null	null	null
D*P		0.03	0.07	0.09	0.13	null	null	null
D*Sb		0.05	0.06	0.06	0.01	null	null	null
D*Sw		0.00	0.00	0.00	0.00	avoided	avoided	avoided
D*decid		0.00	0.00	0.00	0.00	avoided	avoided	avoided
D*mixed		0.00	0.00	0.00	0.00	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			

[73]For explanatory notes see p. 80.

Appendix 3 (continued). Caribou use of 2 timber variable habitat categories.

Winter 1 n=27

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
closure*origin								
A*<=1830		0.00	0.00	0.00	0.00	avoided	avoided	avoided
A*1831-1879		0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*1880-1929		0.00	0.01	0.01	0.01	null	null	null
A*1930-1985		0.01	0.05	0.05	0.01	null	null	null
B*<=1830		0.03	0.03	0.07	0.01	null	null	null
B*1831-1879		0.02	0.00	0.00	0.02	null	avoided	avoided
B*1880-1929		0.03	0.02	0.06	0.05	null	null	null
B*1930-1985		0.07	0.00	0.00	0.05	null	avoided	avoided
C*<=1830		0.21	0.37	0.35	0.10	null	preferred	preferred
C*1831-1879		0.25	0.08	0.07	0.16	null	null	null
C*1880-1929		0.09	0.06	0.05	0.20	null	null	avoided
C*1930-1985		0.21	0.24	0.20	0.22	null	null	null
D*<=1830		0.00	0.00	0.00	0.01	avoided	avoided	avoided
D*1831-1879		0.01	0.06	0.06	0.03	null	null	null
D*1880-1929		0.00	0.00	0.00	0.07	avoided	avoided	avoided
D*1930-1985		0.07	0.06	0.09	0.04	null	null	null
	total	1.00	1.00	1.00	1.00			
height*species								
0*P		0.07	0.03	0.03	0.06	null	null	null
0*Sb		0.07	0.03	0.03	0.02	null	null	null
0*Sw		0.08	0.01	0.00	0.03	null	null	null
0*decid		0.01	0.00	0.00	0.01	null	avoided	avoided
0*mixed		0.00	0.00	0.00	0.03	avoided	avoided	avoided
1*P		0.06	0.22	0.23	0.12	null	null	null
1*Sb		0.00	0.00	0.00	0.02	avoided	avoided	avoided
1*Sw		0.00	0.00	0.00	0.02	avoided	avoided	avoided
1*decid		0.02	0.00	0.00	0.02	null	avoided	avoided
1*mixed		0.05	0.02	0.02	0.04	null	null	null
2*P		0.27	0.20	0.19	0.29	null	null	null
2*Sb		0.07	0.08	0.07	0.04	null	null	null
2*Sw		0.05	0.00	0.00	0.06	null	avoided	avoided
2*decid		0.01	0.00	0.00	0.02	null	avoided	avoided
2*mixed		0.00	0.01	0.01	0.01	null	null	null
3*P		0.01	0.00	0.00	0.10	avoided	avoided	avoided
3*Sb		0.01	0.02	0.06	0.01	null	null	null
3*Sw		0.22	0.39	0.36	0.12	null	preferred	null
3*decid		0.00	0.00	0.00	0.00	avoided	avoided	avoided
3*mixed		0.00	0.00	0.00	0.00	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			

Appendix 3 (continued). Caribou use of 2 timber variable habitat categories.

Winter 1 n=27

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
height*origin								
0*<=1830		0.00	0.00	0.00	0.00	null	null	null
0*1831-1879		0.00	0.00	0.00	0.00	null	null	null
0*1880-1929		0.03	0.03	0.02	0.00	null	null	null
0*1930-1985		0.20	0.04	0.04	0.13	null	null	null
1*<=1830		0.00	0.00	0.00	0.00	null	null	null
1*1831-1879		0.00	0.00	0.00	0.00	avoided	avoided	avoided
1*1880-1929		0.00	0.00	0.00	0.02	avoided	avoided	avoided
1*1930-1985		0.13	0.24	0.25	0.19	null	null	null
2*<=1830		0.04	0.00	0.00	0.04	null	avoided	avoided
2*1831-1879		0.24	0.14	0.13	0.12	null	null	null
2*1880-1929		0.09	0.06	0.09	0.27	null	avoided	null
2*1930-1985		0.03	0.08	0.06	0.00	null	preferred	preferred
3*<=1830		0.20	0.41	0.42	0.09	null	preferred	preferred
3*1831-1879		0.03	0.00	0.00	0.09	null	avoided	avoided
3*1880-1929		0.01	0.00	0.00	0.05	null	avoided	avoided
3*1930-1985		0.00	0.00	0.00	0.00	null	null	null
	total	1.00	1.00	1.00	1.00			
species*origin								
P*<=1830		0.01	0.00	0.00	0.03	null	avoided	avoided
P*1831-1879		0.18	0.07	0.05	0.12	null	null	null
P*1880-1929		0.06	0.05	0.08	0.25	avoided	avoided	avoided
P*1930-1985		0.15	0.33	0.32	0.17	null	null	null
Sb*<=1830		0.01	0.02	0.06	0.02	null	null	null
Sb*1831-1879		0.05	0.08	0.07	0.03	null	null	null
Sb*1880-1929		0.05	0.03	0.02	0.01	null	null	null
Sb*1930-1985		0.04	0.00	0.00	0.02	null	avoided	null
Sw*<=1830		0.22	0.39	0.36	0.08	null	preferred	preferred
Sw*1831-1879		0.04	0.00	0.00	0.06	null	avoided	avoided
Sw*1880-1929		0.01	0.00	0.00	0.04	null	avoided	avoided
Sw*1930-1985		0.08	0.01	0.00	0.04	null	null	avoided
decid*<=1830		0.00	0.00	0.00	0.00	null	null	null
decid*1831-1879		0.00	0.00	0.00	0.00	avoided	avoided	avoided
decid*1880-1929		0.01	0.00	0.00	0.02	null	avoided	avoided
decid*1930-1985		0.03	0.00	0.00	0.03	null	avoided	avoided
mixed*<=1830		0.00	0.00	0.00	0.00	null	null	null
mixed*1831-1879		0.00	0.00	0.00	0.00	avoided	avoided	avoided
mixed*1880-1929		0.00	0.01	0.01	0.01	null	null	null
mixed*1930-1985		0.05	0.02	0.02	0.07	null	null	null
	total	1.00	1.00	1.00	1.00			

Appendix 3 (continued). Caribou use of 2 timber variable habitat categories.[74]

Winter 2 n=32

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
closure*height								
A*0		0.02	0.04	0.05	0.01	null	null	null
A*1		0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*2		0.01	0.00	0.00	0.01	null	avoided	avoided
A*3		0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*0		0.03	0.00	0.00	0.03	null	avoided	avoided
B*1		0.00	0.00	0.00	0.03	avoided	avoided	avoided
B*2		0.10	0.02	0.01	0.06	null	null	null
B*3		0.01	0.04	0.05	0.03	null	null	null
C*0		0.03	0.07	0.08	0.09	null	null	null
C*1		0.14	0.28	0.30	0.14	null	null	null
C*2		0.31	0.25	0.23	0.28	null	null	null
C*3		0.24	0.07	0.06	0.17	null	null	null
D*0		0.01	0.00	0.00	0.01	null	avoided	avoided
D*1		0.04	0.11	0.09	0.03	null	null	null
D*2		0.05	0.12	0.13	0.08	null	null	null
D*3		0.00	0.00	0.00	0.02	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			
closure*species								
A*p		0.02	0.04	0.05	0.01	null	null	null
A*Sb		0.00	0.00	0.00	0.00	null	null	null
A*Sw		0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*decid		0.00	0.00	0.00	0.00	avoided	avoided	avoided
A*mixed		0.01	0.00	0.00	0.01	null	avoided	avoided
B*P		0.07	0.06	0.06	0.06	null	null	null
B*Sb		0.02	0.00	0.00	0.01	null	avoided	avoided
B*Sw		0.05	0.01	0.01	0.04	null	null	null
B*decid		0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*mixed		0.00	0.00	0.00	0.02	avoided	avoided	avoided
C*P		0.36	0.45	0.45	0.37	null	null	null
C*Sb		0.08	0.15	0.15	0.06	null	null	null
C*Sw		0.22	0.07	0.07	0.17	null	null	null
C*decid		0.04	0.00	0.00	0.04	null	avoided	avoided
C*mixed		0.02	0.00	0.00	0.05	null	avoided	avoided
D*P		0.10	0.21	0.20	0.13	null	null	null
D*Sb		0.01	0.00	0.00	0.01	null	avoided	avoided
D*Sw		0.00	0.00	0.00	0.00	avoided	avoided	avoided
D*decid		0.00	0.01	0.01	0.00	null	null	null
D*mixed		0.00	0.00	0.00	0.00	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			

[74]For explanatory notes see p. 80.

Appendix 3 (continued). Caribou use of 2 timber variable habitat categories.

Winter 2 n=32

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
closure*origin								
A*<=1830		0.00	0.00	0.00	0.00	avoided	avoided	avoided
A*1831-1879		0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*1880-1929		0.01	0.00	0.00	0.01	null	avoided	avoided
A*1930-1985		0.02	0.04	0.05	0.01	null	null	null
B*<=1830		0.04	0.00	0.00	0.01	null	avoided	null
B*1831-1879		0.06	0.06	0.06	0.02	null	null	null
B*1880-1929		0.01	0.00	0.00	0.05	null	avoided	avoided
B*1930-1985		0.03	0.00	0.00	0.05	null	avoided	avoided
C*<=1830		0.32	0.10	0.09	0.10	preferred	null	null
C*1831-1879		0.13	0.14	0.12	0.16	null	null	null
C*1880-1929		0.12	0.16	0.14	0.20	null	null	null
C*1930-1985		0.16	0.28	0.31	0.22	null	null	null
D*<=1830		0.00	0.00	0.00	0.01	avoided	avoided	avoided
D*1831-1879		0.00	0.00	0.00	0.03	avoided	avoided	avoided
D*1880-1929		0.09	0.21	0.20	0.07	null	null	null
D*1930-1985		0.02	0.01	0.01	0.04	null	null	null
	total	1.00	1.00	1.00	1.00			
height*species								
0*P		0.05	0.04	0.05	0.06	null	null	null
0*Sb		0.01	0.05	0.06	0.02	null	null	null
0*Sw		0.02	0.02	0.02	0.03	null	null	null
0*decid		0.00	0.00	0.00	0.01	avoided	avoided	avoided
0*mixed		0.00	0.00	0.00	0.03	avoided	avoided	avoided
1*P		0.14	0.30	0.30	0.12	null	null	null
1*Sb		0.01	0.08	0.06	0.02	null	null	null
1*Sw		0.02	0.00	0.01	0.02	null	null	null
1*decid		0.04	0.01	0.02	0.02	null	null	null
1*mixed		0.00	0.00	0.00	0.04	avoided	avoided	avoided
2*P		0.25	0.34	0.33	0.29	null	null	null
2*Sb		0.06	0.03	0.03	0.04	null	null	null
2*Sw		0.11	0.01	0.02	0.06	null	null	null
2*decid		0.00	0.00	0.00	0.02	avoided	avoided	avoided
2*mixed		0.03	0.00	0.00	0.01	null	avoided	avoided
3*P		0.09	0.08	0.08	0.10	null	null	null
3*Sb		0.03	0.00	0.00	0.01	null	avoided	avoided
3*Sw		0.13	0.04	0.03	0.12	null	null	null
3*decid		0.00	0.00	0.00	0.00	avoided	avoided	avoided
3*mixed		0.00	0.00	0.00	0.00	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			

Appendix 3 (continued). Caribou use of 2 timber variable habitat categories.

