Natural Regeneration of Black Spruce (*Picea mariana* (Mill) B.S.P.) On Lowland Clearcut Strips Near Shebandowan, Ontario

Natural Regeneration of Black Spruce (*Picea mariana* (Mill) B.S.P.) On Lowland Clearcut Strips Near Shebandowan, Ontario

by

Krzysztof Sas-Zmudzinski

A Thesis submitted in partial
fulfillment of the requirements for the
Degree of Master of Science in
Forestry

School of Forestry
Lakehead University

Thunder Bay, Ontario

November 22, 1989

ABSTRACT

Sas-Zmudzinski, K. 1989. Natural regeneration of black spruce
(Picea mariana (Mill)B.S.P.) on lowland clearcut strips
near Shebandowan, Ontario. 73p. Major Advisor: R. Clarke

Key Words: advanced growth, clearcut strips, competition,
height and volume growth, *Picea mariana,* seedbeds.

Growing conditions for black spruce natural regeneration on clearcut strips were studied near Shebandowan, Ontario. These conditions were significantly different from those present in the mature, residual forest in the study area. Furthermore, growing conditions changed with increased age of the clearcut strips. The most favourable seedbed (sphagnum) and limited hardwood competition were present only for few years following harvesting. The succession of less favourable seedbeds (sedges, hardwood litter) and severe hardwood competition had a negative impact on density and stocking of spruce regeneration.

Height growth based on stem analysis data of regenerated and residual trees were expressed by a Weibull function. Half of the natural regeneration consisted of advance growth. The growth progressions for both advanced growth and new regeneration closely fit the growth models for the GOOD site disregarding early suppression.

This study demonstrates that utilizing narrow, progressive clearcut strips and control of competition will produce a well stocked new forest as productive as the old forest on lowland, conifer site types.

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation for the support and help of my Major Supervisor, Richard Clarke, and other members of my Advisory Committee, Dr. H.G. Murchison and Dr. Willard H. Carmean who spent many hours reviewing this manuscript. I would also like to thank my external examiner, Dr. K. McClain of the Ontario Forest Research Institute for his helpfull comments.

I am grateful to the Canadian Forestry Service for providing Postgraduate Scholarship in my years of graduate study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

IMPORTANCE OF BLACK SPRUCE

Black spruce (*Picea mariana* (Mill) B.S.P.) is one of the most abundant conifers in Canada. In Ontario, 41 percent of the province's productive forest land and 20 percent of the total land area is covered with black spruce dominated forest (Ketcheson and Jeglum, 1972).

This species is also the most important pulpwood species for Ontario forest industries. Between eight and nine million cubic metres of spruce are harvested every year in the province (OMNR,1986). In the North Central region (OMNR) alone, two million cubic metres of black spruce were harvested in 1985/86.

Black spruce forests are found on both mineral and organic soils. The area of peatland black spruce in Ontario is estimated at approximately 46 percent of the total area of spruce dominated forest (Ketcheson and Jeglum, 1972). These figures illustrate the importance of peatland black spruce to wood production.

EFFECTS OF HARVESTING TECHNIQUES

Harvesting of black spruce forests is typically done by clearcutting or by block or strip cutting. The latter method consists of clearcutting parallel strips and leaving the intervening areas uncut; trees from the uncut strip are removed a few years later. In principle clearcutting appears to be ideal for the regeneration of black spruce in even-aged stands. This method provides for abundant seed on freshly cleared soil, gives maximum wind protection to the exposed edge of timber (LeBarron, 1948), protects the ground surface from excessive drying and heating, and helps to create favourable seedbed conditions (Jeglum, 1980).

Clearcut harvesting, no matter in what form, most often results in evenaged stands subject to natural catastrophies such as fire, insect outbreak and windstorms. Disturbance by logging may result in slow development of spruce regeneration as the disturbance increases competition from trembling aspen (*Populus tremuloides* Michx.), white birch (*Betula papyrifera* Marsh.) and many other deciduous species. Logging may also result in the rapid regeneration of black spruce as the disturbance scarifies the ground and releases advanced growth.

Mature evenaged black spruce stands near Shebandowan are managed in a way that a new forest resembles the original stands. Although relatively productive, these organic soils cannot be managed intensely due to limited access during summer months. Some alterations to the natural stand can be done at the time of harvesting, however, due to limited access few intermediate silvicultural treatments can be applied following regeneration.

Detailed studies of natural regeneration in the Shebandowan area should provide some information on the development of black spruce natural regeneration on organic soils. These studies also should help forest managers decide how peatlands can be managed so as to obtain fully stocked, evenaged, rapidly growing black spruce stands.

STUDY OBJECTIVES

The purpose of this study was to investigate black spruce natural regeneration following progressive strip cutting on organic soils and to compare growth of the new forest with growth of the residual black spruce stand.

The following specific factors were examined:

1/ successional changes in microsites on harvested areas;

2/ density and stocking of black spruce regeneration in relation to microsite changes following harvesting;

3/ age structure of the new forest, and

4/ height / volume growth patterns of black spruce in the new forest in relation to patterns of growth in the original black spruce stand.

Specific objectives of this study were to determine:

a) if growing conditions on regenerated clearcut strips differed from those in the uncut mature forest;

b) if vegetation changed with age of clearcut strip, and

c) if site conditions influenced the height and volume growth patters of regenerated black spruce.

CHAPTER 2

LITERATURE REVIEW

BLACK SPRUCE REQUIREMENTS IN RELATION TO SITE CONDITIONS.

Black spruce requires favourable moisture and light conditions for best establishment and growth, but black spruce can also grow on sites having a limited supply of moisture, nutrients and heat. Black spruce forests occur on a wide variety of soils ranging from very wet or almost completely saturated to shallow or deep sands or gravelly tills. However, black spruce is less common on very dry sites such as coarse sands or areas very shallow to bedrock. Best sites are on moist to wet clay loams and clays found on long gentle slopes and in lowlands (MacLean and Bedell, 1955).

Black spruce is common on mineral soils. It grows on gravelly and bouldery loam and on shallow soil over bedrock where it usually is mixed with other species like jack pine (*Pinus banksiana* Lamb.), and trembling aspen, but most often forms pure stands. Growth is best where the slope is gentle and moisture is plentiful, either from a shallow water table or seepage. Occasionally, spruce is also found on sandy soils with a high water table.

Stands of low productivity are on organic soils that are poorly decomposed yellowish-brown sphagnum peats containing inclusions of wood and ericaceous shrubs. At a depth of more than one meter, this fibric layer may be underlain by brown fibrous sedge peat. In contrast, more productive stands are found on organic soils composed of dark brown to blackish well decomposed peat that frequently contains partially decomposed wood. A layer of sedge peat sometimes underlies these surface peats (Heinselman, 1957).

Growth of black spruce on organic soils is related to the amount of nutrients received from ground water and precipitation. Black spruce on organic soils usually grows in pure stands but may also be mixed with tamarack (*Larix laricina* (DuRoi)K.Koch), northern white cedar (*Thuja occidentalis L.*) and balsam fir (*Abies balsamea*(L.)Mill).

The characteristic pattern of productivity on swamps is for the best growth to be at the perimeter and progressively poorer growth towards the center. Almost invariably, the best growth occurs on mineral soils that borders the swamp. The decline in growth rate towards the center of the swamp may be step like or regular, slow or fast (LeBarron, 1948). The poorest black spruce muskegs are on raised bogs that have a thick accumulation of poorly decomposed yellowish brown sphagnum peat (Hills and Boissoneau, 1960; Wilde *et al.*, 1954).

Surface peats usually range from a pH of 3.5 to 4.5, but pH increases with depth, frequently reaching 6.0 to 7.0 when a calcareous mineral soil substratum is present. Excellent spruce sites often occur where the pH in the upper 20 centimetres is below 4.0. Soil pH alone is a poor indicator of productivity (Heinselman, 1955). Similarly, peat depth alone is not a strong indicator of productivity although there is a tendency for the poorest sites to be associated with thicker peat accumulations. Much more reliable guides to site productivity are the botanical origin of the upper peat, and the degree of peat decomposition.

The most characteristic element of the ground cover in black spruce forests is a profusion of mosses and lichens. Feather mosses predominate on drier sites and under dense spruce stands. Feather mosses include *Hylocomium splendens, Pleurozium schreberi, Hypnum crista-castrensis* and species of *Dicranum* and *Polytrichum spp* (Conway and Verona, 1949). On the wetter bogs, many species of *Sphagnum* are found, often forming a mosaic with the feather mosses. The most common sphagnum mosses are: *S. magellanicum, S. fuscum, S. fallax, S. girgensonnii* and *S. wulfianum*

(Jeglum *et al.,* 1974). The most characteristic bog shrubs are Labrador tea (*Ledum groenlandicum), Chamaedaphne calyculata, Kalmia spp. Vaccinium spp.* and dwarf birches *(Betula spp)*. In some swamps speckled alder (*Alnus rugosa* (Du Roi) Spreng) is the principal shrub (Dansereau and Segadas-Vianna, 1952). On wet sites black spruce occurs in pure stands or is accompanied by varying proportions of white spruce *(Picea glauca* (Moench)Voss) white cedar, trembling aspen, balsam poplar (*Populus balsamifera L.*) larch or balsam fir.

Ontario wetlands were classified by Jeglum *et al.*(1974). According to this classification, merchantable black spruce occurs predominantly on conifer swamps; "*Picea mariana* conifer swamp" is the most common swamp type in Ontario. It has site classes of 1A, 1, 2, 3 (Plonski, 1981). The ground surface of these forests is extremely irregular; pits and channels alternate with mossy mounds, the latter often developing on fallen trees and windthrow mounds. The nutrient status for the depressions ranges from eutrophic to oligotrophic and for the mounds from oligotrophic to very oligotrophic. The moisture regime averages wet. Better sites are usually on measurable slope. Poorer sites are associated with relatively flat land. Black spruce conifer swamps are divided by Jeglum et al. (1974) into four site types according to the leading dominant species in the subordinate strata . In brackets are vegetation and soil types according to the Forest Ecosystem Classification for the North Central Region (OMNR, 1987):

> <u>Black spruce speckled alder.</u> Occurs on drainage channels and seepages bordered by upland, and has a high nutrient status. Cutting in this type results in dense development of speckled alder (V35, S11F)
>
> <u>Black spruce feather moss.</u> Occurs on peat deeper than 30 centimetres with small pools of open water. Shrubs are relatively unimportant owing to the dense canopy of the stands (V33, S11F)
>
> <u>Black spruce labrador tea</u> Contains at least 25 percent cover of Labrador tea. Mature stands of this type are merchantable forests with characteristically open canopies . This type occurs on poorly drained areas. (V34, S11F)

Black spruce sphagnum. Occurs on flat or sloping sites and is characterized by *S.girgensohnii* and *S.fallax* (V36, V37, V38, S11S)

FACTORS AFFECTING REGENERATION

Seed And Vegetative Propagation

The optimum age for seed production is from 50 to 150 years but good crops often occur on trees 200 years old or more (Heinselman, 1954). Seed supply is almost constantly present in stands that are 40 years or older (Johnson, 1977) because cones open gradually thus permiting continuous seed dispersal. A constant seed supply is also secured because seed crop failures seldom occur for two or three consecutive years .

In Minnesota, the average annual number of viable seeds per hectare in new and one-year old cones in a swamp stand was found to vary from 300,000 to over 1,500,000 in a 4-year period (Heinselman, 1955). Dominant trees can produce 3 times more cones than codominant or intermediate trees (Haavisto, 1975).

Annual cone production is related to the physiological condition of the tree, the environment and weather in the current year and in the previous year (Vincent, 1965). Seed production in thinned stands is slightly higher than in unthinned stands (Losee, 1961). Some studies indicate that seedfall mainly occurs during March, April and May with most of it occuring in April (Haavisto, 1975; LeBarron, 1948).

Seed dispersal is predominantely by wind, but seeds of black spruce are not usually carried long distances even though they are small and light in weight (McEwen, 1971). In Minnesota, the seed fall in a clear-cut area adjacent to standing timber declined from a maximum of 650,000 per hectare within a stand to only 45,000 at 30 metres from the edge, and to almost none beyond 100 metres (LeBarron, 1939). Horton and Lees (1961) found acceptable stocking in a burned peat bog in Alberta only within 40 metres of the residual stand. LeBarron (1948) states that seed fall in the center of a 30 metre wide clear cut strip was only 30 percent of that in the stand thus seed dispersal may be expected to be effective for only two or three tree heights.

Black spruce may also reproduce by means of **layering** (LeBarron, 1948; Hosie, 1954; Stanek, 1961). Layering takes place when a living branch becomes imbedded in a moist medium and produces roots (Stanek, 1968). Bellefeuille (1935) states that black spruce reproduces entirely by layering in acid, moist, swamp-type soils. Johnson (1956) studied 19 swamp border and upland black spruce stands in Manitoba and found that 29 percent of the reproduction was by layering.

In Northern Quebec and Ontario, black spruce reproduction through layering often provides the major source of reproduction (Stanek, 1968). Schoenicke and Schneider (1954) found that layers formed 53 percent of all best formed reproduction in an uncut swamp in north central Minnesota and that these trees were the most likely to survive. They considered that layering was particularily important on poor sites and in stands of low density. Buckman and Schneider (1952) suggest that layering is most common on productive true-peat sites less common on medium sites, and is least common on swamp margins. Heinselman (1957a) observed that reproduction on the poorest sites was largely of layer origin. He found that layering is greatest on bog border sites possibly due to the open stand conditions.

Layerings are frequently the only way to naturally restock cutovers on organic soils. Layering saves expense in artificially regenerating large areas, shorten the rotation period, and sustain yield by eliminating unproductive periods (Stanek , 1968).

Another form of black spruce regeneration, **rooting**, was reported by Horton and Lees (1961) in Alberta, and LeBlank (1955) in Quebec. This form of rooting occurs when the roots in the upper layers of the humus within 10 centimetres of the surface develop adventitious shoot. Such regeneration is most common where absence of lower branches makes layering impossible.

Survival On Different Seedbed Types

The forest floor of organic soils has a complex mosaic of seedbeds. The most favourable seedbed types are: (a) sphagnum moss; (b) decayed wood, (c) mineral soil, and (d) hair-cap moss. In contrast unfavourable seedbeds are: (a) litter, (b) slash, and (c) living or dead feather moss (Jarvis and Cayford, 1961). Vincent (1965) listed favourable seedbed types from best to poorest as follows: (a) slow growing sphagnum moss, (b) moist rotten wood, (c) mineral soil, (d) litter, (e) beds of fast growing sphagnum, and (f) feather moss.

Van Nostrand (1971) concludes that mineral soil was by far the most receptive seedbed; it was almost three times more receptive than patches of sphagnum moss which was the next best medium. Van Nostrand found that stocking on deep feather moss was poor in comparison with stocking on sphagnum and on mineral soil. In a greenhouse study, seedbed type had a higher degree of influence on germination than either watering or seedbed preparation (Jeglum, 1979). Seedbeds such as sphagnum that were associated with good germination had high moisture retaining capacities.

Sphagnum

Sphagnum mosses occur in places that are very wet, in openings in stands and most frequently in deforested or sparsely stocked areas. Germination of black spruce seeds increases on sphagnum exposed to the sun (Losee, 1961). Favourable germination on sphagnum also was observed by Jeglum (1979) in his greenhouse experiment.

Sphagnum is a good seedbed for germination apparently because it is almost constantly moist (Heinselman, 1957; Johnston, 1971). The number of black spruce seeds required to produce one seedling per milacre was found to be four times less on sphagnum than on next best seedbed type (Losee, 1961).

In spite of being a good medium for germination, sphagnum does not support good seedling growth. Poor supply of nutrients, particularly nitrogen and possibly phosphorus (Parker, 1962) results in very short stems. Among many sphagnum species, *S. magellanicum* provides better growth in terms of crown and root length than *S. fuscum* and *S. angustifolium* (Jeglum, 1981).

