FOREST ANALYSES AND MODELLING

OF

WINTERING AREAS OF WOODLAND CARIBOU

IN NORTHWESTERN ONTARIO

by

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ABSTRACT

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Key Words: woodland caribou, vertical distribution, horizontal distribution, timber values, lichen, forest ecosystem classification, Landsat, habitat suitability index model.

Twenty-four field trips over 3 summers (1979, 1980, and 1992) to 9 study areas showed that the Forest Ecosystem Classification vegetation type V30 best described woodland caribou wintering areas. Quantitatively, jack pine and or black spruce occupied 95% of the areas in uneven-aged stands with a mean of 1552 stems/ha(38% of a fully stocked stand), 95% of the stems being 12 m or less in height. The mean volume of 116.4 m^3/ha averaged only 68% of a fully stocked stand. Woodland caribou also chose stands that had an open understorey with a mean visual sighting measure of 22.0 m. Caribou showed no preference among forest types at the micro scale but chose plots with ground lichen cover($p<.001$). Caribou did not return to a logged stand until 25 years after harvesting and not until 60 years in natural, fire-origin stands. The oldest stand being used was 98 years old.

Landsat imagery when combined with F.R.I. timber stand descriptions were accurate in predicting wintering areas 100% of the time, but included large areas that were not used by caribou.

A habitat suitability index model based on stand age, crown closure, species composition, and site class was developed to predict potential wintering areas from timber maps and to facilitate habitat management. High index stands tend to be of low economic worth that should be managed for non-timber objectives such as wildlife and parkland.

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INTRODUCTION

Although caribou (Rangifer spp.) have inhabited North America since the time of the mastodon and the giant beaver (Whitehead et al., 1982) there has been little management or understanding in the past (Dagg 1972) and a continued need for further research and management (Cumming 1992). The decline of woodland caribou (Rangifer tarandus caribou, in Ontario, has been reported by several authors (De Voss and Peterson (1951), Cringan (1957) and by Simkin (1965)). The decline may be due to any number of single factors or a combination of factors.

In 1965 Simkin estimated 13,000 woodland caribou in Ontario. Darby et al. (1989) revised this estimate to 15,000. Most of these animals are located in the north-west part of the province around the Hudson Bay Lowlands north of the 50th parallel. Bergerud (1979) estimated thirty woodland caribou at Pukaskwa National Park. He estimated the Slate Island herd to be between 200-300 animals (due to overgrazing and periodic die-offs). One other area in the province that contains woodland caribou is the Lake Nipigon area. Cumming and Beange (1987) estimated that there were 100 animals in this group. The Lake Nipigon area makes up about half of the study area for this paper.

Cumming (1992) summarized the need for forest management to be carried out to benefit caribou. The proposed guidelines for woodland caribou management in Ontario call for the protection of calving areas and wintering areas of caribou (Darby et al. 1989). The protection of wintering areas has been acknowledged in both British Columbia (Stevenson 1979) and in Quebec (Ministere des Forets et al. 1991). Although almost all authors agree that woodland caribou prefer conifer stands of low density with an abundance of lichen, no studies have been carried out to accurately describe these stands by species, vertical distribution and horizontal distributions. These wintering areas, comparable to deer yards where the animals concentrate under conifer cover for reduced snow depths, (Cumming and Beange 1987), are key to caribou survival.

Forest management includes the management of non-timber values (Stoddard 1978). Woodland caribou (Rangifer tarandus caribou) sparsely populate northwestern Ontario as part of the boreal forest ecosystem. Winter habitat is viewed as a critical component to woodland caribou survival. Thus, the objectives of this study are to answer the following three questions.

1. What types of stands do woodland caribou use in winter?
2. Where are these types of stands located?
3. Can we use existing inventory data to model potential woodland caribou winter habitat?

To answer the first question the wintering areas of woodland caribou were defined qualitatively using the Northwestern Ontario Forest Ecosystem Classification system and quantitatively by measuring the horizontal and vertical distribution of trees and the corresponding ground lichen cover of 9 wintering areas. These areas were located on the southern limit of woodland caribou range (approx. 50^0 N Latitude across northwestern Ontario). Data collection was carried out during the summers of 1979, 1980, and 1992.

Once the winter habitat was defined the second question was answered by using two different data bases; the Ontario Ministry of Natural Resources Landsat forest fuel satellite imagery, and Forest Resource Inventory (F.R.I.) of Ontario timber maps. To answer the last question the wintering areas were modelled by a habitat suitability index model using Forest Resource Inventory of Ontario criteria. This model was designed to be used in GIS studies planned for the future.

LITERATURE REVIEW

This review deals with reproduction, predation, disease, habitat, food, and human activities as factors affecting woodland caribou. Corollaries have been drawn from barren-ground caribou (Rangifer tarandus groenlandicus), Newfoundland caribou (Rangifer tarandus terranovae), mountain caribou (Rangifer tarandus montanus), and reindeer (Rangifer tarandus L.). It should be noted that Banfield (1961) classified all caribou as simply Rangifer tarandus L. although this broad classification is being challenged by Geist (1989) who is in favour of four sub-species in North America.

Reproduction

Woodland caribou usually rut in late September and continue to mid October (Bergerud 1975; Bergerud 1973). Bergerud (1975) reports that the gestation period for Newfoundland caribou is 229 days. The gestation period may be longer if the females are undernourished (McEwan and Whitehead, 1972).

The 229 day gestation period means that calving takes place at the end of May and early June (Bergerud 1975). Dauphine and McClure (1974) state that synchronous mating and calving provide a survival advantage for caribou calves. A spring birth allows the calf maximum growth and development time before its first winter.

Multiple births are extremely rare in woodland caribou. The first recorded multiple birth in woodland caribou was reported by Showsmith in 1976. Twinning in reindeer is also very rare and usually occurs only with domestic animals (Novosad 1973). The single calf faces many predators from its late May birth to October. Parental care by the cow is critical for reducing calf mortality going into its first winter(Bergerud 1984).

Espmark (1975) observed that when the calves are born and are being raised by their mothers, there is a high degree of vocal communication and recognition between reindeer calves and their mothers.

The one calf per year combined with the females reaching first estrus at 28-40 months (Schraeder 1982) results in a low breeding potential that does not allow for a rapid population increase, although synchronous mating and birth do increase the calves chances for survival.

Predation

Predation of woodland caribou by wolves is cited as a major reason for the species' decline (Bergerud 1974). Wolves preying on young caribou of the Nelchina herd, in Alaska, were found to be the most consistent limiting factor of this herd (Bergerud and Ballard 1988). Tanner (1975) modelled predator-prey relationships between wolves and barren ground caribou. His model suggests that caribou and wolf populations are cyclic in nature. Dauphine (1975) cites factors other than predation for the disappearance of re-introduced caribou to Cape Breton. The amount of predation on caribou by wolves is often misquoted and overestimated in literature (Kuyt 1973).

This is supported by Hayes *et al* (1989) who agree that wolves are in part responsible for woodland caribou declines in the Yukon but also states that the mortality due to grizzly bears (Ursus arctos) need to be taken into account.

Seip (1989) and Simpkin (1965) suggested that increased moose populations in an area might sustain higher wolf populations that in turn caused greater wolf predation on woodland caribou. Seip also suggests that maintaining spatial separation between moose and caribou may result in lower predation rates which will benifit the caribou without having to get into wolf control programs. In the Lake Nipigon area woodland caribou's southern range coincides with the northerly low density range of moose (Darby et al, 1989).

Cumming (1975) states that caribou may form groups or clumps in the winter as an anti-predation strategy.

Seip (1990) found wolf predation to be equal to recruitment. Such lack of agreement suggests that the effects of predation by wolves on woodland caribou has not been clearly defined. Predation does occur, but the rate is probably a localized occurrence.

Disease

Very little work has been done in the diseases of the genus Rangifer in North America. The work that does exist on infectious and parasitic diseases of woodland caribou is somewhat limited (Neiland and Dukeminer 1972).

The two most common diseases of woodland caribou are the parasites Elasphastrongylus cervi and Parelaphostrongylus tenuis (Anderson 1972; Trainer 1973; Lankester 1976; Lankester et al. 1976; Lankester 1977; Lankester and Northcott 1979). E. cervi causes pneumonia in caribou calves and may be a large factor in calf mortality (Lankester and Northcott 1979). Lankester (1977) also expresses concern that E. cervi can be transmitted to moose (Alces alces).

P. tenuis is another parasite found in woodland caribou (Anderson 1972; Trainer 1973; Lankester 1976). This meningeal worm kills woodland caribou and moose (Trainer 1973). It is transmitted from white-tailed deer (Odocoiles virginianus) to moose, and woodland caribou. This worm is well adapted to its primary host, white-tailed deer. The secondary host is a snail. When an infected snail is eaten by a caribou the misplaced parasite travels up the backbone and into the brain. Once into the brain the worm causes severe neural damage which results in the death of the animal(Trainer 1973; Lankester et al. 1976). P. tenuis has been responsible for the failure of several caribou introductions (Lankester and Fong 1989).

Woodland caribou are also subject to Besnoitiosis, a disease of domestic cattle (Wobeser, 1976, Choquette, 1967), although Besnoitiosis affects cattle much more severely than either reindeer or caribou.

There have been many techniques developed to monitor a caribou's health and growth. External examinations of girth

(Payne 1976), teeth (Miller 1974) and hair (Peterson 1974) combined with the internal analysis of kidney fat (Dauphine 1975), and blood and body fluids (Cameron and Luick 1972; Whitehead and McEwan 1973; Le Resche et al. 1974) make it possible to assess the health of woodland caribou.

Habitat

Most habitat analyses for woodland caribou have dealt with winter range. This is because aircraft can be used to locate winter feeding craters and tracks in the snow (Simkin 1965; Buss and Barbowski 1974). Most authors feel that winter habitat is a key factor affecting woodland caribou survival (Simkin 1965; Buss and Barbowski 1974); Bergerud and Butler 1975; Stardom 1975; Freddy and Erikson 1975; Stevens and Story 1977; Hamilton 1978).

Good winter habitat for woodland caribou consists of open bogs, conifer stands, and rolling topography (Thomasson c1970; Darby and Pruit 1984). An abundance of ground and arboreal lichen is preferred (Simkin 1965; Thomasson c1970; Bergerud 1974; Freddy and Erikson 1975; Bergerud and Butler 1975; Stardom 1975; Hamilton 1978) but not necessary (Bergerud 1974; Euler et al. 1976).

The summer habitat consists of areas with a high content of deciduous species and a diversity of plant species, quite different from their wintering areas. Bergerud et al.(1990) suggested that calving areas are chosen for predator freedom more importantly than good forage. The forest should have many small openings in its canopy, and a maximum of edge. In many cases small islands in large lakes provide the necessary food and cover, as well as a predator-free environment for calving (Bergerud 1974; Bergerud and Butler 1975; Steven and Storey 1977; Cumming and Beange 1987).

Food

The diet of woodland caribou constantly changes throughout the year with changing food abundance and food availability, which affect the general health of woodland caribou (Cameron and Luick 1972; Bergerud 1974; Hanson et al. 1975; Stardom 1975; McEwan et al. 1976). The summer diet of deciduous shrubs and plants is listed by Stevens and Storey (1977). The winter diet and its effect on caribou are major factors in woodland caribou survival.

Several feeding studies have been carried out on reindeer and barren-ground caribou in order to determine caribou winter food requirements (Dieterich and Luick 1971; Hanson et al. 1975). Water flux (the amount of water in an animal) in caribou has also been monitored to observe the seasonal effects on health (Cameron and Luick 1972; Cameron et al. 1976).

Ground and arboreal lichens are eaten by woodland caribou. These species are found in almost all parts of their wintering range (De Vos and Peterson 1951; Ahti 1964; Stardom

1975). The value of lichens as a food source is limited because they are slow growing and fragile (Hale 1961; Thomson 1967; Schofield 1975; Bergerud and Butler 1975; Maikawa and Kershaw 1976).