Winter 2 n=32

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
height*origin								
0*<=1830		0.00	0.00	0.00	0.00	null	null	null
0*1831-1879		0.00	0.00	0.00	0.00	null	null	null
0*1880-1929		0.00	0.00	0.00	0.00	avoided	avoided	avoided
0*1930-1985		0.09	0.11	0.13	0.13	null	null	null
1*<=1830		0.00	0.00	0.00	0.00	null	null	null
1*1831-1879		0.00	0.08	0.06	0.00	null	null	null
1*1880-1929		0.04	0.09	0.07	0.02	null	null	null
1*1930-1985		0.16	0.23	0.25	0.19	null	null	null
2*<=1830		0.14	0.07	0.06	0.04	null	null	null
2*1831-1879		0.15	0.04	0.04	0.12	null	null	null
2*1880-1929		0.16	0.27	0.27	0.27	null	null	null
2*1930-1985		0.00	0.00	0.00	0.00	null	null	null
3*<=1830		0.22	0.04	0.03	0.09	null	null	null
3*1831-1879		0.04	0.08	0.08	0.09	null	null	null
3*1880-1929		0.00	0.00	0.00	0.05	avoided	avoided	avoided
3*1930-1985		0.00	0.00	0.00	0.00	null	null	null
	total	1.00	1.00	1.00	1.00			
species*origin								
P*<=1830		0.11	0.09	0.08	0.03	null	null	null
P*1831-1879		0.09	0.05	0.06	0.12	null	null	null
P*1880-1929		0.19	0.36	0.35	0.25	null	null	null
P*1930-1985		0.15	0.25	0.28	0.17	null	null	null
Sb*<=1830		0.06	0.00	0.00	0.02	null	avoided	avoided
Sb*1831-1879		0.04	0.10	0.09	0.03	null	null	null
Sb*1880-1929		0.00	0.00	0.00	0.01	null	avoided	avoided
Sb*1930-1985		0.01	0.05	0.06	0.02	null	null	null
Sw*<=1830		0.17	0.01	0.01	0.08	null	avoided	avoided
Sw*1831-1879		0.07	0.04	0.03	0.06	null	null	null
Sw*1880-1929		0.00	0.00	0.00	0.04	avoided	avoided	avoided
Sw*1930-1985		0.04	0.02	0.03	0.04	null	null	null
decid*<=1830		0.00	0.00	0.00	0.00	null	null	null
decid*1831-1879		0.00	0.00	0.00	0.00	avoided	avoided	avoided
decid*1880-1929		0.00	0.00	0.00	0.02	avoided	avoided	avoided
decid*1930-1985		0.04	0.01	0.02	0.03	null	null	null
mixed*<=1830		0.02	0.00	0.00	0.00	null	null	null
mixed*1831-1879		0.00	0.00	0.00	0.00	avoided	avoided	avoided
mixed*1880-1929		0.01	0.00	0.00	0.01	null	avoided	avoided
mixed*1930-1985		0.00	0.00	0.00	0.07	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			

Appendix 3 (continued). Caribou use of 2 timber variable habitat categories.[75]

Unlogged n=31

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
closure*height								
A*0		0.02	0.05	0.04	0.01	null	null	null
A*1		0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*2		0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*3		0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*0		0.05	0.00	0.00	0.03	null	avoided	avoided
B*1		0.03	0.00	0.00	0.03	null	avoided	null
B*2		0.06	0.01	0.13	0.06	null	null	null
B*3		0.01	0.00	0.00	0.03	null	avoided	avoided
C*0		0.03	0.00	0.05	0.09	null	avoided	null
C*1		0.07	0.36	0.23	0.14	null	null	null
C*2		0.28	0.50	0.41	0.28	null	null	null
C*3		0.36	0.09	0.14	0.17	null	null	null
D*0		0.06	0.00	0.00	0.01	null	avoided	null
D*1		0.00	0.00	0.00	0.03	avoided	avoided	avoided
D*2		0.02	0.00	0.00	0.08	null	avoided	avoided
D*3		0.00	0.00	0.00	0.02	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			
closure*species								
A*p		0.02	0.05	0.04	0.01	null	null	null
A*Sb		0.00	0.00	0.00	0.00	null	null	null
A*Sw		0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*decid		0.00	0.00	0.00	0.00	avoided	avoided	avoided
A*mixed		0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*P		0.07	0.01	0.12	0.06	null	avoided	null
B*Sb		0.00	0.00	0.00	0.01	null	avoided	avoided
B*Sw		0.04	0.00	0.00	0.04	null	avoided	avoided
B*decid		0.04	0.00	0.00	0.01	null	avoided	avoided
B*mixed		0.00	0.00	0.00	0.02	null	avoided	null
C*P		0.37	0.74	0.58	0.37	null	preferred	null
C*Sb		0.06	0.18	0.13	0.06	null	null	null
C*Sw		0.30	0.02	0.11	0.17	null	avoided	null
C*decid		0.01	0.00	0.00	0.04	null	avoided	avoided
C*mixed		0.01	0.00	0.00	0.05	null	avoided	avoided
D*P		0.02	0.00	0.00	0.13	avoided	avoided	avoided
D*Sb		0.06	0.00	0.00	0.01	null	avoided	null
D*Sw		0.00	0.00	0.00	0.00	avoided	avoided	avoided
D*decid		0.00	0.00	0.00	0.00	avoided	avoided	avoided
D*mixed		0.00	0.00	0.00	0.00	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			

[75]For explanatory notes see p. 80.

Appendix 3 (continued). Caribou use of 2 timber variable habitat categories.

Unlogged n=31

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
closure*origin								
A*<=1830		0.00	0.00	0.00	0.00	avoided	avoided	avoided
A*1831-1879		0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*1880-1929		0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*1930-1985		0.02	0.05	0.04	0.01	null	null	null
B*<=1830		0.02	0.00	0.00	0.01	null	null	null
B*1831-1879		0.01	0.00	0.00	0.02	null	avoided	avoided
B*1880-1929		0.05	0.01	0.12	0.05	null	null	null
B*1930-1985		0.08	0.00	0.00	0.05	null	avoided	avoided
C*<=1830		0.44	0.24	0.21	0.10	preferred	null	null
C*1831-1879		0.02	0.18	0.08	0.16	avoided	null	null
C*1880-1929		0.21	0.34	0.27	0.20	null	null	null
C*1930-1985		0.07	0.18	0.26	0.22	null	null	null
D*<=1830		0.00	0.00	0.00	0.01	avoided	avoided	avoided
D*1831-1879		0.00	0.00	0.00	0.03	avoided	avoided	avoided
D*1880-1929		0.02	0.00	0.00	0.07	null	avoided	avoided
D*1930-1985		0.06	0.00	0.00	0.04	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
height*species								
0*P		0.06	0.05	0.04	0.06	null	null	null
0*Sb		0.10	0.00	0.05	0.02	null	avoided	null
0*Sw		0.00	0.00	0.00	0.03	avoided	avoided	avoided
0*decid		0.01	0.00	0.00	0.01	null	avoided	avoided
0*mixed		0.00	0.00	0.00	0.03	avoided	avoided	avoided
1*P		0.08	0.19	0.15	0.12	null	null	null
1*Sb		0.00	0.18	0.08	0.02	null	preferred	null
1*Sw		0.00	0.00	0.00	0.02	avoided	avoided	avoided
1*decid		0.03	0.00	0.00	0.02	null	avoided	avoided
1*mixed		0.01	0.00	0.00	0.04	null	avoided	avoided
2*P		0.24	0.48	0.51	0.29	null	null	null
2*Sb		0.02	0.00	0.00	0.04	null	avoided	avoided
2*Sw		0.07	0.02	0.02	0.06	null	null	null
2*decid		0.01	0.00	0.00	0.02	null	avoided	avoided
2*mixed		0.00	0.00	0.00	0.01	avoided	avoided	avoided
3*P		0.10	0.08	0.04	0.10	null	null	null
3*Sb		0.00	0.00	0.00	0.01	avoided	avoided	avoided
3*Sw		0.28	0.01	0.10	0.12	null	avoided	null
3*decid		0.00	0.00	0.00	0.00	avoided	avoided	avoided
3*mixed		0.00	0.00	0.00	0.00	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			

Appendix 3 (continued). Caribou use of 2 timber variable habitat categories.

Unlogged n=31

Category Level	Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
height*origin							
0*<=1830	0.00	0.00	0.00	0.00	null	null	null
0*1831-1879	0.00	0.00	0.00	0.00	null	null	null
0*1880-1929	0.03	0.00	0.05	0.00	null	avoided	null
0*1930-1985	0.13	0.05	0.05	0.13	null	null	null
1*<=1830	0.00	0.00	0.00	0.00	null	null	null
1*1831-1879	0.00	0.18	0.08	0.00	null	preferred	null
1*1880-1929	0.00	0.00	0.00	0.02	avoided	avoided	avoided
1*1930-1985	0.12	0.19	0.16	0.19	null	null	null
2*<=1830	0.11	0.15	0.08	0.04	null	null	null
2*1831-1879	0.02	0.00	0.00	0.12	avoided	avoided	avoided
2*1880-1929	0.20	0.34	0.34	0.27	null	null	null
2*1930-1985	0.00	0.00	0.11	0.00	null	null	preferred
3*<=1830	0.36	0.09	0.14	0.09	preferred	null	null
3*1831-1879	0.01	0.00	0.00	0.09	avoided	avoided	avoided
3*1880-1929	0.01	0.00	0.00	0.05	null	avoided	avoided
3*1930-1985	0.00	0.00	0.00	0.00	null	null	null
total	1.00	1.00	1.00	1.00			
species*origin							
P*<=1830	0.14	0.22	0.10	0.03	null	preferred	null
P*1831-1879	0.02	0.00	0.00	0.12	avoided	avoided	avoided
P*1880-1929	0.17	0.34	0.34	0.25	null	null	null
P*1930-1985	0.14	0.24	0.31	0.17	null	null	null
Sb*<=1830	0.00	0.00	0.00	0.02	null	avoided	avoided
Sb*1831-1879	0.00	0.18	0.08	0.03	avoided	null	null
Sb*1880-1929	0.05	0.00	0.05	0.01	null	avoided	null
Sb*1930-1985	0.06	0.00	0.00	0.02	null	avoided	null
Sw*<=1830	0.33	0.02	0.11	0.08	preferred	null	null
Sw*1831-1879	0.01	0.00	0.00	0.06	avoided	avoided	avoided
Sw*1880-1929	0.01	0.00	0.00	0.04	null	avoided	avoided
Sw*1930-1985	0.00	0.00	0.00	0.04	avoided	avoided	avoided
decid*<=1830	0.00	0.00	0.00	0.00	null	null	null
decid*1831-1879	0.00	0.00	0.00	0.00	avoided	avoided	avoided
decid*1880-1929	0.01	0.00	0.00	0.02	null	avoided	avoided
decid*1930-1985	0.04	0.00	0.00	0.03	null	avoided	avoided
mixed*<=1830	0.00	0.00	0.00	0.00	null	null	null
mixed*1831-1879	0.00	0.00	0.00	0.00	avoided	avoided	avoided
mixed*1880-1929	0.00	0.00	0.00	0.01	avoided	avoided	avoided
mixed*1930-1985	0.01	0.00	0.00	0.07	null	avoided	avoided
total	1.00	1.00	1.00	1.00			

Appendix 3 (continued). Caribou use of 2 timber variable habitat categories.[76]

Logged n=28

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
closure*height								
A*0		0.00	0.01	0.01	0.01	null	null	null
A*1		0.00	0.04	0.05	0.01	null	null	null
A*2		0.01	0.01	0.01	0.01	null	null	null
A*3		0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*0		0.03	0.00	0.00	0.03	null	avoided	avoided
B*1		0.00	0.00	0.00	0.03	avoided	avoided	avoided
B*2		0.07	0.01	0.01	0.06	null	null	avoided
B*3		0.03	0.06	0.09	0.03	null	null	null
C*0		0.11	0.08	0.08	0.09	null	null	null
C*1		0.11	0.15	0.16	0.14	null	null	null
C*2		0.38	0.10	0.08	0.28	null	null	avoided
C*3		0.14	0.30	0.28	0.17	null	null	null
D*0		0.00	0.00	0.00	0.01	avoided	avoided	avoided
D*1		0.06	0.12	0.12	0.03	null	null	null
D*2		0.05	0.13	0.13	0.08	null	null	null
D*3		0.00	0.00	0.00	0.02	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			
closure*species								
A*p		0.01	0.06	0.05	0.01	null	null	null
A*Sb		0.00	0.00	0.00	0.00	null	null	null
A*Sw		0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*decid		0.00	0.00	0.00	0.00	avoided	avoided	avoided
A*mixed		0.01	0.01	0.01	0.01	null	null	null
B*P		0.05	0.03	0.03	0.06	null	null	null
B*Sb		0.02	0.02	0.05	0.01	null	null	null
B*Sw		0.06	0.01	0.01	0.04	null	null	null
B*decid		0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*mixed		0.00	0.00	0.00	0.02	avoided	avoided	avoided
C*P		0.33	0.23	0.22	0.37	null	null	null
C*Sb		0.11	0.06	0.06	0.06	null	null	null
C*Sw		0.24	0.32	0.31	0.17	null	null	null
C*decid		0.03	0.00	0.00	0.04	null	avoided	avoided
C*mixed		0.03	0.00	0.00	0.05	null	avoided	avoided
D*P		0.10	0.19	0.19	0.13	null	null	null
D*Sb		0.00	0.05	0.05	0.01	null	null	null
D*Sw		0.00	0.00	0.00	0.00	avoided	avoided	avoided
D*decid		0.00	0.01	0.01	0.00	null	null	null
D*mixed		0.00	0.00	0.00	0.00	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			

[76]For explanatory notes see p. 80.

Appendix 3 (continued). Caribou use of 2 timber variable habitat categories.