After a swamp is disturbed by logging or fire, sphagnum moss quickly invades moist peat and decayed stumps and creates a favourable seedbed (LeBarron, 1948; Vincent, 1966; Heinselman, 1957; Johnston, 1971). If sphagnum growth exceeds 3 centimetres per year, there is a trend towards fewer coniferous seedlings. Excellent seedbeds are provided by species of sphagnum mosses that grow relatively slow such as: *S.girgensohni, S.magellanicum* and *S. wulfianum* . In contrast poorer seedbeds are provided by sphagnum species that grow too fast such as *S. angustifolium* and *S.fuscum*. On these poorer seedbeds black spruce seedlings are outgrown and suppressed resulting in poor growth and survival. Rapidly growing mosses often in response to rising ground water sometimes bury the roots of black spruce so deeply that adventitious roots develop nearer the surface(McEwen, 1966) . Often the tree has four of five strata of roots formed in this manner (LeBarron, 1945 ; Clarke, 1975).

Favourable sphagnum seedbeds for black spruce result in relatively high stocking. Van Nostrand (1961) in Newfoundland, found that although sphagnum patches covered less than 5 percent of the area they supported more than one half of the total number of seedlings. Jarvis and Cayford (1961) found in Manitoba peat lands that sphagnum represented 4.7 percent of all seedbed media but had 67.1 percent of all black spruce regeneration.

Pleurozium

Pleurozium schreberi is abundant in upland black spruce stands and is frequently associated with *Hylocomium splendens. Pleurozium schreberi* grows on the drier parts of sphagnum swamps; this moss cannot endure direct sunlight and disappears after cutting or remains as a sparse layer when protected by shrubs but seldom occurs under alder. The appearance of pleurozium moss on bare litter is beneficial to black spruce seedlings because it provides some protection against drying and rodents (Vincent, 1965). However, this moss often forms dry, poorly decomposed organic layers that limit the establishment of seedlings. Loose surface structure of this moss, and a poorly decomposed lower layer of dead moss allows for easy passage of air and rapid drying. If moisture can be maintained, pleurozium provides excellent growth for seedlings (Jeglum, 1979). Therefore, in situations where the peat underlying pleurozium is constantly moist, it is a better substrate for seedlings growth than sphagnum; pleurozium is also a better supplier of nutrients than sphagnum. Seedbed conditions are much improved by removing or compacting pleurozium moss (Jeglum, 1971; Vincent 1966).

Litter

Undecomposed litter provides a very dry medium for seeds and also prevents seeds from penetrating deeply into the seedbed. Leaf litter is reported as a main deterent of successful germination and growth (LeBarron, 1944). Place (1955) observed that litter seedbeds composed of a variety of plant materials offer more opportunities for seedling establishment than those composed mainly of a single material such as dry, poorly decomposed litter.

Rotten wood

Moist, rotten wood is a good seedbed for black spruce (Dickson and Nickerson, 1958), but dry rotten wood or wood covered by pleurozium moss is a poor seedbed (Van Nostrand, 1971).

Burned surfaces

This type of seedbed results from fire thus the seedbed depends directly on the severity and type of forest fire. Light fires often make a seedbed worse by leaving accumulations of dry litter, or by stimulating growth of competing vegetation. More severe fire lessens competition and has a significant fertilizing effect. Dark coloured burned surfaces have a tendency to become very hot in sunlight and thus may cause a complete failure of germination. LeBarron (1944) found total mortality of seedlings on burned duff on clearcuts as being 90 percent in the first two years.

REPRODUCTION POTENTIALS

Reproduction In Mature Forest

There is almost a constant supply of seeds within black spruce stands. However, black spruce can germinate and become established only when seedbed environments are favourable. Schoenicke and Schneider (1954) found that stocking of black spruce regeneration declines with increased density of the mature stand. They also found that more regeneration occurs on poor sites and that regeneration declined as site quality improved. Horton and Lees (1961) studied an 80 year-old, fully stocked stand in

Alberta and found that stocking of black spruce regeneration averaged 3 percent on moisture regime 4 to 5 (The System of Soil Classification in Canada, 1974), 6 percent on moisture regime 6, and 16 percent on moisture regime 7; they also found that advanced growth was fairly common in open black spruce stands. Larsson and Wilkes (1947) surveyed black spruce swamps near Nipigon and found that advanced growth occured on 5 to 35 percent of the milacre quadrats. A pre-cut survey made by the Ontario Ministry of Natural Resources indicated fair to good stocking of black spruce as soil moisture increases, reaching 96 percent of stocked quadrats at moisture regime 8. On the other hand, Losee (1961) studied an even-aged, 70-year -old stand of black spruce feather moss type and found no advanced growth.

Disturbance To The Mature Stand And Its Effects On Reproduction Potentials

Fire

Fire cycles in black spruce stands may be from 54 to 102 years or as frequent as 36 years in interior Alaska (Johnson, 1979). Black spruce ecosystems are well adapted to large and frequent fires. Black spruce stands are, however, somewhat less flammable in older ages because the soil often becomes colder and wetter with age (Yarie, 1981). Fires reduce organic accumulations, paludification is slowed thus accumulation of peat is avoided resulting in restoration and continuation of productive black spruce ecosystems (Viereck, 1983). Burning is often necessary to obtain spruce regeneration on feather moss sites because fire consumes much of these poor seedbeds and reduces the competition of graminoids and other tall shrubs (Aksamit and Irving, 1983).

Adaptation of black spruce to fire is primarily through semi-serotinous cones. Black spruce produces viable seeds as early as 10 to 15 years, thus pure, well stocked black spruce usually occur after fires. Optimum seed production is usually reached at the age of 100 years (Fowells, 1965). Johnston (1975) found that well stocked black spruce stands occurs on burned areas that are as far as 90 metres from the windward side of the mature stand and 40 metres from the leeward side.

In the Gaspe region of Quebec, regeneration of black spruce began 3 years after fire, reached a peak nine years after fire, and additional regeneration declined rapidly to zero 13 to 18 years after fire (MacArthur, 1964). However, MacArthur found that 20 years after fire regeneration of spruce was still inadequate on 50 percent of a burned area with no sign of an early return to normal stocking. Horton and Lees (1961) examined a one-year old burn in an uncut area and found that stocking was 37 percent on microsites with a moisture regime of 3 but stocking was 87 percent on microsites with a moisture regime of 7.

Stocking is often a reflection of both seed supply and moisture conditions. On more productive sites initial establishment after burning can be good, but competition overtop seedlings and reduce their growth (Johnston, 1975). Johnson found that moderate to severe burned areas averaged 94,000 seedlings per hectare and had four times more seedlings than unburned areas. He found that dense competing vegetation such as willow and aspen developed on burned seedbeds resulting in severe competition for black spruce (Johnston, 1971).

Thomas and Wein (1984) stated that black spruce regeneration is abundant only after very low intensity or high severity fires because of requirements for shelter and it's relatively slow radicle growth.

Logging

Black spruce can be harvested by various methods including shelterwood, partial cutting, group selection, clearcuts in patches and strips, and finally clearcutting. However, in most situations only the last two methods are practiced. Vincent (1965) gathered information on reproduction following cutting in various systems and found that patch cutting seems to provide the best results and group cutting the poorest.

Clearcutting on lowlands should be limited to overmature, decadent stands where other cutting methods are not feasible. Care should be taken to protect existing advanced growth from damage. Advanced growth can be protected and when a seed source is nearby the establishment of new reproduction is favoured by piling and burning slash. Exposure of soil will be helpful to reproduction and the full tree skidding method eliminates heavy slash cover.

Clearcuts sometimes result in detrimental heat and drying conditions (Roe *et.al.*, 1970). For large clearcuts most of the seeds originate from the trees in the residual stand on the edge of the clearcut opening, hence there may be a lack of seeds in the central parts of large cutovers. Johnston (1977) suggests that large clearcutting should be followed by direct seeding or by planting. Natural regeneration on large clearcut areas is often a failure because of adverse heat and moisture conditions and the lack of seed. Jarvis and Cayford (1961) reported that stocking was less than 50 percent on large clearcuts in spruce swamps in Manitoba except for wet to very wet sites where stocking increased to 75 percent.

Results from Ontario (Vincent, 1965) are more positive but success rates only slightly overcome the rates of failure. The effect of seedbed change towards less favourable ones is limited on wet to very wet sites.

The Shelterwood system leaves a considerable overstory of residual trees. In Manitoba lowlands, this method did not produce adequate regeneration, and produced barely acceptable results in Minnesota (Heinselman, 1959). Shelterwood cutting was effective in preventing excessive growth of competing shrubs in New Brunswick upland spruce stands (Baldwin, 1977).

Strip clearcutting

Clearcutting is the most commonly used method of harvesting black spruce stands in Ontario, however, its modification, strip clearcutting is strongly advocated by many authors (Fleming and Crossfield, 1983; Jeglum, 1982). Parallel strips are clearcut and the intervening areas are left to provide seed thus avoiding problems of seed supply that are common with clearcutting. Also, exposure of the ground surface to excessive heating and drying is much less for strip clearcuts compared to clearcutting.

The main disadvantage of strip clearcutting is that the cost of operation may be greater than for clearcutting due to increased road construction and maintenance costs (Ketcheson, 1977). Also, when the final leave strips are removed no residual stand remains for natural seeding of the strip.

Haavisto (1979) studied strip clearcutting on peatlands in the Clay Belt of Ontario and found better stocking and greater density of regeneration when compared with large clearcuts; stocking was one third higher and density was almost doubled on the clearcut strips. Orientation of strips is important. Haavisto (1979) reported that there was a better supply of seeds when residual strips were on the west than on the east of clearcuts.

On lowland sites near Cochrane there was significantly more spruce on the strip clearcuts than in the centre of large clearcuts (Fraser *et al.*, 1976). Centres of large clearcuts had few spruce and significantly more regeneration of other species (speckled alder, trembling aspen, balsam fir) than was observed on two-chain strips. For this same lowland site, older strips were better stocked to black spruce and also to other conifers. This study also found that spruce regeneration is most plentiful on moist sites and is least plentiful on dry sites.

Strip clearcuts on shallow soil near Nipigon resulted in regeneration of over 60 percent three years after cutting (Jeglum, 1982). Strip clearcuts 20 metres wide near

Shebandowan resulted in stocking of black spruce of over 80 percent (Clarke, 1972). Strip clearcuts are not suitable for overmature stands that must be cut at once to avoid loss of merchantable trees. Very old stands may not supply enough seeds which resulted in poor stocking on upland strips in Newfoundland (Van Nostrand, 1971). Factors limiting regeneration on strip clearcuts are deep leaf litter, deep duff and competition from dense growth of speckled alder, sedges and other shrubs. But regeneration is favoured by the presence of sphagnum moss, disturbed surfaces, rotten stumps and wood. Moderate cover from speckled alder also favours regeneration because of shading, increased moisture, and limited development of pleurozium moss.

Advanced Growth

Black spruce advanced growth is most abundant on the wettest and poorest sites and becomes less abundant as sites become drier and site quality improves (Groot, 1984). Advanced growth is a significant percentage of regeneration on black spruce cutovers in contrast to seedling regeneration (Weetman *et al.*, 1973; Fraser *et al.*, 1976). Regeneration of black spruce on peatland was studied by Haavisto (1979) who found that advanced growth constituted 55 percent of regeneration 3 years after harvesting. On another area 14 years after cutting he found that 30 percent of the regeneration was advanced growth. During mechanized harvesting advanced growth may be destroyed, therefore, Haavisto (1979) suggests that modified harvesting be used in winter to protect advanced growth and to minimize proliferation of undesirable species. Alexander (1968) reported that only about one half of the advanced growth in the Frazer Experimental Forest of British Columbia survived logging.

Competition

Black spruce can survive and grow under fairly dense forest canopies or under brush cover; light intensity of about 10 percent is sufficient for seedling establishment (Place, 1955). Seedlings have better opportunities for establishment under the canopy, however, vigour and growth are definitely better in the open.

Dense, even-aged young stands commonly lack an understory of seedlings and saplings, but in older ages stands become more open and understory regeneration is more numerous. After logging or burning black spruce regeneration has to compete with increased amounts of other species that invade the site. Johnston (1971) studied lowland areas in Northern Minnesota and found that speckled alder regrowth was very rapid after clearcutting, thus spruce seedlings were getting an average of only 22 percent of full light by midsummer. He concluded that reduction of vegetation regrowth rather than seedbed preparation was the major requirement for successful direct seeding.

Competition reduces light intensity well below that required for good growth of black spruce seedlings (Logan, 1969). Competition also produces a heavy leaf fall that will smother many seedlings during winter; similar competition problems also occur on burned areas unless the severity of fire is high enough to kill their root systems. Johnston (1971) reports that on light to moderate broadcast burns an average of 60 percent of the stocked plots had spruce seedlings overtopped by other vegetation. Competing vegetation on these lowland areas consist mainly of speckled alder, ericaceous species and sedges.

Genovese (1977) matched percent of competition with Jeglum's (1979) site types and found that alder and labrador tea sites had relatively high levels of competition of 75 to 91 percent. In contrast, feather moss and sphagnum sites had much less competition. Hardwood competition is almost always taller than conifer regeneration on most sites (Richardson, 1979).

Clark and McLean (1975) in a laboratory experiment found that increased density of grass significantly reduced survival, height growth and plant mass of softwood species. Average dry weight of shoots plus roots decreased 10 times with the highest grass density.

Density of shrubs in harvested areas increased greatly in the decade or more following clearcutting of mature spruce (Johnston, 1968). Grass *(Calamagrostis canadensis)* increased from less than 5 percent cover in the forest type to 15 percent cover in brush types. Similarily, raspberries *(Rubus spp.)* increased in frequency from 50 percent to 92 percent. Lowland brush develops from the invasion of shrubs and lesser vegetation from surrounding areas and also from understory plants that are already present when stands are cut. Unless this succession of shrubs is eliminated or at least controlled soon after logging, conditions for establishing black spruce seedlings become unfavourable.

Release of spruce reproduction using herbicides is an accepted silvicultural practice. Richardson (1979) found that herbicide (2,4-D, Tordon) control of hardwoods in Newfoundland was largely transitory and that within one year after treatment rapid regrowth of hardwoods was common. In Ontario, several herbicides are used to control hardwood competition in spruce plantations. Commonly used herbicides are Vision, Velpar and 2,4-D. If applied in late fall or after hardening off, black spruce is tolerant to these substances. Velpar can only be used on fine textured soils but there are no soil texture limitations for use of Vision or 2,4-D. Brush cutting is recommended only for areas where, for environmental reasons, herbicides are unacceptable. Spraying is probably the most practical and efficient way to reduce vegetation regrowth. Haavisto (1979) proposes that any operation to eliminate or control competition from undesirable species be an integral component of all regeneration programs.

BLACK SPRUCE GROWTH AND YIELD

Black spruce is a slow growing, but relatively long-lived species. Depending on site quality and stand density mature merchantable, dominant trees are usually 12-20 metres tall, 15-30 centimetres in diameter at breast height and from 60 to 150 years old.

Early growth of unsuppressed, dominant trees on good swamp sites is somewhat slower than on typical upland sites, and trees may require as much as 20 years before reaching breast height. LeBarron (1948) states that the age to achieve breast height in Minnesota on productive swamps is 13 years, but under heavy shade or on poor sites initial height growth may be much slower. On average sites black spruce reaches merchantable size in 50 years and diameter growth continues at an almost steady rate for 60 to 80 years. After this age growth is slower (Fox and Kruze, 1939; Plonski, 1981).

Productivity of a forest species is closely related to site quality and productivity may be expressed by normal yield tables, site index curves and standard or local volume tables. An estimation on site index is based on age and height measurements of suitable dominanat, uninjured trees. Such trees are especially available in even-aged, fully stocked stands not disturbed by cutting or fires. The total height of a tree and its age is determined, then site index usually at a base age of 50 is estimated from a family of site index curves. Site index curves for black spruce were developed in the United States (Gevorkianz, 1957) and site classes for black spruce were developed in Canada (Plonski, 1981). Local, polymorphic site index curves based on breast height age for black spruce were constructed for the Thunder Bay area (Thrower, 1985) and for North Central Ontario (Sas-Zmudzinski , 1989, [*unpublished*).

