COFRDA REPORT 3309
NWOFTDU TECHNICAL REPORT 24

Stand and Site Conditions Associated with the Occurrence and Distribution of Black Spruce Advance Growth in North Central Ontario

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Burlington, Ontario

1991

Canada-Ontario
Forest Resource Development Agreement
Entente sur la mise en valeur de la ressource forestière

Catalogue No. Fo 29-25/3309E
ISBN 0-662-18573-0
ISSN 0847-2866

Ontario Ministry of Natural Resources Publication 4611

Copies of this publication are available at no charge from:

Communications Services
Great Lakes Forestry Centre
Forestry Canada-Ontario Region
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7

Northwestern Ontario Forest Technology Development Unit
Ontario Ministry of Natural Resources
R.R. #1, 25th Side Road
Thunder Bay, Ontario
P7C 4T9

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Micro Media Inc.
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This report was produced in fulfillment of the requirements of Project 33037, "Association of Stand and Site Conditions with Abundance of Black Spruce Advance Growth in the North Central Region of Ontario", carried out under the Research, Development and Applications Sub-program of the Canada-Ontario Forest Resource Development Agreement. The views, conclusions and recommendations contained herein are those of the authors and should be construed neither as policy nor as endorsement by Forestry Canada or the Ontario Ministry of Natural Resources.

Walsh, S.A. and Wickware, G.M. 1991. Stand and site conditions associated with the occurrence and distribution of black spruce advance growth in North Central Ontario. For. Can., Ont. Region, Sault Ste. Marie, Ont. COFRDA Rep. 3309 and Ont. Min. Nat. Resour., Northwestern Ont. For. Technol. Devel. Unit, Thunder Bay, Ont. Tech. Rep. 24. 37 p.

ABSTRACT

In many mature and overmature stands of black spruce (*Picea mariana* [Mill.] B.S.P.) in Ontario, advance growth originating from layers or seeds could contribute significantly to the restocking of an area, if the young trees can be preserved from damage during the harvesting operation. This project examined the occurrence and distribution of black spruce advance growth in relation to the vegetation types and soil conditions that occur in the North Central Region of Ontario. The survey was carried out within the framework of the Forest Ecosystem Classification for Northwestern Ontario (NWO FEC).

Within the stands examined, 96% of all black spruce advance growth originated from layers. However, the survey showed that stocking levels of advance growth are generally low and very variable. The highest stocking levels were found in stands dominated by black spruce on wet, organic lowland and nutrient-poor upland site types. Only in the unmerchantable black spruce lowland type (NWO FEC Vegetation Type 38) did stocking levels exceed 40%. Upland mixedwood stands with a diverse and abundant herb and shrub component supported only limited amounts of black spruce advance growth. In general, the study showed that black spruce advance growth is best regarded as a supplementary stocking source rather than as a primary form of regeneration.

RÉSUMÉ

Dans de nombreux peuplements mûrs et surâgés d'épinettes noires (*Picea mariana* [Mill.] B.S.P.) de l'Ontario, la régénération préexistante par marcottage ou semences pourrait accélérer considérablement le reboisement d'une région, si les jeunes arbres sont protégés au moment de la coupe. Ce projet avait pour but d'étudier l'occurrence et la distribution de la régénération préexistante de l'épinette noire en fonction des types de végétation et des conditions pédologiques qui règnent dans

le centre-nord de l'Ontario. L'étude a été menée dans le cadre de la Classification des écosystèmes forestiers du nord-ouest de l'Ontario (NWO FEC).

Dans les peuplements observés, 96 % de la régénération préexistante de l'épinette noire est assurée par le marcottage. Toutefois, l'étude a révélé que les niveaux de reboisement associés à la régénération préexistante sont généralement faibles et très variables. Les niveaux de reboisement les plus élevés ont été observés dans les peuplements dominés par l'épinette noire, dans les basses-terres humides à sol organique et sur les plateaux pauvres en nutriments. Ils étaient supérieurs à 40 % uniquement dans les basses-terres peuplées d'épinettes noires non marchandes (type de végétation 38, NWO FEC). Dans les peuplements mélangés des plateaux caractérisés par la présence abondante de plantes herbacées et d'arbustes divers, la régénération préexistante de l'épinette noire était limitée. En général, l'étude a révélé que la régénération préexistante de l'épinette noire constitue plutôt une méthode de reboisement complémentaire qu'un grand type de régénération.

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INTRODUCTION

In recent years, the importance of renewing the forest land base to ensure an adequate future supply of wood has led to increasingly intensive forest land-management practices. Intensified forest renewal activities are currently focused on regenerating the land base to a satisfactory level after harvest. In Ontario, the Ministry of Natural Resources and the private forest sector have been working together to improve regeneration and stand maintenance. This collaboration has led to significant improvements in the overall regeneration effort; for example, the total area treated since 1984 or 1985 has increased by 19%, to a total of 288,500 ha.

In Canada, black spruce (*Picea mariana* [Mill.] B.S.P.) occurs from coast to coast, achieving its main commercial importance in the Boreal Forest Region (Rowe 1972). Black spruce is the most important commercial tree species in Ontario, accounting for one-half the annual volume and value harvested on Crown land (Smyth and Campbell 1987). The wood's long fibers, high density, low resin content and low incidence of defects give it excellent pulping qualities, and it has a natural whiteness that doesn't require bleaching.

Although almost half the wood volume harvested each year in Ontario is black spruce (approximately 8.7 million m^3) but despite its economic importance (approximately $63 million; Smyth and Campbell [1987]), the species continues to be inadequately regenerated. The artificial regeneration of harvested sites to black spruce by planting or seeding is typically an expensive, labor-intensive activity. Moreover, regeneration is only one of several forest management programs competing for limited financial resources. It is essential, therefore, that techniques and materials used to regenerate the forest land base be cost effective.

Although planting has been the most common and successful method of ensuring black spruce regeneration, total nursery production of tree seedlings currently falls short of the quantity required to regenerate the area of black spruce cutover (Wood and Jeglum 1984). This, despite the fact that production of black spruce planting stock has risen over the past 10 years from approximately 12 million trees to 50 million trees (Wickware et al. 1990). In addition, black spruce often occurs on sites that are either easily damaged during harvesting and therefore difficult to regenerate artificially (e.g., organic or shallow soil conditions), or on remote harvesting sites that are infrequently planted or seeded. These sites are often left to regenerate naturally, with varying degrees of success. The result has been a vast area of inadequately restocked forest land or cutover relegated to an ever-increasing "back-log."

Advance growth, which Haavisto (1979) has defined as natural regeneration existing in a stand before harvesting, frequently offers a significant potential source of natural regeneration after harvest. To date, the use of advance growth in Ontario has not been seriously considered as a regeneration strategy, in part because: (1) stand and site conditions associated with abundant advance growth are poorly defined and (2) advance growth is often damaged or destroyed by current forest harvesting techniques. Despite this, advance growth may provide a means to supplement planting or be the sole method by which to ensure sustained productivity on organic or shallow-soil sites.

In order to assess the relationship between advance growth and its biophysical environment, it is necessary to define the range of natural forest stand, soil and site conditions under which advance growth occurs. Over the past decade, Ontario has made progress in defining this range through a series of site classification projects. The classification systems that have been developed extend over most of the Boreal Forest Region in the province. These site classification systems, referred to as Forest Ecosystem Classifications (FEC), are now published for the Northern, North Central and Northwestern regions (Jones et al. 1983, Sims et al. 1989). The latter two regions are combined into one FEC system. Each of the classifications provides an ecological framework for operational forest management activities and related forest research. Information essential to regeneration considerations, such as the quantity of advance growth, can be readily described within such a framework.

This study was formulated to examine the occurrence and distribution of black spruce advance growth across the range of soil and site conditions in the North Central Region. The results are discussed within the context of the Northwestern Ontario Forest Ecosystem Classification (NWO FEC) so that those NWO FEC Vegetation and Soil Types which offer the greatest potential for the occurrence of black spruce advance growth can be readily identified.

Previous Studies

The importance of black spruce to Ontario's forest industry is made clear by the many scientific studies about the species reported in the literature. A number of these studies are particularly relevant to this evaluation of black spruce advance growth and are briefly summarized.

Types of Advance Growth

Black spruce advance growth, which ranges in size from small seedlings to saplings several metres in height, occurs as two predominant types: (1) seedlings, which develop sexually from seed dispersal, and (2) layers, a form of vegetative reproduction (Stanek 1961, 1968; Johnston 1971; Jeglum et al. 1974; Haavisto 1979). Layering occurs when a living branch on the lower portion of the tree becomes embedded in the surface organic material (as a result of moss growth overtaking lower, drooping branches) and adventitious roots develop from the buried portion (Stanek 1961).

Arnup et al. (1988) described a third type of vegetative reproduction termed "rooting", whereby stems arise from near-surface roots. The significance of this form of advance growth as a source of regeneration has not been established.

The relative distribution of seedlings and layers in mature black spruce stands is influenced primarily by stand history. Trees from seedlings predominate in stands of fire origin or in areas of blowdown. However, in the absence of fire, organic material accumulates, and the stand is gradually dominated by trees of layer origin (Stanek 1968). Advance growth resulting from layering is generally recognized as the most abundant form of advance growth in black spruce stands (Johnston 1971, Groot 1984, Jeglum 1984).

The conditions required for seed germination and seedling establishment in cutovers have been thoroughly investigated (Vincent 1966; Arnott 1968; Armson 1975; Marek 1975; Haavisto 1975, 1979; Jeglum 1981, 1982, 1984; Wood and Jeglum 1984). The optimum condition for black spruce establishment is a moist, unsaturated seedbed free of competing vegetation. The best seedbed seems to be provided by exposed mineral soil, preferably mixed humus and mineral soil on upland sites (Fleming et al. 1987) or by *Sphagnum* peat on lowland sites (Johnston 1971).

Black spruce layers generally establish themselves in mature stands where living branches persist low enough on the tree to become embedded, and subsequently root, in the surface organic material (Stanek 1961). In well-stocked mature stands, in young stands, or in shrub-rich stands, black spruce will undergo rapid branch mortality, hence layering does not occur to any significant degree. Under such conditions, crowns are high, and living branches are not normally retained on the lower portion of the stem, so the possibility of layering is significantly reduced (Stanek 1961). Slow-growth stands (typically those associated with conditions high in moisture and low in nutrients, such as in swamps and bogs) are more suited to the establishment of layers. On these sites, *Sphagnum* growth is sufficiently rapid that lower branches become embedded in the surface organic layers.

Impacts of Harvesting on Advance Growth

Although the potential of advance growth as a viable regeneration option is increasingly being recognized, its reliability for post-harvest restocking depends upon its survival after harvesting. A number of studies have been undertaken that attempt to quantify the damage sustained by advance growth as a result of various harvesting techniques.

Vincent and Haavisto (1967) reported losses on the order of 50 to 60% using a clearcut/hand-pile method. The authors suggested that such harvesting practices make it unlikely that an adequately stocked stand could result from surviving advance growth.

A recent study in Quebec compared the impacts of four different harvesting techniques on advance-growth regeneration (Ruel 1988). Stocking levels were reduced by 22 to 35%, depending on the system employed. Full-tree harvesting with a Koehring feller-forwarder proved to be the least destructive system. Most investigators have suggested that damage reduction, particularly on organic or peaty-phase mineral sites, is best achieved through the use of high-flotation tires, winter harvesting, and directional felling with spaced skid trails or careful chainsaw felling and skidding (Haavisto 1979, Jeglum et al. 1983, Groot 1987, Ruel 1988).

Advance Growth and the NWO FEC

The Forest Ecosystem Classification provides a framework for accurately describing stand and site conditions associated with abundant advance growth. Groot (1984) effectively used the Northern Clay Region Forest Ecosystem Classification (Jones et al. 1983) to study stand and site conditions associated with black spruce advance growth in that region. Sampling in various vegetation types and "Operational Groups", Groot determined that attributes such as crown cover, basal area, dominant tree height and cover of Labrador tea (*Ledum groenlandicum* Oeder) were important in predicting the stocking and density of black spruce advance growth.

The occurrence of advance growth in forest stands of the North Central Region has not been extensively documented. Preliminary investigations of shrub cover data collected during the NWO FEC field program (Sims et al. 1989) suggested that black spruce advance growth occurred over a range of vegetation and soil/site conditions throughout the region.

The present study was initiated in order to better document the occurrence of advance growth in the North Central Region, and to examine in more detail the nature of the relationship between black spruce advance growth and soil/site conditions. Because of the comprehensive nature of the NWO FEC dataset, the present study was designed to supplement existing data collected during the NWO FEC program. The NWO FEC dataset includes a number of vegetation and soil/site variables thought to influence black spruce advance growth; however, it does not provide extensive detailed information on the occurrence and abundance of advance growth. In this study, advance growth data was collected by returning to selected plots from the existing network of NWO FEC plots in the North Central Region. This ensured that the information reflected the range of soil and site conditions throughout the region, and that the advance growth data was compatible with the original NWO FEC data. The baseline NWO FEC dataset, supplemented with this advance growth data, provides a comprehensive information base that can be used to better evaluate and predict the quantity of black spruce advance growth across the North Central Region.