Woodland caribou winter diet consists of up to 80% lichens of the Cladonia and Cladina species (Miller, 1980). They provide the caribou mainly with energy and minimal protein. The average amount of energy from these lichens is about 430 kcal/100g. Although the average protein content is about 2.3% (Miller 1980), these values can change from site to site. These lichens are found throughout northern Ontario (Thomson 1967; Hale 1961; Ahti 1964).

Thomson (1967) describes lichen growth by radial and height growth. The lichen mat will therefore spread over a surface (radial growth) as well as grow in height. Miller (1980) also observed this but used the following formula based on the poditium (the total forked stalk ending with an ascus) to simplify the growth of various lichen species:

$$\frac{\text{Length of the living poditium}}{\text{No. of nodes on the living poditium}} = \text{average annual linear growth of the poditium}$$

Andreev (1954) states that there are three stages of life of a given poditium. These are 1) the period of growth, 2) the period of renewal, 3) the period of degeneration. During the first period the entire poditium expands and elongates. In the second period only renewal occurs, the podium grows only to the limit set up in the first period. The third period results when decay from the bottom is faster than growth of the top, and the lichen dies. Andreév (1954) states that the time scale for lichens is about 10 years for the first period, 100 years for the second, and 10 to 20 years for the third. Lichen regeneration after harvesting and fire may be keys to caribou management (Webb pers. comm.;Schaeffer and Pruit 1991).

The time it takes for lichen regeneration after a fire is estimated to be about 50 years (Klein 1982; Carrol and Bliss 1982). This is due to the time required for lichen to re-invade an area after fire. Lichen regeneration after logging is much quicker if the lichen is left on the site (Hollstedt and Harris 1992).

Human Activities

Hunting may also be a factor in the decline of woodland caribou. However, there has been no legal hunting of the species in Ontario since 1929. In Ontario the estimated harvest by natives is 610-730 animals annually or four to five percent of the population (Darby et al. 1989). In British Columbia, Johnson (1985) states that man-caused deaths in an area of no legal hunting still accounted for losses that equalled recruitment for the Selkirk Mountain herd. Reimers

(1975) documented that hunting of wild reindeer in Norway produced a distorted age and sex structure in the population making its recovery more difficult. This may also have happened in Ontario when hunting was allowed.

The effects of man on woodland caribou have been well documented by Bergerud (1974). He states that habitat destruction, hunting, and predators are the major reasons for declining woodland caribou populations. On the habitat side, Cumming(1992) argues for a more holistic approach. He states that forest managers must look at all aspects of the caribou's life and make adjustments according to local conditions. This view is supported by Edmonds (1988) who promotes long-term public education, law enforcement, and habitat protection from industrial and recreational development for goal in woodland caribou management in Alberta.

Aircraft have also been shown to frighten and harass caribou (Des Meules *et al* 1971; Calef *et al*. 1976), although Bergerud and Butler (1975) observed that woodland caribou can become accustomed to aircraft. Klein (1979) summarizes the reaction of *Rangifer* to the various disturbances as follows:

1. Road, railroads, pipelines, powerlines, artificial or altered water courses or other man-made linear features can, independent of other human activities, block, delay or deflect the movements of caribou and reindeer.

2. The level and type of vehicular traffic and other human activities are major factors influencing the reaction of caribou and reindeer because they avoid areas of vehicle and human use.

3. Caribou and reindeer react to obstructions and associated disturbances differently in relation to the season of the year.

4. There are pronounced differences in response to obstructions in relation to sex and age of the animals involved and to group size.

5. Caribou and reindeer, as well as other ungulates, more readily adapt or habituate to obstructions and associates disturbance if they are resident in the area of the obstruction rather than being present only seasonally or during migration.

Barren ground caribou, in Alaska, did not seem to have their movements affected when crossing pipelines or roads. They did however avoid the combination of roads with traffic paralleling pipelines. The combination of disturbances was enough to reduce crossing frequency (Curatolo and Murphy 1986).

Erikson (1975) suggests that many silvicultural practices can be used to benefit reindeer. Perhaps these same practices will also benefit woodland caribou. The development of silvicultural guidelines to benefit woodland caribou may prove to have a positive effect on woodland caribou. Some silviculture considerations include winter cutting to reduce ground lichen disturbance, and to provide arboreal lichens normally out of reach to wintering animals. Erikson also suggests that prescribed burns and aerial herbicide spraying of clearcuts be stopped in wintering areas because they destroy the ground lichen. Euler et al. (1976), based on their work on the predator-free Slate Islands, promote prescribed burning or logging to provide early successional plant communities over part of the range. In either case the need for sound management to meet local conditions must prevail(Cumming 1992).

Forestry operations may be beneficial to woodland caribou, but further research must be carried out before a fair assessment of the situation can be made.

STUDY AREAS AND METHODS

The Royal Commission on the Northern Environment(1980) describes the area around Lake Nipigon(from Wabakimi Lake to Molison Lake) as Canadian Shield made up of granitic rock partially covered by Lacustrine sediments and the occasional ground moraine. The mean daily temperature for January is -19.5 C. The snow covers the ground for 160 to 200 days of the year. In winter the area receives from 160 to 280 cm of snow with an average maximum snow depth of 160 cm. However, during the years in which surveys provided locations for this study, maximum snow depths ranged from 35 cm during the winter of 1977-78, and 65^{+} cm during the 1978-79 winter (Cumming and Beange 1987).

The sample areas were chosen from caribou wintering areas located by Cumming and Beange (1987). Woodland caribou "yard up" in the winter choosing specific locations(Cumming and Beange 1987). The study areas were spread across the Lake Nipigon District and were chosen because of repeated winter sightings of woodland caribou (Figure 1). Table 1 gives the specific co-ordinates of each location and summarizes the type of data collected at each location.

All areas, except Springwater Creek and Lamaune Lake, were virgin forests of the boreal forest zone (Hoise, 1973). Springwater Creek was selectively logged during World War II and Lamaune Lake was clearcut in 1963 (Squires pers comm.) The study areas represent the southern limits to the range of woodland caribou in the Lake Nipigon area (Cumming and Beange 1987).

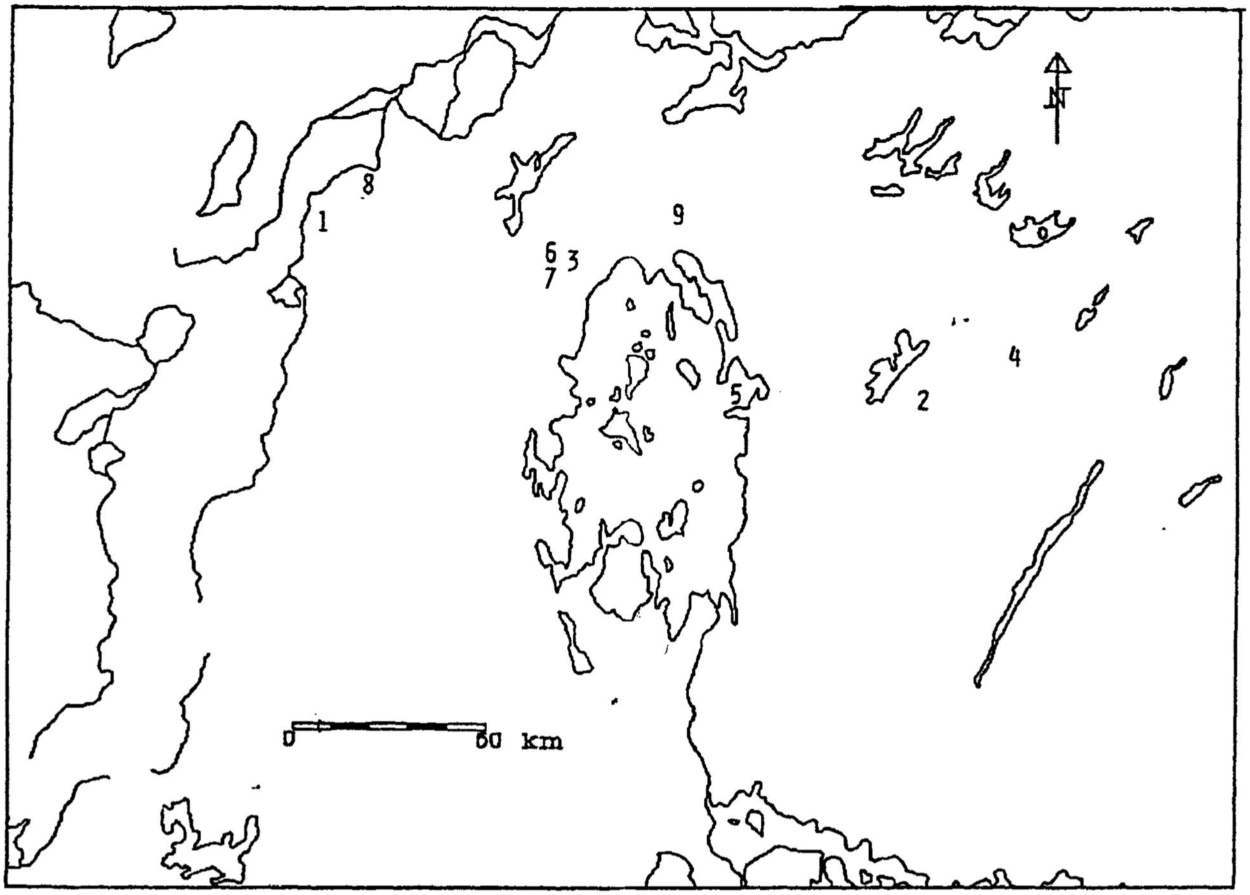

Figure 1: Location of Study Areas

Area Code: 1=Elf Lake, 2=O'Neil Lake, 3=Armstrong Old, 4=Molison Lake, 5=Crocker Point, 6= Armstrong North, 7=Armstrong South, 8=Wabakimi Lake, 9=Lamaune Lake.

Pre-sample

Once the study areas were located and mapped, aerial photographs for each area were obtained and the specific areas to be studied were delineated.

The summer of 1979 was spent conducting a pre-survey sample in order to estimate sampling intensities and to test the effectiveness of the proposed data collection technique. A major concern was the method to be used in this kind of survey that included both forests and wildlife and hence was not conventional. Four different areas were investigated in this trial (Armstrong, Crocker Point, Springwater Creek, and Wabakimi Lake (Table 1)).

Based on the winter observations from the airplane it was decided that the plots would be located where there were exact locations of winter usage. The object of the study was to measure the stands that the caribou were using. The stands that were not being used were not part of this study. The method of data collection was to walk transects through caribou wintering areas for which the general location had been determined by mapping tracks from the air (Cumming and Beange 1987). When a caribou winter pellet group was located it was used as a centre for a modified point sample. The modified point sample plots were measured using either 2m/ha or 5ft/acre B.A.F. prisms. "In" trees were tallied by species and diameter class. The height of an average tree was recorded. In all cases the tree was of the dominant species in the stand. The age of this same tree was determined by an increment core at D.B.H. The amount of ground and arboreal lichens were ocularly assessed using a one metre plot around the plot centre. The shrubs in the one metre plot around the plot centre were also tallied. This was done to assess if ground and shrub layers were factors in a caribou's choice of habitat. A ten metre radius plot was set up around the plot centre and all other caribou signs were recorded.

The low densities of woodland caribou around Lake Nipigon precipitated a re-evaluation of the data collection system and type. Three problems were encountered which may have led to faulty data collection; 1) pellet groups were easier to locate in open areas, thus using them for plot centres may have forced plot centres into open areas (such as rock outcrops) which may not be typical of the stand being sampled, 2) lichen development in many areas occurred only on open rock outcrops on which it was easy to find pellet groups, but were not be indicative of lichen development in forest stands, 3) the chances of finding pellet groups diminished as the summer progressed due to pellet decomposition, leaf litter and ground vegetation covering winter pellets.

Pre-sample Results

All caribou wintering areas were located in conifer stands (57% jack pine and 43% black spruce). The highest winter use by caribou was in the predominantly jack pine plots. Ground lichen was present in 95% of the plots. Tree lichens were also present in 71% of the plots.