Site index curves can be related to tables that predict growth and yield for different stand ages and different levels of site productivity.

Plonski's (1981) yield tables are commonly used in Ontario. These yield tables show that black spruce at 100 years on a very good site (site class 1A) can achieve up to 426 cubic metres per hectare, on a good site (site class 1) 298 cubic metres per hectare, on a medium site (site class 2) up to 237 cubic metres per hectare, and on a poor site (site class 3) 158 cubic metres per hectare or less. Growth and yield varies across the range of the species. For example yield tables for Alberta (Horton and Lees, 1961) indicate yields lower than in Ontario but higher than in Saskatchewan.

CHAPTER 3

METHODS

STUDY AREA DESCRIPTION

The 38 hectare study area is located 80 kilometres north-west of Thuder Bay along Highway 11 in the Upper English River Section B.11 of the Boreal Forest Region (Rowe, 1972) (Figure 1). The area is located at latitude 48 degrees 38 minutes, and longitude 90 degrees 10 minutes.

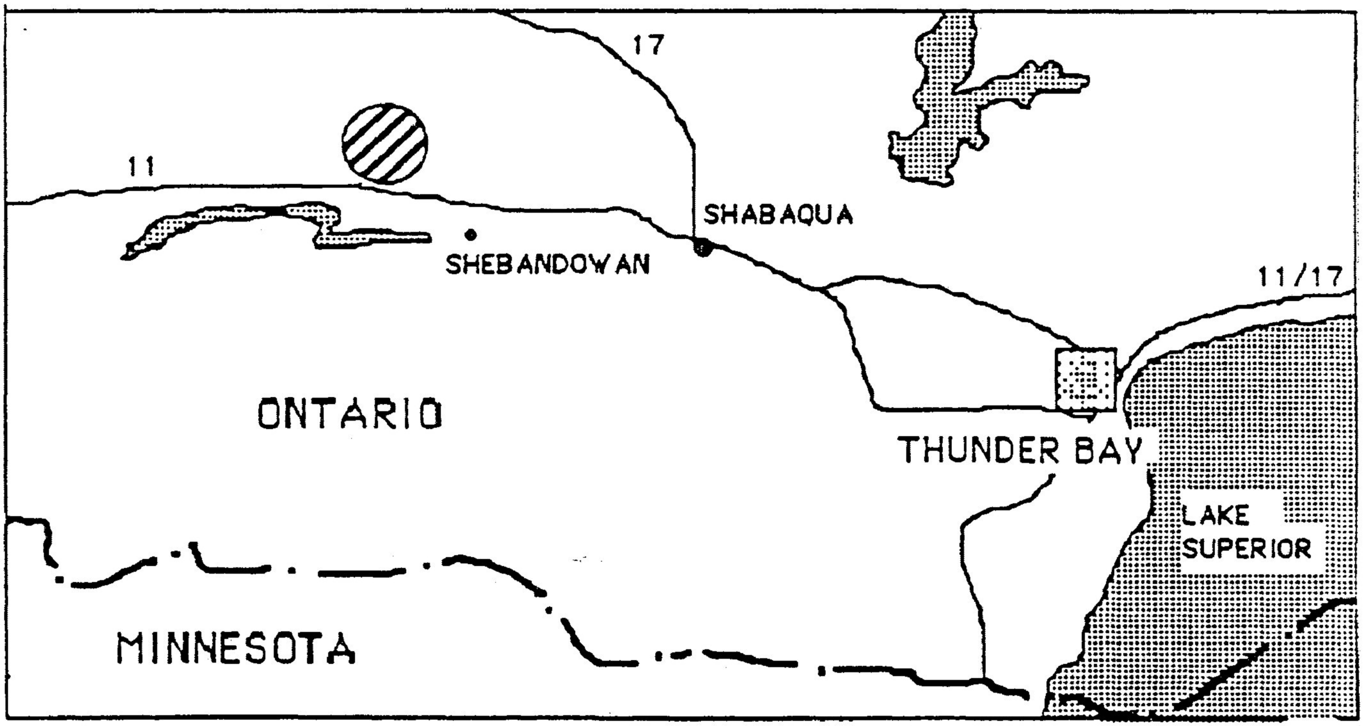

Figure 1. Location of the study area in North Central Ontario.

The Shebandowan area is characterized by long winters, a mean annual precipitation of 740 millimetres, and by an eighty-day frost-free growing season. Topography of the study area is mostly flat with slopes less than 5 degrees. Mineral soil is overlaid by an organic deposit from 0.5 metre to well over 1.0 metre thick.

The vegetation cover of the area is formed by a pure merchantable black spruce forest that can be classified according to Jeglum *et al.* (1974) as a *Picea mariana* (Black spruce) Conifer Swamp. (FEC V34). The ground surface of the residual forest is an irregular mosaic of pits, channels and mossy mounds developed on fallen trees and windrow mounds. A better growing stand occurs on the northrn edge of the area, where slopes are steeper, whereas a poorer growing stand occurs where topography is flat and is characterized by a deep peat deposit.

The residual stand can further be classified as a Black Spruce / Labrador Tea site type (Jeglum *et al.*, 1974). *Ledum groenlandicum* covers at least 25 percent of the site. *Pleurozium schreberi* is a dominant moss in the understory of this mature forest. *Sphagnum* mosses occupy edges of water pools and local depressions. The harvested part of the study area is covered with regeneration of black spruce and competing hardwoods, predominantly speckled alder and trembling aspen of various ages. The forest floor is a mosaic of many mosses, grasses, sedges, rotten wood, and open pools of water.

The area has been strip cut removing successive strips three times during the past twenty years. Approximately 10 percent of the original stand remains uncut (Figure 2) thus the area has clearcut strips of various ages, namely : 3, 13 and 21 years. These clearcut strips provide valuable information on seedbed changes over the years, and on the growth and development of black spruce regeneration.

The first clearcut strips were made in the winter of 1962 when five strips were harvested (including strips no. 3,7 and 9). The second cutting was made in 1970 and 24 additional strips were removed (including strips no. 1,5 and 8). Finally, in 1980 ten of the remaining strips were removed (including strips no. 2,4 and 6) (Figure 2). Strips are 20 metres wide, and are oriented either west-east or north-south. Harvesting operations were done in the winter months using the tree length or full tree logging system. On some clearcut strips slash was windrowed and burned. These strips however, were not part of this study. Slash was also burned at landings, however, a few slash piles still remain along the main access roads and in some strips.

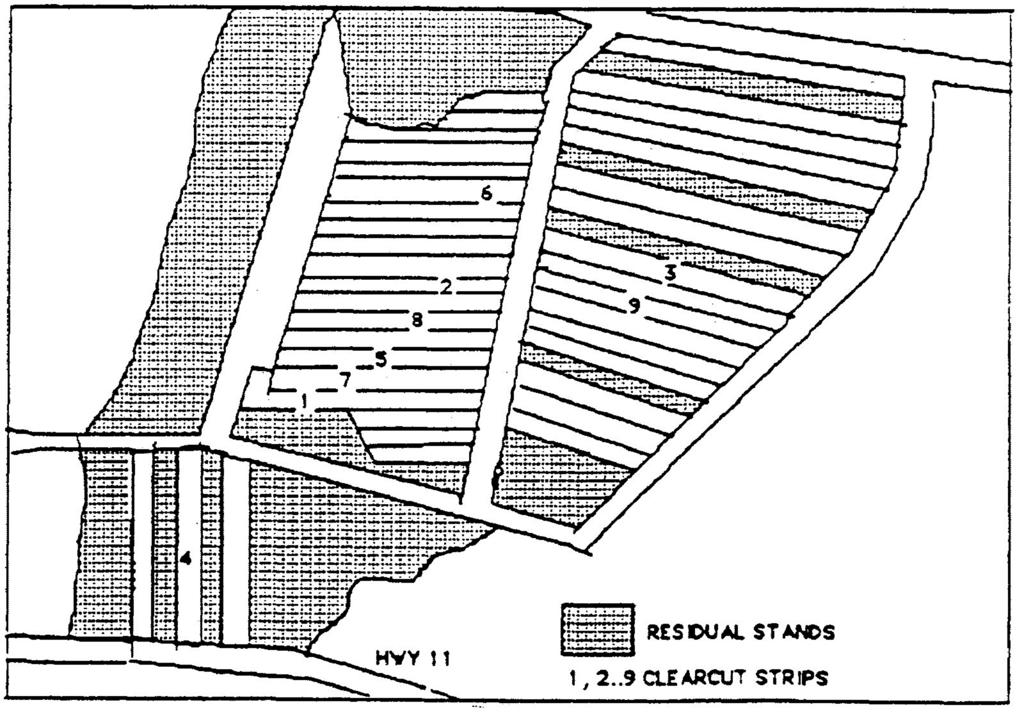

Figure 2. Map of the study area showing the pattern of clearcutting and the remaining original stand.

DATA COLLECTION

Soils

A soil survey was conducted in the summer of 1983 using three survey lines (Figure 3). At 40 metre intervals along each survey line a soil auger was used to extract soil samples. Soil descriptions included the degree of decomposition of organic matter according to the Von Post scale of decomposition (Ontario Institute of Pedology Field Manual for Describing Soils, 1985); pH also was estimated using the field colormetric procedure. Depth of organic matter and texture of the underlaying mineral soil were also recorded.

Vegetation

The area was studied in the summer of 1983. A ground reconnaisance was made to delineate site types based on dominant tree heights, depth of the organic deposit, and topographic conditions.

Residual stands

Three circular 50 square metre plots were randomly located in the uncut portion of the study area. One plot was located on the POOR site and two plots on the GOOD site. [1]

---

[1] These two site types were outlined in a preliminary analysis on a basis of soil and residual stand features. Detailed description is included in the RESULTS section.

Data collected from these three sample plots included:

- density of the residual stand
- total heights, dbh and total age
- seedbed types and distribution
- dominant trees for stem analysis

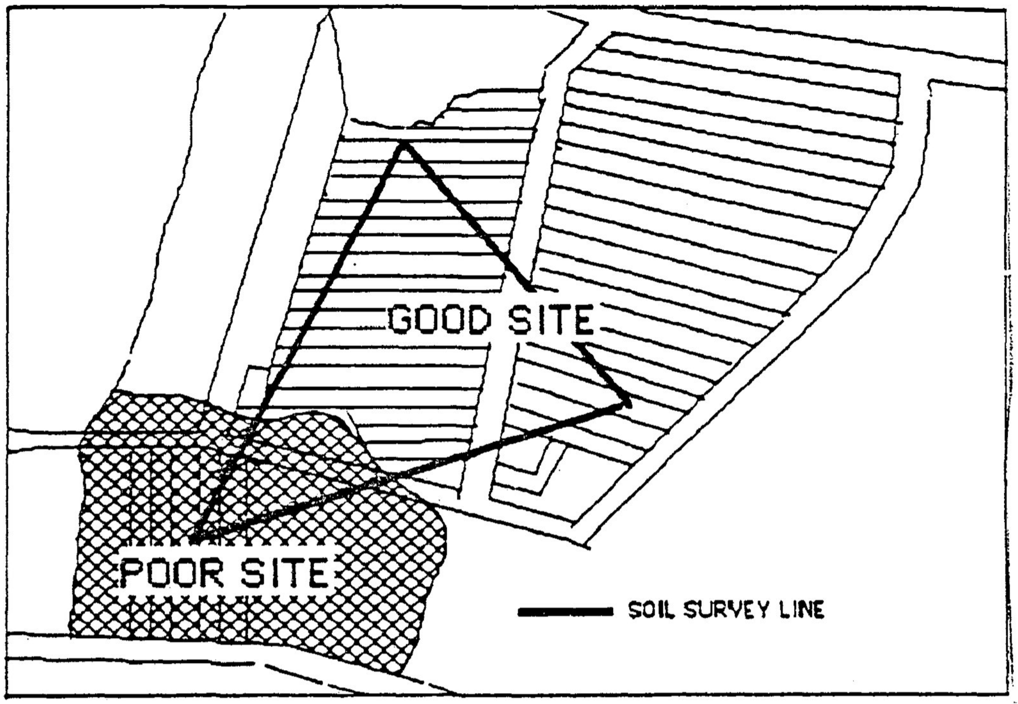

Figure 3. Study area stratified into two sites of different productivity.

Regeneration

Black spruce regenerated on clearcut strips consisted of (a) trees established on strips from seeds after strips were harvested, and (b) advanced growth. **Advanced growth** consists of all black spruce trees that were present under the residual stand canopy before cutting , and that are not older than 20 years. Advanced growth development was closely related to cutting activities on the neighbouring strips.

The age of regeneration was determined in relation to the time of cutting as being older or younger than the cut. Tree age usually could be made by counting internodes on each tree. However, when internodes were indistinct, the tree was cut and the number of rings determined using a section taken at ground level.

Circular plots

Three clearcut strips were randomly selected from each of the three strip age classes, giving a total of nine clearcut strips to be sampled. On each selected strip four circular plots 50 square metres in size were randomly located. Data collected on each study plot included:

- density of regeneration
- location of each tree on the plot
- tree height class (10 cm classes)
- tree total age
- seedbed type, percent cover, and distribution

Seven seedbed types were recognized in this study:

1. Pleurozium moss type. This type included living plants of *Pleurozium schreberi* (PLE)
2. Sphagnum moss type. This type was formed by a continuous mat of *S. girgensohnii, S. magellanicum and S. wulfianum* (SPH)
3. Sedges type. This type included such plants as *Calamagrostis canadensis, Equisetum arvense, Oxycoccus microcarpus* (SED)
4. Ledum type. This type was a continuous mat of *Ledum groenlandicum* (LED)
5. Organic soil 1 type. This organic soil type does not have living plants, and contains mainly dead pleurozium moss (OR1)

6. Organic soil 2 type. This organic soil type was overtopped by speckled alder and willows (*Salix sp.*) and is covered with litter from these species (OR2)
7. Wood debris type. This type was exposed decayed logs and stumps or the same covered by moss (DEB)

Stocking assessment

Each strip was assessed for stocking by systematic zig-zag sampling using clusters of 2x2 metre quandrats. There were 10 quadrats in each cluster and four clusters on each strip. The stocking was defined as the frequency of occurrence of black spruce seedlings and advanced growth as compared to the optimum number of evenly distributed trees that fully occupy a site. This stocking survey was made using methods described in the Manual of Instructions For Regeneration Surveys (OMNR, 1980).

Individual Tree Sampling

On the three circular plots in the uncut residual stand, nine dominant trees free of visible evidence of damage or suppression were chosen to represent maximum height growth. Eight trees were processed in the laboratory of which three were trees from the POOR site and five trees were from the GOOD site; one tree was discarded because of extensive rot that made it impossible to count rings. The nine trees were felled, limbed and the stump was cut at ground level. Total tree height was recorded; radial sections were cut from the bole of each tree at 0.05 metre intervals for the first 3 metres and at 0.5 metre intervals thereafter.

On each circular plot on the clearcut strips two trees showing no visible evidence of damage or suppression were chosen from each height class (0.5 metre intervals) to represent the growth pattern of black spruce regeneration. These trees were cut at the depth of the first root zone which was considered to be the point of germination. Total tree height was also recorded and radial sections were cut from each tree at 0.05 metre intervals. There were 180 trees collected and analysed. Stem analysis was conducted on 110 of these trees. Analyzed trees were distributed as follows:

Table 1. Distribution of sample trees representing different age classes on the strips.

Age of Cutovers (years)	No. of Sample Trees
3	35
13	46
21	29

The remaining 70 trees of the original sample either showed severe suppression, or were older than 20 years and therefore were classified separately from advanced growth as "residuals". Trees in this category originated and grew under the canopy of the mature stand for most of their lives. Growth patterns of these trees were only marginally affected by the openings of the stand through harvesting.

All tree sections were labeled as to plot number, tree number and height and were transported to Lakehead University and stored at 2 degrees Celsius. A Holman Digimicrometer (Jordan and Ballance, 1983) was then used to digitize ring width and to obtain the number of rings for each section. Two algorithms DUFFNO and STEM (Kavanagh, 1983) were used to compute height-age and volume-age relationships.

