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NATURAL REGENERATION OF HARDWOOD AND SOFTWOOD TREE SPECIES FOLLOWING FULL-TREE HARVESTING IN NORTHWESTERN ONTARIO

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ABSTRACT

Throughout northwestern Ontario 71 clear-cut sites, which had been full-tree harvested between 1979 and 1986, were sampled in 1993 and 1994 for ingress of natural regeneration. Sampled sites were stratified by seedbed condition and the preharvest vegetation type that they supported, based on the Northwestern Ontario Forest Ecosystem Classification (Sims et al. 1989). Seedbeds were classified as either intact/mixed forest floor or scalped/mineral soil exposed. Vegetation types were amalgamated into ecologically similar groups or treatment units, which included: jack pine (*Pinus banksiana* Lamb.)/shrub rich, jack pine/feathermoss, and black spruce (*Picea mariana* [Mill.] B.S.P.)–jack pine/feathermoss. The majority of the sites surveyed were classified as black spruce–jack pine/feathermoss with intact/mixed forest floor seedbeds. Both the rate of natural ingress over the first 7 years of the stands' development and the resultant stand structure and composition were examined.

Large amounts of ingress were found on all site types. Average total stem densities ranged from 15 000 to 20 000 stems per hectare 10 years after harvest, but were quite variable. Among treatment units jack pine always exhibited the highest average densities although it was significantly more frequent than other tree species only on the jack pine/feathermoss treatment unit. Black spruce was found at significantly higher densities on black spruce–jack pine/feathermoss sites, whereas poplar (*Populus* spp.) was found at significantly higher densities on jack pine/shrub rich sites. Rate of ingress was based on the first 7 years after harvest for all sites. On average, ingress of natural regeneration continued for 5.5 years following harvest and a minimum of 4 years elapsed before ingress was complete on any site. There were no significant differences in the rate of ingress for any treatment unit, species, or seedbed combination.

RÉSUMÉ

71 sites répartis dans tout le nord-ouest de l'Ontario et situés dans des peuplements coupés à blanc par arbres entiers entre 1979 et 1986 ont été échantillonnés en 1993 et 1994 pour étudier la régénération naturelle. Les sites échantillonnés ont été classés selon l'état du lit de germination et le type de la végétation présente avant la coupe, en appliquant la classification des écosystèmes forestiers du nord-ouest de l'Ontario (Sims et collab., 1989). Les lits de germination ont été classés en 2 groupes: couverture morte intacte/mixte ou sol érodé/minéral exposé. Les types de végétation ont été groupés en 3 unités de traitement ou groupes écologiquement similaires: pin gris (*Pinus banksiana* Lamb.)/strate arbustive riche; pin gris/mousses hypnacées; épinette noire (*Picea mariana* [Mill.] B.S.P.)–pin gris/mousses hypnacées. La majorité des sites ont été classés dans le groupe des sites à épinette noire-pin gris/mousses hypnacées avec couverture morte intacte/mixte. La vitesse de développement de la régénération naturelle pendant les 7 premières années d'établissement des nouveaux peuplements a été examinée, ainsi que la structure et la composition des peuplements résultants.

Une régénération naturelle importante a été observée pour tous les types de sites. En moyenne, les densités totales variaient de 15000 à 20000 tiges par hectare 10 ans après la récolte, mais les chiffres variaient beaucoup. Au niveau des unités de traitement, le pin gris avait toujours les densités moyennes les plus élevées. Il était significativement plus fréquent que les autres essences seulement dans l'unité de traitement à pin gris/mousses hypnacées. L'épinette noire était présente à des densités significativement plus élevées dans les sites à épinette noire-pin gris/mousses hypnacées; le peuplier (*Populus* spp.), l'était dans les sites à pin gris/strate arbustive riche. La vitesse de régénération naturelle a été calculée en considérant les 7 premières années après la récolte pour tous les sites. En moyenne, la régénération naturelle s'est poursuivie pendant 5,5ans après la récolte; à aucun endroit, elle ne s'est terminée avant 4 ans. Aucune différence significative de la vitesse de régénération n'a été mise en évidence en comparant les unités de traitement, les espèces et les lits de germination.

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INTRODUCTION

Contemporary forestry practices in northwestern Ontario involve numerous assumptions regarding their impacts and the manner in which the forest develops both naturally and following disturbance. This includes knowledge of early successional pathways on common forest vegetation types. Data collected by the Survey of Artificially Regenerated Sites (SOARS) Program in 1985–86 showed that 10- to 14-year-old jack pine (*Pinus banksiana* Lamb.) and black spruce (*Picea mariana* [Mill.] B.S.P.) plantations in northwestern Ontario averaged 5 800 stems per hectare.[1] By contrast, initial planting densities averaged only 1 880 stems per hectare. The difference was the result of ingress of natural tree seedlings (henceforth referred to simply as ingress). From a timber optimization perspective, the SOARS data indicate that some clear-cut and planted sites in northwestern Ontario sustain a stem density that is too high.