Revised Methods

After evaluating data from the pre-sample survey, methods were altered to provide a more representative assessment of caribou wintering areas.

In order to fully describe the stands being used as wintering areas by woodland caribou five different data collection and analyses strategies were employed.

1). Northwestern Ontario Forest Ecosystem Classification (NWO FEC) plots developed by the Ontario Ministry of Natural Resources were used to give a qualitative description of the forest.

2). Vertical distribution quantitatively describes the forest canopy by height stratification. Ground coverage by lichen, and caribou usage of each study area were included with the vertical distribution plots.

3). Horizontal distribution give a breakdown by stem density and diameter class.

4). Visual sighting measures were taken to quantify how far a caribou can see in a stand.

5). Lichen regeneration quadrats were undertaken to look at lichen return twelve years after logging at Springwater Creek (a known wintering area).

Data collection consisted of 128 man days in the field. Initial investigations and pre-sampling were conducted during the summer of 1979(Table 2.) In February 1980 caribou winter feeding craters were marked south of Armstrong. They were revisited the following May to determine what winter feeding activity looked like the following summer. The use of arboreal lichens (which may be important) was found to be too inacurrate to quantify based on summer observations of winter use and was deleted from the study. Horizontal and vertical distribution data were collected during the summer of 1980 (Table 2.) NWO FEC plots, visual sighting measures, and lichen regeneration quadrat data were collected in the summer of 1992 (Table 3.).

Landsat imagery of the different study areas was acquired and analyzed during the winter of 1992-1993. This was done to test Landsat's potential to map wintering areas.

When the area to be sampled had been chosen, its boundaries were located on a map and on aerial photographs. The transect lines to be run were then established at right angles to the topography, both to provide for representative sampling and to minimize the need for slope corrections. A detailed description of the type data and how it was collected follows.

Table 1. Location of study areas, type of data collected, and sample size.

Study Area	Location	Data Type and Sample Size
Molison Lake	50° 07'N	VERT(42),HOR(9),NWO FEC(10),
	86° 54'E	VSM(10)
Springwater Creek	50° 05'N	HOR(9),LRQ(20)
	87° 00'E	
O'Neil Lake	49° 55'N	VERT(42),HOR(9),NWO FEC(10),
	88° 07'E	VSM(10)
Lamaune Lake	50° 25'N	VERT(10),HOR(10),NWO FEC(10),
	88° 07'E	
Crocker Point	49° 55'N	VERT(42),HOR(9),NWO FEC(10),
	88° 07'E	VSM(10)
Armstrong Old	50° 17'N	VERT(42),HOR(9),NWO FEC(10)
	88° 56'E	
Armstrong South	50° 16'N	VERT(42),HOR(9),NWO FEC(10)
	89° 00'N	
Armstrong North	50° 17'N	VERT(42),HOR(9),NWO FEC(10)
	89° 00'E	
Wabakimi Lake	50° 45'N	VERT(42),HOR(9)
	89° 45'E	
Elf Lake	50° 30'N	VERT(42),HOR(9),NWO FEC(10)
	89° 50'E	

[1]Type of data collected code:VERT=vertical distribution, HORS=horizontal distribution, NWO FEC=Northwestern Ontario Forest Ecosystem Classification, VSM=visual sighting measure, LRQ=lichen regeneration quadrats.

Table 2. Record of field trips, 1979-1980.

Year	Date	Location	Purpose of trip
1979	June 1-3	Armstrong	Horizontal pre-sample
1979	July 1-6	Crocker Point	Horizontal pre-sample
1979	July 19-20	Springwater Creek	Horizontal pre-sample
1979	Aug. 1-7	Wabakimi Lake	Horizontal pre-sample
1980	Feb. 15-16	Armstrong South	Mark feeding craters
1980	May 10-11	Armstrong North	Horizontal and Vertical transects
1980	May 15-16	Armstrong South	Horizontal and Vertical transects
1980	June 3-5	Armstrong Old	Horizontal and Verticaltransects
1980	June 9-10	Elf Lake	Horizontal and Vertical transects
1980	June 11-13	Wabakimi	Horizontal and Vertical transects
1980	June 14-15	Springwater Creek	Ground recon. of cut area
1980	Aug.15	Crocker Point	Horizontal and Vertical transects
1980	Sept. 3-4	Molison Lake	Horizontal and Vertical transects
1980	Sept. 10-11	O'Neil Lake	Ground recon. of cut area
1980	Sept. 15-16	O'Neil Lake	Horizontal and Vertical transects

Table 3. Record of field trips, 1992.

Year	Date	Location	Purpose of trip
1992	Aug. 18	Armstrong South	NWO FEC plots
1992	Aug. 19	Armstrong North	NWO FEC plots
1992	Aug. 20	Armstrong Old	NWO FEC plots
1992	Aug. 21	Elf Lake	NWO FEC plots
1992	Aug. 26	Crocker Point	NWO FEC plots, VSM
1992	Aug. 27	O'Neil Lake	NWO FEC plots, VSM
1992	Aug. 28	Molison Lake	NWO FEC plots, VSM
1992	Aug. 28	Springwater Creek	LRQ
1992	Sept.28	Lamaune Lake	Horizontal and Vertical transects, NWO FEC plots,VSM

[1]Purpose of trip code: NWO FEC=Northwestern Ontario Forest Ecosystem Classification, VSM=Visual Sighting Measure, LRQ=Lichen Regeneration Quadrats.

Forest Ecosystem Classification

Morash and Racey (1990) describe North Western Ontario Forest Ecosystem Classification (NWO FEC) vegetation types as follows:

> In the NWO FEC system, a forest stand is allocated to one of 38 Vegetation Types (V-types) (Sims et al. 1989). A vegetation field key based on general overstory composition and modified as necessary by the presence, absence or general abundance of a few important understory plants has been developed to assist in the stand allocation process. There are three main groupings: "Mainly **Hardwood**" (11 V-Types), "**Conifer Mixedwood**" (9 V-Types) and "**Conifer**" (18 V-Types) which are described by a numerical identifier and brief description.

The Northwestern Ontario Forest Ecosystem Classification (NWO FEC) system developed by Sims et al. (1989) was used for an initial, qualitative description of the wintering sites in the study area. The descriptions of the various vegetation types found in Stocks et al., (1990) were used to confirm the site assessment. NWO FEC plots were located at 30m intervals on a transect that ran across the same areas that were vertically and horizontally measured. Crown closure was estimated by the author from the ground looking up in accordance with the guidelines and charts (Appendix IV) provided by Sims et al. (1989). Ten plots were located in each of the eight areas measured.

Vertical Distribution

Vertical distributions were measured using the vertical transect method described by Husch et al. (1982).

Briefly, this method of forest inventory involves the tally by height class and species of all trees subtended by a vertical angle of 45 degrees (Appendix III). The sampling is carried out on a continuous strip with samples being gathered at right angles to the line of travel.

Intensity of sampling varies with size of heterogeneity of the stand. A sample rate of 100m of line for every hectare or 100 ft. per acre has been found suitable in the boreal forest(Day pers comm). This sampling intensity agrees with Husch et al. (1982). The systematic location of plots reduced the bias of locating plots only where caribou activity could be documented.

The following sampling design was used in all areas studied (Figure 2). Three transect lines (400m long and 100m apart) were laid out on the photos before the area was sampled. The starting point was randomly located and the lines were oriented to minimize topographic relief. Each line consisted of 14 sample plots, 10m long and 20m apart. This sampling intensity was used because it met the guidelines for sampling set up for vertical transects by the O.M.N.R. (1982) based on Bickerstaff (1961). Therefore, each study area had three lines with 14 vertical sampling plots and 42 corresponding ground lichen and caribou usage plots. The only exception to this sampling design was at Lamaune Lake. There due to access difficulties 10 plots were located 30m apart on a single transect across the stand.

In addition to the forest stand sampling, ground lichen and caribou usage were also sampled. This was done to quantify the amount of ground lichen and caribou usage in the wintering areas. The procedures for sampling lichen and caribou usage were as follows:

1. Ten-1m^2 plots were laid out along the same line used in the vertical stand sampling.

2. Plots 1, 5, 10, were each "framed" using 4-1m sticks and then ocularly assessed for the percentage of ground lichen.

3. Evidence of woodland caribou winter use including pellet groups, browsing, antlers, and bush thrashed trees, were recorded for each plot.

Horizontal Distribution

The horizontal profile of the forest stands were sampled in conjunction with the vertical transect sampling. The horizontal sampling technique followed the explanation and review of Avery (1967) and Husch et al.(1982). Both authors endorse the use of prisms in measuring the horizontal profile, but indicate that there may be a possibility of personal error or bias in the use of prism sampling and concluded that measurement errors were not negligible. They recommended a small BAF prism to be used to reduce any bias(2m^2).

The field procedure for point sampling (used to measure horizontal distribution) was as follows:

1. use a $2m^2$ BAF (Basal Area Factor) prism;
2. locate plot centre;
3. conduct prism sweep with prism at breast height(1.3m);
4. record all "in" trees by species and diameter class;
5. all diameters recorded at 2cm. intervals;
6. diameters were taken with calipers or diameter tape;
7. a chart of limiting distances was used for borderline trees.

Each horizontal plot centre was located at the right-hand corner of the first plot of the vertical sampling series. Plot centres were located at plots 2,7,and 12 on each of the vertical sampling lines (Figure 2).

The results from horizontal sampling were summarized and a stand description based on O.M.N.R. Forest Resource Inventory (F.R.I.) was developed (Table 11).

Visual Sighting Measures

In connection with the NWO FEC plots visual sighting measures were taken at Crocker Point, O'Neil Lake, and Molison Lake. For these, an 8 1/2" by 11" aluminum clipboard was held at breast height (1.3m) at the plot centre. This height was chosen because it is the approximate height of a caribou's eye (Godwin 1990). In each case, the distance along the transect line at the point when the clipboard could no longer be seen was recorded. If the distance was greater than 30 meters it