STUDY OBJECTIVES

The purpose of this study was to examine stand and site conditions associated with the occurrence and abundance of black spruce advance growth in the North Central Region of Ontario. A secondary purpose was to examine and describe a selection of black spruce stands that had arisen from advance growth (second-growth stands).

The specific objectives of the study were to:

1. collect ground observation data of black spruce advance growth within the NWO FEC framework of Vegetation and Soil Types;

2. describe the average physical condition, abundance, type and size of advance growth encountered under these stand and site conditions;

3. examine and analyze the distribution and abundance of black spruce advance growth in relation to stand and site attributes;

4. develop a predictive function for the occurrence of advance growth, integrating the NWO FEC framework; and

5. locate and describe a limited number of second-growth stands of black spruce in the North Central Region.

STUDY AREA

The North Central Region of Ontario encompasses a broad geographic area and includes a wide range of vegetation and soil/site conditions. Figure 1 shows that portion of the region with commercial forest occurring south of the Hudson Bay Lowland. The region is one of four northern administrative areas of the Ontario Ministry of Natural Resources and contains approximately 65,630 km^2 of production forest. The region encompasses the majority of the country north and immediately northwest of Lake Superior, and extends from west of Atikokan to east of Marathon, a distance of 525 km.

The forest is underlain by a range of bedrock conditions, primarily of Archean (Precambrian) origin, although significant areas of Phanerozoic limestone occur in the northeastern part of the study area (Pye 1969). The pattern of glacially associated landforms is distinct and complex as a result of the intense and sometimes repetitive nature of the glacial processes that occurred during the most recent glacial period. Common glacial landforms include undulating ablation and basal tills, as well as distinctive morainal features such as drumlins and end, interlobate and lateral moraines. Glaciofluvial deposits such as eskers, kames, and outwash deltas and plains are common. Also common in the area are fine-textured glaciolacustrine materials deposited in the numerous glacial lakes that covered most of the study area at one time or another during the early post-glacial period. Other surficial materials include aeolian, alluvial and organic deposits.

In general, the climate is microthermal (C'21 to C'22) and humid (B^1 to B^3-B^4) according to the Thornthwaite system (Sanderson 1948). There are, however, two main climatic gradients: seasonal temperatures are moderated to the south (i.e., in closer proximity to Lake Superior), whereas humidity (and precipitation) trend from drier in the west to moist in the east. (Chapman and Thomas 1968).

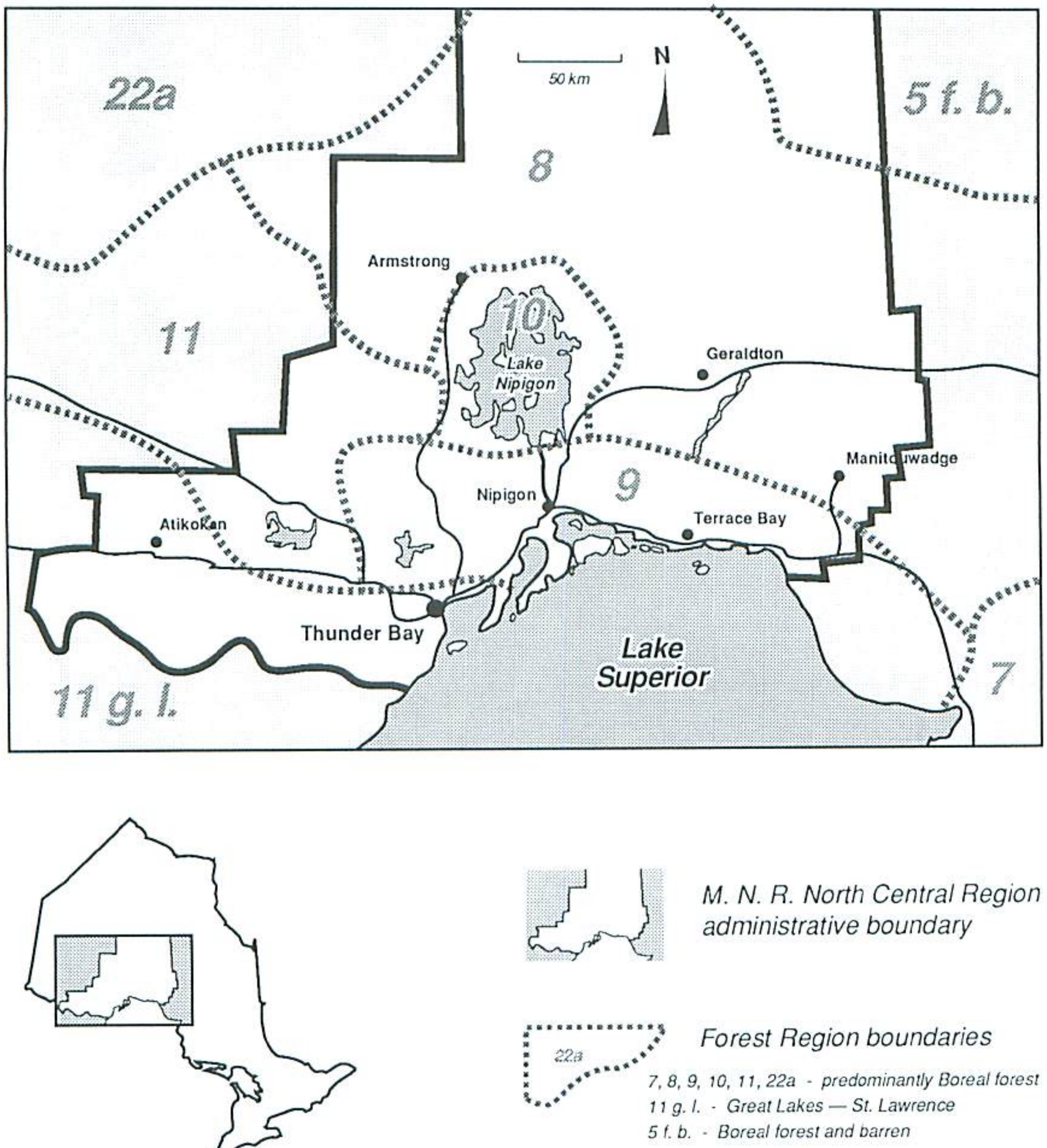


Figure 1. Map of the North Central Region, with Forest Region boundaries.

Most of the study area belongs to the expansive Boreal Forest Region (Sections B.8, B.9, B.10 and B.11) (Rowe 1972) and is characterized by a mosaic of stand ages and compositions. Black spruce, white spruce (*Picea glauca* [Moench] Voss), jack pine (*Pinus banksiana* Lamb.), balsam fir (*Abies balsamea* [L.] Mill.), trembling aspen (*Populus tremuloides* Michx.) and white birch (*Betula papyrifera* Marsh.) all occur either singly or in combination throughout the forests of the region.

While developing the NWO FEC, 1,300 semi-permanent NWO FEC plots were established on representative stand and soil/site conditions across the region from 1983 to 1986. To ensure that the total range of conditions was examined for the occurrence and abundance of advance growth, sampling for this study utilized a representative subsample of the existing NWO FEC sample plots.

METHODS

The database for this study included the NWO FEC dataset (the 1,300 semi-permanent plots mentioned above) and supplementary advance growth data collected during this study from 238 selected NWO FEC plots. For future study purposes, 10 second-growth black spruce stands were also located and described, using standard NWO FEC plot sampling procedures (Siltanen et al. 1986).

NWO FEC Data

The NWO FEC dataset consists of vegetation, soil, site and mensurational data collected on 1,300 semi-permanent sample plots in the North Central Region and 800 plots in the Northwestern Region. Only data from the 1,300 North Central Region plots are considered in this study. Plots were established in mature, natural stands representative of the range of ecological conditions in northwestern Ontario.

Vegetation information includes an estimate of percent cover for all species (trees, shrubs, herbs, graminoids, mosses and lichens) occurring on a 10- x 10-m sample plot located at each site. Regeneration data for all commercial tree species were obtained from approximately 100 of the 1,300 sampled sites, but were not used in this study.

A comprehensive soil profile description at each plot is based on Canadian System of Soil Classification (Canada Soil Survey Committee 1978) standards and included: horizonation (thickness, texture and colors for both organic and mineral horizons); coarse fragment content; moisture regime and drainage; family particle size; occurrence of carbonates, mottles and gley; depth to bedrock; humus form classification; and rooting depth measurements. Detailed soil geochemistry is also available for selected representative plots.

In addition to vegetation and soil data, other site characteristics were recorded at each plot. These included: site position, slope, aspect, elevation, and litter composition. Stand mensurational data was collected on most sites and included heights, ages and diameters at breast height (DBH) of representative trees as well as stocking estimates determined from wedge-prism sweeps.

All NWO FEC data has been electronically coded and is accessible through a VAX8530 computer at the Great Lakes Forestry Centre in Sault Ste. Marie, Ontario.

This comprehensive dataset has been used to develop a system of forest site classification for northwestern Ontario (i.e., the NWO FEC) (Sims et al. 1989). The classification, which is currently being used as a framework for forest management activities in northwestern Ontario, consists of 38 Vegetation Types (Table 1) and 22 Soil Types (Table 2).

Although only recently implemented, the system is already being used to: (1) organize productivity analyses for major commercial tree species of the region (Carmean 1987), (2) develop a precut survey methodology (Towill et al. 1988), and (3) develop management interpretations for various combinations of

Table 1. The 38 NWO FEC Vegetation Types.

V1	balsam poplar hardwood and mixedwood
V2	black ash hardwood and mixedwood
V3	rare hardwoods and mixedwoods
V4	white birch hardwood and mixedwood
V5	aspen hardwood
V6	trembling aspen (white birch) — balsam fir / mountain maple
V7	trembling aspen — balsam fir / balsam fir shrub
V8	trembling aspen (white birch) / mountain maple
V9	trembling aspen mixedwood
V10	trembling aspen — black spruce — jack pine / low shrub
V11	trembling aspen — conifer / blueberry / feathermoss
V12	white pine mixedwood
V13	red pine mixedwood
V14	balsam fir mixedwood
V15	white spruce mixedwood
V16	balsam fir — white spruce mixedwood / feathermoss
V17	jack pine mixedwood / shrub rich
V18	jack pine mixedwood / feathermoss
V19	black spruce mixedwood / herb rich
V20	black spruce mixedwood / feathermoss
V21	cedar (incl. mixedwood) / mountain maple
V22	cedar (incl. mixedwood) / speckled alder / *Sphagnum*
V23	tamarack (black spruce) / speckled alder / Labrador tea
V24	white spruce — balsam fir / shrub rich
V25	white spruce — balsam fir / feathermoss
V26	white pine conifer
V27	red pine conifer
V28	jack pine / low shrub
V29	jack pine / ericaceous shrubs / feathermoss
V30	jack pine — black spruce / blueberry / lichen
V31	black spruce — jack pine / tall shrub / feathermoss
V32	jack pine — black spruce / ericaceous shrubs / feathermoss
V33	black spruce / feathermoss
V34	black spruce / Labrador tea / feathermoss (*Sphagnum*)
V35	black spruce / speckled alder / *Sphagnum*
V36	black spruce / bunchberry / *Sphagnum* (feathermoss)
V37	black spruce / ericaceous shrubs / *Sphagnum*
V38	black spruce / leatherleaf / *Sphagnum*

Table 2. The 22 NWO FEC Soil Types.

Soil Types	
S1	dry / coarse sandy
S2	fresh / fine sandy
S3	fresh / coarse loamy
S4	fresh / silty – silt loamy
S5	fresh / fine loamy
S6	fresh / clayey
S7	moist / sandy
S8	moist / coarse loamy
S9	moist / silty – silt loamy
S10	moist / fine loamy – clayey
S11	moist / peaty phase
S12F	wet / organic [feathermoss]
S12S	wet / organic [*Sphagnum*]
Shallow Soil Types	
SS1	discontinuous organic mat on bedrock
SS2	extremely shallow soil on bedrock
SS3	very shallow soil on bedrock
SS4	very shallow soil on boulder pavement
SS5	shallow – moderately deep / sandy
SS6	shallow – moderately deep / coarse loamy
SS7	shallow – moderately deep / silty – fine loamy – clayey
SS8	shallow – moderately deep / mottling – gley
SS9	shallow – moderately deep / organic – peaty phase

vegetation and soil types (Whitfield and Racey 1988). It is anticipated that the NWO FEC site classification framework will be used for ongoing forest management studies and practices throughout northwestern Ontario.

Black Spruce Advance Growth

NWO FEC Stand Selection

Plot Selection: One of the primary objectives of this study was to develop a predictive model for black spruce advance growth within the NWO FEC framework. To meet this objective it was necessary to supplement the existing NWO FEC database with additional advance growth data. During the summer of 1988, detailed advance growth field data collection surveys were completed on 238 selected NWO FEC plots. By using existing NWO FEC plots it was possible to take advantage of the existing NWO FEC dataset and make comparisons directly with this information.