Logged n=28

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
closure*origin								
A*<=1830		0.00	0.00	0.00	0.00	avoided	avoided	avoided
A*1831-1879		0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*1880-1929		0.01	0.01	0.01	0.01	null	null	null
A*1930-1985		0.01	0.06	0.05	0.01	null	null	null
B*<=1830		0.04	0.03	0.06	0.01	null	null	null
B*1831-1879		0.06	0.04	0.03	0.02	null	null	null
B*1880-1929		0.00	0.00	0.00	0.05	avoided	avoided	avoided
B*1930-1985		0.03	0.00	0.00	0.05	null	avoided	avoided
C*<=1830		0.17	0.28	0.27	0.10	null	null	null
C*1831-1879		0.29	0.11	0.09	0.16	null	null	null
C*1880-1929		0.04	0.01	0.00	0.20	avoided	avoided	avoided
C*1930-1985		0.24	0.23	0.23	0.22	null	null	null
D*<=1830		0.00	0.00	0.00	0.01	avoided	avoided	avoided
D*1831-1879		0.01	0.05	0.05	0.03	null	null	null
D*1880-1929		0.07	0.13	0.11	0.07	null	null	null
D*1930-1985		0.03	0.06	0.08	0.04	null	null	null
	total	1.00	1.00	1.00	1.00			
height*species								
0*P		0.06	0.04	0.03	0.06	null	null	null
0*Sb		0.00	0.03	0.03	0.02	null	null	null
0*Sw		0.08	0.02	0.02	0.03	null	null	null
0*decid		0.00	0.00	0.00	0.01	avoided	avoided	avoided
0*mixed		0.00	0.00	0.00	0.03	avoided	avoided	avoided
1*P		0.11	0.30	0.31	0.12	null	null	null
1*Sb		0.00	0.00	0.00	0.02	null	avoided	avoided
1*Sw		0.02	0.00	0.00	0.02	null	null	null
1*decid		0.04	0.01	0.01	0.02	null	null	null
1*mixed		0.01	0.00	0.00	0.04	null	avoided	avoided
2*P		0.28	0.15	0.13	0.29	null	null	null
2*Sb		0.09	0.08	0.08	0.04	null	null	null
2*Sw		0.10	0.00	0.00	0.06	null	avoided	avoided
2*decid		0.00	0.00	0.00	0.02	avoided	avoided	avoided
2*mixed		0.03	0.01	0.01	0.01	null	null	null
3*P		0.03	0.03	0.03	0.10	null	null	null
3*Sb		0.04	0.02	0.05	0.01	null	null	null
3*Sw		0.10	0.31	0.29	0.12	null	null	null
3*decid		0.00	0.00	0.00	0.00	avoided	avoided	avoided
3*mixed		0.00	0.00	0.00	0.00	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			

Appendix 3 (continued). Caribou use of 2 timber variable habitat categories.

Logged n=28

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
height*origin								
0*<=1830		0.00	0.00	0.00	0.00	null	null	null
0*1831-1879		0.00	0.00	0.00	0.00	null	null	null
0*1880-1929		0.00	0.00	0.00	0.00	avoided	avoided	avoided
0*1930-1985		0.15	0.09	0.08	0.13	null	null	null
1*<=1830		0.00	0.00	0.00	0.00	null	null	null
1*1831-1879		0.00	0.00	0.00	0.00	avoided	avoided	avoided
1*1880-1929		0.04	0.06	0.04	0.02	null	null	null
1*1930-1985		0.14	0.25	0.28	0.19	null	null	null
2*<=1830		0.09	0.00	0.00	0.04	null	avoided	avoided
2*1831-1879		0.31	0.15	0.13	0.12	null	null	null
2*1880-1929		0.08	0.09	0.08	0.27	avoided	null	null
2*1930-1985		0.02	0.01	0.01	0.00	null	null	null
3*<=1830		0.11	0.31	0.33	0.09	null	preferred	preferred
3*1831-1879		0.05	0.05	0.04	0.09	null	null	null
3*1880-1929		0.00	0.00	0.00	0.05	avoided	avoided	avoided
3*1930-1985		0.00	0.00	0.00	0.00	null	null	null
	total	1.00	1.00	1.00	1.00			
species*origin								
P*<=1830		0.02	0.00	0.00	0.03	null	avoided	avoided
P*1831-1879		0.20	0.09	0.08	0.12	null	null	null
P*1880-1929		0.10	0.14	0.12	0.25	null	null	null
P*1930-1985		0.17	0.28	0.30	0.17	null	null	null
Sb*<=1830		0.05	0.02	0.05	0.02	null	null	null
Sb*1831-1879		0.07	0.08	0.08	0.03	null	null	null
Sb*1880-1929		0.01	0.00	0.00	0.01	null	avoided	avoided
Sb*1930-1985		0.00	0.03	0.03	0.02	null	null	null
Sw*<=1830		0.11	0.29	0.28	0.08	null	null	null
Sw*1831-1879		0.09	0.02	0.02	0.06	null	null	null
Sw*1880-1929		0.00	0.00	0.00	0.04	avoided	avoided	avoided
Sw*1930-1985		0.10	0.02	0.02	0.04	null	null	null
decid*<=1830		0.00	0.00	0.00	0.00	null	null	null
decid*1831-1879		0.00	0.00	0.00	0.00	avoided	avoided	avoided
decid*1880-1929		0.00	0.00	0.00	0.02	avoided	avoided	avoided
decid*1930-1985		0.04	0.01	0.01	0.03	null	null	null
mixed*<=1830		0.02	0.00	0.00	0.00	null	null	null
mixed*1831-1879		0.00	0.00	0.00	0.00	avoided	avoided	avoided
mixed*1880-1929		0.01	0.01	0.01	0.01	null	null	null
mixed*1930-1985		0.01	0.00	0.00	0.07	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			

Appendix 4. Caribou use of aspect*timber variable habitat categories.

Pooled n=59

Category Level[a]	Proportion[b] of use as measured by... distance (m)	crts/km[c]	adj crts/km[d]	Expected use	Significance[e] distance	crts/km	adj crts/km
closure*aspect							
A*n	0.00	0.03	0.03	0.01	null	null	null
A*o	0.01	0.02	0.02	0.02	null	null	null
A*s	0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*n	0.01	0.01	0.03	0.02	null	null	null
B*o	0.09	0.04	0.06	0.07	null	null	null
B*s	0.02	0.00	0.00	0.02	null	avoided	avoided
C*n	0.03	0.16	0.16	0.11	avoided	null	null
C*o	0.54	0.39	0.36	0.36	null	null	null
C*s	0.09	0.12	0.11	0.11	null	null	null
D*n	0.01	0.00	0.00	0.02	null	null	null
D*o	0.05	0.14	0.15	0.08	null	null	null
D*s	0.02	0.01	0.01	0.03	null	null	null
other*n	0.01	0.01	0.01	0.02	null	null	null
other*o	0.10	0.06	0.06	0.11	null	null	null
other*s	0.02	0.00	0.00	0.03	null	avoided	avoided
total	1.00	1.00	1.00	1.00			
A*n	0.00	0.03	0.03	0.01	null	null	null
A*o	0.01	0.02	0.02	0.02	null	null	null
A*s	0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*n	0.02	0.01	0.04	0.05	null	avoided	null
B*o	0.10	0.05	0.06	0.10	null	null	null
B*s	0.03	0.00	0.00	0.03	null	avoided	avoided
C*n	0.03	0.18	0.17	0.18	avoided	null	null
C*o	0.62	0.42	0.38	0.41	preferred	null	null

[a] For those familiar with Phase 3 Inventory, the combination variables do not require explanation except as follows: height 3 here includes Phase 3 height 3 and 4; conifer = Phase 3 P, Sb, or Sw in s1 position with no decid (as defined below) in s2 position; P, Sb, and Sw = a breakdown of conifer into its components; decid = Phase 3 A, Aw, or Pb in s1 position with no conifer in s2 position; mixed= decid in s1 position, conifer in s2 position or vice versa; and, muskeg= Phase 3 om and tm. For those unfamiliar with Phase 3 Inventory, a reading of Phase 3 Timber Inventory Specifications, Chapter 3 B. 3. (a) above is required. Aspect categories are as follows: north (n) = 300-60 degrees; south (s) = 120-240 degrees; and, other (o) = 241-299 degrees, 61-119 degrees, and no aspect (slope 10% or less).

[b] Both use and expected proportions are shown to 2 decimal places but calculations were made with 4 decimal places.

[c] Caribou feeding craters/km.

[d] As note c but adjusted for estimated caribou group sizes during tracking.

e Significance involves comparison of observed use proportions with expected. The comparison is based on calculation of simultaneous Bonferonni confidence intervals with α 0.1. The calculation was performed with square root transformed proportions.

Appendix 4 (continued). Caribou use of aspect* timber variable habitat categories.

Pooled n=59

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
C*s		0.10	0.12	0.12	0.09	null	null	null
D*n		0.01	0.00	0.00	0.03	null	avoided	avoided
D*o		0.06	0.15	0.16	0.07	null	null	null
D*s		0.02	0.01	0.01	0.02	null	null	null
	total	1.00	1.00	1.00	1.00			
height*aspect								
0*n		0.00	0.03	0.03	0.03	avoided	null	null
0*o		0.01	0.02	0.02	0.07	avoided	null	null
0*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
1*n		0.01	0.01	0.03	0.04	null	null	null
1*o		0.09	0.04	0.06	0.10	null	null	null
1*s		0.02	0.00	0.00	0.04	null	avoided	avoided
2*n		0.03	0.16	0.16	0.07	null	null	null
2*o		0.54	0.39	0.36	0.24	preferred	null	null
2*s		0.09	0.12	0.11	0.07	null	null	null
3*n		0.01	0.00	0.00	0.02	null	null	null
3*o		0.05	0.14	0.15	0.12	null	null	null
3*s		0.02	0.01	0.01	0.04	null	avoided	avoided
other*n		0.01	0.01	0.01	0.02	null	null	null
other*o		0.10	0.06	0.06	0.11	null	null	null
other*s		0.02	0.00	0.00	0.03	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
0*n		0.00	0.03	0.03	0.03	avoided	null	null
0*o		0.01	0.02	0.02	0.08	avoided	avoided	avoided
0*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
1*n		0.02	0.01	0.04	0.05	null	avoided	null
1*o		0.10	0.05	0.06	0.12	null	null	null
1*s		0.03	0.00	0.00	0.04	null	avoided	avoided
2*n		0.03	0.18	0.17	0.08	null	null	null
2*o		0.62	0.42	0.38	0.28	preferred	null	null
2*s		0.10	0.12	0.12	0.08	null	null	null
3*n		0.01	0.00	0.00	0.02	null	null	null
3*o		0.06	0.15	0.16	0.15	null	null	null
3*s		0.02	0.01	0.01	0.04	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
origin*aspect								
<=1830*n		0.01	0.16	0.16	0.01	null	preferred	preferred
<=1830*o		0.26	0.12	0.13	0.10	preferred	null	null
<=1830s		0.03	0.00	0.00	0.01	null	avoided	avoided
1831-1879*n		0.01	0.02	0.01	0.03	null	null	null
1831-1879*o		0.19	0.14	0.13	0.15	null	null	null

Appendix 4 (continued). Caribou use of aspect* timber variable habitat categories.

Pooled n=59

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
1831-1879*s		0.03	0.01	0.00	0.03	null	avoided	avoided
1880-1929*n		0.01	0.01	0.04	0.07	avoided	avoided	avoided
1880-1929*o		0.12	0.16	0.14	0.20	null	null	null
1880-1929*s		0.05	0.03	0.03	0.08	null	null	null
1930-1985*n		0.02	0.03	0.03	0.07	avoided	null	null
1930-1985*o		0.22	0.22	0.23	0.18	null	null	null
1930-1985*s		0.05	0.09	0.09	0.06	null	null	null
	total	1.00	1.00	1.00	1.00			
<=1830*n		0.01	0.15	0.15	0.01	null	preferred	preferred
<=1830*o		0.23	0.11	0.13	0.08	preferred	null	null
<=1830*s		0.02	0.00	0.00	0.01	null	avoided	avoided
1831-1879*n		0.01	0.02	0.01	0.02	null	null	null
1831-1879*o		0.17	0.13	0.12	0.12	null	null	null
1831-1879*s		0.03	0.01	0.00	0.03	null	null	avoided
1880-1929*n		0.01	0.01	0.03	0.06	avoided	avoided	null
1880-1929*o		0.11	0.15	0.13	0.17	null	null	null
1880-1929*s		0.04	0.03	0.03	0.07	null	null	null
1930-1985*n		0.02	0.03	0.03	0.06	null	null	null
1930-1985*o		0.19	0.20	0.21	0.16	null	null	null
1930-1985*s		0.04	0.09	0.09	0.05	null	null	null
cc*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
cc*o		0.00	0.00	0.00	0.01	avoided	avoided	avoided
cc*s		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*n		0.01	0.01	0.01	0.02	null	null	null
other*o		0.10	0.06	0.06	0.10	null	null	null
other*s		0.02	0.00	0.00	0.02	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
species*aspect								
conifer*n		0.05	0.21	0.22	0.13	null	null	null
conifer*o		0.64	0.58	0.55	0.48	null	null	null
conifer*s		0.11	0.12	0.11	0.12	null	null	null
decid*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
decid*o		0.02	0.01	0.01	0.02	null	null	null
decid*s		0.02	0.00	0.00	0.02	null	avoided	avoided
mixed*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
mixed*o		0.03	0.01	0.01	0.03	null	null	null
mixed*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
ds*n		0.00	0.01	0.01	0.01	null	null	null
ds*o		0.03	0.03	0.03	0.04	null	null	null
ds*s		0.01	0.00	0.00	0.00	null	avoided	avoided
cs*n		0.00	0.00	0.03	0.01	null	avoided	null

Appendix 4 (continued). Caribou use of aspect* timber variable habitat categories.