The actual height that individual trees attained in a growing season is underestimated at the point where tree sections were taken. The data were adjusted to remove this bias using the following formula (Carmean, 1972):

Adjusted Tree Height = Section Height + (bolt length / age difference) / 2 [1]

COMPUTATIONS

Plot data from the residual stand and from regenerated areas were analysed

- by age classes (residual stand and regenerated strips of three ages), and
- by site quality classes (POOR site and GOOD site)

In the latter stratification, sites were compared to determine the influence of site quality on establishment conditions and growth patterns.

Data collected on the regenerated plots was analysed using the chi-square test on the STATISTIX microcomputer package .

Growth Patterns

The height and volume growth patterns of trees from the residual stand and from the regenerated areas were mathematically expressed using the modified Weibull function (Young et al., 1978). The modfied Weibull function has been applied in recent years as a model for the diameter distribution of mixed stands (Little, 1982), as a model of survival in even-aged stands (Somers *et al.*, 1980), and most commonly as a growth function (Yang *et al.*, 1978; Smith and Kozak, 1984). This model was used to separately fit height and volume growth data of the residual stand, from the GOOD and POOR sites, from the various regenerated strips:

$$HT = \beta_1\left(1 - e^{-\beta_2\, age^{\beta_3}}\right) + \varepsilon \qquad [2]$$

where :

HT = height

ß1, ß2, ß3 = model parameters to be estimated

e = error of the model

The Weibull function is a nonlinear, sigmoidal model . Every coefficient has a biological connotation: ß1 defines the upper asymptote of the growth function; ß2 describes the monotonic growth rate after the point of inflection (scale parameter); and ß3 defines the allometric increase in growth before the point of inflection (shape parameter). The modified Weibull function passes through the origin with age=0, and secondly it approaches a maximum asymptotically when age approaches infinity.

Coefficients for growth models were estimated using the NONLINWOOD program described by Daniel and Wood (1980). This program is an interative, nonlinear least-square regression program that uses Marquardt's (1963) maximum likelihood method of minimalization. Initial estimates of parameter ß1 were taken from Phillips (1983). One of the model parameters was held constant while the others were varied. The program iterated until a minimum change in the residual sum of squares for the model coefficients was achieved.

The three coefficients of the Weibull model for each data group can be compared for statistical differences using 95 percent confidence limits of each coefficient (Alban and Prettyman, 1984).

The Weibull function was also used to estimate the early height growth for each Plonski's black spruce site class.

CHAPTER 4

RESULTS

Preliminary analysis involved stratifying, the study area into GOOD and POOR site quality areas on the basis of differences in soil profiles and differences in forest stand conditions (Figure 3).

SOIL DESCRIPTION

Soil at all locations of the survey line was an organic layer thicker than 40 centimetres with forest humus classified as a fibric peaty mor. Depth of the organic layers on the GOOD site was no more than 100 centimetres and with the organic matter underlain by loamy medium sand. Towards the center of the poor site depth of the organic layers exceeded 100 centimetres. The GOOD site was slightly elevated as compared to the POOR site.

On a basis of degree of decomposition there were two types of organic soil profiles . The type 1 profile (Table 2) occured on 21 (out of 29) locations in the GOOD site area (Figure 3). The top part of this soil profile was fibric and the bottom part was mesic. Depth to water table (in undisturbed parts of the study area) was approximately 30 centimetres. The moisture regime was moderately wet and the drainage was very poor. The pH of the Om1 horizon was 5.5. This soil type can be called a <u>mesic phase of wet organic soil.</u>

Table 2. Type 1 soil description for the GOOD site area

PROFILE	DEPTH	von POST	pH
Of1	0 - 5	1	5.5
Of2	5 - 21	2	5.5
Of3	21 - 45	3	5.5
Om1	45 - 70	5	5.5
Om1	70 - 100	6	5.5

The type 2 profile (Table 3) occured on 8 locations in the POOR site area (Figure 3). The entire profile of this organic soil was fibric without the partially decomposed mesic layers found below 45 centimetres in the type 1 profile.

Table 3. Type 2 soil description for the POOR site area

PROFILE	DEPTH	von POST	pH
Of1	0 - 30	1	4
Of2	31 - 80	2	4
Of3	80 - 100+	3	4

The moisture regime and drainage values were the same as for Type 1, but pH values were lower indicating a more acidic environment. The degree of decomposition for the Type 2 soil profile was not as advanced as for Type 1 resulting in a greater accumulation of peat. Type 2 was clearly a fibric phase of a wet organic soil.

VEGETATION SURVEY

Residual Stand

Stand characteristics

Trees on the GOOD site were generally larger and older than on the POOR site with tree ages varying between 119 and 195 years. Tree ages were not distributed evenly throughout the range, but they were not concentrated around any specific ages. The large range indicates great diversity in ages of trees on the GOOD site (range of 76 years). Many trees on this site had characteristically curved stems at the base which indicates that they originated from layers rather than from seeds. This stand would be classified as an unevenaged stand even though the physical appearance suggests evenaged.

Table 3. Preharvest Forest Conditions.

STAND CHARACTERISTIC	MEAN	S. D.	MIN	MAX	NR. OF TREES SAMPLED
AGE					
GOOD	130.4	19.3	119	195	46
POOR	114.9	5.22	103	119	20
HEIGHT					
GOOD	20.6	2.03	18	24	46
POOR	14	0.65	13	15	20
DBH					
GOOD	23.8	5.75	15	32	46
POOR	18.1	2.73	10	23	20
SITE INDEX (PLONSKI, 1981)					
GOOD 13*					
POOR 7*					

* Based on dominant, uninjured, free growing trees.

Trees on the POOR site were not only younger but ages were also much less variable than on the GOOD exhibiting an age range of 16 years (Table 3). This stand on the POOR site can be classified as an even-aged stand in contrast to the GOOD site. The POOR site stems were straight at the base and were more uniform in height and dbh. This POOR site stand probably originated after wild fire, although no evidence of fire was found.

Seedbed conditions

The residual black spruce stands on both the GOOD and POOR sites were well stocked. Regeneration was sparce with few competing brush species which reflects the limited light as influenced by the dense canopy.

Ground water was close to the surface but did not saturate the site, except for small pools of open water. Sphagnum occupied the edges of the small water pools with the predominant species on the forest floor being pleurozium (Table 5).

Table 5. Distribution of seedbeds in the residual stand expressed in percent cover.

PLOT	NR. OF MATURE TREES / PLOT	PLE	SPH	LED
		(Percentages)		
1 (GOOD site)	4	80	10	10
2 (GOOD site)	6	70	15	15
3 (POOR site)	4	70	10	20
MEAN	4.7	73.3	11.7	15
S. D.	1.15	5.8	2.9	5

PLE- Pleurozium seedbed

SPH- Sphagnum seedbed

LED - Ledum seedbed

In the mature black spruce stands there were few openings caused by tree mortality and these openings provided increased light penetration to the forest floor. These more open conditions were associated with a slightly different seedbed as compared to the seedbeds in the more dense portions of the stand. This less dense area had *Ledum groenlandicum* that overtopped the pleurozium and sphagnum mosses, however, the openings were apparently too small to allow for the development of a speckled alder understory or regeneration.

Clearcut Strips

Removal of the residual stand created a dramaticaly different microenvironment. Most likely, sudden exposure of the forest floor on the strips resulted in increased light, fluctuating daily temperatures and decreased humidity. Ground water levels on these organic soils also tended to rise resulting in open water pools. Accordingly, this changed light, temperature and moisture had a resulting effect on seedbed occurance, regeneration and competing vegetation.

Seedbed conditions

Table 6 lists the seedbed distribution for the 3, 13 and 21-year old strips, and shows significant changes in seedbed distribution when compared to the residual stands (Table 5).

Table 6. Distribution of seedbeds in the 3, 13 and 21 year old clearcut strips expressed in percent cover.

Age of clearcut stips	Seedbed type[1]						
	PLE	SPH	OR1	OR2	LED	DEB	SED
	percent						
3	1.3	58.7	16.5	0.7	14.0	5.3	3.5
13	32.5	33.5	5.8	3.8	11.6	1.8	11.2
21	0	8.3	1.3	81.6	6.3	0.9	1.6

[1] PLE - Pleurozium seedbed
SPH - Sphagnum seedbed
OR1 - Organic type 1 seedbed
OR2 - Organic type 2 seedbed
LED - Ledum seedbed
DEB - Wood debris seedbed
SED - Sedges seedbed

The amount of living pleurozium on the 3 year old clearcut strips was marginal. Most of the pleurozium died following harvesting therefore abundant (16.5 percent) patches of dead pleurozium (OR1) occured.

On the three year old strips sphagnum (SPH) was the predominant seedbed type with 59 percent occupancy. There was also a noticeable increase in the ledum seedbed type (LED) on the edges of strips overlapping the sphagnum moss type (SPH). Three years after cutting there was still some decaying wood debris (DEB), remaining from the logging operations.

On the 13 year old strips there were noticeable changes in seedbed composition. Invasion of light dependent species such as birch, speckled alder, and trembling aspen had created some partial shade on the strips. Under this reduced light pleurozium (PLE) developed and formed 32.5 percent of the seedbeds .

There was also an increase in the occurance of the sedge seedbed type (SED). Sphagnum (SPH) on the 13 year old strips decreased almost by one half when compared to the 3 year old strips. Seedbeds associated with litter of speckled alder and trembling aspen (OR2) became more frequent, illustrating the increased presence of these species.

The twenty one year old strips showed a further decrease in the pleurozium, sphagnum and ledum seedbed types when compared to the 3 and 13 year old strips. In contrast, at 21 years there was a great increase in the litter layer from speckled alder and trembling aspen (OR2). A *chi-square test* of the relative frequency of seedbed types on the 3, 13 and 21 year old strips indicated that the frequency of seedbed type varies by age of strip (see Appendix). The reliability of the test was at the 0.05 level of probability. Changes in seedbed distribution by age of strip are illustrated graphically in Figure 4.

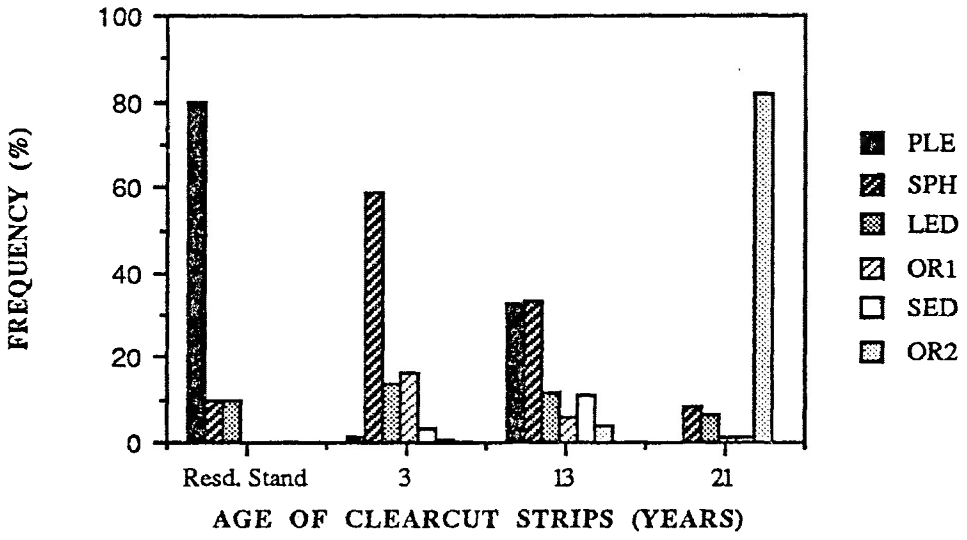

Figure 4. Distribution of seedbed types on the clearcut strips.

Distribution Of Black Spruce Regeneration

Density

Seedbed types had an influence on black spruce regeneration. The relationship of seedbed type and age of strip to the number of spruce seedlings is shown in Table 7.

Table 7. Average numbers of black spruce seedlings per plot on seedbeds by age of strips

Age of clearcut strips	Seedbeds[1]							
	PLE	SPH	OR1	OR2	LED	DEB	SED	TOTAL
3	0	29	8	0	6	2	1	46
13	4	14	1	1	3	3	0	26
21	0	7	0	0	1	1	0	9

[1] PLE - Pleurozium seedbed SPH - Sphagnum seedbed

OR1 - Organic type 1 seedbed OR2 - Organic type 2 seedbed

LED - Ledum seedbed	DEB - Wood debris seedbed
SED - Sedges seedbed	

The number of black spruce seedlings was positively related to the increased occurrence of the sphagnum seedbed type (SPH). Hardwood litter (OR2) and sedges (SED) were inhibiting factors to spruce occurance. Hardwood competition also increases with age of strip therefore, older strips had less spruce regeneration. A *chi-square test* performed on the relative frequency of black spruce regeneration on seedbed types showed that the amount of spruce regeneration on the strips was related to the amount of favourable seedbeds.

There was a negative relationship between age of strip and number of seedlings. Numbers of black spruce seedlings and hardwood competition changed with time (Figure 5). The number of stems per hectare of black spruce dropped from 10,000 on the 3 year old strips to 2,700 on the 21-year old strips. At the same time the number of stems per hectare of competing species (alder, poplar, balsam fir, willow) increased from 2,800 to 4,300 stems per hectare for the 3 and 21 year old strips respectively. The data for 13 year old strips fall in between. A *chi-square* test indicates that the proportion of spruce regeneration in relation to hardwood competition on 3-year old strips is not the same as the proportion of spruce regeneration on 13 and 21-year old strips.

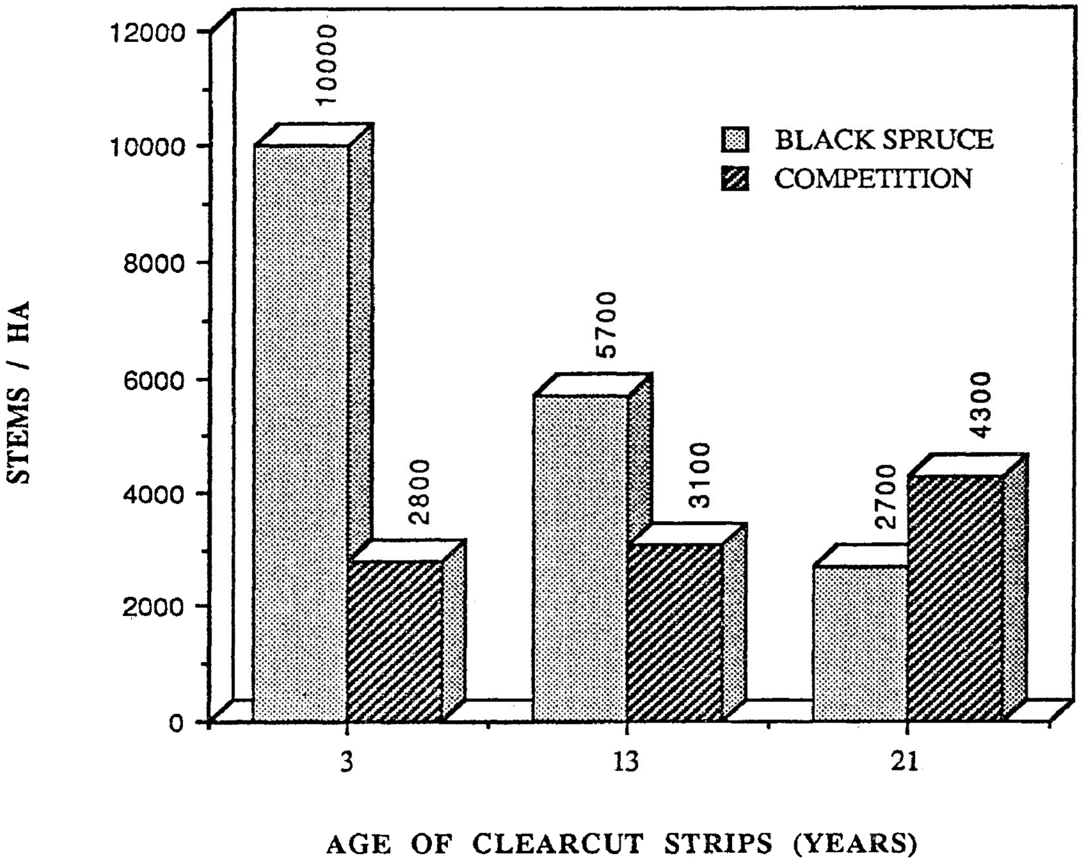

Figure 5. Number of black spruce regeneration and other competing species on the cleacut strips.