Selection of the 238-plot subset was accomplished by stratifying the NWO FEC dataset using Vegetation Types and Soil Types as selection criteria. Vegetation Types were used initially to create subsets of the plots. Soil Types were then used to ensure that a range of soil conditions was also included. Since most Vegetation Types occur across a range of soil conditions (Sims et al. 1989), selecting a range of Vegetation Types ensured that most Soil Types were encountered.

Selection Criteria: For a Vegetation Type to be included in the study, black spruce in the shrub layer had to occur in at least 20% of the plots comprising the Vegetation Type. There were 28 Vegetation Types that met this criterion (types 2, 5, 8-11, 15-20, 22, 23, and 25-38) (Sims et al. 1989). Ten sample plots for each Vegetation Type were initially selected for field sampling. During the early stages of field sampling, however, it became obvious that balsam fir and white spruce Vegetation Types (V15, V16, V24, V25) had only limited occurrence of black spruce advance growth. Sampling in these types was subsequently discontinued in order to concentrate on Vegetation Types with a greater potential for black spruce advance growth. Sampling emphasis was put on all jack pine and black spruce Vegetation Types (V8-V11, V17-V20, V27-V38), the lowland cedar type (V22) and the larch type (V23). These Vegetation Types typically had 50% or greater occurrence of black spruce in the shrub layer. Two hardwood Vegetation Types (V2 and V5) were also included in the sample group.

Vegetation Type distribution is uniform across the region, with individual Vegetation Type plots chosen to ensure regional coverage for advance growth data collection.

Although it was anticipated that a minimum of 10 plots would be sampled for each Vegetation Type, changes to the classification system during the fall of 1988 resulted in a reassignment of numerous plots to revised Vegetation Types and Soil Types. As a result, a number of Vegetation Types evaluated during this study have fewer advance growth sample plots than originally intended.

Previously recorded NWO FEC information was used to locate each sample plot. Occasionally, the sample stand was located but the NWO FEC plot itself could not be identified. (In most instances, this was because the plots had been lost as a result of recent harvesting.) In such cases, a new plot within the same stand judged similar to original plot conditions was established.

Stand Sampling: On each 10- x 10-m NWO FEC plot, a limited number of vegetation, soil, site and stand features were recorded. These included the Vegetation Type and Soil Type (using the NWO FEC Vegetation Type key), humus form and thickness, depth of mineral soil, percent of the plot covered by surface stones, percent exposed bedrock, and percent cover of feathermoss and *Sphagnum* species. Percent cover estimates for Labrador tea, green alder (*Alnus crispa* [Ait.] Pursh), speckled alder (*A. rugosa* [Du Roi] Spreng.), and for all other shrubs combined were recorded. A visual estimate of the percent crown closure was also determined for each species. Stand age was determined from breast height (1.3-m) core samples of five dominant/codominant trees on or near the plot. Basal area was determined from a prism sweep (BAF10 wedge prism) done from the plot center.

Along the perimeter of each 10- x 10-m NWO FEC plot, 20 2- x 2-m quadrats were arranged in which all advance growth was counted. Four species were recorded: black spruce, white spruce, jack pine, and balsam fir. Each was recorded in one of four height classes: (1) <10.0 cm, (2) 10.0 to 49.9 cm, (3) 50.0 to 199.9 cm, or (4) ≥200.0 cm in height to 2.5 cm DBH.

The type and form of black spruce advance growth was also recorded. Three types of advance growth were recognized during the field program, the two most important being seedlings and layers. Seedlings and layers were differentiated primarily through appearance. Stems were classified as layers if the bottom portion of the stem curved from the horizontal to the vertical (Groot 1984). The type of advance growth was occasionally verified by identifying the layer's branch connection. Improper identification is always possible, since under certain growing conditions seedlings and layers can have very similar stem forms (Vincent 1965, Stanek 1968). A third type of advance growth, "rooting", was identified where the stem had the bent appearance of a layer but a branch connection was not obvious. LeBlanc (1955) encountered similar stems, but subsequent examination of their microscopic structure proved them to be branch layers. Since tissue analysis of rooted stems encountered during this study was not undertaken, rooted stem tallies were combined with layerings for purposes of analysis.

The form of black spruce advance growth was defined as either upright, bent or oppressed. An upright stem is one growing vertically with a straight stem, even if the base is curved like a layered stem. A bent stem has gross curvatures along its length, and an oppressed stem is identified by its non-vigorous appearance.

Second-growth Stands

In addition to data collected from 238 plots in mature, natural stands, a sample of 10 second-growth stands was located and described. Stand selection for this aspect of the study was random and was achieved primarily with the aid of Forest Resource Inventory maps. Stands chosen were 35 to 50 years old, had a minimum 50% black spruce component and were judged to have developed from advance growth after harvesting. Stands were also selected to represent a range of biophysical conditions and to maximize regional distribution.

Each second-growth stand was sampled using NWO FEC sampling procedures and format (Siltanen et al. 1986). All site, vegetation and soil information was recorded on NWO FEC field data-collection cards. The NWO FEC forestry data collection format was altered slightly to include the advance growth tally.

In each second-growth stand, a 10- x 10-m sample plot was established. Within the plot, all plant species, and the percent cover of each, were recorded. Stand Vegetation Type was also recorded. A soil pit (1 x 1 x 1 m) was dug in the center of each plot and a complete description of the profile recorded. Samples of the dominant surface and subsurface soils were taken for laboratory textural analyses. Soil Types were determined from the soil descriptions. Site features were recorded as outlined on the site card.

Forest mensurational information collected included DBH, height, age, and stem count for determination of stand basal area and occurrence of advance growth. Height, age and DBH were measured on a minimum of five dominant/codominant trees. Breast-height diameter measurements were recorded for all "in" stems during the prism sweep from the plot center (BAF10 wedge prism). The stem count derived from this prism sweep was used to calculate stand basal area. All advance growth stems of the four coniferous species (black spruce, jack pine, white spruce and balsam fir) were counted in 20 2- x 2-m quadrats along the plot perimeter.

Data Analysis

All advance growth data was electronically coded and entered into the VAX8530 computer at the Great Lakes Forestry Centre. The data was analyzed both as an independent data set and in conjunction with the NWO FEC data for the 238 resampled plots. Multivariate and ANOVA statistical techniques were used to analyze the data. Data on second-growth stands, although not analyzed as part of this study, has been electronically coded and entered into the computer for later analysis.

Mature Stands

Advance growth data was initially entered and verified on a microcomputer using dBase III Plus (Anon. 1986) database software. Variable coding followed the North Central FEC coding formats (Siltanen et al. 1986) wherever possible to ensure that advance growth data was compatible with NWO FEC datasets. Five data files were created: (1) vegetation/soil data, (2) prism data, (3) age data, (4) black spruce advance growth data, and (5) other conifer species regeneration data. The data files were subsequently uploaded to the computer.

As a result of classification revision, all plots were reassigned to new Vegetation Types and Soil Types. The data was then summarized within the new Vegetation Type definitions using SAS (Anon. 1985b) and BMDP (Anon. 1983) programs. Sample data descriptions included the frequencies for each Vegetation Type and Soil Type, and the distribution of seedlings and layers across all sampled types.

Stocking, used as a measure of distribution (advance growth occurrence) and defined as the proportion of 2- x 2-m quadrats with at least one advance growth stem (Groot 1984), was calculated for each plot. Density, defined as the number of advance growth stems per hectare (Groot 1984), was used as a measure of the abundance of advance growth. Stem densities were determined for each plot. Mean values of black spruce advance growth stocking and density were calculated for each Vegetation Type and Soil Type. This latter information established the basis for summarizing advance growth data within the NWO FEC classification framework.

Further summary of advance growth data by Vegetation Type included the distribution of sites within stocking and height classes. Four stocking classes were defined using Robinson's (1974) criteria for black spruce stocking levels: (1) 0 to 40%, (2) 41 to 60%, (3) 61 to 80% and (4) >80%. All sites were assigned to a stocking class and site frequency within these classes. Similar distribution comparisons were done for all advance growth stems within the four height classes described previously. The number of stems counted in each height category was calculated and summarized for each Vegetation Type.

Ordination overlays were used to define patterns in Soil Type groups and soil/site variables. NWO FEC vegetation data for each of the 238 sampled stands was ordinated by means of DECORANA (Hill 1979). The resulting ordination illustrates relative similarities and dissimilarities in the sampled stands on the basis of vegetation composition. Individual values of different soil and site variables were superimposed onto this ordination diagram in order to examine vegetation and soil/site relationships.

Simple correlation and multiple linear regression analyses were used to quantify relationships between advance growth stocking and density, and soil or site parameters of stands. Variables from both the NWO FEC and advance growth datasets were used in this analysis. Stepwise discriminant analysis was used to determine the vegetation, soil and site features that best discriminate the four stocking classes.

From these various analyses, a preliminary model for predicting the occurrence of black spruce advance growth for each NWO FEC Vegetation Type was developed.

Second-growth Stands

Data for second-growth stands was electronically coded following the North Central FEC coding formats (Siltanen et al. 1986). Basic data description summaries were obtained and used to develop factsheets for each stand. Second-growth stand descriptions are presented separately.

RESULTS AND DISCUSSION

The results of the data analyses reflect the range of black spruce advance growth occurrence and the diversity of stand conditions sampled. In general, black spruce advance growth occurs in most Vegetation Types and on a wide range of soil and site conditions across northwestern Ontario. Its abundance in any particular Vegetation Type or soil/site condition is extremely variable, however, making it difficult to predict with any degree of confidence the stocking or density of black spruce advance growth at any particular site. Nevertheless, trends in the occurrence and abundance of advance growth across the region were recognized, and they provide some useful insight into the nature, abundance and distribution of advance growth for regeneration management purposes.

Type and Distribution of Advance Growth

A total of 6,272 black spruce advance growth stems were counted on the 238 study plots (4,760 2- x 2-m quadrats). Layered stems account for 96% of the total; seedlings, 4%.

Seedling and layered stem densities (stems/ha) for each Vegetation Type are shown in Table 3. Seedling densities are low for all Vegetation Types, reflecting the limited importance of seedlings as a form of advance growth in the region. Only in Vegetation Type 38, a lowland black spruce type, does it achieve a degree of significance. The density of layerings is significant on a range of Vegetation Types and showed a generally increasing trend in abundance as the level of occurrence of black spruce in the tree layer increased.

Using the data in Table 3, the mean layer density (stems/ha) of four major NWO FEC Vegetation

Table 3. Comparison of seedling and layer densities in NWO FEC Vegetation Types.

Vegetation Type	Density (stems/ha)	
	Seedlings	Layers
4	0	3860
5	10	210
7	0	0
8	0	100
9	50	830
10	0	690
11	80	1130
15	100	0
16	30	30
17	40	1100
18	70	3550
19	140	1790
20	70	6550
21	0	0
22	140	1440
23	10	840
24	0	0
25	0	0
28	0	300
29	10	4730
30	60	5660
31	40	960
32	90	3050
33	60	2450
34	60	3060
35	490	2290
36	70	3050
37	190	4340
38	1250	8680

Type groupings (Sims et al. 1989) was examined to see whether trends in general forest cover-type groupings could be ascertained. Similar trend analyses have been carried out by Sims et al. (1986) and Whitfield and Racey (1988) for other soil/site variables within the context of the NWO FEC. Although there are variations within each group, these cover-type groupings clearly show a general trend that suggests increasing black spruce advance growth with increasing occurrence of black spruce in the overstory. The cover-type groupings include:

1. hardwood-dominated mixedwoods (V4-V11): 1,136 stems/ha;
2. conifer-dominated mixedwoods (V15-V20): 2,604 stems/ha;
3. mixed conifer types (V21-V30 and V32): 2,670 stems/ha;
4. black spruce-dominated coniferous types (V33-V38 and V31): 3,978 stems/ha (includes upland and lowland types).

The mean layer density for black spruce Vegetation Types in which *Sphagnum* dominates in the moss layer (Vegetation Types 35-38) was 4,590 stems/ha.

From the data in Table 3, another grouping of Vegetation Types based on the abundance of black spruce advance growth is suggested:

Extremely low (0-99):
V7, V15, V21, V24, V25, V16

Low (100-1,8500):
V5, V8, V9, V10, V11, V17, V22, V23, V28, V31

Moderate (1,500-2,500):
V19, V33, V35

High (2,5008-3,500):
V34, V36

Extremely high (>3,500):
V4, V18, V20, V29, V30, V37, V38

Vegetation Types that occurred in the moderate to extremely high classes offer significant potential for supplementary stock under an area-based black spruce regeneration program where a minimum density of 2,000-2,500 stems/ha is required (W.D. Towill, Ontario Ministry of Natural Resources, Thunder Bay, Ont., personal communication). Of the 12 Vegetation Types in these classes, only three (V4, V18, V19) are not included in the "mixed conifer" or "black spruce conifer" groups noted earlier. Vegetation Types 18 and 19 are conifer-dominated mixedwoods, and V4 is a "white birch hardwood and mixedwood", typically with a conifer-dominated shrub understory (Sims et al. 1989).