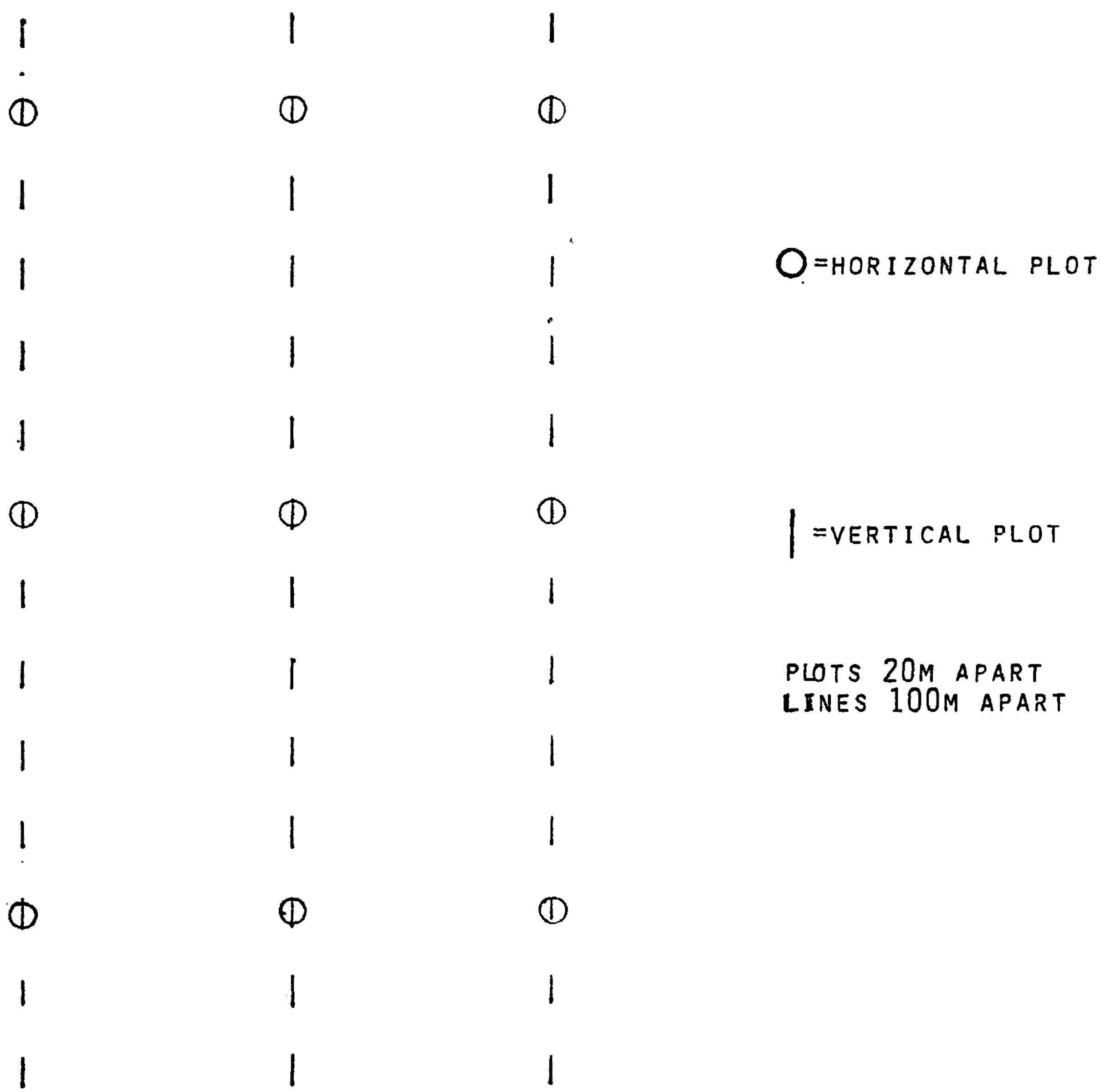

FIGURE 2. SAMPLING PATTERN FOR VERTICAL AND HORIZONTAL DISTRIBUTION PLOTS.

was recorded as 30^{+}m. Comparative measures in fully stocked mature black spruce stands were taken near Thunder Bay, Ontario.

Lichen Regeneration

The Springwater Creek site showed the effects of logging on lichen regeneration eleven and forty years after logging. The Lamaune Lake study area showed lichen regeneration thirty years after harvesting. When re-visiting the Springwater Creek sight in 1992 the cutover was checked to see if lichen regeneration had taken place. A transect line was run from the old cutover stand into the new cutover (now 12 years old). Ten sampling stations of 2-1m^2(side by side) plots spaced five metres apart were measured in the old cutover stand. The same sampling design was then used in the adjacent new cutover.

Landsat Imagery

H.R. Timmerman of the Ontario Ministry of Natural Resources, provided Landsat imagery for Northwestern Ontario. The imagery had already been developed, analyzed and summarized into 15 possible themes (for forest fuel analysis) to be used for fire management by the Ministry. The 15 themes are as follows:

1. Water
2. Dense coniferous forest- Jack Pine and Black Spruce

3. Open coniferous forest (<70% crown closure) with extensive bedrock exposure and some high density treed bogs
4. Mixed forest, mainly coniferous
5. Mixed forest, mainly deciduous
6. Dense deciduous
7. Open deciduous forest
8. Very old cutover or burned areas with mixed regeneration; conifer understory
9. New cutover areas (0-10 years)
10. Old cutover areas (over 10 years)
11. New burned areas
12. Poor forest cover, some barren and scattered
13. Wetlands (bogs and fens)
14. Agricultural lands, built up areas and clearings
15. Large urban areas, exposed soil, mines and roads

Data analyses showed that theme 3 (open conifer) best described woodland caribou winter habitat. The procedure to produce maps of theme 3 areas follows (Myketa pers. comm.).

The Landsat MSS data with a 50 metre resolution was corrected to UTM co-ordinates and a supervised classification was performed to produce 15 forest fuel classes by the O.M.N.R. The dates of the imagery range from 1976 to the mid-1980's. The classified data (data which has already been analyzed into specific classes or themes) were downloaded from CCT's onto a Sun IPX workstation using the LGSOWG format at 6250 bpi.

Using ERDAS-version 7.5 software, a raster-based image analysis system, the scenes were displayed and clipped to remove "garbage" pixels. A statistical listing was displayed for each scene to determine the area for theme 3 (open coniferous forest), water, and the total area.

In order to facilitate plotting, the scenes were converted to vector format using ArcInfo version 6.0 software, a vector-based geographical information system. In the conversion process, each scene was converted to a grid using the 'ERDASGRID' command and then converted to a coverage using 'GRIDPOLY' with the generalize option. The arcs were generalized to 35 metres to reduce the number of arcs without changing the integrity of the data.

Maps were plotted using an 8-pen Calcomp 1026 plotter. When resolution was too detailed for the printer, scenes were photographed to provide hard copy from the screen by displaying the coverage with the Arcplot program and shading the desired classes (water and open coniferous forest).

Imagery analysis produced maps of each study area showing the water and theme 3 (open conifer). To calculate the percentage of each map that was covered by theme 3; total area, area of water, and area of theme 3 were computed for each map.

The accuracy and reliability of forest fuel mapping by Landsat was checked by contacting the O.M.N.R. fire control centres in Thunder Bay and Sault Ste. Marie, Ontario. The only testing available was operational. The mapping system worked very well and met operational requirements (Mr. Turner and Mr. Checkley ,O.M.N.R. fire control officers, pers. comm).

Test Case of Habitat Predictors

The area around Wabakimi Lake was chosen as a test case for using theme 3 and F.R.I. timber maps to identify wintering areas of woodland caribou. This location was chosen because it was free from disturbance (a provincial park), and its well documented winter use of woodland caribou. Maps of winter use based on fixed wing, helicopter and telemetry studies were obtained from the O.M.N.R. The results from eight winter surveys of caribou activity locations from 1978-1984 and 1989-1991(no surveys conducted from 1985-1988)(Gollat pers. comm.) were compared with Landsat theme 3 areas and F.R.I. stand descriptions. The purpose was to test the predictive ability of the imagery and F.R.I. against known wintering areas. F.R.I. stand descriptions were obtained from the values used in the habitat suitability index model which would have resulted in an overall rating of "good habitat". These values are as follows: age-60 to 100 yrs., crown closure-70% or less, percent occurance of jack pine and or black spruce-90% or greater, site class-3 or 4. Fifty locations of winter activity (feeding craters, telemetry locations, track aggregations, and visual sightings) were tested.

Woodland Caribou Habitat Suitability Index(HSI) Model

Berry (1984) reviewed the development, testing and application of wildlife-habitat models. She states that habitat suitibility index models were first developed in the mid-1970's for various government agencies. The HSI models relate carrying capacity to biological and physical attributes. The U.S. Fish and Wildlife Service in 1981 set standards for the development of habitat suitibility index models.

The approach and design of this model is based on habitat suitability index models for moose in the Lake Superior Region (Allen, Jordan, and Terrell 1987) and woodland caribou year round habitat in Saskatchewan (Yurach *et al.* 1991).

This model has been developed to evaluate the winter habitat requirements of woodland caribou in northwestern Ontario. The model is designed to evaluate habitat based on the Forest Resource Inventory of Ontario criteria. This data base was chosen because it covers all of the 795,000 km^2 of productive forest land in Ontario (O.M.N.R. 1978) and it is the inventory currently being used for management in the area of this study. This woodland caribou winter habitat suitability index model is a first approximation. It may need to be modified to better reflect the habitat requirements after testing. The model assumes that all stands are naturally occurring and have not been manipulated in any way.

The woodland caribou model variables are species composition, site class, stand age, and stand crown closure. These variables are indicators of ground lichen abundance. Other factors such as predation, predator avoidance, travel corridors, and disturbance are not accounted for in this model. Further research is required to include these variables.

The Model

HSI values are assigned to each variable in the model equation. The overall HSI value for each stand is determined by multiplying all variable HSI values together.

$$HSI(overall) = ((species\ comp.\ HSI)(site\ class\ HSI)(age\ HSI)(crown\ closure\ HSI))^{1/4}$$

The variables are multiplied together because any one variable has the potential to decrease the positive attributes of all other variables when indexing stands for potential wintering areas. The product is then taken to the quarteric root to eliminate the effect of four multiplicand decimal multiplication. The end result is an HSI overall value that will fall between 0<>1.0. Potential woodland caribou habitat can then be rated on a scale of 0-.33=poor; .34-.66=fair; and .67-1.0=good. Examples of HSI calculations appear in Appendix II.

RESULTS

All study areas showed signs of winter use (previous to the following summer fieldwork) by caribou(Table 4). Winter usage calculated by the number of plots showing caribou sign (pellet groups, cast antlers, browsing, and brush-thrashed trees) compared with those that showed no sign of usage in each study area ranged from 21% to 60% with a mean of 34.8%. When caribou dug feeding craters only small patches of lichen were eaten. The disturbed snow hardened around the crater making it difficult to dig thus preventing overuse of the area.

Forest Ecosystem Classification

The Northwestern Ontario FEC class Jack Pine-Black Spruce/Blueberry/Lichen(V30)(Plate 1.) described 86.25% of the plots followed by Black Spruce-Jack Pine/Tall Shrub/ Feathermoss(V31) 6.25%, Jack Pine-Black Spruce/Ericaceous Shrub/Feathermoss(V32) 5.00%, Jack Pine/Low Shrub(V28) 1.25%, Black Spruce/Labrador Tea/Feathermoss(Sphagnum(V34) 1.25% (Table 14). The FEC plots that were not V30 were usuallylocated on water catchment areas between humps of exposed bedrock. This micro-climate difference was often enough to change the classification based on the 10m x 10m plot used to classify an area.

The FEC plots were either predominantly jack pine or black spruce or mixes of both with the occasional trembling aspen. The mean estimated crown closure (from the ground looking up) was 25% (S.D.=10). Shrubs regularly found in the plots were blueberry (Vaccinium spp.), jack pine and black spruce regeneration, with sparse occurrences of wild rose (Rosa acicularis), saskatoon (Amelanchier alnifolia), tag alder (Alnus crispa), white birch, willow (Salix spp.), and Canada yew (Taxus canadensis). The herb layer consisted of a mean ground coverage of 51.76% (S.D.=20.80) lichen (Cladina spp.) and 33.40% (S.D.=18.08) feathermoss (Pleurozium

Plate 1.

V30

Source: Stocks <u>et al</u> 1990

schreberi and *Dicranum polysetum*). The vascular herbs commonly found in the plots were bunchberry (*Cornus canadensis*), Indian pipe (*Monotropa uniflora*), and bearberry (*Arctostaphylus uvi-ursi*). Less common were sarsaparilla (*Aralia nudicaulis*), Lily of the Valley (*Maianthemum canadense*), spreading dogbane (*Apocynum androsaemifolium*), star flower (*Trientalis borealis*), pink corydalis (*Corydalis sempervirens*), lady slipper (*Cypripedium acaule*), creeping snowberry (*Symphoricarpos occidentallis*), and horsetails (*Equsetium spp.*). The three study areas at Armstrong were on deep sand with the rest of the areas on bedrock.

The areas seemed nearly devoid of wildlife. Only occasional moose tracks and a few spruce grouse and red squirrels were sighted on these transects.

Vertical Distribution

All trees were relatively short, with no stands reaching the height over age requirements to be included in site class 1 (Plonski 1981). Overall, 99.93% of the trees were in the 15m height class or less, and 94.95% were in the 12m height class or less.

Vertical distribution surveys showed no significant difference between the used and unused plots($t=1.71$, $df=8$, $p>0.1$). Therefore all plots within each study area were combined for an overall description of the area(Table 5). All stands were coniferous. Species composition within each study area and between study areas showed no significant differences(t=.32, df=16, p>.0.5; t=.59, df=16, p>0.5). They were black spruce and jack pine mixed stands. Other species within the study areas included white birch(<u>Betula papyrifera</u> Marsh), trembling aspen(<u>Populus tremuloides</u> Michx.), larch(<u>Larix laricina</u> (du Roi) K. Koch) and balsam fir(<u>Abies balsamea</u> (L.) Mill.). None of these, nor any combination in total, constituted more than 5% of the stems in any of the study areas. When stems per ha by height class and study area were tested ANOVA showed no significant difference between study areas(F=1.411, df=8,45, p=.2181) but, as suspected, a highly significant difference between height classes within study areas(F=5.82, df=5,40, p=.0004).