Pooled n=59

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
cs*o		0.02	0.02	0.02	0.02	null	null	null
cs*s		0.00	0.00	0.00	0.00	null	avoided	avoided
muskeg*n		0.00	0.00	0.00	0.00	null	null	null
muskeg*o		0.04	0.00	0.00	0.02	null	null	null
muskeg*s		0.00	0.00	0.00	0.00	null	avoided	avoided
cc*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
cc*o		0.00	0.00	0.00	0.01	avoided	avoided	avoided
cc*s		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*o		0.01	0.01	0.01	0.02	null	null	null
other*s		0.01	0.00	0.00	0.01	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
P*n		0.03	0.04	0.07	0.09	null	null	null
P*o		0.32	0.40	0.36	0.31	null	null	null
P*s		0.07	0.10	0.09	0.09	null	null	null
Sb*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
Sb*o		0.10	0.11	0.12	0.05	null	null	null
Sb*s		0.02	0.02	0.02	0.01	null	null	null
Sw*n		0.02	0.16	0.15	0.03	null	preferred	preferred
Sw*o		0.22	0.08	0.07	0.12	null	null	null
Sw*s		0.03	0.00	0.00	0.03	null	avoided	avoided
decid*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
decid*o		0.02	0.01	0.01	0.02	null	null	null
decid*s		0.02	0.00	0.00	0.02	null	avoided	avoided
mixed*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
mixed*o		0.03	0.01	0.01	0.03	null	null	null
mixed*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
ds*n		0.00	0.01	0.01	0.01	null	null	null
ds*o		0.03	0.03	0.03	0.04	null	null	null
ds*s		0.01	0.00	0.00	0.00	null	avoided	avoided
cs*n		0.00	0.00	0.03	0.01	null	avoided	null
cs*o		0.02	0.02	0.02	0.02	null	null	null
cs*s		0.00	0.00	0.00	0.00	null	avoided	avoided
muskeg*n		0.00	0.00	0.00	0.00	null	null	null
muskeg*o		0.04	0.00	0.00	0.02	null	null	null
muskeg*s		0.00	0.00	0.00	0.00	null	avoided	avoided
cc*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
cc*o		0.00	0.00	0.00	0.01	avoided	avoided	avoided
cc*s		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*o		0.01	0.01	0.01	0.02	null	null	null
other*s		0.01	0.00	0.00	0.01	null	avoided	avoided

Appendix 4 (continued). Caribou use of aspect* timber variable habitat categories.

Pooled n=59

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
	total	1.00	1.00	1.00	1.00			
P*n		0.04	0.05	0.07	0.11	null	null	null
P*o		0.37	0.42	0.40	0.36	null	null	null
P*s		0.08	0.11	0.10	0.10	null	null	null
Sb*n		0.00	0.00	0.00	0.02	avoided	avoided	avoided
Sb*o		0.11	0.11	0.13	0.06	null	null	null
Sb*s		0.02	0.03	0.03	0.01	null	null	null
Sw*n		0.02	0.18	0.17	0.04	null	preferred	preferred
Sw*o		0.25	0.08	0.08	0.15	null	null	null
Sw*s		0.03	0.00	0.00	0.03	null	avoided	avoided
decid*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
decid*o		0.02	0.01	0.01	0.02	null	null	null
decid*s		0.02	0.00	0.00	0.02	null	avoided	avoided
mixed*n		0.00	0.00	0.00	0.02	avoided	avoided	avoided
mixed*o		0.04	0.02	0.02	0.04	null	null	null
mixed*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.[77]

Winter 1 n=27

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
closure*aspect								
A*n		0.00	0.05	0.05	0.01	null	null	null
A*o		0.00	0.01	0.01	0.02	null	null	null
A*s		0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*n		0.03	0.02	0.05	0.02	null	null	null
B*o		0.05	0.03	0.06	0.07	null	null	null
B*s		0.04	0.00	0.00	0.02	null	avoided	avoided
C*n		0.04	0.25	0.23	0.11	avoided	null	null
C*o		0.57	0.30	0.25	0.36	null	null	null
C*s		0.05	0.13	0.11	0.11	null	null	null
D*n		0.01	0.01	0.01	0.02	null	null	null
D*o		0.03	0.10	0.11	0.08	null	null	null
D*s		0.03	0.01	0.01	0.03	null	null	null
other*n		0.01	0.01	0.01	0.02	null	null	null
other*o		0.11	0.09	0.08	0.11	null	null	null
other*s		0.02	0.00	0.00	0.03	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
A*n		0.01	0.05	0.05	0.01	null	null	null
A*o		0.00	0.01	0.01	0.02	null	null	null
A*s		0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*n		0.04	0.02	0.06	0.05	null	null	null
B*o		0.06	0.04	0.07	0.10	null	null	null
B*s		0.04	0.00	0.00	0.03	null	avoided	avoided
C*n		0.04	0.28	0.26	0.18	avoided	null	null
C*o		0.66	0.33	0.28	0.41	null	null	null
C*s		0.06	0.14	0.13	0.09	null	null	null
D*n		0.01	0.01	0.01	0.03	null	null	null
D*o		0.03	0.11	0.13	0.07	null	null	null
D*s		0.04	0.01	0.01	0.02	null	null	null
	total	1.00	1.00	1.00	1.00			
height*aspect								
0*n		0.03	0.00	0.00	0.03	null	avoided	avoided
0*o		0.15	0.07	0.05	0.07	null	null	null
0*s		0.03	0.00	0.00	0.02	null	avoided	avoided
1*n		0.00	0.05	0.05	0.04	null	null	null
1*o		0.07	0.06	0.08	0.10	null	null	null
1*s		0.03	0.11	0.10	0.04	null	null	null
2*n		0.02	0.03	0.06	0.07	null	null	null
2*o		0.27	0.20	0.17	0.24	null	null	null
2*s		0.05	0.03	0.03	0.07	null	null	null

[77]For explanatory notes see p. 96.

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.

Winter 1 n=27

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
3*n		0.03	0.25	0.23	0.02	null	preferred	preferred
3*o		0.17	0.12	0.14	0.12	null	null	null
3*s		0.01	0.00	0.00	0.04	null	avoided	avoided
other*n		0.01	0.01	0.01	0.02	null	null	null
other*o		0.11	0.09	0.08	0.11	null	null	null
other*s		0.02	0.00	0.00	0.03	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
0*n		0.03	0.00	0.00	0.03	null	avoided	avoided
0*o		0.17	0.07	0.06	0.08	null	null	null
0*s		0.03	0.00	0.00	0.02	null	avoided	avoided
1*n		0.01	0.05	0.05	0.05	avoided	null	null
1*o		0.08	0.06	0.08	0.12	null	null	null
1*s		0.04	0.12	0.11	0.04	null	null	null
2*n		0.03	0.03	0.07	0.08	null	null	null
2*o		0.31	0.22	0.18	0.28	null	null	null
2*s		0.06	0.04	0.03	0.08	null	null	null
3*n		0.03	0.28	0.26	0.02	null	preferred	preferred
3*o		0.20	0.13	0.16	0.15	null	null	null
3*s		0.01	0.00	0.00	0.04	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
origin*aspect								
<=1830*n		0.03	0.28	0.26	0.01	null	preferred	preferred
<=1830*o		0.21	0.13	0.16	0.10	null	null	null
<=1830s		0.00	0.00	0.00	0.01	avoided	avoided	avoided
1831-1879*n		0.02	0.00	0.00	0.03	null	null	null
1831-1879*o		0.25	0.13	0.12	0.15	null	null	null
1831-1879*s		0.01	0.01	0.00	0.03	null	null	null
1880-1929*n		0.01	0.02	0.06	0.07	avoided	null	null
1880-1929*o		0.09	0.04	0.04	0.20	null	avoided	avoided
1880-1929*s		0.04	0.03	0.02	0.08	null	null	null
1930-1985*n		0.04	0.06	0.06	0.07	null	null	null
1930-1985*o		0.22	0.18	0.17	0.18	null	null	null
1930-1985*s		0.09	0.12	0.11	0.06	null	null	null
	total	1.00	1.00	1.00	1.00			
<=1830*n		0.03	0.25	0.23	0.01	null	preferred	preferred
<=1830*o		0.18	0.12	0.14	0.08	null	null	null
<=1830*s		0.00	0.00	0.00	0.01	avoided	avoided	avoided
1831-1879*n		0.01	0.00	0.00	0.02	null	null	null
1831-1879*o		0.21	0.12	0.11	0.12	null	null	null

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.

Winter 1 n=27

Category Level	Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
1831-1879*s	0.01	0.01	0.00	0.03	null	null	null
1880-1929*n	0.01	0.02	0.05	0.06	avoided	null	null
1880-1929*o	0.07	0.04	0.03	0.17	null	null	avoided
1880-1929*s	0.03	0.03	0.02	0.07	null	null	null
1930-1985*n	0.04	0.05	0.05	0.06	null	null	null
1930-1985*o	0.19	0.16	0.16	0.16	null	null	null
1930-1985*s	0.08	0.11	0.10	0.05	null	null	null
cc*n	0.00	0.00	0.00	0.00	avoided	avoided	avoided
cc*o	0.00	0.00	0.00	0.01	avoided	avoided	avoided
cc*s	0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*n	0.01	0.01	0.01	0.02	null	null	null
other*o	0.11	0.09	0.08	0.10	null	null	null
other*s	0.02	0.00	0.00	0.02	null	avoided	avoided
total	1.00	1.00	1.00	1.00			
species*aspect							
conifer*n	0.08	0.32	0.34	0.13	null	null	null
conifer*o	0.61	0.41	0.42	0.48	null	null	null
conifer*s	0.09	0.14	0.13	0.12	null	null	null
decid*n	0.00	0.00	0.00	0.01	avoided	avoided	avoided
decid*o	0.00	0.00	0.00	0.02	avoided	avoided	avoided
decid*s	0.03	0.00	0.00	0.02	null	avoided	avoided
mixed*n	0.00	0.00	0.00	0.01	avoided	avoided	avoided
mixed*o	0.04	0.02	0.02	0.03	null	null	null
mixed*s	0.00	0.00	0.00	0.02	avoided	avoided	avoided
ds*n	0.00	0.01	0.01	0.01	null	null	null
ds*o	0.05	0.04	0.05	0.04	null	null	null
ds*s	0.02	0.00	0.00	0.00	null	avoided	avoided
cs*n	0.00	0.00	0.00	0.01	null	avoided	avoided
cs*o	0.03	0.03	0.03	0.02	null	null	null
cs*s	0.00	0.00	0.00	0.00	avoided	avoided	avoided
muskeg*n	0.00	0.00	0.00	0.00	avoided	avoided	avoided
muskeg*o	0.03	0.01	0.01	0.02	null	null	null
muskeg*s	0.00	0.00	0.00	0.00	null	avoided	avoided
cc*n	0.00	0.00	0.00	0.00	avoided	avoided	avoided
cc*o	0.00	0.00	0.00	0.01	avoided	avoided	avoided
cc*s	0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*n	0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*o	0.01	0.01	0.01	0.02	null	null	null
other*s	0.00	0.00	0.00	0.01	avoided	avoided	avoided
total	1.00	1.00	1.00	1.00			

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.