Table 4 compares stem densities of seedlings and layers within each NWO FEC Soil Type. Black spruce advance growth resulting from layering is least abundant on fine loamy, silty and clayey soil conditions (S4, S6, SS7, S10, S8), where mean density (number of layers) is 348 stems/ha, and is most abundant under shallow-soil conditions (SS6, S12S, SS3, SS1, SS2), where mean density is 5,872 stems/ha. Mean density under the remaining soil conditions (mainly sandy and coarse loamy textures of variable moisture conditions) is 1,647 stems/ha and ranges from 1,130 to 2,760 stems/ha. No trends with respect to texture, moisture, drainage or other site factors are apparent within this group. The general lack of advance growth on the more finely textured soils is characteristic of the North Central Region, where hardwood and hardwood-dominated mixedwoods typically occur, and where, as noted from Table 3, advance growth is generally low in these Vegetation Types. The abundance of advance growth on shallow soils reflects the typical development of thick organic humus layers, which provide ideal conditions for black spruce layering.

Although seedlings are not abundant under most soil conditions, their near-total absence on shallow soil types is striking.

Because of the overwhelming importance of layering as the primary source of black spruce advance growth in the region, seedlings and layers were combined for all further analyses, and subsequent reference to black spruce advance growth should be interpreted as the total of seedlings and layers. Similarly, the majority of advance growth stems exhibited good growth form, and all stems were considered upright.

Relation of Advance Growth to NWO FEC Vegetation Types

The sampling frequency for Vegetation Types is shown in Table 5. As noted earlier, revisions to the vegetation classification after the contract work was underway and modification of the sampling strategy resulted in variation in sample sizes for the Vegetation Types. Sampling in Vegetation Types V15, V16, V24 and V25, the balsam fir and white spruce types, was discontinued early during data collection because of the general absence of black spruce advance growth.

Although all sampled Vegetation Types were stocked to some degree, stocking levels were generally low and exhibited extreme within-type variability (Fig. 2). Mean stocking levels exceeded 60% in only one Vegetation Type (V38) (typically an unmerchantable type). Only three other Vegetation Types (V20, V34, V37) were stocked to >40%, and stocking levels were highly variable in these types, ranging from 0 to

Table 4. Comparison of stem densities for seedlings and layers in each sampled NWO FEC Soil Type.

	Density (stems/ha)	
Soil Type	Seedlings	Layers
S1	90	1940
S2	30	2140
S3	30	1660
S4	0	50
S5	400	2270
S6	0	300
S7	70	1500
S8	0	530
S9	210	1130
S10	50	460
S11	50	2760
S12F	80	1500
S12S	350	3890
SS1	100	6020
SS2	0	10180
SS3	0	5400
SS5	0	1670
SS6	40	3870
SS7	0	400
SS8	0	1400

Table 5. Sampling fequency in NWO FEC Vegetation Types surveyed in the 1988 black spruce advance growth project.

Vegetation Type	No. of sites
4	7
5	9
7	1
8	4
9	4
10	11
11	17
15	1
16	3
17	11
18	10
19	10
20	11
21	1
22	10
23	9
24	1
25	1
28	7
29	11
30	10
31	12
32	16
33	10
34	12
35	10
36	11
37	14
38	4

90%. These four Vegetation Types are all spruce-dominated, although not the only spruce-dominated types in the classification, and tend toward moister sites with thicker feathermoss surface forest humus forms or *Sphagnum* organic soils.

Variability within Vegetation Type stocking levels can be attributed to a number of factors, including the inherent heterogeneity associated with each NWO FEC Vegetation or Soil Type. Each of the NWO FEC classes reflects a range of conditions associated with the plots constituting the class. This range of conditions may give rise to internal class differences that may or may not be significant for a particular management application (Sims et al. 1989). Moisture conditions, for example, can vary significantly within a number of the Vegetation Types. On those sites where slightly drier conditions prevail, conditions for black spruce advance growth may not be optimal, whereas better opportunities may occur on slightly moister sites. Since moisture appears to be a key environmental factor governing the conditions that give rise to black spruce advance growth, this internal class heterogeneity may contribute to within-class variability for black spruce advance growth. There are, of course, other factors that may contribute to this variability, including stand age and relative density (crown closure). As stands mature or become overmature, breakup in the stand creates openings and opportunities for regeneration.

To better define the occurrence and distribution of advance growth and related stocking levels to management needs, four advance growth stocking classes were defined: (1) 0 to 40%, (2) 41 to 60%, (3) 61 to 80% and (4) >80%. Each of the 238 sampled sites was assigned to a class. The frequency occurrence of sites within each Vegetation Type across the four stocking classes is shown in Table 6.

The majority of sampled stands occurred in stocking class 1, with less than 40% stocking to black spruce advance growth. In Ontario, 60% stocking is the required level for black spruce; less than 40% stocking is considered a failure (Robinson 1974). Haavisto (1979) suggested that stocking in the 41–60% range should be considered marginal, but acceptable. Stocking in most mature stands falls into this range and densities range from 2,400 to 3,000 stems/ha. This stocking range should also be acceptable for peatlands. Of the five lowland Vegetation Types (V34 to V38) typically associated with peatland conditions, three (V34, V37, V38) attain mean stocking levels within that acceptable range (Fig. 2). The unmerchantable stand type, V38, is the only Vegetation Type to exceed the standards,

Table 6. Frequency of occurrence of black spruce advance growth stratified by stocking class for the NWO FEC Vegetation Types.

	Stocking class			
Vegetation Type	1 ≤40%	2 41-60%	3 61-80%	4 >80%
4	7	-	-	-
5	9	-	-	-
7	1	-	-	-
8	4	-	-	-
9	4	-	-	-
10	11	-	-	-
11	16	-	1	-
15	1	-	-	-
16	3	-	-	-
17	11	-	-	-
18	8	1	-	1
19	9	-	1	-
20	5	4	2	-
21	1	-	-	-
22	9	1	-	-
23	8	-	-	1
24	1	-	-	-
25	1	-	-	-
28	7	-	-	-
29	9	-	2	-
30	6	2	2	-
31	11	1	-	-
32	10	5	1	-
33	8	-	-	2
34	6	2	2	2
35	6	3	1	-
36	6	2	3	-
37	7	3	3	1
38	-	-	1	3
Total	185	24	19	10

with 86% stocking to black spruce advance growth.

Advance growth stocking levels shown in Figure 2 and Table 6 are based on pre-harvest conditions. Ruel (1988) suggests that reductions in advance growth stocking of 20 to 35% can be expected after harvesting. Assuming the loss of advance growth stocking is restricted to 20%, only V38 would be considered satisfactorily stocked after harvest. All other Vegetation Types would have stocking levels substantially below 40%.

These results suggest that black spruce advance growth should be more realistically viewed as a supplemental regeneration source, rather than as a primary source.

Advance growth stems were tallied in one of four height classes: (1) 1.0 to 9.9 cm, (2) 10 to 49.9 cm, (3) 50 to 199.9 cm or (4) ≥200 cm to 2.5 cm DBH. Figure 3 shows that the greatest proportion of stems were in the first two height classes, up to 50 cm. In some cases, there were a number of dead stems in the 200-cm height range (i.e., small saplings) that were not counted. Since age data for the advance growth was not collected, it remains uncertain whether the stems are unsustainable as they get taller or whether the majority of stems are simply not old enough to have attained greater heights (i.e., they are recent layerings). Vincent (1965) reported that available light is one of the most significant environmental factors influencing regeneration. Since black spruce is a less shade-tolerant species than balsam fir or white cedar (*Thuja occidentalis* L.) (Johnston 1971), it is possible that smaller trees would benefit from a more open canopy.

In the mainly hardwood Vegetation Types (V4 – V11), stem densities (stems/ha), with the exception of V4, are typically low, and most of the advance growth is associated with height classes 2 – 4 (Fig. 3). In the conifer-dominated mixedwoods (V15 – V20) and conifer types (V21 – V38), advance growth can occur in all height classes. In Vegetation Types V5 and V8, all the advance growth falls into height class 2. Of the upland, mainly hardwood, Vegetation Types, only V4, a "white birch hardwood and mixedwood" type (Sims et al. 1989) shows any potential for black spruce advance growth.

Stocking, Density and Distribution

The recommended planting density on artificially regenerated sites is 2,000 to 2,500 trees/ha (Robinson 1974). To achieve this, trees are planted at 2-m spacing (one tree per 2- x 2-m quadrat). Advance growth stem densities were

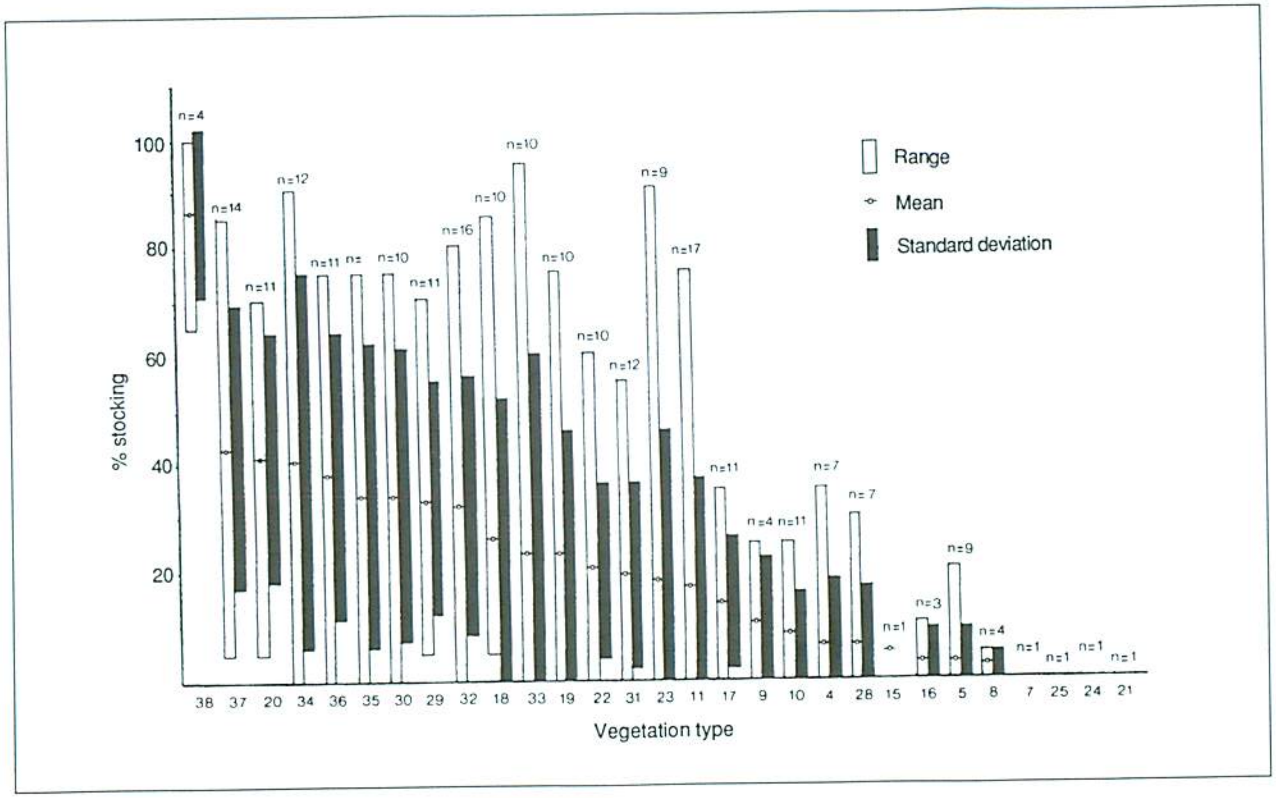


Figure 2. Black spruce advance growth stocking levels in NWO FEC vegetation types.