Vertical distribution of total stems per ha (Table 6) on the plots compared with values from Normal Yield Tables (Plonski 1981) showed study areas always with fewer stems per ha (t=2.75, 8 df, p<.05) averaging 38.8% of a fully stocked stand. Woodland caribou winter in a range of canopy densities which are significantly less than fully stocked stands (Table 6). The overhead canopy is open allowing sunlight to the forest floor.

Lichen Distribution

Lichen distribution was recorded in conjunction with the vertical sampling plots and was analyzed as a separate variable. The average amount of ground covered by lichen in plots that showed usage was 38.99% (S.D.=12.40) compared to a covering of 12.49% (S.D.=11.69) in the unused plots. Within each study area lichen distribution was tested between the plots that showed caribou usage and those that did not(Table 7.) Caribou showed a highly significant preference for the plots with a greater coverage of lichen (t=6.54, df=8, P<.001).

Horizontal Distribution

Among areas the presence or absence of caribou usage (Table 8) was tested and no significant difference in usage was found (t=1.32, df=8, P>0.2). Therefore the data from each area was amalgamated.

Species composition (Table 9) of the study areas was the same as for vertical distribution and showed no significant difference between species (t=.97, df=15, P>.30). Only 1.7% of the total volume was composed of species other than black spruce or jack pine. Six of the areas were predominantly black spruce and three were predominantly jack pine. ANOVA showed no significant difference in the volumes between study areas(F=1.248, df=8,117, p=.2774) but a highly significant difference between diameter classes within study areas(F=7.528, df=13,104, p=.0001). This is to be expected with the larger volumes occurring in the upper diameter classes.

Total volume per ha from all study areas compared with the volumes from Normal Yield Tables (Plonski 1981) (Table 10) showed that the study areas would yield highly significantly lower volumes ($t=3.91$, $df=8$, $P<.01$). On average they supported 68% of the volume expected from the Normal Yield Tables and ranged from 48% to 98% of the table volumes.

Among plots basal area did not differ significantly ($t=1.68$, $df=8$, $P>.05$) between plots that showed usage and those that did not(Table 12). The basal area for each study area when compared with the basal area from the Normal Yield Tables (Plonski 1981) (Table 13) were found to be highly significantly less ($t=6.42$, $df=8$, $P<.01$). The study areas had a mean basal area of 14.14 m^2/ha which is less the mean table value of 24.00 m^2/ha. The differences ranged from 37% to 87% below the table values.

The naturally occurring fire-origin stands ranged in age from 60 to 98 years, while the harvest-origin stand at Lamaune Lake was 25 years old (Table 11).

Visual Sighting Measures

The 10 measures taken at each area (Table 16) were compared to look for differences between areas. No significant differences among the three areas(ANOVA $F=1.226$, $df=2,27$, $p=.309$) were found. Thus areas were combined for a mean visual distance was 22.0m with a standard deviation of 7.3m . That was compared to a fully stocked, mature, site class 1. The black spruce stand used for comparison showed a much shorter distance (mean=10.8, S.D.=1.9). The wintering areas were highly significantly more open (higher visual sighting) than the comparison area ($t=4.76$, $df=38$, $p<.001$).

Lichen Regeneration

The new cutover and the old cutover were parts of the same stand in 1979. It was only partially cut because half the stand was left as a buffer strip along Springwater Creek.

The recently cut stand (12 years ago) had lichen in only 10% of its plots. Caribou use had been recorded in 1979 before it was logged in 1980. There was no sign of further usage of the area when it was revisited in 1980 and again 1992.

In contrast, in 1992, lichen was recorded in 80% of the twenty plots located in the old cutover (selectively logged in the 1940's) (Table 15).

Landsat Imagery

All study areas were located within the theme 3 classification range. The maps produced covered a total area of 515,753 ha of which 107,260 ha (20.79%) was water and 345,544 ha (21.38%) was theme 3. An example of a Landsat theme 3 map is shown in Appendix I.

Test Case

All 50 locations of wintering use were predicted correctly: 37 times by Landsat theme 3 and 38 times by F.R.I.

When both were combined woodland caribou winter habitat was predicted 50 times out of 50 (100%).

Model Variables

The HSI value of each variable was determined by reviewing the data, the data base, and the literature, and then assigning the appropriate value. The HSI values assigned to the variables are based on the values derived by the expert systems approach used by Yurach *et al* (1991). However, their Saskatchewan woodland caribou habitat suitability model is based on a different inventory base (Saskatchewan Forest Inventory), is year-round, and does not take site class into consideration. The maximum HSI values for species composition, age, and crown closure were based on the author's data and the findings of Racey et *al* (1992). The HSI values for site class were based on the author's data. The major assumption is that lichen is the key to winter stand usage. The HSI values rate the ability of FRI descripters to predict the likelihood of ground lichen. There are no 0 values because this would result in one 0 giving all other values a 0 and there is always a chance that a caribou can be anywhere. The major change points are derived from the results of this study with other values being drawn from the literature.

Stand age in years have the following HSI values. When a stand is first being established there is little or no lichen and therefore a very low value is assigned 0-20=.01(mid-range value). As stand age increases so does the amount of lichen with the corresponding values 20-60=.5(mid-range value). The period of greatest lichen availability which corresponded with the range of ages of the study areas was given the highest values 60-100=1. The older stands would have a diminishing amount of lichen over time and have the folowing values 100-150=.75(mid-range value).(Fig. 3)

Crown closure have the following HSI values. Stands with no crown closure to the development of a canopy would be very young and were rated as 0-10%=.5(mid-range value). Maximum lichen growth requires an open canopy therefore 10%-70%=1. As the canopy closes the amount of lichen decreases with the corresponding values 70%-100%=.45(mid-range value).(Fig. 4)

Species composition of the stands is expressed in terms of the total percentage of jack pine and black spruce in the stand. The HSI values are as follows. There were no caribou found in mixed stands so a low value was assigned 0-70%=.025(mid-range value). The constraints of timber mapping often demand that small pockets of decidious trees be included in what would otherwise be a pure conifer stand. As the conifer component (suggesting a dry site) increases there is an increase in the likelihood of lichen (Sims *et al* 1989) and the folowing values were assigned: 70%-80%=.05(mid-range value), and 80%-90%=.45(mid-range value). Pure conifer stands were the stands being used and were given the highest rating 90%-100%=1.(Fig. 5)

Site class based on the relationship of tree height over age as defined by Plonski(1981) have the following HSI values. Site class is affected by the moisture and nutrients avalable on a site. The lower the site class the drier or poorer the site which makes it more suitable for lichen. Since no caribou were found in site class X or 1 they were assigned the lowest value. X and 1=.1. Since 2 of the 9 study areas were site class 2 they were assigned a medium value 2=.5.The remaining site classes,3 and 4, made up 78% of the study areas and were given the highest values 3=1, 4=1. (Fig. 6)

Table 4. The percentage of plots in each study area that showed some signs[1] of caribou usage.

Location	No. of Plots surveyed	No. of plots used by caribou	%
Elf Lake	42	13	31
O'Neil Lake	42	14	33
Armstrong Old	42	9	21
Molison Lake	42	15	36
Crocker Point	42	11	26
Armstrong North	42	17	40
Armstrong South	42	17	40
Wabakimi Lake	42	11	26
Lamaune Lake	10	6	60

[1] Signs include pellet groups, feeding craters, antlers, and thrashed trees.

Table 5. Vertical distribution (stems/ha) of all tree species by area and height class.

Area	3m	6m	9m	12m	15m	18m	Total
Elf Lake	619	329	442	127	90	16	1623
O'Neil Lake	1302	627	138	28			2095
Armstrong Old	250	56	151	190	283		930
Molison Lake	1310	645	907	240	2		3106
Crocker Point	516	552	809	369	3		2249
Armstrong North	158	83	90	105	237	71	744
Armstrong South	143	48	190	335	128		844
Wabakimi Lake	333	492	796	433	16		1981
Lamaune Lake	190	119	85				394
MEAN	536	328	401	228	108	44	1552
S.D.	439	241	325	132	106	28	834

Table 6. Vertical distribution comparison of each area with Normal Yield Tables (Plonski 1981).

Area	Sample (stems/ha)	N. Y. Tables (stems/ha)
Elf Lake	1623	3584
O'Neil Lake	2095	5140
Armstrong Old	930	1611
Molison Lake	3106	3673
Crocker Point	2249	3099
Armstrong North	744	3490
Armstrong South	844	1815
Wabakimi	1981	4020
Lamaune	394	9495
MEAN	1552	3992
S.D.	834	2194

Table 7. Lichen distribution (percentage by area) for plots showing caribou usage and those with no sign of usage.

Area	% of lichen in plots used by Caribou	% of lichen in plots not used by Caribou
1	43.1	13.7
2	27.3	.6
3	50.0	22.7
4	30.9	1.9
5	24.5	1.9
6	41.6	31.5
7	63.1	8.9
8	24.8	2.1
9	45.6	29.1

[1] Area code: 1=Elf Lake, 2=O'Neil Lake, 3=Armstrong Old, 4=Molison Lake, 5=Crocker Point, 6=Armstrong North, 7=Armstrong North, 8=Wabakimi Lake, 9=Lamaune Lake.

Table 8. Horizontal distribution; volume comparison of all areas based on plots where caribou sign was present or absent.

Area	Total m^3/ha	Caribou Sign Present m^3/ha	Caribou Sign Absent m^3/ha
Elf Lake	93.55	51.16	85.21
O'Neil Lake	55.90	75.40	42.06
Armstrong Old	143.70	136.87	149.77
Molison Lake	174.82	93.15	219.33
Crocker Point	138.31	99.20	178.21
Armstrong North	117.08	188.35	108.75
Armstrong South	108.81	115.93	163.65
Wabakimi Lake	150.44	99.82	179.40
Lamaune Lake	65.39	32.41	53.84
Mean	116.44	99.14	131.14
S.D.	37.47	43.48	57.97

Table 9. Horizontal distribution; volume/ha by species, all areas.

Area	Black Spruce m^3/ha	Jack Pine m^3/ha	Others m^3/ha
Elf Lake	71.06	21.18	3.31
O'Neil Lake	51.59	4.31	
Armstrong Old	15.22	128.48	
Molison Lake	169.03	5.79	
Crocker Point	129.96		8.35
Armstrong North	19.91	97.27	
Armstrong South	16.28	92.53	
Wabakimi Lake	142.40	5.94	2.10
Lamaune Lake	37.01	28.38	
Mean	72.50	47.99	4.59
S.D.	56.2	46.71	2.34

Table 10. Horizontal distribution; total volumes and Normal Yield Table[1] volumes of all areas.

Area	Total Volume m^3/ha	Table Volume m^3/ha	%
Elf Lake	94	155	61
O'Neil Lake	56	78	72
Armstrong Old	144	302	48
Molison Lake	175	248	71
Crocker Point	138	246	56
Armstrong North	117	200	59
Armstrong South	109	200	55
Wabakimi Lake	150	155	97
Lamaune Lake	65	66	98
Mean	116	183	
S.D.	37	74	

[1]Normal Yield Tables(Metric) for Major Forest Species of Ontario (Plonski 1981).

Table 11. Forest Resourse Inventory of Ontario stand description for each area.

Area	Age	Height (m)	Working Group	Site Class	Crown Closure
1	90	11.0	Pj	4	40%
2	60	6.5	Sb	3	50%
3	70	18.0	Pj	2	60%
4	98	15.1	Pj	3	40%
5	90	12.0	Sb	2	40%
6	65	13.2	Pj	3	80%
7	65	13.2	Pj	3	80%
8	87	11.4	Sb	3	50%
9	25	4.2	Sb	3	40%

Area code: 1=Elf Lake, 2=O'Neil Lake, 3=Armstrong Old, 4=Molison Lake, 5=Crocker Point, 6=Armstrong North, 7=Armstrong North, 8=Wabakimi Lake, 9=Lamaune Lake.