Stocking

For the 40 sampling quadrats located on each strip, on average the largest number of quadrats stocked to black spruce occurred on the youngest strips. The average number of spruce decreased with age of strip. A similar decreasing trend is visible when the number of quadrats with dominant black spruce on them is considered. On 3 year old strips 75 percent of the quadrats had black spruce as a dominant species. This percentage dropped to 43 percent on 13 year old strips and to 3 percent on 21 year old strips. The stocking figures were 80, 70 and 50 percent respectively. The overall stocking of black spruce on regenerated strips was 66 percent (Table 8).

Table 8. Black spruce stocking on clearcut strips.

STOCKING	Age of clearcut strips 3	13	21
No. of quadrats stocked to Sb	32	28	20
No. of quadrats with dom. Sb	30	17	1
Percent Stocking	80	70	50
Average stocking on Study Area (%) 66			

Black spruce age structure

Stem analysis of selected black spruce trees provided information on exact age of spruce regeneration.

On every strip there were trees regenerated after harvesting (regeneration) and trees regenerated before harvesting(advanced growth). The proportion of one category of trees to the other varied slightly between strips but was close to 50:50. On the older strips the number of trees in each category decreased, but the proportion between them remained the same.

Figure 6 shows the numbers for the two categories of spruce regeneration present on the strips.

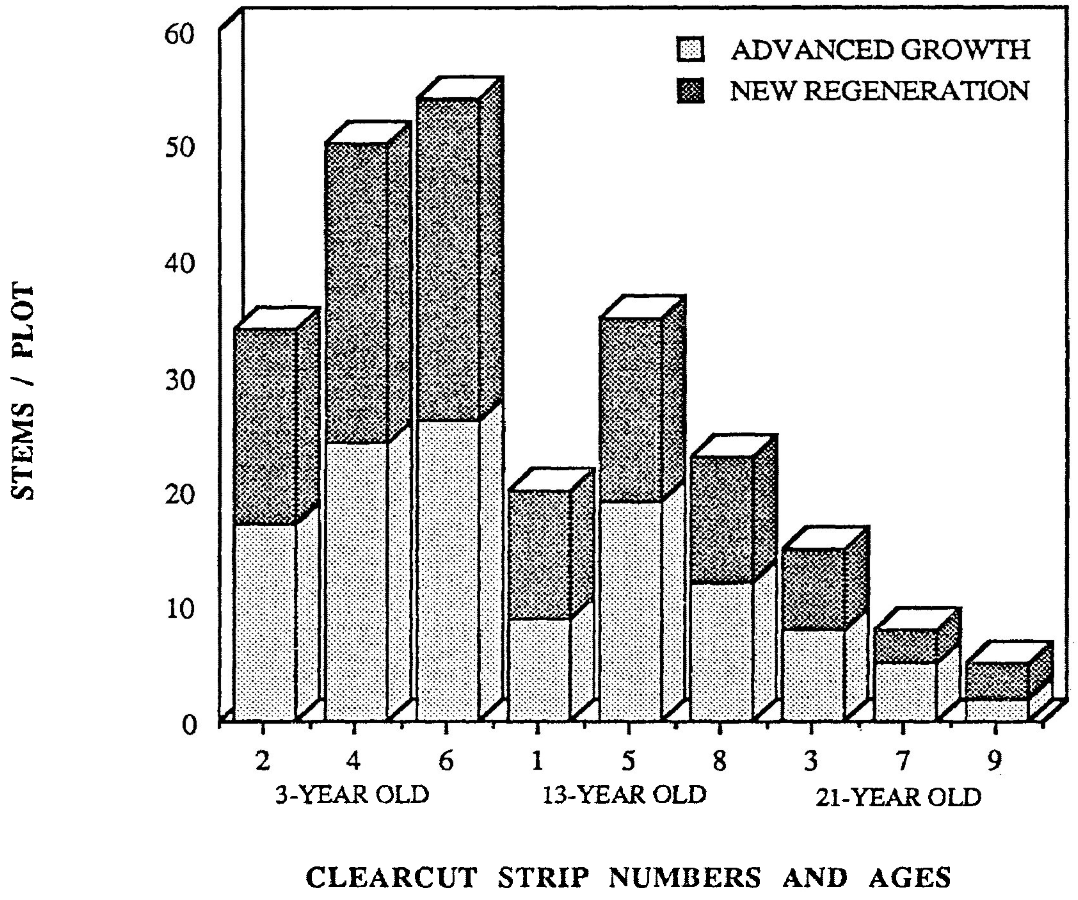

Figure 6. Cumulative total numbers of black spruce regeneration and advanced growth on the clearcut strips.

GROWTH PATTERNS OF BLACK SPRUCE

Height

Coefficients and statistics for the Weibull model (equation 2) fit to data from the different areas are given in Table 9. All coefficients are statistically different from zero with 95 percent confidence.

Table 9. Coefficients for the Weibull function (eq.2) using combined height growth data for all clearcut strips

SAMPLING GROUP	PARAM.	ESTIMATE	STD. ERR.	CONFID. LIMITS	
		OF COEFF.	COEFF.	LOWER	UPPER
Residual Stand On Good Site	ß1	20.3			
	ß2	91.86	0.89	90.1	93.6
	ß3	2.231	0.032	2.17	2.3
Residual Stand On Poor Site	ß1	20.7			
	ß2	105.8	0.49	105	107
	ß3	1.24	0.0059	1.23	1.26
New Forest Regeneration	ß1	20.7			
	ß2	250.26	30.9	182	318
	ß3	0.9282	0.035	0.851	1.01
New Forest Advanced Growth	ß1	20.7			
	ß2	74.19	4	65.9	82.5
	ß3	2.166	0.083	1.99	2.34

The ß1 coefficients governing the upper asymptote of the growth model were kept constant in the model for all sampled groups. The new forest regeneration and advanced growth were assigned the same ß1 coefficient as the residual stands in order to force the model to achieve a realistic height and volume asymptote as the mature stands.

Coefficent ß2 describes the monotonic growth rate <u>after</u> the point of inflection. This indicates that the height growth rate was highest for the new forest regeneration and lowest for the advanced growth .

The third coefficient, ß3 defines the allometric increase in growth <u>before</u> the point of inflection. This was lowest in the new forest regeneration i.e. the growth rate was high, therefore, early suppression was insignificant. The residual stand on the GOOD site (Figure 7) and the advanced growth (Figure 10) displayed large ß3 coefficients thus indicating a similar slow rate of early growth . Figures 7 and 10 illustrate the relationships and trends described above.

Comparison of the coefficient confidence limits between sampling groups provides information on the similarity between sampling groups. The coefficients were considered not to be statistically different if the confidence limits for a given coefficient overlapped another sampling group. Inspection of the ß2 and ß3 coefficients (Table 9) shows, that the coefficients from each sampling group are statistically different from each other.

Figure 7 represents the average height growth pattern of dominant trees on the GOOD site (solid line); dotted lines indicate site class curves by Plonski (1981) for black spruce. The field survey using dominant trees indicated that the site index value for the GOOD site was 8 m. This site index would be the case if the height growth patterns resembled the site index 8 line of Plonski's site index curves. However, stem analysis of 5 dominant trees on this site showed a much different pattern of height growth than predicted by Plonski.

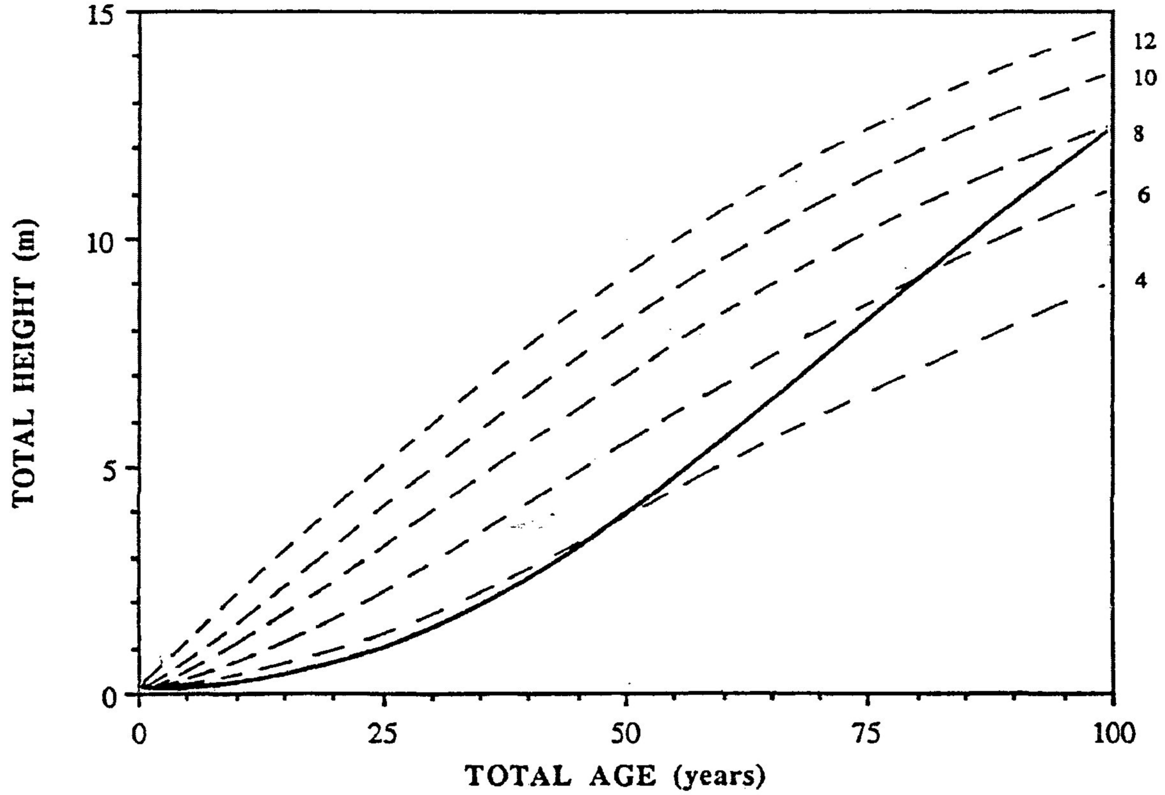

Figure 7. Average height growth pattern of dominant trees on GOOD sites in the residual stand. Also shown are Plonski (1981) site class curves (dotted lines)

Dominant trees on this site had very slow initial growth and 28 years were needed to reach breast height. In contrast, the Plonski curves indicate that only eleven years were required for site index 8 trees to reach breast height (Figure 7). This slow initial height growth on this site indicates a severe case of early suppression. Trees displayed a height growth pattern similar to the Plonski site index line 4 until 35 years of age. However, at 35 years height growth increased indicating that trees were growing free of suppression. Despite the slow initial height growth trees were vigorous enough to cross the site index 8 line at age 100; trees reached a height of 14.2 metres at age 100, and reached a height of 21.3 metres at age 141.

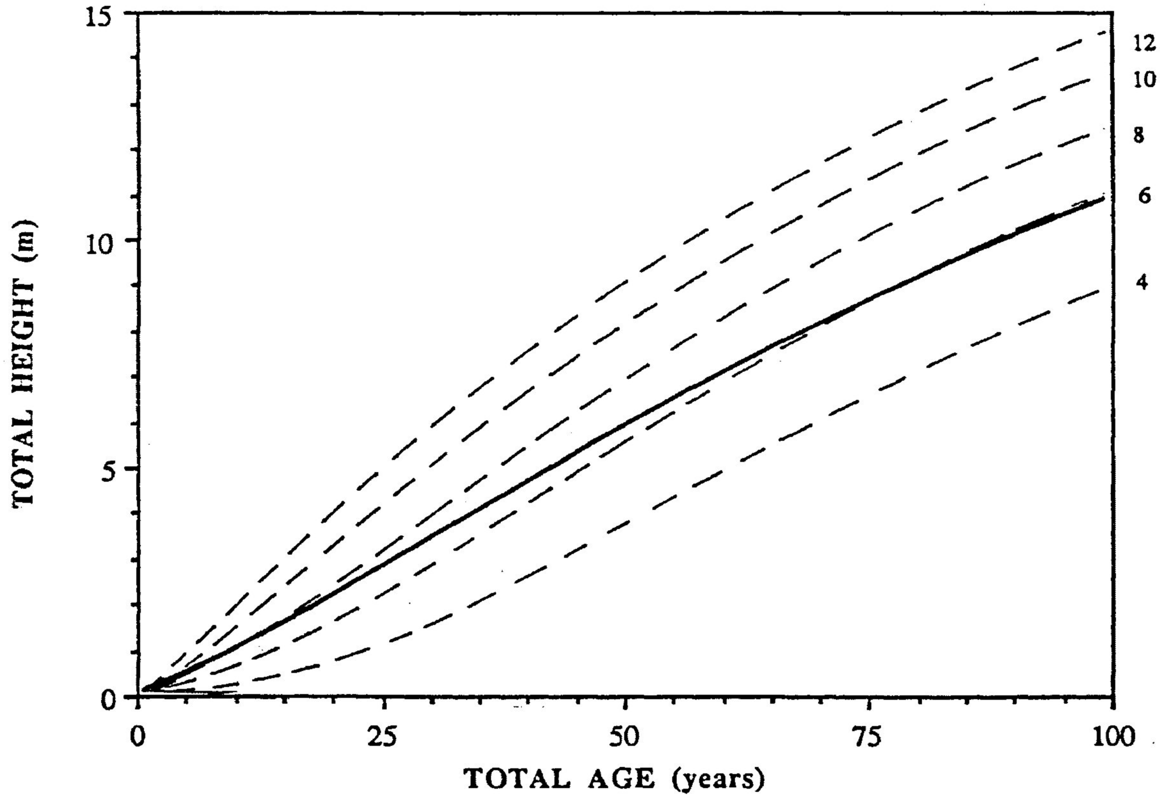

Figure 8. Average height growth pattern of dominant trees on POOR sites in the residual stand. Also shown are Plonski (1981) site class curves (dotted lines) formulated using Ek's equation.

Dominant trees on the POOR site had a steady rate of height growth throughout all their life (Figure 8), unlike the trees on the GOOD site. They reached breast height at age

12 and continued to grow at a constant rate until age 55; at age 50 dominant trees were 6 metres tall, thus indicating a site index of 6 metres (Table 4). After age 55 height growth slowed and eventually reached 13.2 metres at age 116. The height growth pattern on this POOR site closely resembled the site index 6 line of Plonski (Figure 8).

There is no evidence of suppressed height growth for these POOR site trees. The slower rate of height growth after 50 years is the normal height growth pattern for older trees. In contrast, trees on the GOOD site showed an increased rate of height growth at 50 years indicating that they were recovering from suppression.

Basing height growth curves and site index on breast -height eliminates the suppressed early height growth observed on the GOOD site resulting in a more regular and consistent growth pattern (Figure 9). When these breast -height age curves are used we can estimate that this GOOD site has a site index about 10 metres. The height -growth curve for the POOR site based on breast height age also eliminated some early, slow, and erratic growth. Thus, site index for the POOR site is estimated to be about 8 metres based on breast -height age (Figure 9). The field survey indicated a site index of 7 metres for this POOR site (Table 4).