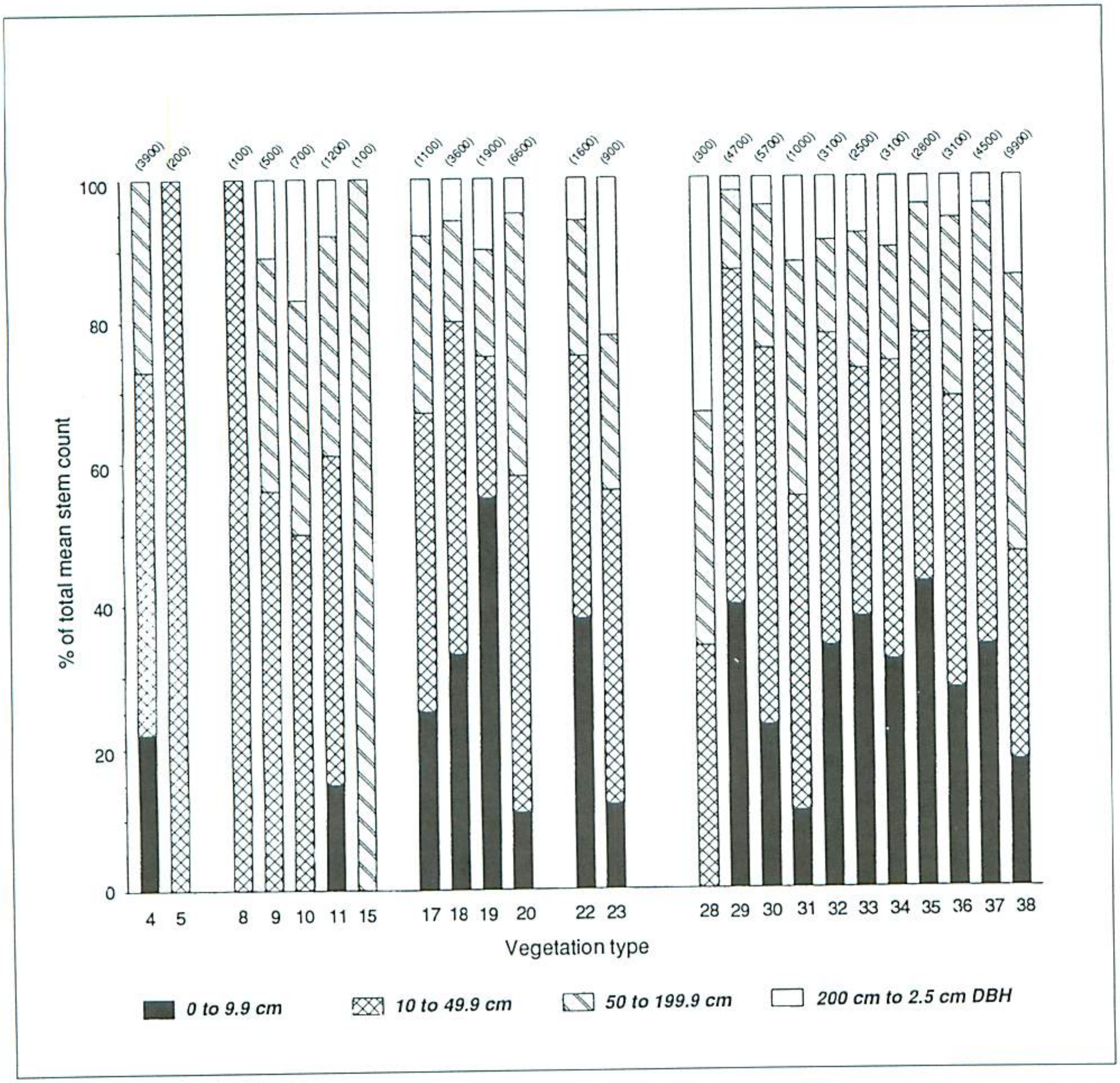


Figure 3. Distribution of black spruce advance growth in four height classes. (Total stems/ha are shown for each Vegetation Type at the top of each bar.)

calculated for all stands sampled in this study and a mean stem density was calculated for each Vegetation Type. The mean stocking and mean stem densities for each Vegetation Type are compared in Table 7. Densities of stems, particularly in most of the pure conifer Vegetation Types (V29 to V38), as well as Vegetation Types V4, V18 and V20 are above the recommended 2,000 to 2,500 trees/ha. The apparently high densities associated with so many of the Vegetation Types creates a somewhat misleading perception with respect to advance growth potential in these Vegetation Types, since stocking levels (a measure of the distribution of the stems) in these same Vegetation Types are typically low.

To better understand the relationship between density and stocking, the distribution of stems in a stand was examined in more detail. In general, advance growth stems tended to occur in clumps across a plot (stand) rather than being evenly

Table 7. Comparison of black spruce advance growth stocking and stem densities for NWO FEC Vegetation Types.

Vegetation Type	Stocking[a] (%)	Density (stems/ha)
4	6	3900
5	3	200
7	0	0
8	3	100
9	10	900
10	8	700
11	17	1200
15	5	100
16	3	100
17	15	1100
18	27	3600
19	23	1900
20	41	6600
21	0	0
22	21	1600
23	18	900
24	0	0
25	0	0
28	6	300
29	34	4700
30	34	5700
31	19	1000
32	32	3100
33	24	2500
34	40	3100
35	34	2800
36	38	3100
37	43	4500
38	86	9900

[a]Based on the proportion of 2- x 2-m quadrats with at least one stem of black spruce advance growth.

distributed. As illustrated in Figure 4, several consecutive quadrats would have high stem counts followed by several quadrats with no stems at all. Such distribution patterns can be expected in stands with a high frequency of layer-type advance growth. A layering tree will typically give rise to numerous offspring about its base (Stanek 1961), thus a 2- x 2-m quadrat encompassing the base of a layering tree could have a substantial stem count.

It has been reported that regeneration problems are related more to distribution than to density (Arnott 1968). Results of this study support these observations. The preferred systematic 2-m spacing of regenerating trees will seldom be achieved in nature because advance growth stems typically occur in scattered clumps. If advance growth is to provide the primary means of stand regeneration, then uneven distribution of stems must be expected, and subsequent fill-in planting may be required to attain desirable stocking levels.

The importance of the relationship between density and stocking becomes an even more important consideration as the Ontario Ministry of Natural Resources moves towards an area-based regeneration assessment program in the North Central Region. Using this approach, it is possible to take full advantage of advance growth as greater planting flexibility is realized.

Relation of Advance Growth to NWO FEC Soil Types

In sampling the range of vegetation conditions, most NWO FEC soil types were encountered. Descriptions for each of the NWO FEC Soil Types are given in Sims et al. (1989). The sampling frequency for each Soil Type is provided in Table 8.

Although all sampled Soil Types were stocked to some degree with black spruce advance growth, only three types, SS2, SS3 and S12S, attained a stocking level of 40% (Fig. 5). Wall and Towill (1988) also found these same Soil Types to have high stocking levels. SS2, a shallow soil condition with <5 cm mineral soil and a 5- to 20-cm-thick organic layer, had the highest mean stocking (60%). S12S is a deep, peaty organic soil derived primarily from *Sphagnum* mosses. Variability within the Soil Types is considerable, with S12S ranging from 0 to 100% stocking. Furthermore, only four Soil Types did not have

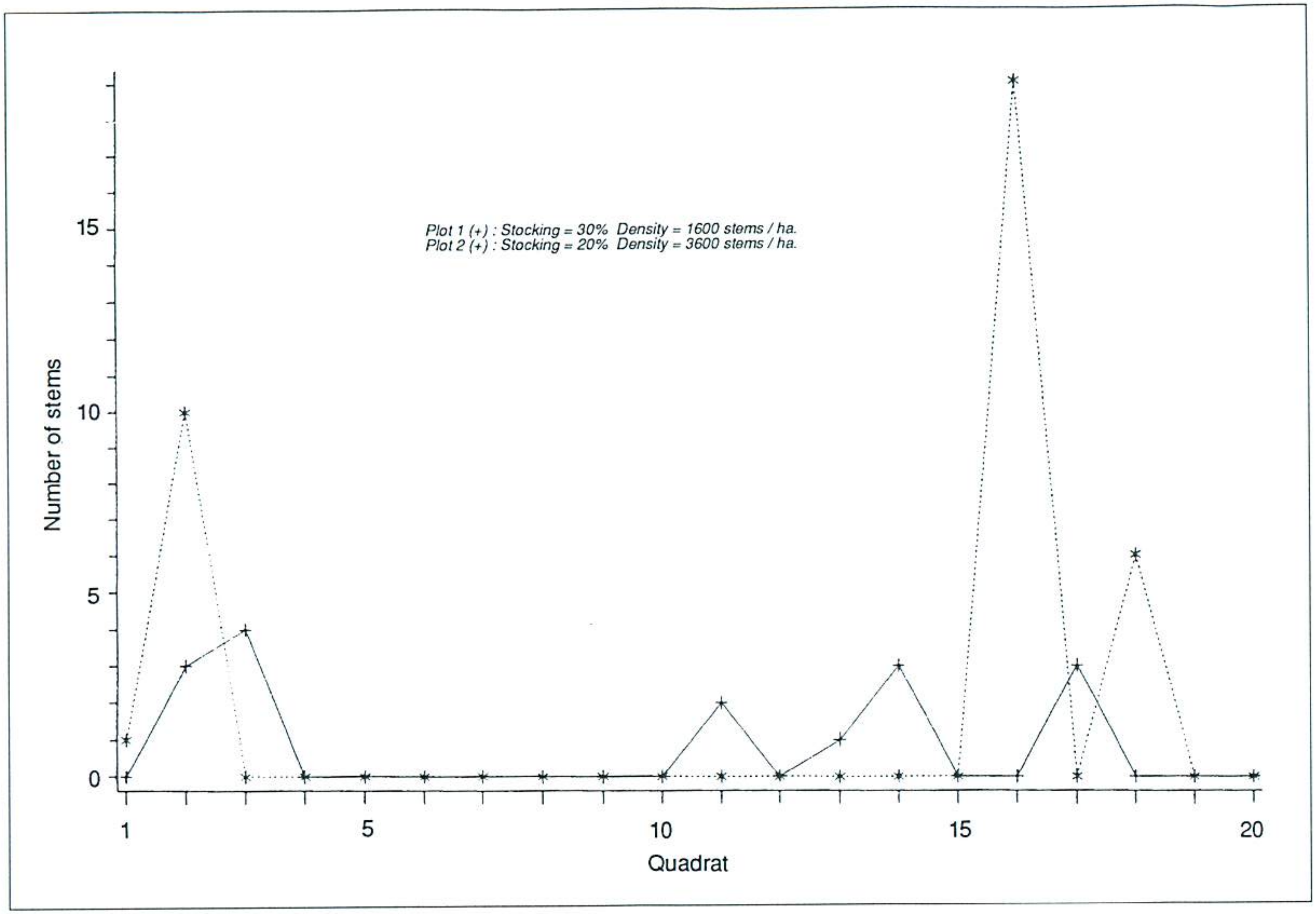


Figure 4. Comparison of stem distribution of advance growth in two stands (NWO FEC Vegetation Type 37).

Table 8. Sampling frequency for NWO FEC Soil Types surveyed during the 1988 black spruce advance growth project.

Soil Type	No. of sites
S1	34
S2	30
S3	31
S4	2
S5	3
S6	2
S7	6
S8	7
S9	7
S10	11
S11	8
S12S	36
S12F	16
SS1	5
SS2	6
SS3	3
SS4	-
SS5	3
SS6	22
SS7	4
SS8	2
SS9	-

"0%" for their lower limits. Jeglum (1981, 1984) and Johnston (1971) reported *Sphagnum* peat to be the ideal seedbed for black spruce seed germination and establishment. There is a considerable range in actual stocking levels associated with most Soil Types (Fig. 5). These large ranges, similar to those discussed in the previous section, reflect the inherent variation associated with each Soil Type.

Other Soil Types, such as S11, S12F, S1, S2, S3 and S10, exhibit relatively high stem densities, although stocking levels remain low. This condition, although giving rise to a potentially misleading perception of advance growth potential (on the basis of currently used evaluation methods), does suggest that advance growth potential is significant, but that some form of stand management (to redress the spacing or distribution problem) may be required.

Relationships Between Soil Parameters and NWO FEC Vegetation Types

Relationships between NWO FEC Vegetation Types and soil parameters have been examined with ordination diagrams. The NWO FEC vegetation data for the 238 plots surveyed in this project were ordinated using DECORANA (Hill 1979). Each plot was represented on the ordination diagram by a single point. The point coordinates for each plot in a Vegetation Type were then averaged to give a single point coordinate for each Vegetation Type. This simplified ordination provided the basis for evaluating relationships between the NWO Vegetation Types and various soil parameters. In Figure 6, each point represents a Vegetation Type, and the position of each point reflects the relative similarities (or dissimilarities) between Vegetation Types. (To help the reader, the major Vegetation Type groupings have been highlighted on each of the ordination diagrams.) Although the ordination is based on the floristic composition of the Vegetation Types, environmental gradients can often be ascribed to each of the axes. In this particular ordination, the vertical (Y) axis defines a moisture gradient, dry to wet, upward along the axis, and a nutrient gradient, poor to rich, from left to right along the horizontal (X) axis. On the left side of the ordination, the lowland black spruce (V34 to V38), white cedar (V22) and larch (*Larix laricina* (Du Roi) K. Koch) Types (V23) dominate. These Vegetation Types are typically associated with organic soils, but tend to have low understory species cover and diversity as a result of dense canopy cover (e.g., V22) or poor nutrient conditions. In contrast, the remaining Vegetation Types, tending to the right side of the ordination, are typically associated with upland, mineral soil conditions. Floristic diversity is much greater in these stand types, and understory species reflect a richer nutrient regime.