Working group code: Pj=jack pine, Sb= black spruce

Table 12. Basal areas and volumes of plots used by caribou and those not used.

	USED BY CARIBOU		NOT USED BY CARIBOU	
Area	Basal area (m^2/ha)	Merch. Volume (m^3/ha)	Basal area (m^2/ha)	Merch. Volume (m^3/ha)
1	11.3	85.2	11.7	97.7
2	9.7	2.6	10.9	42.1
3	16.0	136.9	16.0	149.4
4	9.3	93.2	26.3	219.4
5	12.7	99.2	21.7	178.2
6	22.0	187.4	12.6	108.8
	13.5	110.9	19.2	163.7
8	12.7	99.8	14.7	176.7
9	5.3	32.4	21.7	53.8
Mean	12.5	94.2	17.2	133.2
S.D.	4.4	50.7	5.0	57.6

Area code: 1=Elf Lake, 2=O'Neil Lake, 3=Armstrong Old, 4=Molison Lake, 5=Crocker Point, 6=Armstrong North, 7=Armstrong North, 8=Wabakimi Lake, 9=Lamaune Lake.

Table 13. Basal area of all study areas compared with Normal Yield Tables[1].

Area	Basal area m^2/ha (from sample)	Basal Area m^2/ha (from table)	% Difference
Elf Lake	12.2	23.8	51
O'Neil Lake	10.7	19.9	54
Armstrong Old	9.6	25.7	37
Molison Lake	20.7	23.9	87
Crocker Point	17.2	34.2	50
Armstrong North	17.6	22.7	78
Armstrong South	13.3	22.7	59
Wabakimi Lake	18.7	29.1	64
Lamaune Lake	7.2	14.0	51
Mean	14.1	24.0	
S.D.	4.4	5.3	

[1]Normal Yield Tables(Metric) for Major Forest Species of Ontario (Plonski 1981).

Table 14. Northwestern Ontario Forest Ecosystem Classification (NWO FEC) plots summary for all areas sampled.

Location	Type and number of plots (10 per location)				
	V28	V30	V31	V32	V34
Molison Lake		10			
O'Neil Lake		7	3		
Lamaune Lake		10			
Crocker Point		7	2		1
Armstrong Old		10			
Armstrong South		10			
Armstrong North	1	7		2	
Elf Lake		8		2	

[1]NWO FEC descriptions: V28=Jack Pine/Low Shrub, V30=Jack Pine-Black Spruce/Blueberry/Lichen, V31=Black Spruce-Jack Pine/Tall Shrub/Feathermoss, V32=Jack Pine-Black Spruce/Ericaceous Shrub/Feathermoss, V34=Black Spruce/Labrador Tea/Feathermoss (Sphagnum).

Table 15. Lichen regeneration quadrats in 50^{+} year old and 12 year old cutover stands at Springwater Creek.

Plot no.	Old Cutover		Recent Cutover	
	quadrat 1 (%)	quadrat 2 (%)	quadrat 1 (%)	quadrat 2 (%)
1	80	70	60	30
2	60	80	0	0
3	10	0	0	0
4	10	40	0	0
5	5	15	0	0
6	40	10	0	0
7	0	0	0	0
8	80	50	0	0
9	30	60	0	0
10	10	0	0	0

Table 16. Visual sighting measures(m).

Plot no.	Area		
	Crocker Point	O'Neil Lake	Molison Lake
1	30+	30+	20.4
2	30+	30+	21.7
3	19.9	30+	24.0
4	30+	16.4	13.2
5	17.0	14.4	21.8
6	13.1	21.8	15.0
7	30+	12.1	16.6
8	17.4	30+	10.5
9	30+	30+	18.6
10	7.0	27.8	30+
Mean	22.4	24.3	19.2
S.D.	8.2	7.0	5.4

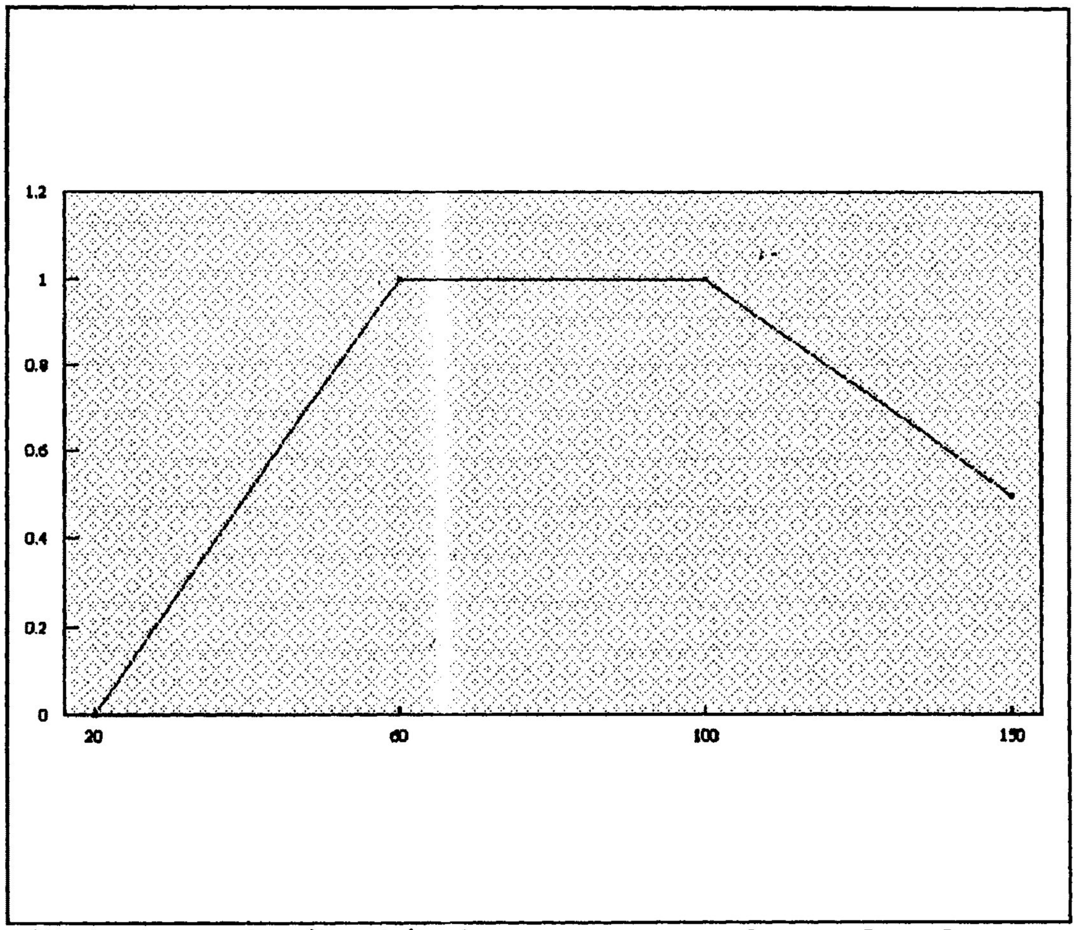

Figure 3. Relationship between HSI and age for forest wintering areas of woodland caribou in Ontario.

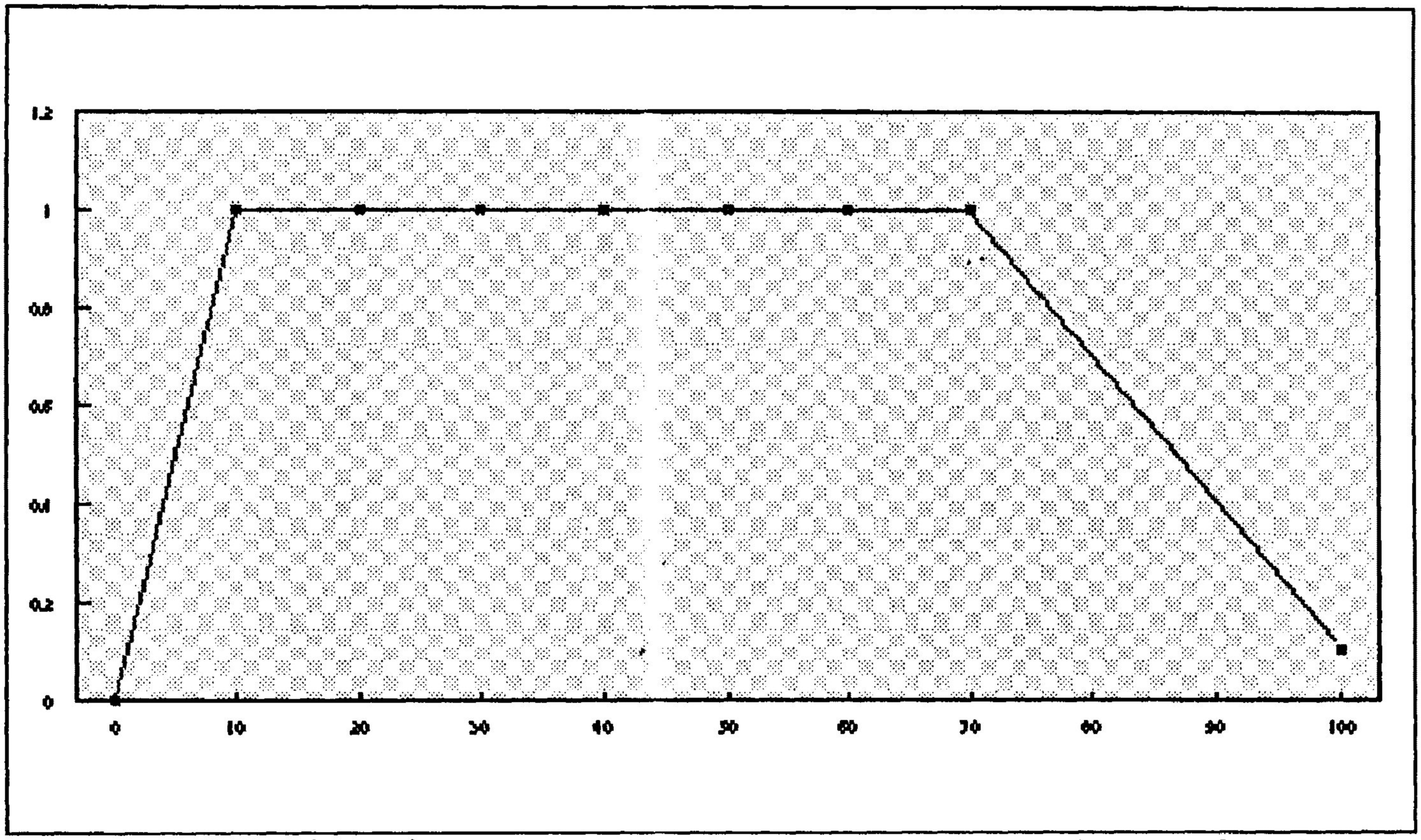

Figure 4. Relationship between HSI and percent crown closure for forest wintering areas of woodland caribou in Ontario.