Winter 1 n=27

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
P*n		0.05	0.07	0.11	0.09	null	null	null
P*o		0.23	0.19	0.18	0.31	null	null	null
P*s		0.06	0.14	0.12	0.09	null	null	null
Sb*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
Sb*o		0.10	0.11	0.14	0.05	null	null	null
Sb*s		0.03	0.01	0.00	0.01	null	null	null
Sw*n		0.03	0.25	0.23	0.03	null	preferred	preferred
Sw*o		0.27	0.11	0.10	0.12	null	null	null
Sw*s		0.00	0.00	0.00	0.03	avoided	avoided	avoided
decid*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
decid*o		0.00	0.00	0.00	0.02	avoided	avoided	avoided
decid*s		0.03	0.00	0.00	0.02	null	avoided	avoided
mixed*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
mixed*o		0.04	0.02	0.02	0.03	null	null	null
mixed*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
ds*n		0.00	0.01	0.01	0.01	null	null	null
ds*o		0.05	0.04	0.05	0.04	null	null	null
ds*s		0.02	0.00	0.00	0.00	null	avoided	avoided
cs*n		0.00	0.00	0.00	0.01	null	avoided	avoided
cs*o		0.03	0.03	0.03	0.02	null	null	null
cs*s		0.00	0.00	0.00	0.00	avoided	avoided	avoided
muskeg*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
muskeg*o		0.03	0.01	0.01	0.02	null	null	null
muskeg*s		0.00	0.00	0.00	0.00	null	avoided	avoided
cc*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
cc*o		0.00	0.00	0.00	0.01	avoided	avoided	avoided
cc*s		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*o		0.01	0.01	0.01	0.02	null	null	null
other*s		0.00	0.00	0.00	0.01	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			
P*n		0.06	0.08	0.12	0.11	null	null	null
P*o		0.27	0.21	0.20	0.36	null	null	null
P*s		0.07	0.15	0.13	0.10	null	null	null
Sb*n		0.00	0.00	0.00	0.02	avoided	avoided	avoided
Sb*o		0.12	0.12	0.15	0.06	null	null	null
Sb*s		0.03	0.01	0.00	0.01	null	null	null
Sw*n		0.03	0.28	0.26	0.04	null	preferred	preferred
Sw*o		0.32	0.12	0.11	0.15	null	null	null
Sw*s		0.00	0.00	0.00	0.03	avoided	avoided	avoided
decid*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
decid*o		0.00	0.00	0.00	0.02	avoided	avoided	avoided

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.

Winter 1 n=27

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
decid*s		0.04	0.00	0.00	0.02	null	avoided	avoided
mixed*n		0.00	0.00	0.00	0.02	avoided	avoided	avoided
mixed*o		0.05	0.03	0.03	0.04	null	null	null
mixed*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.[78]

Winter 2 n=32

Category Level	Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
closure*aspect							
A*n	0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*o	0.02	0.04	0.05	0.02	null	null	null
A*s	0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*n	0.00	0.00	0.00	0.02	avoided	avoided	avoided
B*o	0.11	0.06	0.06	0.07	null	null	null
B*s	0.01	0.00	0.00	0.02	null	null	null
C*n	0.02	0.03	0.03	0.11	avoided	null	null
C*o	0.52	0.53	0.53	0.36	null	null	null
C*s	0.12	0.09	0.10	0.11	null	null	null
D*n	0.01	0.00	0.00	0.02	null	avoided	avoided
D*o	0.07	0.22	0.21	0.08	null	null	null
D*s	0.00	0.00	0.00	0.03	null	avoided	avoided
other*n	0.01	0.01	0.01	0.02	null	null	null
other*o	0.08	0.02	0.01	0.11	null	avoided	avoided
other*s	0.02	0.00	0.00	0.03	null	avoided	avoided
total	1.00	1.00	1.00	1.00			
A*n	0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*o	0.02	0.04	0.05	0.02	null	null	null
A*s	0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*n	0.00	0.00	0.00	0.05	avoided	avoided	avoided
B*o	0.13	0.06	0.06	0.10	null	null	null
B*s	0.02	0.00	0.00	0.03	null	null	null
C*n	0.02	0.03	0.03	0.18	avoided	avoided	avoided
C*o	0.59	0.55	0.54	0.41	null	null	null
C*s	0.13	0.10	0.10	0.09	null	null	null
D*n	0.02	0.00	0.00	0.03	null	avoided	avoided
D*o	0.08	0.22	0.22	0.07	null	null	null
D*s	0.00	0.00	0.00	0.02	null	avoided	avoided
total	1.00	1.00	1.00	1.00			
height*aspect							
0*n	0.00	0.00	0.00	0.03	avoided	avoided	avoided
0*o	0.08	0.06	0.07	0.07	null	null	null
0*s	0.00	0.05	0.06	0.02	null	null	null
1*n	0.01	0.00	0.00	0.04	null	avoided	avoided
1*o	0.15	0.38	0.38	0.10	null	preferred	preferred
1*s	0.00	0.00	0.00	0.04	avoided	avoided	avoided
2*n	0.01	0.00	0.00	0.07	avoided	avoided	avoided
2*o	0.34	0.33	0.32	0.24	null	null	null

[78]For explanatory notes see p. 96.

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.

Winter 2 n=32

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
2*s		0.07	0.04	0.05	0.07	null	null	null
3*n		0.01	0.03	0.03	0.02	null	null	null
3*o		0.16	0.08	0.08	0.12	null	null	null
3*s		0.05	0.00	0.00	0.04	null	avoided	avoided
other*n		0.01	0.01	0.01	0.02	null	null	null
other*o		0.08	0.02	0.01	0.11	null	avoided	avoided
other*s		0.02	0.00	0.00	0.03	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
0*n		0.00	0.00	0.00	0.03	avoided	avoided	avoided
0*o		0.09	0.06	0.07	0.08	null	null	null
0*s		0.00	0.05	0.06	0.02	null	null	null
1*n		0.01	0.00	0.00	0.05	null	avoided	avoided
1*o		0.17	0.39	0.38	0.12	null	preferred	preferred
1*s		0.01	0.00	0.00	0.04	avoided	avoided	avoided
2*n		0.01	0.00	0.00	0.08	avoided	avoided	avoided
2*o		0.39	0.34	0.33	0.28	null	null	null
2*s		0.08	0.05	0.05	0.08	null	null	null
3*n		0.01	0.03	0.03	0.02	null	null	null
3*o		0.18	0.08	0.08	0.15	null	null	null
3*s		0.06	0.00	0.00	0.04	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
origin*aspect								
<=1830*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
<=1830*o		0.30	0.10	0.09	0.10	preferred	null	null
<=1830s		0.05	0.00	0.00	0.01	null	null	null
1831-1879*n		0.01	0.03	0.03	0.03	null	null	null
1831-1879*o		0.14	0.16	0.15	0.15	null	null	null
1831-1879*s		0.04	0.00	0.00	0.03	null	avoided	null
1880-1929*n		0.02	0.00	0.00	0.07	null	avoided	avoided
1880-1929*o		0.15	0.33	0.31	0.20	null	null	null
1880-1929*s		0.05	0.04	0.04	0.08	null	null	null
1930-1985*n		0.00	0.00	0.00	0.07	avoided	avoided	avoided
1930-1985*o		0.22	0.28	0.32	0.18	null	null	null
1930-1985*s		0.00	0.05	0.06	0.06	avoided	null	null
	total	1.00	1.00	1.00	1.00			
<=1830*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
<=1830*o		0.27	0.10	0.09	0.08	null	null	null
<=1830*s		0.04	0.00	0.00	0.01	null	null	null
1831-1879*n		0.01	0.03	0.03	0.02	null	null	null
1831-1879*o		0.13	0.15	0.14	0.12	null	null	null

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.

Winter 2 n=32

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
1831-1879*s		0.04	0.00	0.00	0.03	null	null	null
1880-1929*n		0.02	0.00	0.00	0.06	null	avoided	avoided
1880-1929*o		0.13	0.32	0.30	0.17	null	null	null
1880-1929*s		0.05	0.04	0.04	0.07	null	null	null
1930-1985*n		0.00	0.00	0.00	0.06	avoided	avoided	avoided
1930-1985*o		0.20	0.27	0.31	0.16	null	null	null
1930-1985*s		0.00	0.05	0.06	0.05	avoided	null	null
cc*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
cc*o		0.00	0.00	0.00	0.01	avoided	avoided	avoided
cc*s		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*n		0.01	0.01	0.01	0.02	null	null	null
other*o		0.08	0.02	0.01	0.10	null	avoided	avoided
other*s		0.02	0.00	0.00	0.02	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
species*aspect								
conifer*n		0.03	0.03	0.03	0.13	avoided	null	avoided
conifer*o		0.67	0.83	0.83	0.48	null	preferred	preferred
conifer*s		0.14	0.10	0.11	0.12	null	null	null
decid*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
decid*o		0.04	0.01	0.01	0.02	null	null	null
decid*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
mixed*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
mixed*o		0.02	0.00	0.00	0.03	null	avoided	avoided
mixed*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
ds*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
ds*o		0.01	0.00	0.00	0.04	null	avoided	avoided
ds*s		0.00	0.00	0.00	0.00	avoided	avoided	avoided
cs*n		0.00	0.00	0.00	0.01	null	avoided	avoided
cs*o		0.01	0.00	0.00	0.02	null	avoided	avoided
cs*s		0.00	0.00	0.00	0.00	null	avoided	avoided
muskeg*n		0.01	0.01	0.01	0.00	null	null	null
muskeg*o		0.05	0.00	0.00	0.02	null	avoided	avoided
muskeg*s		0.00	0.00	0.00	0.00	null	avoided	avoided
cc*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
cc*o		0.00	0.00	0.00	0.01	avoided	avoided	avoided
cc*s		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*o		0.01	0.02	0.01	0.02	null	null	null
other*s		0.01	0.00	0.00	0.01	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.

Winter 2 n=32

Category Level	Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
P*n	0.02	0.00	0.00	0.09	null	avoided	avoided
P*o	0.40	0.70	0.64	0.31	null	preferred	preferred
P*s	0.07	0.04	0.04	0.09	null	null	null
Sb*n	0.00	0.00	0.00	0.01	avoided	avoided	avoided
Sb*o	0.09	0.10	0.08	0.05	null	null	null
Sb*s	0.01	0.05	0.05	0.01	null	null	null
Sw*n	0.01	0.03	0.03	0.03	null	null	null
Sw*o	0.17	0.03	0.04	0.12	null	null	null
Sw*s	0.05	0.01	0.00	0.03	null	null	null
decid*n	0.00	0.00	0.00	0.01	avoided	avoided	avoided
decid*o	0.04	0.01	0.01	0.02	null	null	null
decid*s	0.00	0.00	0.00	0.02	avoided	avoided	avoided
mixed*n	0.00	0.00	0.00	0.01	avoided	avoided	avoided
mixed*o	0.02	0.00	0.00	0.03	null	avoided	avoided
mixed*s	0.00	0.00	0.00	0.02	avoided	avoided	avoided
ds*n	0.00	0.00	0.00	0.01	avoided	avoided	avoided
ds*o	0.01	0.00	0.00	0.04	null	avoided	avoided
ds*s	0.00	0.00	0.00	0.00	avoided	avoided	avoided
cs*n	0.00	0.00	0.09	0.01	null	avoided	null
cs*o	0.01	0.00	0.00	0.02	null	avoided	avoided
cs*s	0.00	0.00	0.00	0.00	null	avoided	avoided
muskeg*n	0.01	0.01	0.01	0.00	null	null	null
muskeg*o	0.05	0.00	0.00	0.02	null	avoided	avoided
muskeg*s	0.00	0.00	0.00	0.00	null	avoided	avoided
cc*n	0.00	0.00	0.00	0.00	avoided	avoided	avoided
cc*o	0.00	0.00	0.00	0.01	avoided	avoided	avoided
cc*s	0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*n	0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*o	0.01	0.02	0.01	0.02	null	null	null
other*s	0.01	0.00	0.00	0.01	null	avoided	avoided
total	1.00	1.00	1.00	1.00			
P*n	0.02	0.00	0.00	0.11	avoided	avoided	avoided
P*o	0.45	0.72	0.72	0.36	null	preferred	preferred
P*s	0.08	0.04	0.04	0.10	null	null	null
Sb*n	0.00	0.00	0.00	0.02	avoided	avoided	avoided
Sb*o	0.10	0.10	0.09	0.06	null	null	null
Sb*s	0.01	0.05	0.06	0.01	null	null	null
Sw*n	0.01	0.03	0.03	0.04	null	null	null
Sw*o	0.19	0.04	0.04	0.15	null	avoided	null
Sw*s	0.06	0.01	0.00	0.03	null	null	avoided
decid*n	0.00	0.00	0.00	0.01	avoided	avoided	avoided

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.