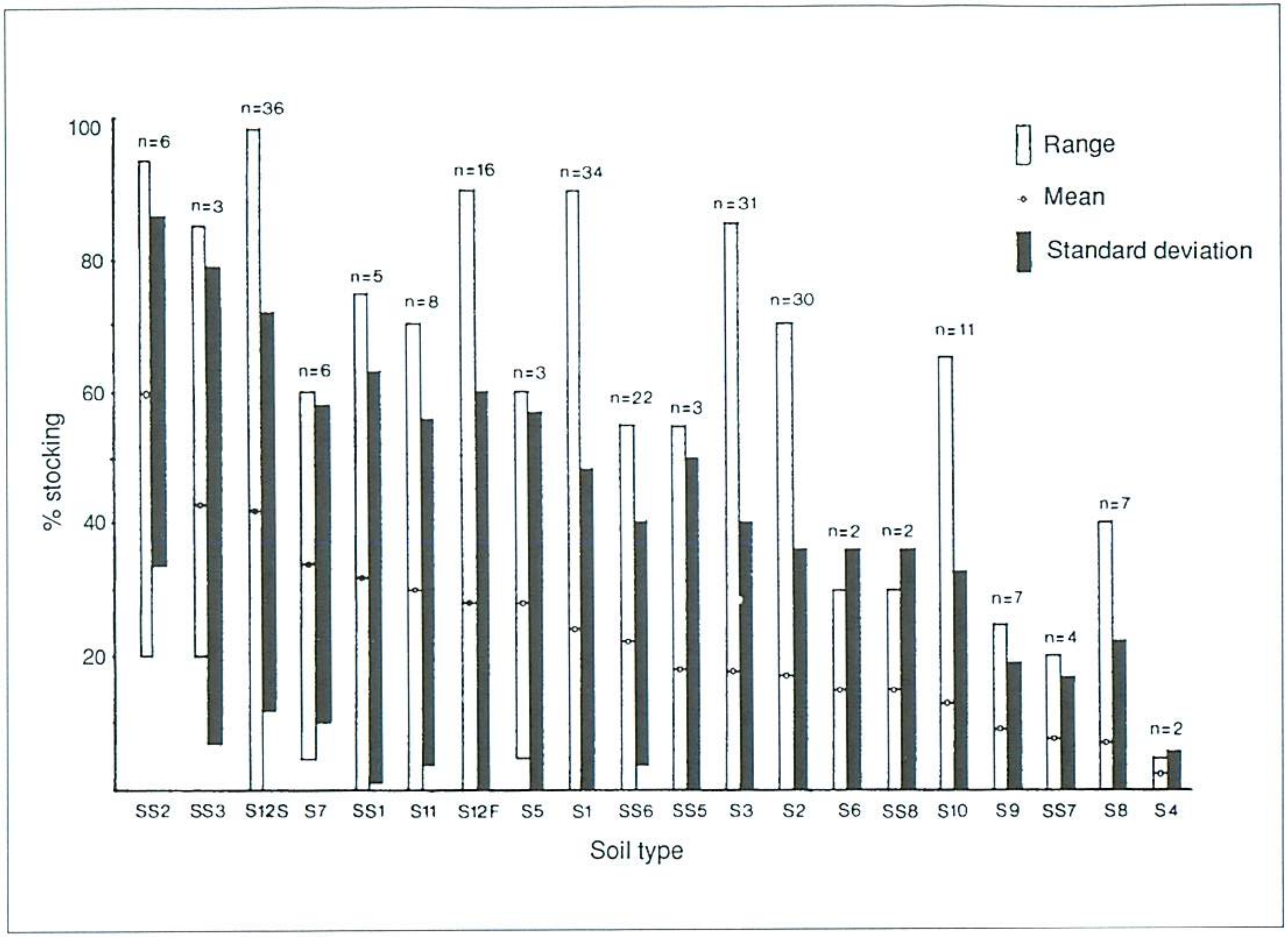


Figure 5. Black spruce advance growth stocking levels for NWO FEC soil types.

Similar patterns are depicted when stand- and soil-related parameters are superimposed on the ordination diagram. Figure 7 (when superimposed over Figure 6) shows the mean percent stocking of black spruce advance growth for each Vegetation Type. The highest stocking tends to occur on the left side of the diagram, corresponding to lowland black spruce Vegetation Types. Figure 8 shows the density (stems/ha) of black spruce advance growth (layers and seedlings) by sampled Vegetation Type. Trends are similar to those observed in Figure 7, with advance growth densities highest in the lowland and upland conifer types. Vegetation Type V4 again stands out in the hardwood-dominated mixedwood group with high stem density. Figure 9 shows the distribution of organic and mineral soil conditions described in one of eight generalized NWO FEC soil classes (Sims et al. 1989). Figure 10 shows the average thickness of organic peat for each Vegetation Type. Organic soils, with accumulations of at least 20 cm of peat, are depicted on the left side of the ordination; mineral soils tend to occur on the right side of the diagram. The wettest soil moisture regimes (Anon. 1985a), which are typical of deep organic soils or lower slope and depressional landscape positions, are also concentrated on the left side of the ordination (Fig. 11).

Significant stocking levels are also indicated in Vegetation Types V20, V29, V30 and V32 (Fig. 7, 8 and 9). These upland Vegetation Types include poorer upland conditions, with a range in moisture conditions trending from drier to slightly wetter, as indicated by their relative positions on the ordination. They are characterized by a moderately abundant shrub layer dominated by ericaceous or conifer species, herb-poor understory conditions and an expansive feathermoss mat. Vegetation cover in V30 is typically sparse as a result of significant bedrock exposure associated with these sites (Sims et al. 1989). Depressions in the bedrock, however, frequently give rise to small, wet organic microsites with vegetation similar to that associated with lowland, organic sites.

On the basis of the ordinations, the highest stocking levels of black spruce advance growth are associated with wet and nutrient-impoverished site conditions (Fig. 6 and 7). Stand types with the greatest potential for black spruce advance growth are wet, organic lowland types and nutrient-poor upland types. Upland, hardwood-dominated mixedwood stands that have a diverse and abundant herb and shrub component exhibit limited potential for black spruce advance growth.

Prediction of Occurrence of Advance Growth Using Soil/Site Parameters

Correlation Analysis

Simple correlation analysis was used to quantify the relation of various soil/site parameters to black spruce advance growth stocking and density. Table 9 summarizes the correlation coefficients (r) determined for these variables.

None of the individual variables can be said to be highly correlated with either stocking or stem density of black spruce advance growth. However, those variables with higher correlations confirm expected and observed trends in the occurrence and distribution of black spruce advance growth.

Variables with the greatest positive correlation with black spruce advance growth stocking include percent cover by *Sphagnum* moss or Labrador tea, as well as the proportion of black spruce in the total stand basal area. These factors are similar to those reported by Groot (1984) and have been shown to be significantly correlated with black spruce advance growth stocking. These variables are typical of lowland (peatland) stand conditions, normally characterized as dominantly black spruce with peaty organic soils, and significant cover by Labrador tea or other ericaceous shrubs (e.g., leatherleaf).

The more interesting negative correlations are observed between advance growth stocking and

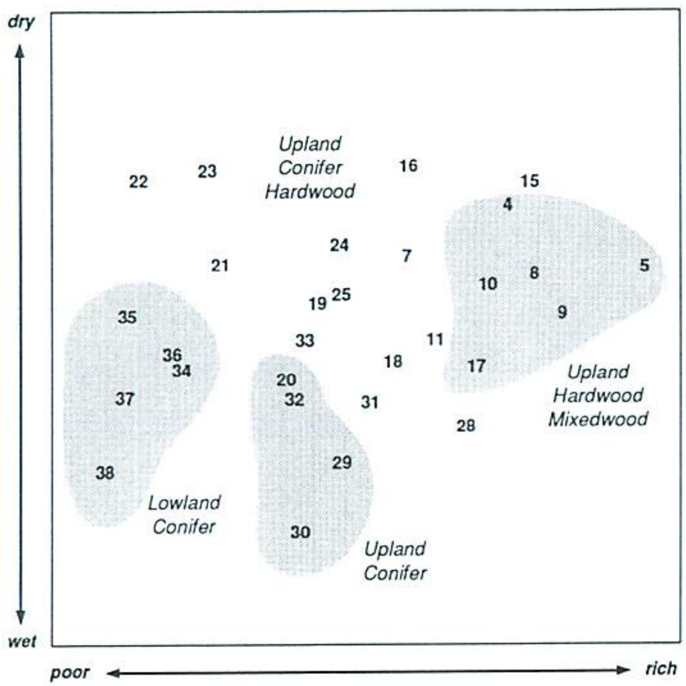


Figure 6. *Ordination of NWO FEC Vegetation Types sampled in the 1988 black spruce advance growth project.*

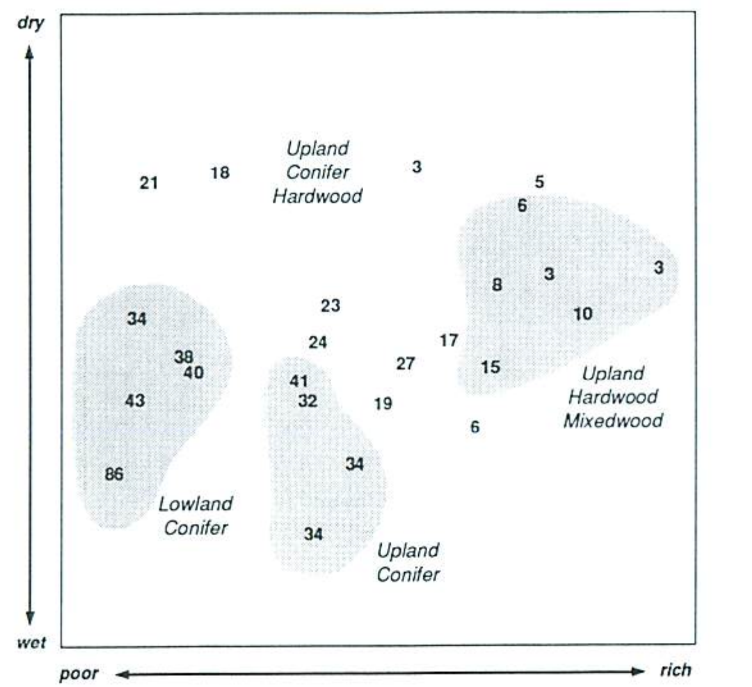


Figure 7. *Average stocking to black spruce advance growth associated with each of the NWO FEC Vegetation Types ordinated in Figure 6.*

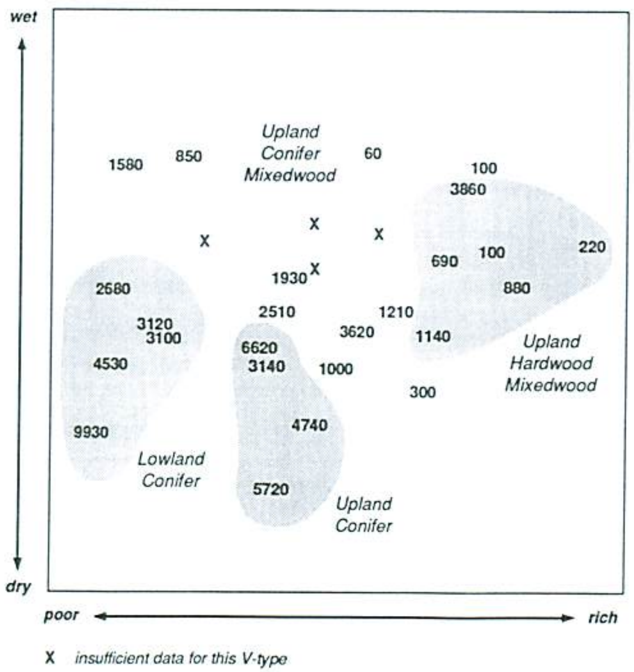


Figure 8. Density of black spruce advance growth superimposed on the ordination of NWO FEC Vegetation Types.

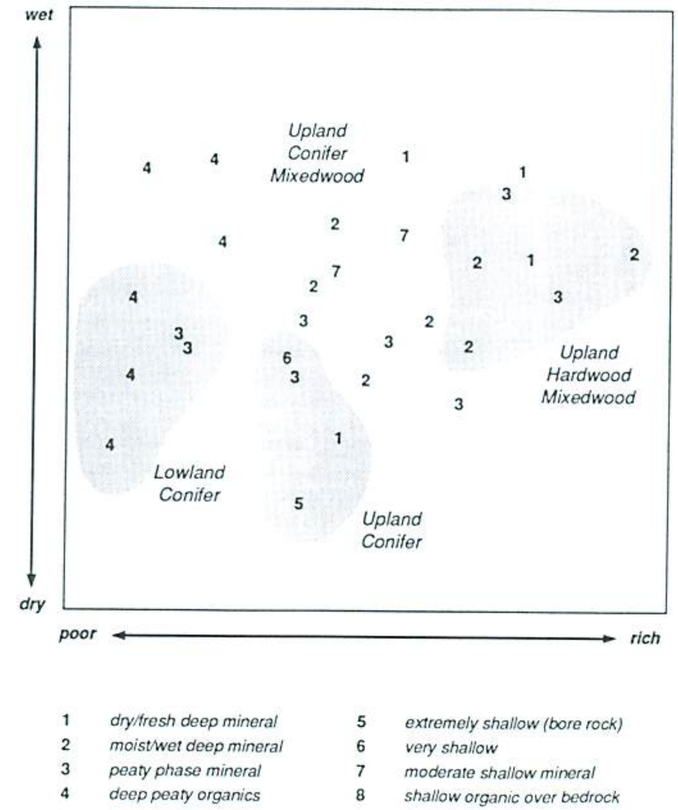


Figure 9. Average soil type conditions superimposed on the NWO FEC Vegetation Types.