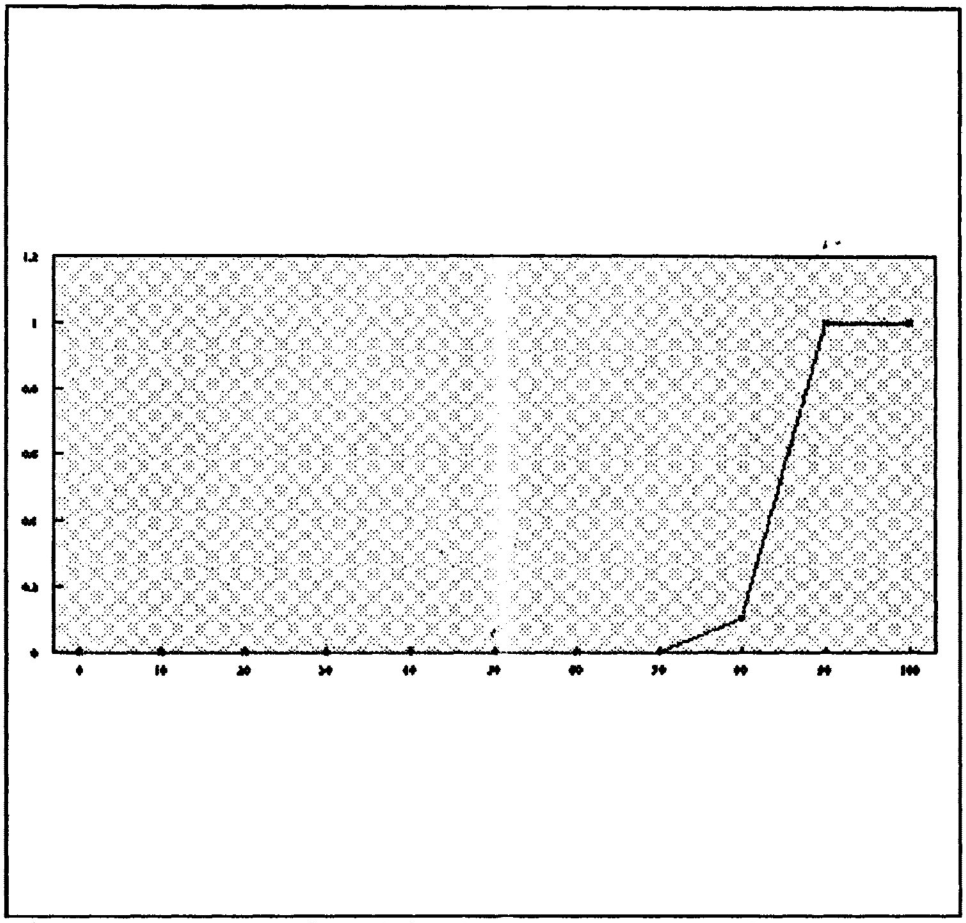

Figure 5. Relationship between HSI and percent occurrence of jack pine and or black spruce for forest wintering areas of woodland caribou in Ontario.

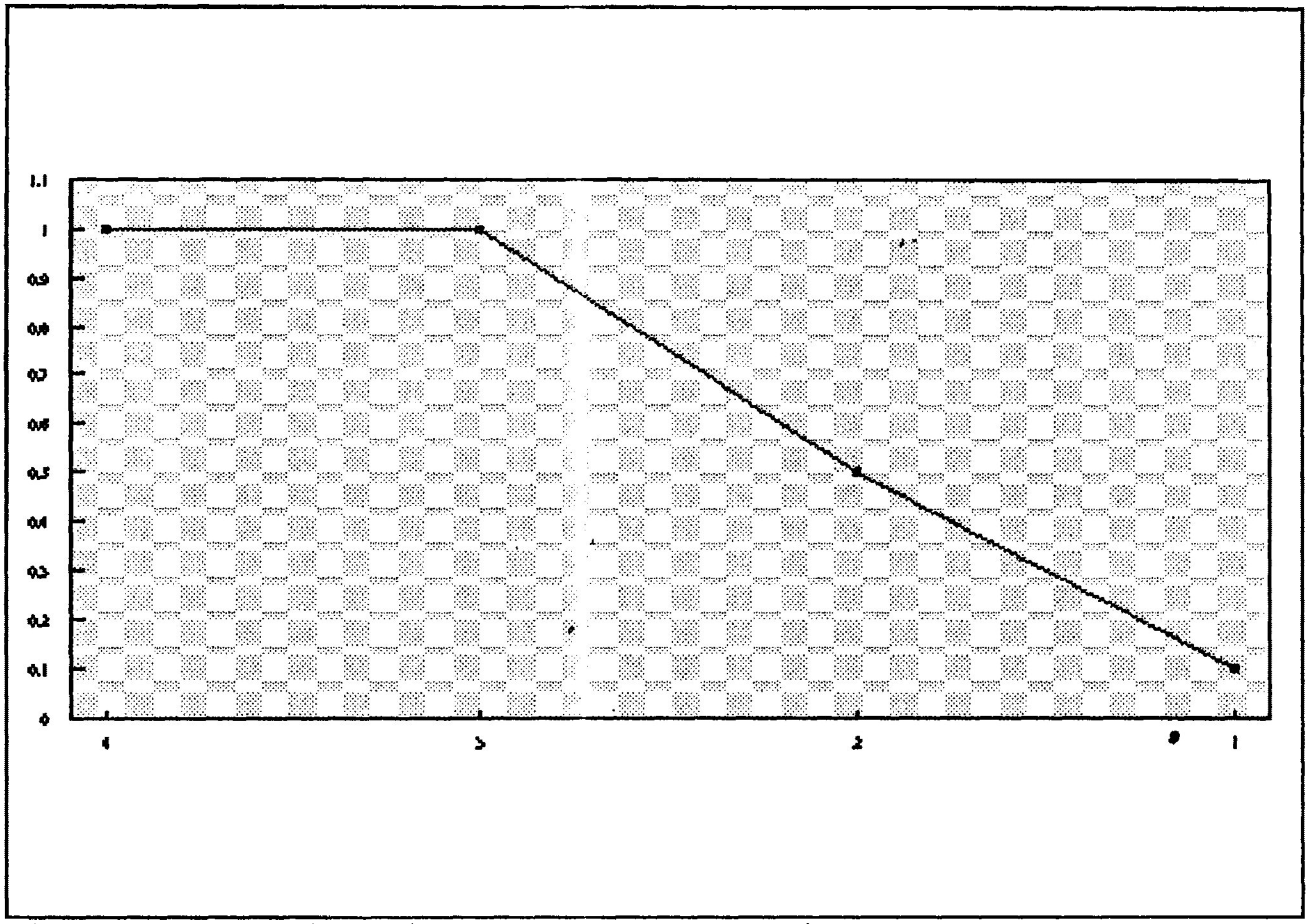

Figure 6. Relationship between HSI and site class for forest wintering areas of woodland caribou in Ontario.

DISCUSSION

Results showed that woodland caribou choose specific forest types that can be described qualitatively and quantitatively. The uniformity of winter habitat selection allowed mapping wintering areas using Landsat forest fuel maps in conjunction with F.R.I. timber maps.

Forest Ecosystems Classification

V30 proved to be the dominate description for woodland caribou winter range. Species composition mirrored the results of both vertical and horizontal analysis. These findings support Morash and Racey (1990) who first used NWO FEC to describe woodland caribou habitat. The NWO FEC system of habitat analysis is an excellent tool for qualitatively describing woodland caribou habitat. However, it lacks quantitative analysis capability. If vegetative types were chosen that could be Landsat mapped or derived from existing inventory, an area figure could be applied. Without quantitative analysis qualitative results cannot be applied in management.

Vertical Distribution

The results showed that the mean density, for all study areas, was 1552 trees per ha with a corresponding 39% lichen ground cover. The maximum density of 3106 trees per ha

(Molison Lake) had 31% lichen cover. Rencz and Auclair (1978) in northern Quebec found that a mean black spruce density of 556 trees per ha resulted in a 97% ground cover of lichen. Moore and Vesrspoor (1973) found that tree densities between 3080 and 4840 per ha constituted a transition range between lichen and moss as ground cover. A mid-point of 3960 per ha may be the limiting density for lichen growth. Lichen growth is limited by the amount of sunlight that reaches the ground. Hale(1961) estimated that lichens have between 10% and 25% the amount of chlorophyll of regular plants. They are therefore slow growing and require large amounts of sunlight for growth. The amount of sunlight in the study area stands was sufficient to provide the growing conditions for fruticose lichens.

Conifer forest canopy reduces the hardness and thickness of snow cover (Schaefer and Pruit, 1991) when compared with open sites. Caribou move into these stands in the winter because of the more favourable snow conditions (Darby and Pruit 1984). Therefore these low density conifer areas produce lichens which are easier to access for food in the winter. The range of height distributions may affect snow conditions during different times of the winter and in differing winters. A range of canopy types may be required to provide optimal feeding throughout the winter and over a series of different winters. Choosing one specific canopy density may not provide the best winter habitat for all snow conditions. An overhead canopy which is open enough to allow lichen growth in the summer yet closed enough to reduce ground snow depths is important to caribou winter survival.

The distribution of trees across a number of height classes suggests that these are uneven aged stands made up of an overstory of shade intolerant jack pine and an understory of black spruce on the sandy sites (around Armstrong) and a mixture of jack pine and black spruce on the bedrock sites (all others).

If these areas were harvested, to insure the return of a similar forest, the slash would have to be spread across the site to distribute the serotinious and semi-serotinious cones to allow them to open by the heat near the ground (Burns 1983). This would simulate regeneration after fire better than planting and would leave lichen on site for its' regeneration. Sims (1990) suggests a rotation age of 70 to 80 years on low growth jack pine and black spruce stands. This corresponds to harvesting during their peak period of use by caribou. Therefore the rotation age should be extended to over 100 years to avoid harvesting during peak periods of caribou use.

Horizontal Distribution

Low basal areas and volumes coincide with the modest densities and the relatively short height (95% are 12m or less in height) to make these stands of little interest economically. The maximum product would be 2-16ft sawlogs per tree from the tallest trees in the stands. Low stocked stands produce trees that are heavily limbed with tapering trunks (Stoddard 1978) which reduces the value of the sawlog.

Near Armstrong, the three study areas although low in volume, might be economical to harvest because of existing road access and the flat sandy country which allows for low harvest costs.

Low wood volumes in wintering areas may make individual stands undesirable for harvest. The disturbance of harvesting in an area should also be considered when setting up cutting plans.

Lichen Regeneration

The observation of significantly more lichen on used than on unused plots suggests that lichen regeneration is crucial for the re-establishment of caribou winter habitat after harvesting. No lichen was recorded eleven years after logging while heavy lichen regeneration was present on the sites logged thirty and fifty years ago. Although this is a small sample it does agree with Carrol and Bliss (1982), in northern Saskatchewan, who found successful lichen regeneration to be reached on the average of 45 years after fires. Auclair (1985), in northern Quebec, found the same after 47 years. At the treeline of northern Quebec, Morneau and Payette found that lichen cover of 40% was reached in 65 years. In northwestern Ontario, Webb (Doctoral thesis on lichen regeneration, in progress) observed that lichen regeneration may be sooner after logging than by fire, because the lichen is already on the site and does not have to re-invade the site (Webb, pers comm).

Visual Sighting Measure

The three measured areas showed almost total lack of shrub understory to block ground vision. Since these were summer measurements which could be reduced by broadleaf species, equal or greater visual sighting measures could be expected in the winter. The open understory may provide three important advantages for caribou. Firstly the ground is not shaded allowing for good lichen growth. Secondly, caribou feeding in these areas in the winter will be able to detect predators (wolves) approaching, providing greater escape time. Thirdly, caribou escape will not be hindered by understory.

The lack of shrubs in these areas also means a reduction of browse for moose. Allen *et al* (1987) when modelling moose habitat calculated that a moose would require 3 kg of browse per day in concentrated patches to survive. These areas would probably not support moose in the winter (Harry 1953, Dodds 1960, Telfer 1974, Crete and Bedard 1975, Miquelle and van Ballenberghe 1989).

Landsat Imagery.

Landsat imagery maps designed for forest fuel analysis provide a good tool to map and analyze potential woodland caribou winter habitat. The classification system is broad and probably overestimates woodland caribou wintering areas. This is due to the fact that only open conifer stands are identified, which may or may not have the ground lichen component required for woodland caribou. The maps are useful to locate potential areas of woodland caribou winter usage. Landsat imagery covers large areas (186km x 186km) with no loss of detail. The imagery shows that caribou are found in areas of extensive habitat and are not found in small isolated pockets of habitat. This allows an animal a variety of winter micro-habitats to choose from for ideal feeding and predator reduced wintering areas. The measurement of water shows the added need for predator escape areas. Native hunters and trappers have stated that caribou run from the forest out unto frozen lakes if threatened by wolves. Once in the open where they can see the wolves they calm down and move off staying to the centre of the lake. The author has seen this behaviour exhibited many times with barren ground caribou when they winter inside the treeline.