Winter 2 n=32

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
decid*o		0.04	0.01	0.01	0.02	null	null	null
decid*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
mixed*n		0.00	0.00	0.00	0.02	avoided	avoided	avoided
mixed*o		0.02	0.00	0.00	0.04	null	avoided	avoided
mixed*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.[79]

Unlogged n=31

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
closure*aspect								
A*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*o		0.02	0.02	0.04	0.02	null	null	null
A*s		0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*n		0.03	0.03	0.11	0.02	null	null	null
B*o		0.05	0.01	0.01	0.07	null	avoided	avoided
B*s		0.04	0.00	0.00	0.02	null	avoided	avoided
C*n		0.02	0.07	0.07	0.11	avoided	null	null
C*o		0.48	0.61	0.53	0.36	null	null	null
C*s		0.11	0.15	0.13	0.11	null	null	null
D*n		0.01	0.00	0.00	0.02	null	avoided	avoided
D*o		0.04	0.00	0.00	0.08	null	avoided	avoided
D*s		0.02	0.00	0.00	0.03	null	avoided	avoided
other*n		0.02	0.01	0.01	0.02	null	null	null
other*o		0.14	0.09	0.10	0.11	null	null	null
other*s		0.02	0.00	0.00	0.03	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
A*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
A*o		0.02	0.03	0.04	0.02	null	null	null
A*s		0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*n		0.04	0.04	0.12	0.05	null	null	null
B*o		0.07	0.01	0.01	0.10	null	avoided	avoided
B*s		0.05	0.00	0.00	0.03	null	avoided	avoided
C*n		0.02	0.07	0.08	0.18	avoided	null	null
C*o		0.58	0.68	0.60	0.41	null	preferred	null
C*s		0.14	0.17	0.15	0.09	null	null	null
D*n		0.01	0.00	0.00	0.03	null	avoided	avoided
D*o		0.04	0.00	0.00	0.07	null	avoided	avoided
D*s		0.02	0.00	0.00	0.02	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
height*aspect								
0*n		0.03	0.00	0.00	0.03	null	avoided	avoided
0*o		0.08	0.08	0.09	0.07	null	null	null
0*s		0.03	0.00	0.00	0.02	null	avoided	avoided
1*n		0.00	0.00	0.00	0.04	avoided	avoided	avoided
1*o		0.06	0.18	0.16	0.10	null	null	null
1*s		0.02	0.05	0.04	0.04	null	null	null
2*n		0.02	0.03	0.11	0.07	null	null	null
2*o		0.22	0.34	0.28	0.24	null	null	null
2*s		0.06	0.10	0.09	0.07	null	null	null

[79]For explanatory notes see p. 96.

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.

Unlogged n=31

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
3*n		0.01	0.07	0.07	0.02	null	null	null
3*o		0.23	0.05	0.05	0.12	null	null	null
3*s		0.06	0.00	0.00	0.04	null	avoided	avoided
other*n		0.02	0.01	0.01	0.02	null	null	null
other*o		0.14	0.09	0.10	0.11	null	null	null
other*s		0.02	0.00	0.00	0.03	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
0*n		0.03	0.00	0.00	0.03	null	avoided	avoided
0*o		0.09	0.09	0.10	0.08	null	null	null
0*s		0.04	0.00	0.00	0.02	null	avoided	avoided
1*n		0.00	0.00	0.00	0.05	avoided	avoided	avoided
1*o		0.07	0.20	0.19	0.12	null	null	null
1*s		0.03	0.06	0.05	0.04	null	null	null
2*n		0.02	0.04	0.12	0.08	null	null	null
2*o		0.27	0.37	0.31	0.28	null	null	null
2*s		0.08	0.11	0.10	0.08	null	null	null
3*n		0.02	0.07	0.08	0.02	null	null	null
3*o		0.27	0.06	0.06	0.15	null	null	null
3*s		0.07	0.00	0.00	0.04	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
origin*aspect								
<=1830*n		0.02	0.07	0.08	0.01	null	null	null
<=1830*o		0.37	0.14	0.13	0.10	preferred	null	null
<=1830s		0.06	0.00	0.00	0.01	null	null	null
1831-1879*n		0.00	0.00	0.00	0.03	avoided	avoided	avoided
1831-1879*o		0.03	0.10	0.08	0.15	avoided	null	null
1831-1879*s		0.00	0.00	0.00	0.03	avoided	avoided	avoided
1880-1929*n		0.02	0.04	0.12	0.07	null	null	null
1880-1929*o		0.18	0.21	0.18	0.20	null	null	null
1880-1929*s		0.09	0.11	0.10	0.08	null	null	null
1930-1985*n		0.04	0.00	0.00	0.07	null	avoided	avoided
1930-1985*o		0.13	0.27	0.26	0.18	null	null	null
1930-1985*s		0.07	0.06	0.05	0.06	null	null	null
	total	1.00	1.00	1.00	1.00			
<=1830*n		0.01	0.07	0.07	0.01	null	null	null
<=1830*o		0.30	0.13	0.12	0.08	preferred	null	null
<=1830*s		0.05	0.00	0.00	0.01	null	null	null
1831-1879*n		0.00	0.00	0.00	0.02	avoided	avoided	avoided
1831-1879*o		0.02	0.09	0.07	0.12	avoided	null	null
1831-1879*s		0.00	0.00	0.00	0.03	avoided	avoided	avoided
1880-1929*n		0.02	0.03	0.11	0.06	null	null	null

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.

Unlogged n=31

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
1880-1929*o		0.15	0.19	0.16	0.17	null	null	null
1880-1929*s		0.07	0.10	0.09	0.07	null	null	null
1930-1985*n		0.03	0.00	0.00	0.06	null	avoided	avoided
1930-1985*o		0.11	0.24	0.23	0.16	null	null	null
1930-1985*s		0.05	0.05	0.04	0.05	null	null	null
cc*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
cc*o		0.00	0.00	0.00	0.01	avoided	avoided	avoided
cc*s		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*n		0.02	0.01	0.01	0.02	null	null	null
other*o		0.14	0.09	0.10	0.10	null	null	null
other*s		0.02	0.00	0.00	0.02	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
species*aspect								
conifer*n		0.06	0.10	0.18	0.13	null	null	null
conifer*o		0.57	0.64	0.58	0.48	null	null	null
conifer*s		0.14	0.15	0.13	0.12	null	null	null
decid*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
decid*o		0.00	0.00	0.00	0.02	avoided	avoided	avoided
decid*s		0.04	0.00	0.00	0.02	null	avoided	avoided
mixed*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
mixed*o		0.01	0.00	0.00	0.03	null	avoided	avoided
mixed*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
ds*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
ds*o		0.07	0.08	0.09	0.04	null	null	null
ds*s		0.02	0.00	0.00	0.00	null	avoided	avoided
cs*n		0.00	0.00	0.00	0.01	null	avoided	avoided
cs*o		0.02	0.01	0.01	0.02	null	null	null
cs*s		0.00	0.00	0.00	0.00	avoided	avoided	avoided
muskeg*n		0.01	0.01	0.01	0.00	null	null	null
muskeg*o		0.05	0.00	0.00	0.02	null	avoided	avoided
muskeg*s		0.00	0.00	0.00	0.00	avoided	avoided	avoided
cc*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
cc*o		0.00	0.00	0.00	0.01	avoided	avoided	avoided
cc*s		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*o		0.00	0.00	0.00	0.02	avoided	avoided	avoided
other*s		0.00	0.00	0.00	0.01	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			
P*n		0.05	0.03	0.11	0.09	null	null	null
P*o		0.29	0.48	0.43	0.31	null	null	null
P*s		0.07	0.15	0.13	0.09	null	null	null
Sb*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.

Unlogged n=31

Category Level	Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
Sb*o	0.08	0.15	0.12	0.05	null	null	null
Sb*s	0.02	0.00	0.00	0.01	null	avoided	avoided
Sw*n	0.01	0.07	0.07	0.03	null	null	null
Sw*o	0.21	0.02	0.03	0.12	null	avoided	avoided
Sw*s	0.05	0.00	0.00	0.03	null	avoided	avoided
decid*n	0.00	0.00	0.00	0.01	avoided	avoided	avoided
decid*o	0.00	0.00	0.00	0.02	avoided	avoided	avoided
decid*s	0.04	0.00	0.00	0.02	null	avoided	avoided
mixed*n	0.00	0.00	0.00	0.01	avoided	avoided	avoided
mixed*o	0.01	0.00	0.00	0.03	null	avoided	avoided
mixed*s	0.00	0.00	0.00	0.02	avoided	avoided	avoided
ds*n	0.00	0.00	0.00	0.01	avoided	avoided	avoided
ds*o	0.07	0.08	0.09	0.04	null	null	null
ds*s	0.02	0.00	0.00	0.00	null	avoided	avoided
cs*n	0.00	0.00	0.00	0.01	null	avoided	avoided
cs*o	0.02	0.01	0.01	0.02	null	null	null
cs*s	0.00	0.00	0.00	0.00	avoided	avoided	avoided
muskeg*n	0.01	0.01	0.01	0.00	null	null	null
muskeg*o	0.05	0.00	0.00	0.02	null	avoided	avoided
muskeg*s	0.00	0.00	0.00	0.00	avoided	avoided	avoided
cc*n	0.00	0.00	0.00	0.00	avoided	avoided	avoided
cc*o	0.00	0.00	0.00	0.01	avoided	avoided	avoided
cc*s	0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*n	0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*o	0.00	0.00	0.00	0.02	avoided	avoided	avoided
other*s	0.00	0.00	0.00	0.01	avoided	avoided	avoided
total	1.00	1.00	1.00	1.00			
P*n	0.06	0.04	0.12	0.11	null	null	null
P*o	0.36	0.53	0.49	0.36	null	null	null
P*s	0.08	0.17	0.14	0.10	null	null	null
Sb*n	0.00	0.00	0.00	0.02	avoided	avoided	avoided
Sb*o	0.09	0.17	0.14	0.06	null	null	null
Sb*s	0.02	0.00	0.00	0.01	null	avoided	avoided
Sw*n	0.02	0.07	0.08	0.04	null	null	null
Sw*o	0.25	0.02	0.03	0.15	null	avoided	avoided
Sw*s	0.06	0.00	0.00	0.03	null	avoided	avoided
decid*n	0.00	0.00	0.00	0.01	avoided	avoided	avoided
decid*o	0.00	0.00	0.00	0.02	avoided	avoided	avoided
decid*s	0.05	0.00	0.00	0.02	null	avoided	avoided
mixed*n	0.00	0.00	0.00	0.02	avoided	avoided	avoided
mixed*o	0.01	0.00	0.00	0.04	null	avoided	avoided
mixed*s	0.00	0.00	0.00	0.02	avoided	avoided	avoided
total	1.00	1.00	1.00	1.00			

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.[80]

Logged n=28

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
closure*aspect								
A*n		0.00	0.04	0.04	0.01	null	null	null
A*o		0.01	0.02	0.01	0.02	null	null	null
A*s		0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*n		0.00	0.00	0.00	0.02	avoided	avoided	avoided
B*o		0.11	0.06	0.08	0.07	null	null	null
B*s		0.01	0.00	0.00	0.02	null	null	null
C*n		0.03	0.21	0.20	0.11	null	null	null
C*o		0.59	0.29	0.27	0.36	null	null	null
C*s		0.07	0.10	0.10	0.11	null	null	null
D*n		0.01	0.01	0.01	0.02	null	null	null
D*o		0.06	0.21	0.22	0.08	null	null	null
D*s		0.01	0.01	0.01	0.03	null	null	null
other*n		0.00	0.01	0.01	0.02	null	null	null
other*o		0.06	0.04	0.04	0.11	null	null	null
other*s		0.02	0.00	0.00	0.03	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
A*n		0.00	0.04	0.05	0.01	null	null	null
A*o		0.01	0.02	0.02	0.02	null	null	null
A*s		0.00	0.00	0.00	0.01	avoided	avoided	avoided
B*n		0.00	0.00	0.00	0.05	avoided	avoided	avoided
B*o		0.12	0.06	0.09	0.10	null	null	null
B*s		0.01	0.00	0.00	0.03	null	avoided	avoided
C*n		0.04	0.22	0.21	0.18	avoided	null	null
C*o		0.65	0.30	0.29	0.41	null	null	null
C*s		0.07	0.10	0.11	0.09	null	null	null
D*n		0.01	0.01	0.01	0.03	null	null	null
D*o		0.07	0.22	0.23	0.07	null	null	null
D*s		0.02	0.01	0.01	0.02	null	null	null
	total	1.00	1.00	1.00	1.00			
height*aspect								
0*n		0.00	0.00	0.00	0.03	avoided	avoided	avoided
0*o		0.13	0.05	0.05	0.07	null	null	null
0*s		0.00	0.03	0.03	0.02	null	null	null
1*n		0.01	0.04	0.04	0.04	null	null	null
1*o		0.15	0.19	0.20	0.10	null	null	null
1*s		0.02	0.07	0.07	0.04	null	null	null
2*n		0.02	0.01	0.01	0.07	null	avoided	avoided
2*o		0.37	0.21	0.20	0.24	null	null	null
2*s		0.06	0.01	0.01	0.07	null	avoided	avoided

80 For explanatory notes see p. 96.

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.