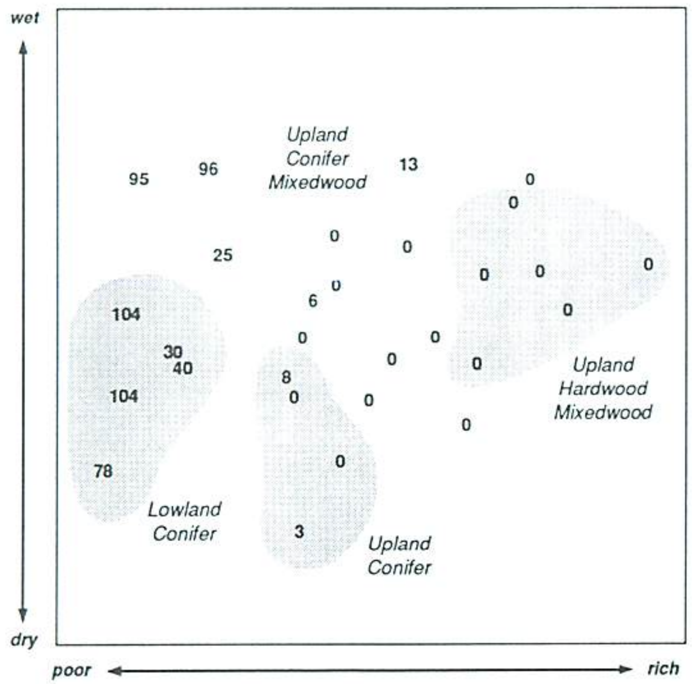
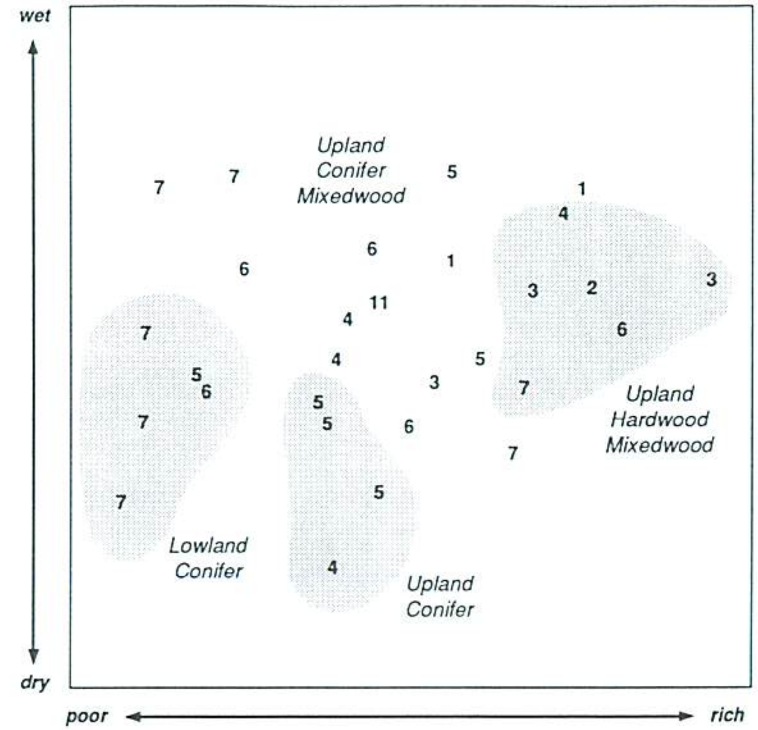


Figure 10. Average thickness of peat organic layer superimposed on the ordination of NWO FEC Vegetation Types.



1	*moderately fresh*	7	*moderately wet*
2	*fresh*	8	*wet*
3	*very fresh*	9	*very wet*
4	*moderately moist*	10	*dry*
5	*moist*	11	*moderately dry*
6	*very moist*		

Figure 11. Average soil moisture regime superimposed on the ordination of NWO FEC Vegetation Types.

Table 9. Selected correlation coefficients (r values) determined for black spruce advance growth stocking and density relationships with vegetation and site variables.

Variable[a]	Stocking (%) to black spruce advance growth	Density (stems/ha)
HUMTHCK	0.247 *	–
FMOSS	0.239 *	0.199 *
SPHAG	0.356 *	0.181 *
CANOPY	-0.416 *	-0.341 *
LEDUM	0.394 *	0.221 *
STAND AGE	0.272 *	0.246 *
HERB	-0.376 *	-0.313 *
CHAMCAL	0.296 *	–
LFLIT	-0.353 *	-0.255 *
BASB	0.227 *	–
BAPOT	-0.279 *	-0.218 *
BATOT	-0.307 *	-0.231 *
PROPSB	0.448 *	0.274 *
PROPPOT	-0.285 *	-0.223 *
ARALDA	-0.308 *	-0.232 *

* significant at P = 0.01

[a]HUMTHCK	=	thickness of humus layer
FMOSS	=	% cover by feathermoss species *Pleurozium schreberi* (Schreber's moss), *Hylocomium splendens* (step moss), *Ptilium crista-castrensis* (plume moss)
SPHAG	=	% cover by any *Sphagnum* species
CANOPY	=	% canopy closure
LEDUM	=	% cover by *Ledum groenlandicum* (Labrador tea)
STAND AGE	=	mean age of 5 (co-) dominant trees
HERB	=	% cover by all herbaceous species combined
CHAMCAL	=	% cover by *Chamaedaphne calyculata* (leatherleaf)
LFLIT	=	% cover by broadleaf litter
BASB	=	basal area for black spruce
BAPOT	=	basal area for *Populus tremuloides* Michx. (trembling aspen)
BATOT	=	total basal area of black spruce, white spruce, jack pine, cedar, balsam fir, white birch, trembling aspen, balsam poplar and larch (tamarack)
PROPSB	=	proportion of total basal area comprised by black spruce
PROPPOT	=	proportion of total basal area comprised by trembling aspen
ARALDA	=	% cover by *Aralia nudicaulis* (wild sarsparilla) + *Diervilla lonicera* (bush honeysuckle) + *Aster macrophyllus* (large-leaved aster)

percent cover by herbaceous species, broadleaf litter and the percent canopy closure. These variables are typically associated with upland stand conditions, for which floristic diversity is highest, a significant hardwood component is present in the main canopy and stand conditions are not favorable for advance growth.

In black spruce-dominated uplands where stocking to spruce is relatively high, and canopy closure is also high, the negative correlation likely reflects branch mortality, which occurs at the base of the trees in the absence of light. This mortality reduces the opportunity for layering, hence the lower levels of advance growth on such sites. Black spruce advance growth can therefore be expected to be abundant in lowland stands dominated by black spruce and on sites with a *Sphagnum* organic layer. In contrast, the abundance of black spruce advance growth tends to be limited under upland conditions because of shading provided by a full canopy (negative correlation), by the abundance of herbaceous vegetation, and by reduced opportunity for layering in densely stocked stands.

Multiple Regression Analysis

The use of individual soil/site variables to predict black spruce advance growth on various Vegetation Types is limited, as individual variables typically account for only 15 to 20% of the observed variation (Table 9). Multiple regression analysis was used to determine the potential for using these variables in combination to predict black spruce advance growth. Table 10 summarizes those multivariate equations which exhibit the best predictive capability.

Table 10. Regression equations to predict stocking to black spruce advance growth.

1. $STK = 48.0 - 0.19CANOPY - 0.33HERB + 0.85CHAMCAL - 0.36BATOT + 17.3PROPSB$
   $R^2(adjusted) = 35.77\%$

2. $STK = 45.5 - 0.34HERB - 0.60BATOT + 23.06PROPSB$
   $R^2(adjusted) = 32.04\%$

3. $STK = 30.12 - 0.57BATOT + 16.38PROPSB + 0.20FMOSS + 0.24SPHAG$
   $R^2(adjusted) = 31.14\%$

where,

STK	=	% stocking to black spruce advance growth
CANOPY	=	% of 10- x 10-m plot covered by tree canopy
HERB	=	% of 10- x 10-m plot covered by herbs
CHAMCAL	=	% of 10- x 10-m plot covered by *Chamaedaphne calyculata* (leatherleaf)
FMOSS	=	% of 10- x 10-m plot covered by feathermoss species: *Pleurozium schreberi* (Schreber's moss), *Hylocomium splendens* (step moss), *Ptilium crista-castrensis* (plume moss)
SPHAG	=	percent of 10- x 10-m plot covered by any *Sphagnum* moss species
BATOT	=	total basal area of black spruce, white spruce, jack pine, cedar, balsam fir, white birch, trembling aspen, balsam poplar and larch (tamarack)
PROPSB	=	proportion of total basal area comprised by black spruce

Although accurate prediction of the occurrence of black spruce advance growth is limited, trends in black spruce advance growth observed using previous analyses are again confirmed. Variables that had the best correlations are those that, when combined, gave the best predictive regression equation.

Trends in all three equations suggest that stocking to black spruce advance growth is highest in black spruce-dominated stands with organic soils, poor drainage and high *Sphagnum* cover. Conversely, as stands become more floristically diverse (i.e., develop increased herb cover), as the canopy becomes more closed, and as the total stand basal area increases, there is a general reduction in stocking.

Stepwise Discriminant Analysis

Stepwise discriminant analysis was employed to determine which soil and site variables would most effectively discriminate between the four classes of advance growth stocking (0 to 40%, 41 to 60%, 61 to 80%, >80%). The four groups proved to be distinct. As shown in Table 11, 64 to 79% of the sites were correctly assigned in three of the groups but only 22% were correctly assigned in the 61 to 80% stocking class.

Variables that were useful in the regression equations were similar to those that discriminated among the four stocking classes. These variables included the proportion of black spruce in the total basal area (PROPSB), peat thickness (HUMTHCK), total basal area (BATOT), and stand age (STAND AGE).

Evaluation of Advance Growth Abundance

The development of equations for the prediction of advance growth based on the limited data from this study is clearly not practical. However, the results do indicate trends in the occurrence and stocking of advance growth in a number of NWO FEC Vegetation Types.

Table 12, which shows the percent frequency of occurrence of stands in relation to four advance growth stocking classes, suggests a framework within which the potential for black spruce advance growth occurrence might be indicated. The majority of stands in all Vegetation Types have less than 40% stocking to black spruce advance growth. V38 is the only exception to this trend, with >80% stocking. An additional 14 Vegetation Types have limited occurrences in at least one of the three stocking classes greater than 40%.

Trends in these frequency occurrence data are more apparent in Figure 12, an ordination diagram derived from the complete NWO FEC vegetation dataset (Sims et al. 1989). All Vegetation Types in the classification are represented, and percent occurrence information for each Vegetation Type is provided symbolically.

With some knowledge of the Vegetation Type descriptions (Sims et al. 1989) and an

Table 11. Site assignment to stocking classes by stepwise discriminant analysis.

Group	Stocking class	Percent correct	Number of sites classified into each group			
			0-40%	41-60%	61-80%	>80%
1	0 to 40%	78.8	115	20	6	5
2	41 to 60%	64.3	3	9	0	2
3	61 to 80%	22.2	5	1	2	1
4	>80%	75.0	0	1	0	3

Table 12. Percent frequency of occurrence of stands in four advance growth stocking classes.[a]

Vegetation Type (n=)	Stocking class 1 ≤40%	2 41-60%	3 61-80%	4 >80%
4 (7)	100	0	0	0
5 (9)	100	0	0	0
8 (4)	100	0	0	0
9 (4)	100	0	0	0
10 (11)	100	0	0	0
16 (3)	100	0	0	0
17 (11)	100	0	0	0
18 (10)	80	10	0	10
19 (10)	90	0	10	0
20 (11)	45	36	18	0
22 (10)	90	10	0	0
23 (9)	89	0	0	11
28 (7)	100	0	0	0
29 (11)	82	0	18	0
30 (10)	60	20	20	0
31 (12)	92	8	0	0
32 (16)	62	31	6	0
33 (10)	80	0	0	20
34 (12)	50	17	17	16
35 (10)	60	30	10	0
36 (11)	54	18	27	0
37 (14)	50	21	21	7
38 (4)	0	0	25	75

[a]Totals may not add to 100 due to rounding.

understanding of the ordination diagram, the pattern of occurrence of black spruce advance growth is readily explained. The axes of this ordination have been described by representing a nutrient gradient, poorer to richer, from left to right along the horizontal, and a moisture gradient, from wetter to drier, upward along the vertical (Sims et al. 1989).

The Vegetation Types in the lower left corner tend to be lowland types, typically black spruce-dominated (also cedar and larch) developing on saturated organic soils. The Vegetation Types in the upper left portion of the ordination are considerably drier types, since they occur on upland sites. Stands are usually pure conifers (black spruce and/or jack pine) with extensive feathermoss mats, and they develop on a range of deep mineral soil types. Vegetation Types on the right side of the diagram have a relatively richer nutrient status, which is reflected in greater species diversity and abundance. The majority of Vegetation Types on the right side are hardwood-conifer mixed stand types. Those Vegetation Types in the lower right section are characterized by wetter stand conditions on moderately deep organic or fine-textured mineral soils. Greater nutrient availability, however, results in a greater variety and abundance of moisture-tolerant herb and shrub species.