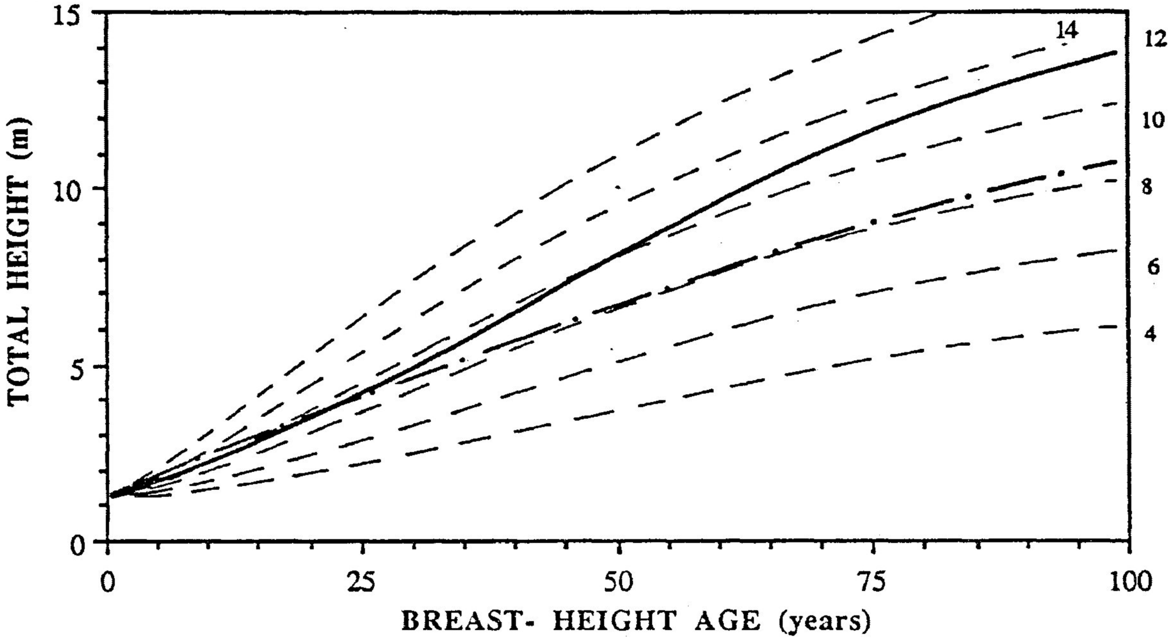

Figure 9. Height growth curves for dominant black spruce trees from GOOD (solid line) and POOR (dotted line) sites when curves are based on breast height age. Also shown are site index curves for black spruce in the Thunder Bay area (Thrower, 1986).

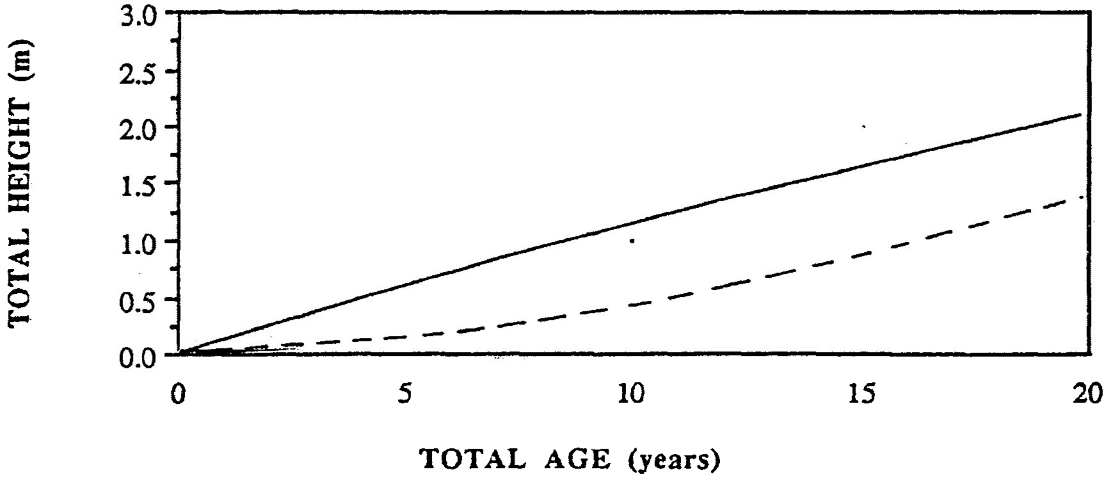

Figure 10. Height growth patterns of new regeneration (solid line) and advanced growth (dashed line) based on stem analysis of selected trees on the strips.

Stem analysis for selected trees on the strips is shown in Figure 10. Preliminary analysis based on an inspection on height-age curves for each sampled tree showed overlapping thus indicating that height growth on both the GOOD and the POOR site was similar. These comparisons indicated that differences found in height growth were not due to site quality. Thus all trees on the strips were divided into recent regeneration and advanced regeneration regardless of wheather they came from the GOOD site or the POOR site. The uppermost line in Figure 10 represents height growth of newly regenerated trees on the strips. These trees do not show suppression in height growth. These are free growing dominant trees in areas free of hardwood competition; these trees reached breast height in about 12 years.

The lower line represents the height growth pattern of advanced regeneration on the strips. Trees from this group grew for almost half their life under severe suppression. For about the first 10 years they were growing under the canopy of the residual stand. After the removal of this canopy trees accelerated in height growth; breast height was reached at age 22 on the average.

The ß2 and ß3 coefficients for the regeneration and the advanced growth are statistically different (Table 9).

Volume

The Weibull model (Equation 2) was fit to the volume growth data for trees cut from the various areas. Coefficients for these volume growth equations are given in Table 10 where it can be seen that volume growth prediction models were different for each sampling group, but similarily to height growth models, some phases of growth are similar..

For example, the ß2 coefficients are statistically similar for the residual stand on the GOOD site and for the regeneration thus indicating similar growth after the point of inflection. ß3 coefficients for the advanced growth and for the residual stand on the GOOD site also were similar thus indicating similar initial growth for these two sampling groups. Apparently trees on these two groups were similarily suppressed for several years after establishment (Figures 11 and 12).

Table 10. Coefficients for volume growth prediction models

SAMPLING GROUP	PARAM.	ESTIMATE OF COEFF.	STD. ERR. COEFF.	95 % CONFID. LIMITS	
				LOWER	UPPER
Residual Stand On Good Site	ß1	242.5			
	ß2	95.29	0.469	94.4	96.2
	ß3	5.74	0.0511	5.64	5.84
Residual Stand On Poor Site	ß1	230.4			
	ß2	118.03	1.28	115	121
	ß3	2.416	0.0298	2.36	2.48
New Forest Regeneration	ß1	242.5			
	ß2	123.6	14.9	91.1	156
	ß3	3.15	0.168	2.78	3.52
New Forest Advanced Growth	ß1	242.5			
	ß2	73.61	3.74	65.8	81.4
	ß3	5.99	0.249	5.48	6.51

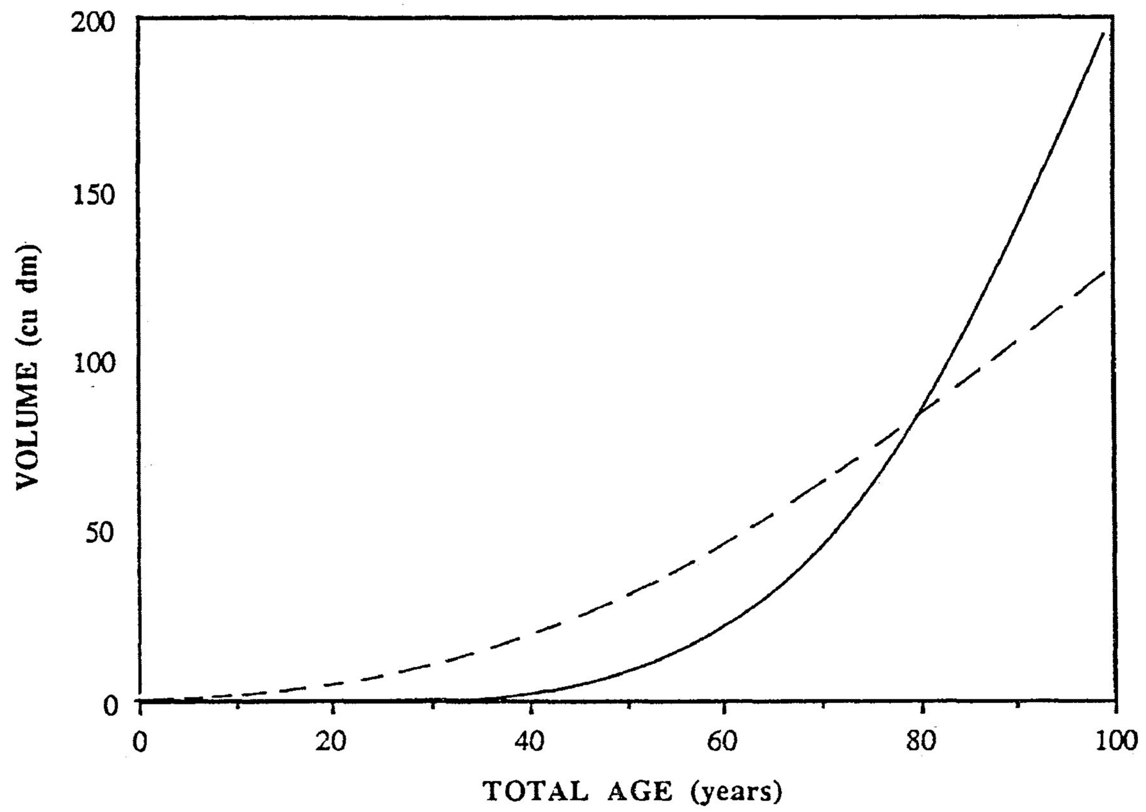

Figure 11. Volume growth curves for residual stand on the GOOD site area (solid line) and on the POOR site (dashed line)

The resultant patterns of volume growth for the dominant trees were similar to their height growth patterns (Figures 7 and 8). The POOR site trees in the residual stand slowly increased in both height and volume growth having almost a linear increase until age 100. This uniform but slow rate of volume growth attained a relatively low dominant tree volume of 120 cubic decimetres at 100 years (Figure 11).

Dominant trees from the GOOD site in the residual stand showed that the effect of early suppression on both height growth and volume growth was significant. By age 35 both heigh growth and volume growth rapidly accelerated and continued until age 100. By age 80 volumes of dominants for the GOOD and the POOR sites were equal; at age 100 years trees on the GOOD site were 200 cubic decimetres in volume. Thus, at 100 years the GOOD site provided volumes 60 percent greater than trees on the POOR site even though these GOOD site trees were severily suppressed until 35 years of age.

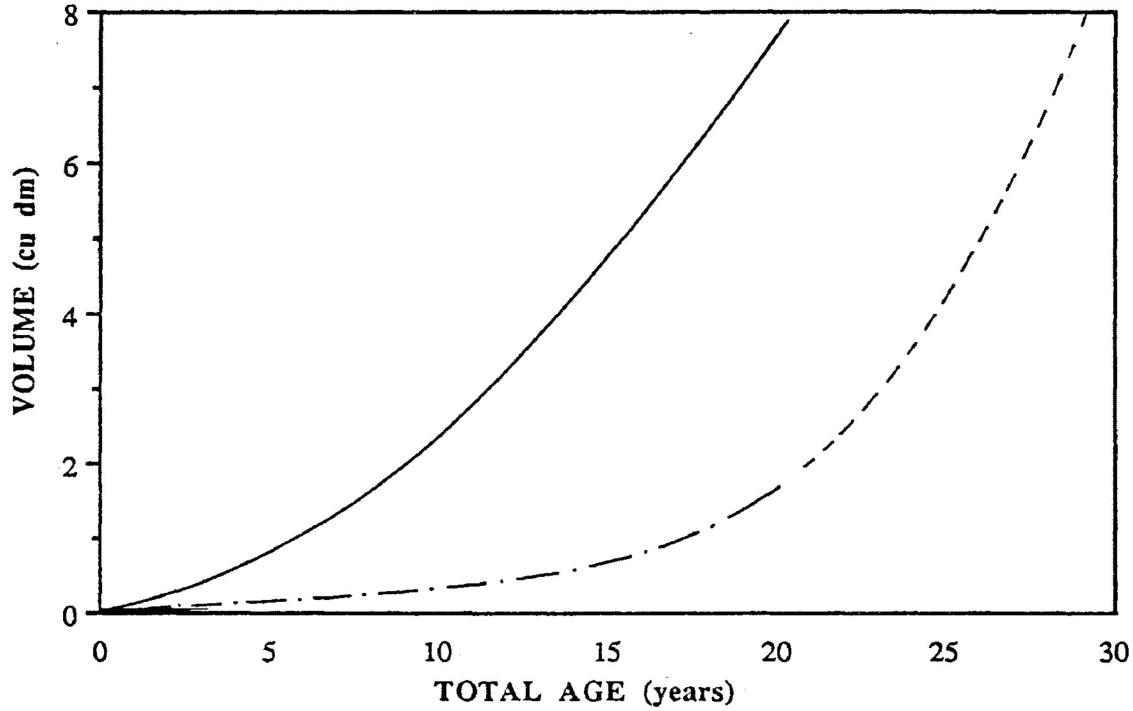

Figure 12. Volume growth curve for new regeneration (solid line) and for advanced growth (dashed line) on the clearcut strips

Volume growth curves for both new regeneration and advanced regeneration on the strips were also computed. More rapid growth of new regeneration resulted in a significantly greater volume of wood in the first 21 years in contrast to the slower growing advanced regeneration trees. Advanced regeneration was suppressed and had slow volume growth for the first 21 years. But at age 17, volume rate of growth of this advanced regeneration increased. Volume growth thus may eventually be similar for both new regeneration and advanced regeneration. Volume growth was extrapolated from age 21 to age 30 in Figure 12.

TESTING FOR GOODNESS OF FIT

The height and volume growth curves were validated for possible estimation errors. The procedure for testing goodness of fit for the Weibull model (equation 2) follows those of Freese (1960). The *chi-square* test fulfills three requirements: (a) it provides a statement of accuracy desired, (b) it measures accuracy attained, and, (c) it provides an objective method for deciding if the accuracy attained is equal to the accuracy required. The *chi-square* test rejects an inaccurate technique regardless of the source of error. The model was assumed adequate unless there was evidence to the contrary. For Freese's procedure the null hypothesis tested was:

$$Ho : E(D)=0 \; ; \; VAR(D) < e^2/X^2(1-a)(1)$$

where: $a=0.05$

E(D)- inherent bias of the model

e- acceptable error set by the user

$X^2(1-a)(1)=(1-a)$- 100 percent quantile with (1) degree of freedom.

The test statistic was used as the measure of accuracy for the model. If E(D) =0 and $VAR(D)=e^2/X^2(1-a)(1)$ then the test statistic

$$X^2(1-a)(n)=S\ Di^2 X^2(1-a)(1)/e^2$$

had a *chi-square* distribution with n degrees of freedom. The null hyphotesis was rejected at the 0.05 level of significance if the calculated statistic exceeds the tabulated value of $X^2(1-a)(n)$.

The height growth and volume growth models were tested for goodness of fit using the null hypothesis. Results for height growth and volume growth are presented in Table 11 and 12, respectively.

Table 11. Standard *chi-square* test for estimated HEIGHT within 'E'(accuracy) units of desired height.

DATA SET	ACCURACY (m)	D. F.	CHI - SQUARE CALCULATED	CHI - SQUARE TABULAR
Residual Trees On Good Site	0.25	58	62.3	76.77
Residual Trees On Poor Site	0.15	58	35.7	76.77
New Forest Regeneration	0.1	16	7.3	24.71
New Forest Advanced Growth	0.15	18	14.2	28.58

Table 12. Standard *chi-square* test for estimated VOLUME within 'E'(accuracy) units of volume.

DATA SET	ACCURACY (m)	D. F.	CHI - SQUARE CALCULATED	CHI - SQUARE TABULAR
Residual Trees On Good Site	0.3	58	56.5	76.77
Residual Trees On Poor Site	1.2	58	26.28	76.77
New Forest Regeneration	0.02	15	7.8	24.21
New Forest Advanced Growth	0.03	18	22.7	28.58

For the specified accuracy the calculated test statistic did not exceed the tabulated value in any case. Thus, it was calculated that the applied models of height growth and volume growth adequately described the data with the probability of a Type 1 error at 0.05percent.