Because 42% of the area is either theme 3 or water the remaining habitat may not be large enough or of the right composition to support high moose and the subsequent wolf populations.

The Model

The model can be used for three purposes. Firstly, it can be combined with a GIS digitized FRI map to rate an area for woodland caribou winter potential. Secondly, it can be used to predict the effects that changes to the forest will have on woodland caribou winter habitat. Lastly, it could be used to map V30 FEC sites which are likely to occur in the high HSI value sites.

The HSI values assigned to the variables may require modification for different areas. Other variables such as predation and snowfall could be added at a later date to further define the winter habitat of woodland caribou.

IMPLICATIONS FOR MANAGEMENT

The timber values of the stands being used as wintering areas of woodland caribou are not high. Seventy eight percent of the stands studied were either site class 4 (protection forest, which is already set aside from harvsting) or site class 3 which is the most fragile and least productive of the merchantable stands. The stands are slow growing, low density, and on dry, fragile sites (sand and bedrock) that would be hard or impossible to regenerate to fully stocked stands. Considering the low product value, the cost of harvesting when combined with low densities make these stands economically marginal at best. Harvesting such stands for caribou management purposes should result in the areas being removed from production because optimizing regeneration and growth would not be in the best interests of caribou winter habitat production.

To manage these stands for caribou requires management for optimal lichen production with a suitable canopy to reduce snow depths and hardness. The new stands must have an open canopy and understory to 1) provide food (lichen) for the caribou, 2) allow for predator detection and escape, and 3) reduce the food for the alternate prey for wolves. Harvesting of natural stands should not occur during the peak lichen period between age 60 to 100 years. Harvesting these areas may return them to caribou winter habitat in a shorter time span than natural causes (after fire). This may accelerate lichen regeneration, but further studies are needed to ascertain if adequate crown closure can be developed to coincide with peak lichen development. The wintering areas would require a range of canopies to provide adequate micro-winter habitat to allow for changing snow conditions.

Logging should only occur on areas that have sufficient alternate habitat away from the disturbance. Erikson (1975) recommends winter harvesting which reduces lichen disturbance and may provide arboreal lichens for food. These factors may be outweighed by the negative aspects of winter harvesting. Harvesting activities should be carried out in the late summer to reduce hunting (poaching) and road kill mortality. This will also eliminate plowed winter roads which are easy travel corridors for wolves. Late summer harvesting will also reduce the impact during the reproductive stage of many birds and mammals (Telfer pers comm).

Landsat imagery combined with FRI (using the HSI model for high potential) will map areas of woodland caribou winter habitat. The model can be used to evaluate changing forest conditions as the forest is "grown" and "harvested" on computer GIS programs. Then this allows the manager to see what he has now and to predict the consequences of planned future actions.

High HSI value stands are correspondingly of low economic worth. If large concentrations of these stands occur in an area the whole area may be a candidate for non-timber management objectives such as parkland and wildlife areas.

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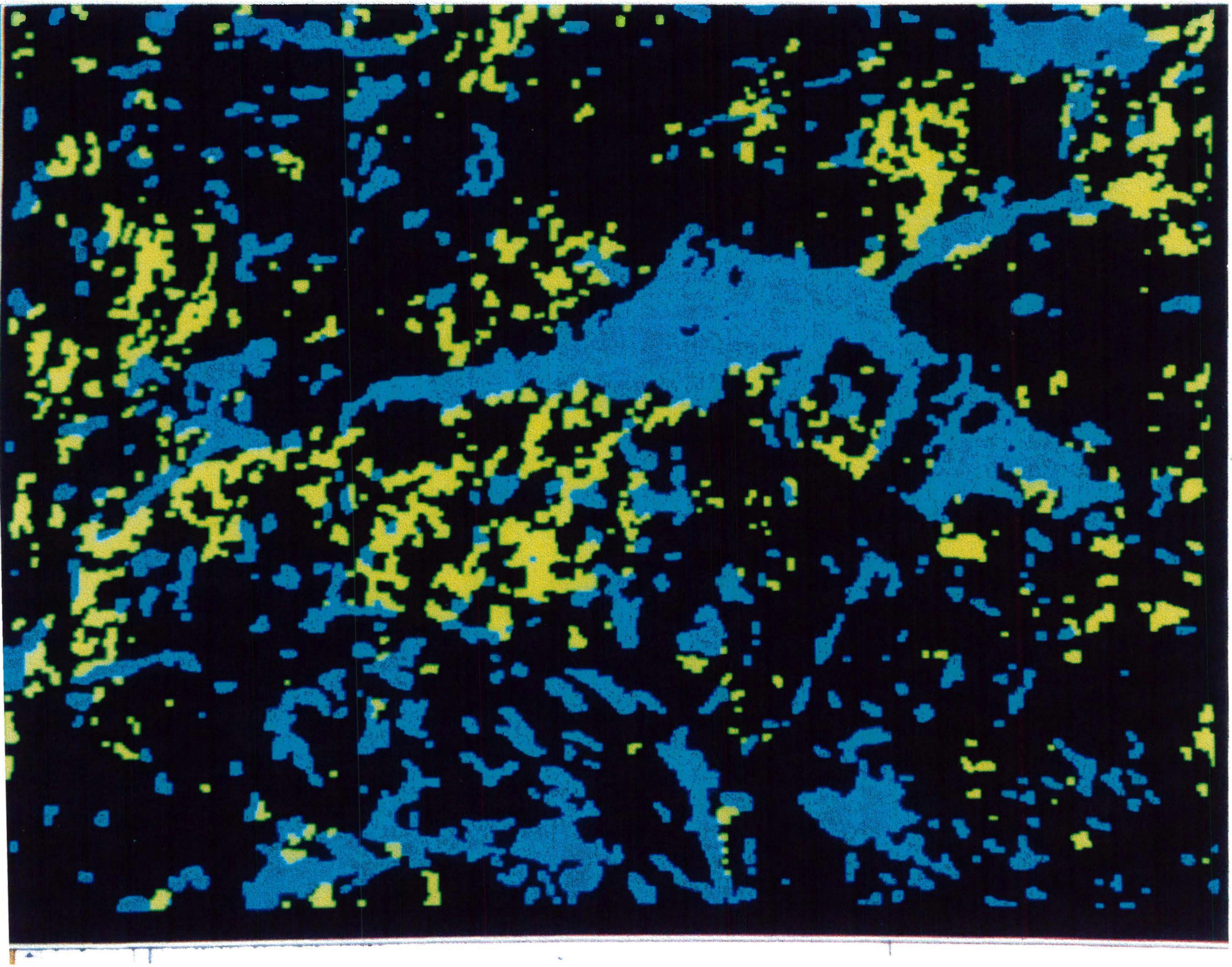
APPENDICES

APPENDIX I

AN EXAMPLE OF A LANDSAT IMAGERY MAP SHOWING THEME 3(OPEN CONIFER)



Legend

blue=water
yellow=theme3
(open
conifer)
black=other

Scale
1cm=1km
(approx.)

N

APPENDIX II

EXAMPLES OF HSI CALCULATIONS

Example 1.

1) A FRI stand is 100% jack pine, site class 2, 90 years old, and is 80% stocked (crown closure).

2) Look up the HSI values for each variable (Figures 3, 4, 5, 6) and insert in the formula below.

$$HSI(overall) = ((\text{species comp. HSI})(\text{site class HSI})(\text{age HSI})(\text{crown closure HSI}))^{1/4}$$

$$=((1)(1)(.5)(.6))^{1/4}$$

$$=(.3)^{1/4}$$

$$=.74$$

Therefore the stand would be rated as good habitat.

Example 2.

1) A FRI stand is 60% birch, 40% black spruce, site class 3, 50 years old, and is 60% stocked.

2) Look up and insert the HSI values.

$$HSI\ (overall) = ((.01)(1)(.8)(1))^{1/4}$$

$$= (.008)^{1/4}$$

$$= .299$$

Therefore the stand would be rated as poor habitat.

APPENDIX III

Vertical distribution: Diagram to show the selection of trees.

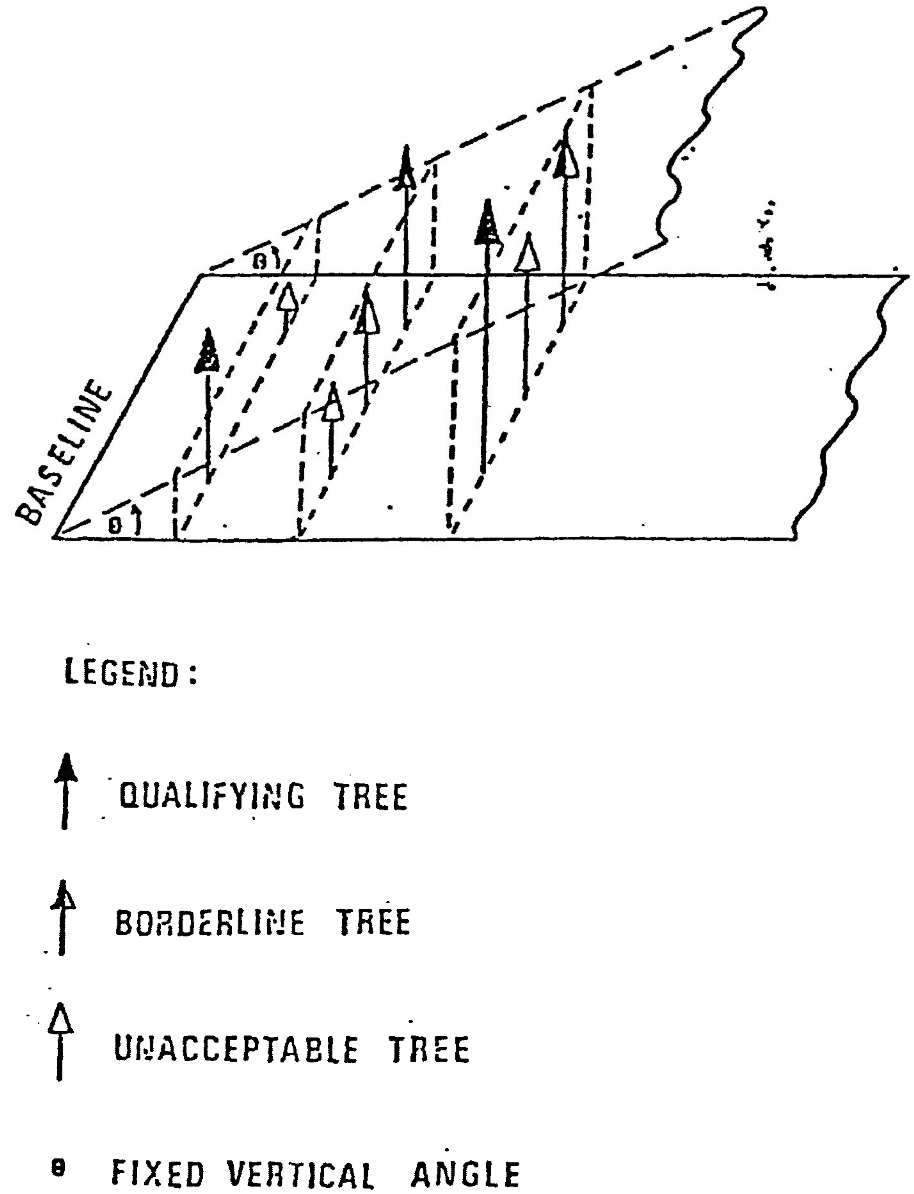


Figure 1 Diagram to show selection of trees. The fixed vertical angle is 45° and the direction of travel is along the baseline.

Source: (Ont. Min. Nat. Res. 1980)

APPENDIX IV

Cover percentage charts found in Sims et al 1989.

Cover percentage charts (Ontario Institute of Pedology 1985)