Vegetation Types in the upper right corner of the ordination are typically upland mixedwood types. Stands of these Vegetation Types, though developing on drier mineral soils, exhibit considerable species richness in all strata. Since there is more broadleaf litter in these mixedwood types, moss cover is restricted.

The advance growth occurrence data, superimposed on this ordination, illustrate that any occurrences of black spruce advance growth stocking at levels greater than 40% are associated with those Vegetation Types on the left side of the ordination diagram (Fig. 12). These types occur across a range of moisture conditions (vertical axis) but tend to have relatively poor stand nutrient conditions (horizontal axis).

Although Vegetation Types associated with abundant black spruce advance growth encompass a range of soil moisture regimes and occur on both lowland and upland conditions, they share common trends in vegetation composition. Essentially all are pure conifer types dominated by black spruce or jack pine. The forest floor is typically covered by extensive moss mats — feathermoss on upland sites and *Sphagnum* on lowland sites. Abundance and diversity of herb species in these lowland Vegetation Types are very limited. Diversity of shrub species is also limited, the most abundant species being Labrador tea and other ericaceous shrubs.

Black spruce advance growth in Vegetation Types on the right side of the ordination (Fig.

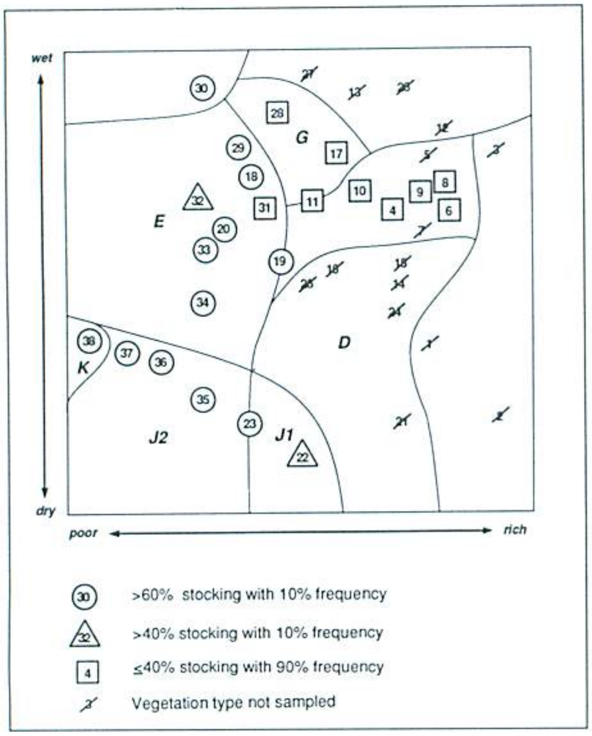


Figure 12. Frequency of occurrence of black spruce advance growth with stocking >40% in NWO FEC Vegetation Types.

12) do not typically exceed 40% stocking. In contrast to stand types associated with higher stocking levels of black spruce advance growth, these Vegetation Types are characterized by mixedwood, species-rich (herb layer) conditions. Most of these Vegetation Types are hardwood-conifer mixedwoods. The two pure conifer types (V28 and V31) that have less than 40% stocking of black spruce advance growth share the shrub-rich conditions associated with these mixedwood Vegetation Types. Shrubs tend to be broadleaf, non-ericaceous species such as beaked hazel (*Corylus cornuta* Marsh.), mountain maple (*Acer spicatum* Lam.) and bush honeysuckle (*Diervilla lonicera* Mill.). Herb species are equally diverse and abundant in these stand types. Moss cover is lacking because of the large accumulations of broadleaf litter afforded by the abundant deciduous species.

Results of this study confirm those of Groot (1984) by showing that abundant black spruce advance growth is associated with wetter, poorer site conditions.

Although, on the basis of results from this study, it is difficult to accurately predict the abundance of black spruce advance growth by means of predictive equations, an understanding of the trends can lead to a simplistic method for evaluating the potential occurrence of black spruce advance growth. A simple key has been developed to aid this evaluation (Fig. 13). The key is derived from percent occurrence data for the 238 stands sampled in this study. The key is very preliminary and based on a relatively small sample size. (Field application and testing will undoubtedly result in refinement.) The key is used in a manner similar to those developed for the NWO FEC classification. The user simply begins at the top ("start") and proceeds, answering each of the questions in turn and following the arrows as appropriate. For example, the user would begin the keying exercise by first deriving the appropriate Vegetation Type from the NWO FEC Vegetation Type field key (Sims et al. 1989), then, using the key provided in Figure 13, would follow the arrow from the derived Vegetation Type. The user is reminded of the variability in stocking associated with each Vegetation Type by the "frequency of occurrence" column. The frequency of occurrence is simply the percentage of sites sampled during this study that fall into one of the four provincially derived stocking classes. At this point, the user assigns the appropriate provincially defined stocking class.

As indicated in Table 12, most of the stands sampled in this study had less than 40% stocking to black spruce advance growth. There were relatively few occurrences of stands with greater than 40% stocking. This key makes it possible to determine those Vegetation Types that have some potential for black spruce advance growth stocking levels greater than 40%.

Since few Vegetation Types share similar distribution of stands across the stocking classes, the trends in individual types had to be generalized. Hence, broad and sometimes overlapping ranges of percent occurrence are defined for the groups of Vegetation Types at each decision point. However, in working through this simple key, the trend is toward

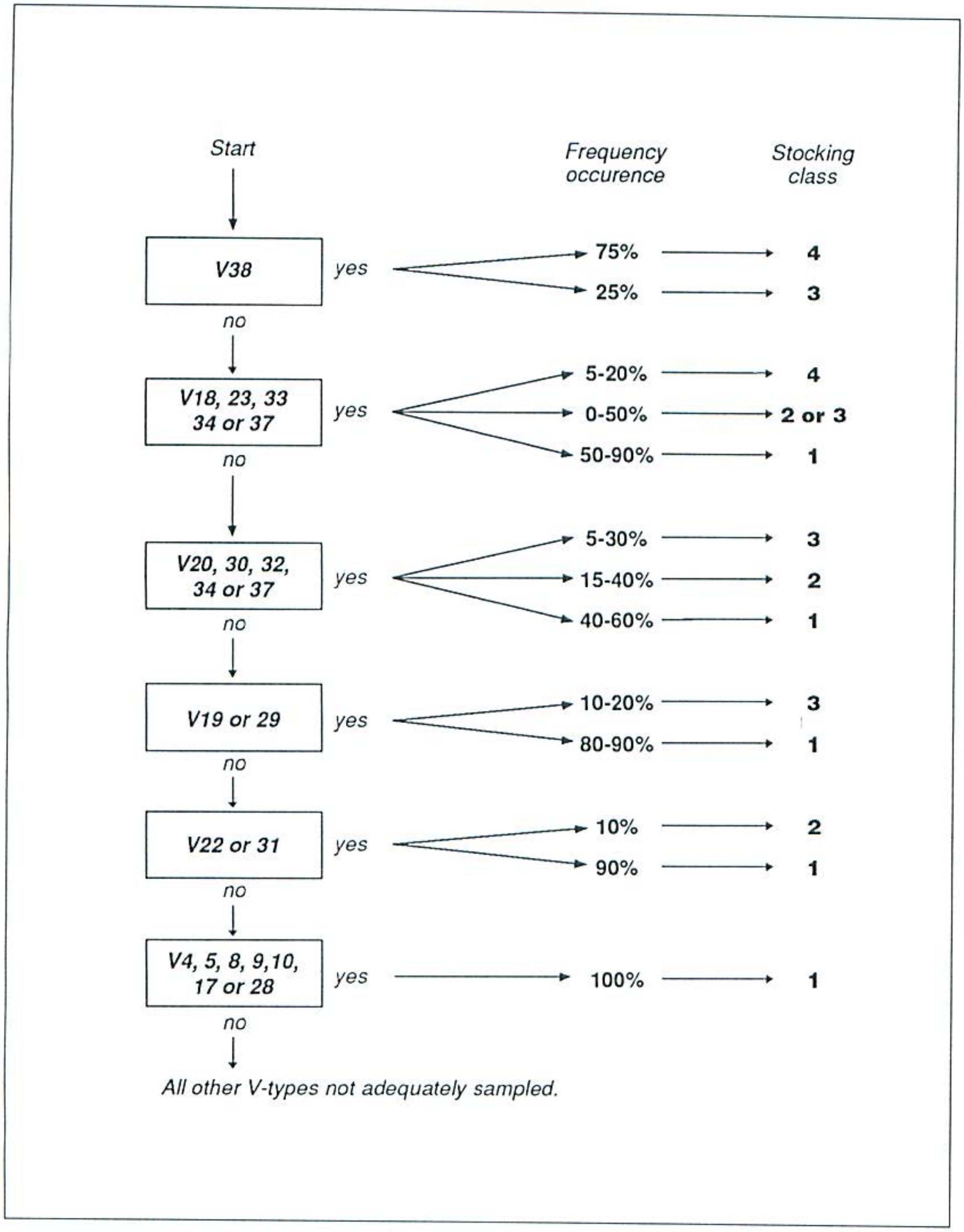


Figure 13. Key to evaluating the occurrence of black spruce advance growth in North Central Ontario.

those Vegetation Types with the least potential for abundant (>40% stocking) black spruce advance growth.

SUMMARY AND CONCLUSIONS

This study was designed to quantify advance growth in the North Central Region within the NWO FEC framework of Vegetation Types and Soil Types and to develop a model for estimating the potential occurrence of black spruce advance growth in each of these Vegetation Types. To provide the advance growth data for this study, 238 NWO FEC plots, representing a range of vegetation and soil conditions, were resampled. This data was combined with the baseline NWO FEC data for those sample plots. The entire dataset was then analyzed and summarized within the NWO FEC framework.

Black spruce advance growth was found to be primarily of layer origin. Seedlings accounted for less than 5% of the total established black spruce advance growth. Most stems were growing upright to a dominant height of 50 cm.

Black spruce advance growth occurs to some degree in most NWO FEC Vegetation Types and Soil Types. Because these types represent a broad range of conditions, and because there is considerable variation within any one type in the amount of advance growth encountered, accurate prediction of black spruce advance growth occurrence using mathematical formulae was impractical. However, for each Vegetation Type sampled, the frequency of occurrence of stands within one of four stocking classes was determined. The stagnant, unmerchantable stands of V38 proved to have the greatest occurrence of black spruce advance growth. Fourteen additional Vegetation Types have potential for black spruce advance growth to a stocking level greater than 40%. The frequency of such occurrences is typically low.

Black spruce advance growth occurs in Vegetation Types that span the range of moisture conditions — from wet lowland types to drier upland types. The abundance of black spruce advance growth tends to be greater in stands that have black spruce in the overstory, exhibit low herbaceous cover and have an extensive moss mat. Vegetation Types characterized as shrub- and herb-rich mixedwoods tend to have black spruce advance growth at stocking levels of less than 40%.

Trends in the occurrence of black spruce advance growth are incorporated into a simple key derived from the frequency of occurrence of advance growth in four stocking classes for each Vegetation Type. This model, though not based on probabilities of occurrence, is useful for a pre-harvest assessment of advance growth conditions. Since the determination of NWO FEC Vegetation Types is already, or can easily be, incorporated into existing precut survey methods, this key ensures that the evaluation of advance growth does not unduly complicate the precut survey methodology.

Based on the data collected during this study, this model provides the best means of assessing potential black spruce advance growth in mature forest stands of the North Central Region. It is recommended that further studies be initiated to refine this model. Suggested areas of additional research include:

1. Rigorous field testing of the advance growth evaluation key developed in this study.

2. Obtaining age data for advance growth and relating this to height data in order to determine whether a range in heights reflects a range in ages.

3. Sampling a wider range of stand ages, particularly younger stands (<50 years), to determine succession patterns. Is advance growth established all at once or is it an ongoing process?

4. Redefining the scope of this study by:
   a. studying a smaller, more homogeneous geographic area,
   b. sampling in a Vegetation Type grouping (e.g., upland or lowland types or within a defined working group designation),

c. undertaking an intensive sample of an individual Vegetation Type. In each, the range of conditions would be reduced and an adequate sample size could be ensured to permit the development of a predictive model within a Vegetation Type or group of Vegetation Types.

5. Obtaining data that can be used to more precisely define the influence of light and shading on advance growth occurrence.

6. Continuing to study the effects of harvesting on advance growth. This too could be done within the NWO FEC framework, allowing a determination of the impacts on different site types. Since this predictive model was developed from stands in the pre-harvest condition, it would be equally useful to be able to predict advance growth occurrence in the post-harvest condition.

ACKNOWLEDGMENTS

The authors wish to acknowledge the following individuals for their contributions to the project: Fred Haavisto of Forestry Canada, Ontario Region (FCOR), scientific authority for this project, for his on-going interest and thoughtful comments; Dr. Richard Sims (FCOR), for his efforts in initiating the study, preparing the terms of reference and facilitating access and use of the original NWO FEC data base; Bill Baker and Bill Towill of the Northwestern Ontario Forest Technology Development Unit in Thunder Bay, who provided comments, insight and support throughout the project.

Financial support for this project was provided through the Forestry Canada Direct Delivery Research Component of the Canada–Ontario Forest Resource Development Agreement.

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