CHAPTER 5

DISCUSSION

SOIL DESCRIPTION

There are two different soil types present on the study area that provide different conditions for growth of black spruce. The southern part of the study area is a POOR site that is laid close to the centre of the swamp. In contrast, the northern part is a GOOD site that is close to the swamp perimeter. The differences in productivity as expressed by black spruce height and volume growth follow a characteristic pattern described by LeBarron (1948).

The most significant difference between the two soil types was the degree of decomposition of organic substances at depths greater than 50 centimetres. Roots of regenerated black spruce do not usually reach that depth, therefore, establishment and initial growth probably are not influenced by site productivity. In contrast, the growth of trees in the mature residual stand are profoundly affected by these soil differences.

VEGETATION SURVEY

Residual Stand

Growth and yield in the two mature black spruce stands was influenced by site conditions (expressed by site index values), and also by conditions of early establishment that are independent of site quality. These establishment conditions were associated with the presence of a fire on the POOR site, and by the lack of fire on the GOOD site.

The POOR site residual stand was an even-aged stand because stem analysis shown that regeneration was completed in no more than 16 years, similarily to the findings of MacArthur (1964). Trees apparently originated from seeds, and did not experience early suppression and competition from hardwoods. In contrast, the GOOD site stand was not affected by fire; this is characteristic of the patchy character of forest fires in lowland areas. This stand was distinctly uneven-aged and the bole form of trees as well as very slow early height growth shown by stem analysis suggest that most of the trees originated by means of layering. This type of reproduction is very common in black spruce stands in Northern Quebec and Ontario (Stanek, 1968). Open stand conditions created by natural mortality in the GOOD site stand favoured this type of regeneration.

The predominant seedbed under the mature stands was pleurozium (PLE). This moss cannot endure direct sunlight, therefore, but grows well under dense canopy conditions. Lack of spruce regeneration by seed can be explained by the predominant presence of pleurozium that forms a dry, poorly decomposed organic layer, that is an unfavourable seedbed.

Clearcut Strips

Removal of the spruce overstory stimulated a series of significant seedbed changes that also resulted in large differences in regeneration and early growth of black spruce. Sudden exposure of the forest floor when the clearcut strips were made resulted in increased light and daily temperatures and decreased humidity. Clearcutting also probably raised ground water levels on these organic soils resulting in local poorly drained depressions. This changed light, temperature and moisture environment had a profound effect on post cut seedbeds.

The major seedbed changes during the 21 year period after cutting were as follows:

1/ Before clearcutting, the understory of the residual forest was dominated by pleurozium (PLE). However, soon after clearcutting the pleurozium dies resulting in many patches of dead moss. The strips were then invaded by sphagnum mosses and labrador tea.

2/ Within 5-10 years the strips were invaded by hardwood species that changed the amount of light and litter reaching the forest floor. This favoured the invasion of pleurozium moss and caused a gradual decrease in sphagnum moss.

3/ By 20 years the hardwoods on the strips had a closed canopy and hardwood litter covered the forest floor inhibiting the development of other seedbeds. Soon after clearcutting there was a great variety of seedbeds, but by 20 years after cutting the hardwood litter (OR2) seedbed dominated the strips and only a few other seedbeds remained.

There is a strong relationship between seedbed type and the presence of black spruce regeneration (Table 6). The favourable seedbeds found in this study were generally the same as reported by Van Nostrand (1961) in Newfoundland, by Jarvis and Cayford (1961) in Manitoba, and by Jeglum (1978) in his greenhouse experiment. Suitability of favourable seedbeds to support establishment and early growth of black spruce is as follows in descending order of importance: slower growing species of sphagnum, moist wood debris, ledum, organic soil, pleurozium, sedges, hardwood litter.

The youngest strips had the greatest number of seedbeds favourable for spruce regeneration while, in contrast, the older strips were less favourable seedbeds . As a direct result of hardwood competition and by limited area of favourable seedbeds, the amount of spruce regeneration dropped significantly from the 3 year old strips to the 21 year old strips (Table 7).

Density and stocking of black spruce regeneration (Table 8) decreased with time indicating that the initial good establishment of spruce was later inhibited by competing hardwoods. These hardwood species influenced black spruce regeneration in two ways. First, invasion of hardwoods on the clearcut strips changed seedbed types from favourable to unfavourable for spruce germination. Secondly, suppression by hardwoods resulted in decreased height and diameter growth of established spruce regeneration. Decreased area of favourable seedbeds resulted in a decreased number of new spruce seedlings every year following clearcutting. Hardwood competition caused changes in the height and volume growth pattern of seedlings and resulted in increased seedling mortality . As a result, the number of spruce trees on the clearcut strips decreased over time.

Stocking values for regeneration on the 3,13 and 21 year old clearcuts were satisfactory by standards applied on Crown lands in Ontario. If stocking assessments were completed in the 5th year after establishment would probably have resulted in values between 70 percent and 80 percent for these clearcut strips. However, this study shows greatly decreased stocking of spruce in the older aged strips, and this decrease will probably result in the future failure of natural regeneration. This failure would occur in the absence of tending because of suppression from hardwood species.

The OMNR Stocking Guidelines for North Central region require at least 40% stocking, a minimum height of 1m, and the lack of an overtopping competing canopy 8-12 years after cutting. Results of this study shows that 13 years after cutting black spruce regeneration had met the MNR stocking and height requirements, however, this study also shows that spruce trees were increasingly overtopped by competing hardwoods and were outnumbered and severely suppressed by age 21.

Spruce regeneration ages were based on annual ring counts and on branch whorl counts. Trees classified as new regeneration (see Methods chapter), were the same age as clearcuts or were up to 4 years younger. These regeneration measurements showed an absence of trees established later than 4 years after disturbance thus indicating that no new trees were established later than 4 years after clearcutting. Probably the combination of hardwood competition and decreased area of favourable seedbeds are responsible for the lack of new regeneration on strips that are older than four years after cutting.

Measurements also showed that many understory trees were older than the clearcuts and this regeneration was classified as advanced growth. Advanced growth on all clearcut strips formed about one half of the black spruce regeneration. On the 3 year old clearcut strips advanced growth of black spruce was outnumbered by new black spruce regeneration because seedbed conditions were favourable immediately following cutting. Advanced growth of spruce on these strips was substantial, however, and was close to one half of the spruce present on the 3 year old strips. Abundant advanced growth on the strips may be related to substantial amounts of light received on both edges of the residual stand before cutting that is due to the closeness of nearby clearcut strips. Thus, increased light from nearby strips stimulated establishment of advanced regeneration before the strips were cut.

The 13 year old clearcut strips were often the first openings in the residual stand and thus were not bordered by recently cut strips. Therefore, there was less light to the forest floor from bordering strips, thus fewer numbers of advanced growth was established. Presence of advanced growth on these strips also was favoured by disturbance resulting from passing logging equipment that compacted the moss thus favouring regeneration; a few openings also were made on this strip prior to final removal of stand. Because of these disturbances the amount of advanced growth on 13 year old strips was on average similar to the amount on the 3 year old strips. But the amount of new regeneration is somewhat lower than on the 3 year old strips, due to greater mortality from greater hardwood competition .

The 21-year old clearcut strips had far fewer black spruce than did the younger strips probably due to increased competition. Also there was substantially less advanced growth on these older clearcut strips than on the 3 and 13 year old clearcut strips. Stem analysis for the regeneration indicated that almost all of the advanced regeneration was older than 30 years ("residuals") and was probably established from layers. After the canopy was removed this advanced regeneration showed increased growth.

These proportions of advanced growth to new regeneration were similar to results reported by Haavisto (1979) and Fraser *et al.*(1976). Advanced growth was most abundant on the organic soils that are wet and poor in nutrients. There are no data showing how much advanced growth might have been destroyed during harvesting operations when the clearcut strips were made, however, cuts were done in the winter so losses of advanced growth were probably minimal. Haavisto (1979) suggests that only winter harvesting should be practiced in stands with a large amount of advanced growth.

GROWTH PATTERNS OF BLACK SPRUCE

Height growth and volume growth curves developed from the stem analysis show that there were two different residual stands and two different sites on the study area. The uneven-aged black spruce stand growing on the GOOD site had trees of various ages and sizes. Stem analysis showed that dominant trees from this stand had very slow early growth (Figure 7). This slow early growth was observed by Groot (1984) as characteristic for advanced regeneration developed from layerings. These layerings on the study area were probably growing under a canopy of a mature stand for many years as shown by the initial slow height and volume growth patterns (Figures 7, 10, 11). These suppressed trees reached breast height after 25 years of growth. In contrast, for the even-aged stand on the POOR site only 10 years was required for black spruce to reach breast height. Suppressed trees such as occur on GOOD site were not suitable for use in estimating site index. When the height growth curves were compared to the 'normal' growth patterns (Plonski, 1981), it was found that site index was estimated to be only 4 metres. In contrast, when early suppression was avoided by basing curves on breast height age it was found that site index of dominant trees on the GOOD site was10 metres (Figure 9).

Early suppression of height and volume growth occured in the uneven-aged stand on the GOOD site resulting in loss of wood volume that might have been produced by freely growing trees that utilize fully the productive potential of the site. For example, the dominant trees on the POOR site were less suppressed during early years of development and thus in the first 50 years were able to produce more wood than the dominant trees on the GOOD site. If the dominant trees on the GOOD site had been free growing this area could have produced much greater volumes.

Height and volume growth patterns of both new regeneration and advanced growth on the clearcut strips had growth patterns similar to those observed in the residual stands. Black spruce trees established beneath the residual stand canopy as advanced regeneration were growing suppressed for many years. After these trees were released by clearcutting, height and volume growth was greatly accelerated. Growth patterns of this released advanced growth on the strips was similar to the growth pattern of dominant trees in the residual stand growing on the GOOD site.

New black spruce regeneration established on the clearcut strips did not show early suppression. This new regeneration had rapid height and volume growth patterns for the first 20 to 30 years similar to the dominant trees on the POOR site. This new spruce regeneration was growing faster and produced more wood than did the advanced growth on clearcut strips. Early height and volume growth for new regeneration was similar for trees on both the GOOD site and the POOR site.

SUMMARY AND CONCLUSIONS

The preliminary analysis demonstrated that the study area has two distinct site types. These site types were differentiated by thickness of organic layer and by the degree of decomposition, as well as the growth characteristics of residual, mature black spruce. Growth and development of the black spruce natural regeneration has not been influenced by soil differences in the same two site types.

The study demonstrated that there are profound changes in the composition of seedbeds following removal of trees from the site. These changes were favourable for natural regeneration of black spruce as slow growing sphagnum mosses replaced dry pleurozium. Changes in seedbeds continued over the years with the general trend of seedbeds becoming less diversified and less favourable to black spruce regeneration. The optimum time for spruce to regenerate is when there is an abundance of favourable seedbeds in particular sphagnum and very limited hardwood competition. This period extended for approximately ten years following harvest.

The study has shown that the occurance and abundance of favourable seedbed types decreased on older cutover strips. Also, the number of regenerated black spruce decreased on older clearcut strips as compared to more recent cutovers. Therefore, the mortality of spruce regeneration occurred in relation to depletion of favourable microsites.

Hardwood competition has been an increasing detrimental factor in the development of spruce regeneration. The proportion of black spruce regeneration to hardwood competition changed from favourable for black spruce on young cutover strips, to unfavourable, causing severe suppression and mortality on older cutover strips.

The stocking assessment of black spruce regeneration demonstrated a decrease in overall stocking levels to an almost unacceptable level on the oldest cutovers dominated by hardwood competition.

Two types of natural regeneration of black spruce were identified: advanced growth and new regeneration. It was found that roughly the same amount of black spruce was represented on clearcut strips by advanced growth as by post-cut , new regeneration. This proportion did not change with increasing age of clearcuts. Both groups were impacted by the detrimental effect of hardwood competition.

Early suppression of the mature stand on the GOOD site accounted for initial low production of wood. Advanced growth showed similar early suppression. However, after overcoming this initial suppression period advanced growth performed similarily to the post-cut regeneration. Also the same trend in height and volume growth was observed in trees on the GOOD site once they pased the early suppression period. Site quality did not influence the growth of regeneration. If the same pattern of growth of mature trees occurs to rotation as was expressed in the two site types it is reasonable to expect that the POOR site new forest will have a lower yield than the GOOD site.

Initial regeneration of black spruce on the clearcut strips met stocking criteria for satisfactory regenerated sites. However, measurements on the 13 and 21 year old strips showed increased dominance by hardwoods and decreasing numbers and vigour of black spruce regeneration. Accordingly, it seems evident that by 20 years black spruce on untended clearcut strips will fall to a level below that which is considered satisfactory. Silvicultural treatments, possibly chemical release of regeneration from competing hardwoods should be considered before regeneration reaches 14 years.

This study demonstrates that utilizing narrow, progressive clearcut strips and control of competition will produce a well stocked new forest as productive as the old forest on lowland, conifer site types.

LITERATURE CITED

Alban, D.H. and D.H.Prettyman. 1984. Height growth of red pine on fine-textured soils. USDA For. Serv. North Cent. For. Exp. Stn. Res. Pap. NC-249.,6p.

Alexander, R. R. 1968. Natural reproduction of spruce - fir after clearcutting in strips, Fraser Experimental Forest. USDA. For. Serv. Rocky Mtn.For.and Range Exp. Stn. Serv. Res. Note RM - 101. 4 p.

Aksamit, S. E. and F.D.Irving. 1983. Prescribed burning for lowland black spruce regeneration in Northern Minnesota. Can. J. For. Res. 14 : 107 - 113.

Baldwin, V. E. Jr., 1977 Regeneration following shelterwood cutting in a New Brunswick Softwood Stand. Can. For. Serv. Marit. For. Res. Centre. Inf. Rep. M - X - 76. 23 p.

Bellefeuille, R. 1935. La production des peuplements d'epinette noire dans les forets du Nord - Quebec. For. Chron. 11 : 323 - 379.

Buckman, R. E. and A. E.Schneider 1952. Regeneration following cutting in black spruce swamps. Univ. Minn. Sch. For., Note 42. 8 p.

Canada Soil Survey Committee, Subcommittee on Soil Classification. 1978. The Canadian system of soil classification. Can. Dep. Agric., Ottawa, Ont. Publ. 1646. 164 p.

Carmean, W.H. 1972. Site index curves for upland oaks in the Central States. For.Sci. 18:109 - 120.

Clark, M. B. and A McLean. 1975. Growth of lodgepole pine seedlings in competition with different densities of grass. British Columbia For. Serv. Res. Note 70, 5 p.

Clarke, F.R. 1972. A comparison of sampling designs for regeneration cruising. Univ. Toronto. Fac.For., 34 p.

Clarke, F.R. 1975. Root texture: an Important Factor in Survival and Growth of Outplanted Black Spruce. Univ. Tor., M.Sc.F. Thesis., 69 p.

Conway, and M. Verona . 1949. The bogs of Central Minnesota. Ecol. Monog. 19 : 173-206.

Daniel, C.and F.S.Wood. 1980. Fitting Equations to Data , Computer Analysis of Multifactor Data.(2nd ed.),John Wiley and Sons, New York, 458 p.

Dansereau, P. and F. Segadas-Vianna. 1952. Ecological study of the peat bogs of eastern North America. Can. J. Bot. 30 : 490 - 520.

Dickson, W.A., and D.E. Nickerson. 1958. Factors affecting natural regeneration on cut-over and burned-over lands, Newfoundland. Can. Dep. North. Aff. Nat. Resour:, For. Br., For. Res. Div. Mimeo S&M 58-3. 16 p.

Fleming, R.L. and R.M. Crossfield. 1983. Strip cutting in shallow-soil upland black spruce near Nipigon, Ontario. III windfall and mortality in the leave strips: preliminary results. Dep. Env. Can. For. Serv. Inf. Rep. 0-X-354. 27 p.

Fox, G.D. and G.W. Kruze. 1939. A yield table for well-stocked stands of black spruce in north-eastern Minnesota. J. For. 37: 565-567.

Fowells, H. A. 1965. Silvics of forest trees of the United States pp.282-929, USDA For.Serv.Handb. 271, Washington, D.C., 762 p.