Logged n=28

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
3*n		0.02	0.21	0.20	0.02	null	preferred	preferred
3*o		0.12	0.12	0.15	0.12	null	null	null
3*s		0.01	0.00	0.00	0.04	null	avoided	avoided
other*n		0.00	0.01	0.01	0.02	null	null	null
other*o		0.06	0.04	0.04	0.11	null	null	null
other*s		0.02	0.00	0.00	0.03	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
0*n		0.00	0.00	0.00	0.03	avoided	avoided	avoided
0*o		0.14	0.06	0.05	0.08	null	null	null
0*s		0.00	0.03	0.03	0.02	null	null	null
1*n		0.01	0.04	0.05	0.05	null	null	null
1*o		0.16	0.20	0.21	0.12	null	null	null
1*s		0.02	0.07	0.08	0.04	null	null	null
2*n		0.02	0.01	0.01	0.08	null	avoided	avoided
2*o		0.41	0.22	0.21	0.28	null	null	null
2*s		0.07	0.01	0.01	0.08	null	avoided	avoided
3*n		0.03	0.22	0.21	0.02	null	preferred	preferred
3*o		0.13	0.13	0.16	0.15	null	null	null
3*s		0.02	0.00	0.00	0.04	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
origin*aspect								
<=1830*n		0.01	0.20	0.19	0.01	null	preferred	preferred
<=1830*o		0.19	0.11	0.13	0.10	null	null	null
<=1830s		0.00	0.00	0.00	0.01	null	avoided	avoided
1831-1879*n		0.02	0.02	0.02	0.03	null	null	null
1831-1879*o		0.29	0.16	0.15	0.15	null	null	null
1831-1879*s		0.05	0.01	0.01	0.03	null	null	null
1880-1929*n		0.01	0.00	0.00	0.07	avoided	avoided	avoided
1880-1929*o		0.08	0.14	0.12	0.20	null	null	null
1880-1929*s		0.02	0.00	0.00	0.08	null	avoided	avoided
1930-1985*n		0.01	0.05	0.05	0.07	avoided	null	null
1930-1985*o		0.28	0.20	0.21	0.18	null	null	null
1930-1985*s		0.03	0.11	0.11	0.06	null	null	null
	total	1.00	1.00	1.00	1.00			
<=1830*n		0.01	0.19	0.18	0.01	null	preferred	preferred
<=1830*o		0.17	0.10	0.13	0.08	null	null	null
<=1830*s		0.00	0.00	0.00	0.01	null	avoided	avoided
1831-1879*n		0.02	0.02	0.02	0.02	null	null	null
1831-1879*o		0.27	0.15	0.14	0.12	null	null	null
1831-1879*s		0.04	0.01	0.01	0.03	null	null	null
1880-1929*n		0.01	0.00	0.00	0.06	avoided	avoided	avoided

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.

Logged n=28

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
1880-1929*o		0.08	0.14	0.12	0.17	null	null	null
1880-1929*s		0.02	0.00	0.00	0.07	null	avoided	avoided
1930-1985*n		0.01	0.05	0.05	0.06	avoided	null	null
1930-1985*o		0.25	0.19	0.20	0.16	null	null	null
1930-1985*s		0.03	0.10	0.11	0.05	null	null	null
cc*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
cc*o		0.00	0.00	0.00	0.01	avoided	avoided	avoided
cc*s		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*n		0.00	0.01	0.01	0.02	null	null	null
other*o		0.06	0.04	0.04	0.10	null	null	null
other*s		0.02	0.00	0.00	0.02	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
species*aspect								
conifer*n		0.05	0.26	0.25	0.13	null	null	null
conifer*o		0.69	0.55	0.56	0.48	null	null	null
conifer*s		0.09	0.11	0.11	0.12	null	null	null
decid*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
decid*o		0.03	0.01	0.01	0.02	null	null	null
decid*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
mixed*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
mixed*o		0.05	0.02	0.02	0.03	null	null	null
mixed*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
ds*n		0.00	0.01	0.01	0.01	null	null	null
ds*o		0.00	0.00	0.00	0.04	avoided	avoided	avoided
ds*s		0.00	0.00	0.00	0.00	avoided	avoided	avoided
cs*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
cs*o		0.02	0.02	0.02	0.02	null	null	null
cs*s		0.00	0.00	0.00	0.00	null	avoided	avoided
muskeg*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
muskeg*o		0.03	0.00	0.01	0.02	null	null	null
muskeg*s		0.01	0.00	0.00	0.00	null	avoided	avoided
cc*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
cc*o		0.00	0.00	0.00	0.01	avoided	avoided	avoided
cc*s		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*o		0.01	0.02	0.01	0.02	null	null	null
other*s		0.01	0.00	0.00	0.01	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
P*n		0.02	0.05	0.05	0.09	null	null	null
P*o		0.34	0.36	0.33	0.31	null	null	null
P*s		0.07	0.07	0.07	0.09	null	null	null
Sb*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided

Appendix 4 (continued). Caribou use of aspect*timber variable habitat categories.

Logged n=28

Category Level		Proportion of use as measured by... distance (m)	crts/km	adj crts/km	Expected use	Significance distance	crts/km	adj crts/km
Sb*o		0.11	0.09	0.12	0.05	null	null	null
Sb*s		0.01	0.04	0.03	0.01	null	null	null
Sw*n		0.03	0.21	0.19	0.03	null	avoided	null
Sw*o		0.23	0.11	0.09	0.12	null	null	null
Sw*s		0.01	0.00	0.00	0.03	null	avoided	avoided
decid*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
decid*o		0.03	0.01	0.01	0.02	null	null	null
decid*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
mixed*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
mixed*o		0.05	0.02	0.02	0.03	null	null	null
mixed*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
ds*n		0.00	0.01	0.01	0.01	null	null	null
ds*o		0.00	0.00	0.00	0.04	avoided	avoided	avoided
ds*s		0.00	0.00	0.00	0.00	avoided	avoided	avoided
cs*n		0.00	0.00	0.05	0.01	avoided	avoided	null
cs*o		0.02	0.02	0.02	0.02	null	null	null
cs*s		0.00	0.00	0.00	0.00	null	avoided	avoided
muskeg*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
muskeg*o		0.03	0.00	0.00	0.02	null	null	null
muskeg*s		0.01	0.00	0.00	0.00	null	avoided	avoided
cc*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
cc*o		0.00	0.00	0.00	0.01	avoided	avoided	avoided
cc*s		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*n		0.00	0.00	0.00	0.00	avoided	avoided	avoided
other*o		0.01	0.02	0.01	0.02	null	null	null
other*s		0.01	0.00	0.00	0.01	null	avoided	avoided
	total	1.00	1.00	1.00	1.00			
P*n		0.03	0.05	0.05	0.11	null	null	null
P*o		0.38	0.37	0.36	0.36	null	null	null
P*s		0.07	0.08	0.08	0.10	null	null	null
Sb*n		0.00	0.00	0.00	0.02	avoided	avoided	avoided
Sb*o		0.12	0.09	0.13	0.06	null	null	null
Sb*s		0.02	0.04	0.04	0.01	null	null	null
Sw*n		0.03	0.22	0.21	0.04	null	preferred	preferred
Sw*o		0.25	0.11	0.10	0.15	null	null	null
Sw*s		0.01	0.00	0.00	0.03	null	avoided	avoided
decid*n		0.00	0.00	0.00	0.01	avoided	avoided	avoided
decid*o		0 04	0.01	0.01	0.02	null	null	null
decid*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
mixed*n		0.00	0.00	0.00	0.02	avoided	avoided	avoided
mixed*o		0.05	0.02	0.02	0.04	null	null	null
mixed*s		0.00	0.00	0.00	0.02	avoided	avoided	avoided
	total	1.00	1.00	1.00	1.00			

Appendix 5. Mean lichen abundance (% cover) at feeding v. non-feeding sites - data subsets (P ≤.05).[81]

winter 1

Lichen type	Feeding (n=155)	SD	Non-feeding (n=239)	SD	F	Prob.	Sig. diff.?
Cladina mitis	5.08	8.23	2.04	4.95	37.60	0.00	yes
C. rangifernia	0.73	2.82	0.09	0.43	26.50	0.00	yes
C. stellaris	0.09	1.12	0.00	0.00	1.54	0.21	no
Cladonia spp.	0.66	1.50	0.25	0.76	26.51	0.00	yes
Certraria spp.	0.09	0.73	0.00	0.04	3.58	0.06	no
Peltigera spp.	2.96	5.63	1.23	2.67	26.12	0.00	yes
Stereocaulon spp.	2.63	6.90	0.81	5.11	26.15	0.00	yes
Cladonia uncialis	0.76	3.17	0.26	1.61	12.47	0.00	yes
Other	0.46	2.22	0.07	0.67	12.06	0.00	yes

winter 2

Lichen type	Feeding (n=116)	SD	Non-feeding (n=222)	SD	F	Prob.	Sig. diff.?
Cladina mitis	2.18	4.80	0.47	3.75	73.00	0.00	yes
C. rangifernia	0.03	0.17	0.01	0.08	6.86	0.01	yes
C. stellaris	0.00	0.01	0.00	0.02	0.01	0.94	no
Cladonia spp.	0.97	2.00	0.20	0.60	79.89	0.00	yes
Certraria spp.	0.00	0.01	0.00	0.01	0.00	0.95	no
Peltigera spp.	0.57	1.16	0.58	1.47	1.13	0.29	no
Stereocaulon spp.	1.34	5.07	0.08	0.32	29.99	0.00	yes
Cladonia uncialis	0.19	0.92	0.13	1.39	2.84	0.09	no
Other	0.18	1.67	0.00	0.04	4.42	0.04	yes

unlogged

Lichen type	Feeding (n= 127)	SD	Non-feeding (n=191)	SD	F	Prob.	Sig. diff.?
Cladina mitis	3.66	7.42	1.25	3.95	44.59	0.00	yes
C. rangifernia	0.73	3.07	0.05	0.36	17.94	0.00	yes
C. stellaris	0.11	1.24	0.00	0.00	1.51	0.22	no
Cladonia spp.	0.64	1.18	0.18	0.55	51.15	0.00	yes
Certraria spp.	0.11	0.80	0.01	0.05	3.60	0.06	no
Peltigera spp.	2.29	5.64	0.79	2.27	19.09	0.00	yes
Stereocaulon spp.	3.53	7.73	0.74	5.48	43.85	0.00	yes
Cladonia uncialis	0.73	2.72	0.18	1.51	14.54	0.00	yes
Other	0.57	2.84	0.02	0.15	11.09	0.00	yes

[81]Actual means are shown but the table F values, probabilities.and significance of the difference between feeding and non-feding sites are based on an analysis of variance using square root transformed data.

logged

Lichen type	Feeding (n=144)	SD	Non-feeding (n=270)	SD	F	Prob.	Sig. diff.?
Cladina mitis	3.99	6.84	1.31	4.83	46.88	0.00	yes
C. rangifernia	0.17	0.62	0.04	0.28	15.26	0.00	yes
C. stellaris	0.00	0.01	0.00	0.02	0.00	0.96	no
Cladonia spp.	0.92	2.10	0.25	0.77	45.59	0.00	yes
Certraria spp.	0.00	0.01	0.00	0.01	0.01	0.93	no
Peltigera spp.	1.63	3.11	1.00	2.15	9.23	0.00	yes
Stereocaulon spp.	0.80	4.08	0.26	1.45	8.31	0.00	yes
Cladonia uncialis	0.33	2.25	0.22	1.51	2.95	0.09	no
Other	0.14	0.65	0.05	0.62	6.00	0.01	yes

winter 1, unlogged

Lichen type	Feeding (n=66)	SD	Non-feeding (n= 83)	SD	F	Prob.	Sig. diff.?
Cladina mitis	6.12	9.64	2.54	5.71	17.68	0.00	yes
C. rangifernia	1.38	4.17	0.11	0.53	14.35	0.00	yes
C. stellaris	0.21	1.72	0.00	0.00	1.26	0.26	no
Cladonia spp.	0.40	1.05	0.10	0.23	13.11	0.00	yes
Certraria spp.	0.21	1.11	0.02	0.07	2.78	0.10	no
Peltigera spp.	3.98	7.39	1.09	3.07	21.66	0.00	yes
Stereocaulon spp.	5.17	9.74	1.54	8.23	19.95	0.00	yes
Cladonia uncialis	1.10	3.56	0.05	0.25	14.82	0.00	yes
Other	0.80	3.26	0.03	0.22	7.10	0.01	yes

winter 1, logged

Lichen type	Feeding (n=89)	SD	Non-feeding (n=156)	SD	F	Prob.	Sig. diff.?
Cladina mitis	4.31	6.96	1.78	4.49	17.94	0.00	yes
C. rangifernia	0.25	0.76	0.08	0.37	11.15	0.00	yes
C. stellaris	0.00	0.00	0.00	0.00	0.00		no
Cladonia spp.	0.84	1.74	0.33	0.91	18.00	0.00	yes
Certraria spp.	0.00	0.02	0.00	0.02	0.02	0.88	no
Peltigera spp.	2.20	3.72	1.31	2.43	6.56	0.01	yes
Stereocaulon spp.	0.74	2.22	0.43	1.88	4.24	0.04	yes
Cladonia uncialis	0.50	2.85	0.37	1.98	1.78	0.18	no
Other	0.21	0.81	0.09	0.81	4.23	0.04	yes

winter 2, unlogged

Lichen type	Feeding (n=61)	SD	Non-feeding (n=108)	SD	F	Prob.	Sig. diff.?
Cladina mitis	0.99	0.92	0.25	0.62	61.45	0.00	yes
C. rangifernia	0.03	0.11	0.02	0.11	2.20	0.14	no
C. stellaris	0.00	0.00	0.00	0.00			no
Cladonia spp.	0.89	1.26	0.25	0.70	51.10	0.00	yes
Certraria spp.	0.00	0.01	0.00	0.01	0.01	0.91	no
Peltigera spp.	0.46	1.04	0.56	1.34	0.00	0.92	no
Stereocaulon spp.	1.75	4.06	0.12	0.40	29.03	0.00	yes
Cladonia uncialis	0.33	1.23	0.28	1.99	1.46	0.23	no
Other	0.32	2.31	0.01	0.04	2.89	0.09	no

winter 2, logged

Lichen type	Feeding (n=55)	SD	Non-feeding (n=114)	SD	F	Prob.	Sig. diff.?
Cladina mitis	3.49	6.68	0.68	5.20	35.23	0.00	yes
C. rangifernia	0.04	0.21	0.00	0.00	5.15	0.02	yes
C. stellaris	0.00	0.01	0.00	0.03	0.01	0.91	no
Cladonia spp.	1.06	2.59	0.15	0.48	30.65	0.00	yes
Certraria spp.	0.00	0.01	0.00	0.01	0.00	0.98	no
Peltigera spp.	0.70	1.28	0.59	1.60	1.96	0.16	no
Stereocaulon spp.	0.88	6.01	0.04	0.22	3.77	0.05	no
Cladonia uncialis	0.04	0.27	0.00	0.01	3.30	0.07	no
Other	0.02	0.09	0.00	0.05	2.45	0.12	no

Appendix 6. Key features and criticisms of the United States *Endangered Species Act.*

Purpose

The purpose of the *Endangered Species Act*[82] (ESA) as set forth in § 1531(b) is to protect species from extinction and to conserve the ecosystems on which they depend. In "Patching the Ark: Improving Legal Protection of Biological diversity"[83], Holly Doremus says that the ESA misses the mark in terms of protecting biodiversity. She suggests that the proper focus should be preservation of extant biota and preservation of the capacity for future evolution through an emphasis on ecosystem rather than species preservation.

Listing

The listing of species into one of two categories, threatened or endangered, is the trigger for the ESA's other provisions. The administrators[84] of the Act are required pursuant to § 1533 to list endangered and threatened species. The Act defines endangered species in § 1532 as a species in danger of extinction throughout all or a significant part of its range and a threatened species as one likely to become endangered in the foreseeable future. § 1533 requires the administrators to consider five risk criteria solely on the basis of the best scientific and commercial data available in making decisions about listing. Listing may be initiated by the administrators or by private party petitions. The administrators have timelines to decide on the sufficiency of petitions but there are also procedures for extensions. Temporary emergency listings are possible.

The listing process has been the subject of criticism from many directions. The lack of funding for the listing process[85], the gathering of the scientific data necessary to support a listing decision, and the delays inherent in the process of deciding on petitions has meant that listing can be protracted[86]. One ESA commentator cites a 1992 estimate by the U.S. Fish and Wildlife Service that about three dozen species went extinct awaiting listing[87]. The ESA, it would appear, does not take a precautionary approach. The listing process has also been criticized for in practice emphasizing creatures of charismatic appeal to the

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[82]Title 16 U.S.C. §§ 1531-1544 (1988).

[83](1991), 18 no. 2 *Ecology Law Quarterly* 265.

[84]The U.S. Secretary of the Interior, acting through the U.S. Fish and Wildlife Service, administers the ESA with respect to terrestrial species and the Secretary of Commerce, acting through the National Marine Fisheries Service, handles marine species.

[85]There was a moratorium on listings and critical habitat designations earlier this year because of a lack of agreement between the Presidential administration and Congress on funding; see Sierra Club Legal Defense Fund, "A New Approach Toward Saving Rare Animals & Plants", Summer 1996 *In Brief* pp. 1 and 17-19.

[86]See J. Kunich, "The Fallacy of Deathbed Conservation Under the Endangered Species Act" (1994), 24 no. 2 *Environmental Law* 501 at 533-534 and N. Kubasek, *et al.*, "The Endangered Species Act: Time for a New Approach?" (1994), 24 no. 2 *Environmental Law* 392.

[87]Kunich, *id*, at 534.

public rather than giving priority to those species of greatest importance to biodiversity[88]. Listing has also been seen as an inflexible process because no economic consequences can be considered in listing. In concert with other ESA provisions the result may be that the administrators lose control of their protection agenda to the detriment of overall species protection[89]. Still another critic faults the listing process as not safeguarding against petitioners triggering the ESA to stop a development rather than in the interests of species protection[90].

Critical Habitat

The administrators of the ESA, pursuant to § 1533, must also designate critical habitat for each listed species unless impossible or imprudent. This designation is based on the best scientific data available but economic consequences must be considered. Critical habitat designations must be made despite economic consequences if a failure to designate would result in extinction. Designation of critical habitat is to take place with the listing of the species but a one year extension is possible. The designation of critical habitat includes a description of the area and an evaluation of public or private activities that might destroy or adversely modify the critical habitat.

This feature has been criticized because it provides opportunities to restrict the area of critical habitat and an option of not designating critical habitat[91].

Recovery Plans

In addition to designation of critical habitat, § 1533 requires the administrators to develop and implement recovery plans for listed species unless such a plan will not promote conservation of the species. To the "maximum extent practicable" each plan should include a description of site specific management action needed, objective measurable criteria that when met will result in delisting, and time and cost estimates for plan actions[92]. The enforceability of recovery plans is a matter of uncertainty. Current authority suggests a mandatory duty to develop recovery plans but that the administrators cannot be compelled to implement a given plan's specifics[93]. The administrators are also required to establish a priority list for recovery plans with species most likely to benefit having top priority, especially those imperiled by economic activity.

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[88]*id.* at 554.
[89]See J. Ruhl, "Section 7(a)(1) of the 'New' Endangered Species Act: Rediscovering and Redefining the Untapped Powers of Federal Agencies' Duty to Conserve Species" (1995), 25 no. 4 *Environmental Law* 1107 at 1121-1122.
[90]S. Somach, "What Outrages Me About the Endangered Species Act" (1994), 24 no. 2 *Environmental Law* 801.
[91]Kunich, *supra*, note 87, at 537.
[92]See 1995 amendments to ESA § 1533 referenced in Cheever, note 95 *infra*.
[93]See note 95, *infra*, at 58-72.

In "The Road to Recovery: A New Way of Thinking About the Endangered Species Act"[94] Federico Cheever persuasively argues that recovery planning should be the centrepiece of the ESA. Instead the focus to date has been on ESA provisions, discussed below, that prohibit certain actions. Some of the benefits of an emphasis on recovery planning that he sees are a reversing of the ESA's failure to date in bringing species back to the point where they no longer require protection (p. 12); removing the false sense of victory at the halting of a specific project while a species continues to be at risk (p. 13); enhancement of a species' prospects without having to deal with an immediate, inflexible, and potentially politically charged threat from a specific project (p. 26); and, a change in perception of the invoking of the prohibitive provisions of the ESA from extreme government intervention to problem solving tools (pp. 4,7,73).

Takings Prohibition

The ESA prohibits the taking of endangered fish and wildlife species in § 1538. It does not include plants[95]. Taking is defined broadly to include harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect. Regulations further define harm as significant habitat modification where it actually kills or injures wildlife by significantly impairing behavioral patterns, including breeding, feeding, or sheltering[96]. The takings prohibition can be extended to threatened species where needed to conserve the species. This has been done for all threatened animals under the U.S. Fish and Wildlife Service's jurisdiction[97]. These provisions are not restricted to designated critical habitat nor government lands. Federal agencies can be exempted from liability for takings incidental to their actions if certain procedures are followed. Private individuals can also obtain permits for takings incidental to otherwise lawful activity after submitting habitat conservation plans convincing the administrators that the proposed action will, to the maximum extent practicable, minimize and mitigate the impacts of such taking and will not appreciably reduce the likelihood of the survival and recovery of the species in the wild.

The takings prohibition appears to be the most controversial aspect of the ESA. The complaints range from the provisions being wrongly interpreted as interfering with a fundamental right to the exclusive use and enjoyment of one's property[98] to habitat conservation plans being cost prohibitive to small landowners[99]. It appears that the two most important ways in which it affects property rights are the restrictions it can impose

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[94](1996), 23 no. 1 *Ecology Law Quarterly* 1.

[95]Listed plants are protected to a significant degree in § 1538 but the protection does not use the taking terminology. For example, the malicious damaging of listed plants on federal lands is prohibited as is removing, damaging or destroying listed plants in knowing violation of state law; see Kunich, *supra*, note 87, at 547.

[96] See Kubasek *et al.*, *supra*, note 87, at 334.

[97]See R. Meltz, "Where the Wild Things Are: The Endangered Species Act and Private Property" (1994), 24 no. 2 *Environmental Law* 369 at 375.

[98]A. Gidari, "The Endangered Species Act: Impact of Section 9 on Private Landowners" (1994), 24 no. 2 *Environmental Law* 419.

[99]Meltz, *supra*, note 98, at 382.

on development[100] and that it prohibits farmers and ranchers from taking direct defensive measures against livestock predation by threatened species to which the takings prohibition has been extended[101]. Property rights advocates feel that the general law or the American constitution should require compensation from the government for losses in these circumstances. In fact, with a few possible exceptions, it appears that the law does not require compensation[102].

Government Agency Obligations

Under § 1536 of the ESA all U.S. federal agencies must ensure that their actions are not likely to jeopardize the continued existence of endangered and threatened species or adversely affect critical habitat. These agencies are required to consult with the ESA administrators to determine if listed species or critical habitat are in the proposed action area. If so, the agency must prepare a biological assessment identifying listed species likely to be affected by the action. If the species is likely to be affected then a formal consultation with the ESA administrators takes place and the administrators issue an opinion as to whether the proposed action would jeopardize the species or critical habitat. If the opinion is that the agency action would put the species in jeopardy, then it also recommends alternatives that would not jeopardize the species while still allowing the project to proceed. The agency need not follow the recommendations; it can take alternative, reasonably adequate steps to insure the species continued existence but must act on the best scientific and commercial data available. The agency, an applicant seeking the agency's approval, or the governor of the affected state can also seek[103] an exemption for the agency from the Endangered Species Committee if certain criteria exist.

The no-jeopardy provisions have drawn the ire of developers as unduly restricting economic growth but the statistics suggest otherwise[104].

The ESA also affirmatively requires federal agencies to use their authorities to carry out programs for the conservation of listed species[105]. This provision appears to have escaped criticism probably because it has been little used.

[100]The extent to which the takings prohibition applies to habitat modification has been litigated, see discussions in Ruhl, *supra*, note 90, at 1115-1119, and Cheever, *supra*, note 95, at 20-21 and 48-52.

[101]Special rules have been adopted allowing government agents to humanely take grizzlies and red wolves involved in livestock predation where relocation has failed, see Meltz *supra*, note 98 at 391-392.

[102]Meltz, *supra*, note 98.

[103]This exemption has been rarely sought and only once granted as at 1994, see Kunich, *supra*, note 87, at 544.

[104]Kubasek *et al.*, *supra*, note 87, at 399.

[105]Ruhl, *supra*, note 90, argues that this should be the centrepiece of the ESA.

Citizen Suit Provisions

The ESA in § 1540 expressly authorizes court action by any person to enjoin any person, including the government, alleged to be in violation of the ESA or its regulations.

These provisions, in concert with judicially created standing rules, have been criticized as giving environmental groups an unfair advantage over development interests[106]. As an example, environmental groups are apparently given standing as intervenors when a developer seeks judicial review of a listing decision but developers cannot intervene in an environmental group's action to stop an alleged violation of the ESA.

ESA Scheme Criticisms

Some criticisms of the ESA do not easily relate to specific provisions. I find two of these to be particularly cogent. First, the ESA represents deathbed conservation, coming into a play when a species is in danger of extinction. Intervention at such a late date may only delay the inevitable[107]. Second, because of the burdens it can impose on private landowners, the ESA may, perversely, actually encourage some people to rid their property of endangered species. This is colloquially referred to as the "3S" option: shoot, shovel, and shut up[108].

[106]Somach, *supra*, note 91.
[107]Kunich, *supra*, note 87.
[108]*id*, at 561.