Fraser,J.W., V.F. Haavisto, J.K. Jeglum, T.S. Dai. and D.W. Smith. 1976. Black spruce regeneration on strip cuts and clearcuts in the Nipigon and Cochrane areas of Ontario. Dept.Env.,Can.For.Serv.,Rep. 0-X-246, 33p.

Freese, F. 1962. Elementary forest sampling. USDA. For. Serv., Agric. Handbk. 232, Washington, D.C.,91 p.

Genovese, G.A. 1977. Site type relationships of logged and unlogged productive forest land in the Kapuskasing district. Ontario Ministry of Natural Resources, 53p.

Gevorkiantz, S.R. 1957. Site index curves for black spruce in the Lake States. USDA For.Serv. Lake States For. Exp. Stn. Tech. Note 475, 2p.

Groot, A. 1984. Stand and site conditions associated with abundance of black spruce advance growth in the northern clay section of Ontario. Can. For. Serv. Inf. Rep. 0 - X - 358. 15 p.

Haavisto, V. F. 1975. Peatland black spruce seed production and dispersal in North Eastern Ontario. p. 250 - 264 *in* Black Spruce Symp. Can. For. Ser. Symp. 0 - P - 4., Sault Ste.Marie, Ont., 289 p.

Haavisto, V.F. 1979. Some considerations for regenerating black spruce on peatlands in the northern clay forest section , Ontario. Dept. Env.,Can.For.Serv.,Rep. 0-X-295, 31p.

Heinselman, M. L. 1955. Natural regeneration of swamp black spruce in Minnesota under various cutting systems. USDA. For. Serv., Prod. Res. Rep. 32., St.Paul, MN., 32 p

Heinselman, M. L. 1957. Wind - caused mortality in Minnesota swamp black spruce in relation to cutting methods and stand conditions. Proc. Soc. Amer. For. 74 - 77.

Heinselman, M. L. 1957a. Living sphagnum found most favourable seedbed for swamp black spruce in Minnesota study. USDA For.Serv., Lake States For. Exp.Stn., Tech. Note No.504. 2 p.

Heinselman, M.L. 1957. Silvicultural characteristics of black spruce (Picea mariana). USDA For.Serv.,Lake States For.Exp.Stn. Pap.No 45, St.Paul, MN., 30 p.

Heinselman, M.L. 1959. Natural regeneration of swamp black spruce in Minnesota under various cutting systems. USDA Prod. Res. Rep. 32, St.Paul, MN., 22 p.

Hills, G. A. and A.N. Boissoneau. 1960. The Glackmeyer report of multiple land-use planning. Ont. Dept. Of Lands And For. Res. suppl. 112-210.

Horton, K. W. and J.C. Lees. 1961. Black spruce in the foothills of Alberta. Can. Dep. For. For. Res. Br. Tech. Note. 110, 54 p.

Hosie, R. C. 1954. The regeneration of cutover areas. For. Chron. 30 : 128 - 130.

Jarvis, J. M. and J.H. Cayford. 1961. Regeneration following various methods of cutting in black spruce stands in Manitoba. For. Chron. 37 : 339 - 349.

Jeglum, J.K. 1971. Plant indicators of pH and water level in peatlands at Candle Lake, Saskatchewan. Can. J. Bot. 49: 1661-1676.

Jeglum, J.K. 1974 . Relative influence of moisture-aeration and nutrients on vegetation and black spruce growth in northern Ontario. Can. J. For. Res. 4:114-126.

Jeglum, J.K. 1979. Effects of some seedbed types and watering frequencies on germination and growth of black spruce : a greenhouse study. Dept.Env., Can.For.Serv.,Rep.0-X-292, 33p.

Jeglum, J.K. 1980. Strip cutting in shallow -soil upland black spruce near Nipigon, Ontario. I. Study establishment and site conditions. Dept.Env.,Can.For.Serv.,Rep.0-X-315, 61p.

Jeglum, J.K. 1981. Black spruce seedling growth and nutrition on sphagnum and feather moss peats from a Northern Ontario peatland. Dept.Env.,Can.For.Serv.,Rep.0-X-326, 20p.

Jeglum, J.K. 1982. Strip cutting in shallow-soil upland black spruce near Nipigon, Ontario. II. Regeneration in the first study area. Dept.Env.,Can.For.Serv.,Inf.Rep. 0-X-337, 24p.

Jeglum, J.K., A.N. Boissonneau, V.F. Haavisto. 1974. Towards a wetland classification for Ontario. Dept.Env.,Can.For.Serv.Inf.Rep. 0-X-215, 54p.

Johnson, H. J. 1956. Some aspects of black spruce reproduction in the central Boreal Forest Region Of Manitoba, Canada. Dept. North. Aff. and Nat. Res. For. Br. For. Res. Div. S & M. 56 - 3. 15 p.

Johnson, E. R. 1979. Fire reoccurrance in the subarctic and its implications on vegetation composition. Can. J. Bot. 57 : 1374 - 1379.

Johnston, W. F. 1968. Lowland brush in clearcut spruce swamps develops from residual vegetation - not from invasion. J. For. 66: 566 - 567.

Johnston, W. F. 1971. Management guide for black spruce type in the Lake States. USDA For.Serv., North. Centr. For. Exp. Stn. Res. Pap. NC - 64. St.Paul, MN., 12 p.

Johnston, W.F. 1975. Reproducing lowland conifer forests. J.For. 73: 17-20.

Johnston, W.F. 1977. Manager's handbook for black spruce in the north central States. USDA For. Serv. North Cent. For. Exp. Stn. Gen. Tech. Rep. NC-34, St.Paul, MN., 12 p.

Jordan, G.A. and R.H.Ballance. 1983. A microcomputer -based annual ring measurement system. For.Chron. 59: 21-25.

Kavanagh, J. 1983. Stem analysis: sampling techniques and data processing. Lakehead Univ. Sch.For. Thesis (M.Sc.F.) 80p., Thunder Bay, Ont.

Ketcheson, D.E. and J.K. Jeglum. 1972. Estimates of black spruce and peatland areas in Ontario. Dept. Env.,Can. For.Serv.,Inf. Rep. 0-X-172, 29p.

Ketcheson, D.E. 1977. The impact of strip cutting on logging roads costs. Can. For. Serv., Sault Ste. Marie, Ont. , Report 0-X-263. 19p.

Larsson, H.C. and A.C. Wilkes. 1947. Forest regeneration survey on cut-over spruce and pine lands in the Thunder Bay region. Toronto 1947 1 v.(Ontario Dept. of Lands and For. Res. Rep. 14).

LeBarron, R.K. 1939. The role of forest fires in the reproduction of black spruce. Minn.Acad.Sci.Proc. 7:10-14.

LeBarron, R. K. 1944. Influence of controllable environmental conditions on regeneration of jack pine and black spruce. J. Agr. Res. 68 : 97 - 119.

LeBarron, R. K. 1945. Adjustment of black spruce root systems to increasing depth of peat. Ecol. 26 : 309 - 311.

LeBarron, R. K. 1948. Silvicultural management of black spruce In Minnesota. USDA For. Serv., Lake. States For. Exp. Stn. Circ. 791. St. Paul, MN., 55 p.

LeBlank, J. H. 1955. A mode of vegetative propagation in black spruce. Pulp and Pap. Mag. of Canada. 56 : 146 - 153.

Lenthall, D. 1985. Height growth and site index of jack pine (Pinus banksiana Lamb.) in the Thunder Bay area. Lakehead Univ. Sch. For. M. Sc. F. thesis. 95 p., Thunder Bay, Ont.

Little, S.N. 1982. Weibull diameter distributions for mixed stands of western conifers. Can.J.For.Res. 13: 85-88

Logan, K. T. 1968. Growth of tree seedlings as affected by light intensity. Can. Dep. Fish. For. Publ. 1256, 12 p.

Losee, S.T.B. 1961. Results of group cutting for black spruce regeneration at the Abitibi Woodlands Laboratory. Pulp Pap. Mag. Can. ,Oct. 1961. Woodl. Sect. Index No 2086 (F-2). 7 p.

MacArthur, J. D. 1964. A study of regeneration after fire in the Gaspe region. Can. Dep. For. Pub. 1074. 20 p.

Maclean, D. W. and G.H.D. Bedell . 1955. Northern Clay Belt growth and yield survey. Can. Dep. North. Aff. Nat. Res., For. Res. Div. Tech. Note No. 20. 31 p.

Marquardt, D.W. 1963. An algorithm for least-squares estimation of nonlinear parameters. J.Soc. Indust. Appl.Math. 11:431-441.

McEwen, J.K. 1966. An Effect of Sphagnum on the Growth of Black Spruce. For. Chron. 42:178-183.

McEwen, J.K. 1971. Aerial dispersion of black spruce seed. For.Chron. 47: 1-2.

Ontario Institut of Pedology, Univ. Guelph, 1985. Field Manual for Describing Soils. 3rd ed. Publ. No. 85(3). 38 p.

Ontario Ministry of Natural Resources, 1980. Manual of Instructions for Regeneration Surveys. Second Ed. 62p., Toronto, Ont.

Ontario Ministry of Natural Resources. 1986. Statistics 1986.,Toronto, Ont., 75 p.

Ontario Ministry of Natural Resources. 1987. Field Guide to Forest Ecosystem Classification for the North Central Region. Toronto.

Parker, R.E. 1962. The problems of peatland forestry. Irish For. XIX(1): 4-14.

Perala, D.A. 1971. Growth and yield of black spruce on organic soils in Minnesota. USDA For.Serv.North Cent.For.Exp.Stn.,Res.Pap. NC-56.,15p., St. Paul, MN.

Phillips,L.A. 1983. Investigation of mature growth prediction with the Weibull function. Lakehead Univ. Sch.For. B.Sc. For. thesis..70p., Thunder Bay, Ont.

Place, I. C. M. 1955. The influence of seedbed conditions on the regeneration of spruce and balsam fir. Can. Dept. North. Aff. and Nat. Res. For. Br. Bull. 117. 87 p.

Plonski, W.L. 1981. Normal yield tables (metric) for major forest species of Ontario. Ont. Minist. Nat. Resourc., Div.For., Toronto, Ont., 40 p.

Richardson, J. 1979. Relation between natural reproduction of hardwoods and softwoods in western Newfoundland. Fish & Env. For. Serv. Nfld. For. Res. Centre. Inf. Rep. N - X - 166. 21 p.

Roe, A.L., R.R.Alexander, and M.D. Andrews. 1970. Engelmann spruce regeneration practices in the Rocky Mountains. USDA. For. Serv., Rocky Mtn. For. & Range Exp. Stn. Res. Rep. 115 32 p.

Rowe, J. S. 1972. Forest regions of Canada. Can. For. Serv. Publ. . 1300. 172 p.

Sas-Zmudzinski, K. 1989. Site Index Curves for black spruce in North Central Ontario. Unpublished manuscript.

Schoenicke, R. E. and A.E. Schneider 1954. The extent and character of regeneration in uncut black spruce (*Picea mariana*) swamp stand of north Central Minnesota. Univ. Minn. School . For. Note 26., St. Paul, MN., 2 p.

Smith, J.H.G. and A. Kozak. 1984. New non-linear models can improve estimates of growth and yield. Commonw. For.Rev. 63 :41-45

Somers,G.L., R.G.Oderwald, W.R.Harms and O.G. Wangdon 1980. Predicting mortality with a Weibull distribution. For. Sci. 26: 291-300.

Stanek, W. 1961. Natural layering of black spruce in Northern Ontario. For. Chron. 37 : 245 - 258.

Stanek, W. 1968. Development of black spruce layers in Quebec and Ontario. For. Chron. 44: 25 - 48.

Stanek, W. 1977. Ontario clay belt peatlands-are they suitable for forest drainage?. Can.J.For.Res. 7:656-665.

Thomas P. A. and R.W. Wein . 1984. The influence of shelter and the hypothetical effect of fire severity on the postfire establishment of conifers from seed. Can. J. For. Res. 15 : 148 - 155.

Thrower, J.S. 1986. Black Spruce Height Growth Curves for the Thunder Bay Area. Lakehead University. x+6 p.

Van Nostrand, R. S. 1961. Progress report. Southwest Gander black spruce seedbed study. Project NF - 23. Unpublished rep. Can. Dept. For. For. Res. Br. Nfld. Reg. 11 p.

Van Nostrand, R.S. 1971. Strip cutting black spruce in central Newfoundland to induce regeneration. Dep.Fish. For.,Can.For.Serv.,Publ.1294, 21p

Viereck, L.A. 1983. The effects of fire in black spruce ecosystems of Alaska and northern Canada.pp 201-219. In: Ross,W.and MacLean,D.A.,(eds).The role of fire in Northern Ecosystems. John Wiley & Sons Ltd.

Vincent, A. B. 1965. Black spruce : Review of its silvics, ecology, and silviculture. Can. Dept. For. Pub. 1100, 79 p.

Vincent, A. B. 1966. A better seedbed for black spruce on peatlands. Can. Dep. For. Inf. Rep. 0 - X - 29. 8 p.

Weetman, G. F. *et al.* 1973. Reproduction and ground conditions 5 years after pulpwood harvesting. Results from 37 study areas in Eastern Canada. Logging Res. Rep. 51. Pulp Pap. Res. Inst. Can. 97 p.

Wilde, S. A., G.K.Voigt and R.S. Pierce 1954. The relationship of soils and forest growth in the Algoma District of Ontario, Can. J. Soil Sci. 5 : 22-8.

Yang, R.C., A.Kozak, and J.H.G. Smith 1978. The potential of Weibull-type functions as flexible growth curves. Can.J.For.Res. 8:424-431.

Yarie, J. 1981. Forest fire cycles and life tables : a case study from interior Alaska. Can. J. For. Res. 11 : 554-562.

APPENDIX

CHI SQUARE TESTS FOR SEEDBED DISTRIBUTION

AVERAGE NUMBER OF BLACK SPRUCE SEEDLINGS BY SEEDBEDS VERSUS AGE

		VARIABLE							
AGE		PLE	SPH	OR1	OR2	LED	DEB	SED	ROW TOTALS
3	OBSERVED	0	29	8	0	6	2	1	46
	EXPECTED	2.27	28.40	5.11	0.57	5.68	3.41	0.57	
	CELL CHI SQ	2.27	0.01	1.63	0.57	0.02	0.58	0.33	
13	OBSERVED	4	14	1	1	3	3	0	26
	EXPECTED	1.28	16.05	2.89	0.32	3.21	1.93	0.32	
	CELL CHI SQ	5.75	0.26	1.24	1.44	0.01	0.60	0.32	
21	OBSERVED	0	7	0	0	1	1	0	9
	EXPECTED	0.44	5.56	1.0	0.11	1.11	1.93	0.32	
	CELL CHI SQ	0.44	0.38	1.0	0.11	0.01	0.17	0.11	
	COLUMN TOTALS	4	50	9	1	10	6	1	81

OVERALL CHI SQ	17.25
P VALUE	0.1406
DEGREE OF FREEDOM	12
CHI SQ TAB.	21.03
P	0.05

SEEDBED OCCURANCE VERSUS AGE

		VARIABLE							
AGE		PLE	SPH	OR1	OR2	LED	DEB	SED	ROW TOTALS
3	OBSERVED	1	58	16	0	14	5	3	97
	EXPECTED	11.04	33.11	7.36	28.10	10.37	2.01	5.02	
	CELL CHI SQ	9.13	18.70	10.15	28.10	1.27	4.46	0.81	
13	OBSERVED	32	33	5	3	11	1	11	96
	EXPECTED	10.92	32.77	7.28	27.81	10.26	1.99	4.97	
	CELL CHI SQ	40.66	0.00	0.72	22.13	0.05	0.49	7.33	
21	OBSERVED	0	8	1	81	6	0	1	97
	EXPECTED	11.04	33.11	7.36	28.10	10.37	2.01	5.02	
	CELL CHI SQ	11.04	19.05	5.49	99.61	1.84	2.01	5.02	
	COLUMN TOTALS	33	99	22	84	31	6	15	290

OVERALL CHI SQ	286.3
P VALUE	0.0000
DEGREE OF FREEDOM	12

CHI SQ TAB.	21.03
P	0.05