These results demonstrate the need for a tool to help predict the rate and density of natural regeneration on clear-cut sites. Many cutovers are artificially regenerated only to require later tending (spacing) to reduce stem density to acceptable levels for desired crop plans. Administrative requirements that specify a minimum postharvest stand composition at Year 5 (e.g., 60 percent stocking of acceptable species) are the primary reason for this conservative (and costly) approach to forest regeneration. The principal objective of this study was to determine if a link exists between selected site types defined by the Forest Ecosystem Classification for northwestern Ontario (NWOFEC) (Sims et al. 1989), and the rate and density of ingress that occurred on full-tree harvested sites.

Information on the ingress of naturals may help to reduce the costs of regenerating the forests of northwestern Ontario by improving the reliability of silvicultural decisions during the crop planning process. Managers may choose to harvest and site prepare, and then leave those NWOFEC site types where it is considered that sufficient natural regeneration may occur. Planting could then become a tool to be used only on those areas where site-specific situations make it absolutely necessary, opting instead to seed or fill-plant those sites where ingress of naturals has proven to be less successful.

Promotion of natural regeneration could not only reduce the costs of forest renewal, but site-specific knowledge on the ingress of naturals may allow managers to be flexible in timing regeneration surveys and in setting performance standards. For example, if the ingress of natural regeneration continues for 7 years after logging, then surveys carried out at Year 5 will capture only part of the immature stand structure. This becomes particularly critical when fifth-year survey information is used to initialize models projecting stand development, as is increasingly becoming the case with crop planning techniques. .

Increasing concern for the maintenance of forest biodiversity across the northwestern Ontario landscape is also an important issue. The prospect that single-species plantations may lead to monocultures is of particular concern. Do all cutovers resulting from full-tree logging tend to support monocultures after a single species has been planted? This study describes the stand structure and composition of selected full-tree harvested sites approximately 10 years after harvest. From these site portraits tree stratum diversity concerns have been examined.

LITERATURE REVIEW

Ingress of natural regeneration appears to be highly related to site type. Several studies (Hatcher 1960, Godin 1985, Harvey and Bergeron 1991) have described postharvest stand conditions composed largely of balsam fir advanced regeneration, and indicate that little or no subsequent ingress occurred. Yet ingress clearly makes a major contribution to overall regeneration success on other sites.

On sites that do experience ingress, several studies have been conducted that include some discussion regarding the rate of ingress of natural regeneration onto clear-cut sites. In Alberta, Day and Duffy (1963) examined 2 800 plot clusters from 80 sampled areas and concluded that ingress continued into the second decade of stand development. Stocking, rather than density, was preferred as a measure of success, and microenvironmental factors were cited as more important than macroclimatic factors during the regeneration phase of a forest.

Crossley (1976) suggested that most of the ingress on lodgepole pine (*Pinus contorta* Dougl.) sites occurred by the third year after site preparation and lasted between 8 to 12 years following such preparation. The success of lodgepole pine regeneration was a function of time since harvest. Four years after harvest, 32 of the blocks studied

[1] Andison, D.W.; Callaghan, B.P. 1986. Survey of artificially regenerated sites in north central Ontario. Ont. Min. Nat. Resour., Toronto, ON. Unpublished report. 140 p.

would have been classified as regeneration failures under the Alberta government's stocking standard of 40 percent. Yet due to ingress of natural regeneration, 7 years later approximately 90 per cent of the same sites qualified as successes based on the same definition. Delays in scarification of the site resulted in lower densities.

Similar results with lodgepole pine in Alberta were reported by Johnstone (1976). Ingress occurred over the first 15 years after harvest on a cutover that previously supported lodgepole pine. Because only softwoods were examined, no information was presented for hardwood densities or rate of ingress. Mean densities ranged from 10 000 to 15 000 stems per hectare, although there was a high degree of variation. It was recommended that regeneration assessments be delayed until the eighth year following harvest to account for continued ingress occurring on the study sites. To ensure sufficient levels of natural regeneration on a site, prompt scarification was recommended.

In a study near Nipigon, Ontario, Lyon and Thomson (1979) examined ingress on a harvested jack pine site. Ingress occurred over a long duration, into the second decade of stand development. After the site experienced repeated burns, beginning in the late 1940s, it was aerially seeded in 1957 and resurveyed in 1974. Jack pine density remained constant at about 4 700 stems per hectare during an 11-year period between surveys. However, significant numbers of trees entered the stand in two distinct "waves". The first wave began immediately after sowing in 1957 and the second occurred 12 years later, thereby indicating a dynamic process underlying a static stem density. Unfortunately, there was no differentiation of the source of the initial population. Were these trees truly a result of the aerial seeding or could they have arisen from cones scattered on the site? It was noted that the acceptability of the seedbed for natural regeneration changed as the stand developed, but the importance of late ingress on a site was questioned. Recommendations were made that ingress and its duration is a process that should be included in stocking standard determinations, and it was suggested that the current 60 percent stocking requirement 5 years after harvest may be too high.

Two recent studies describe the potential for ingress, but do not address the rate question. Wiltshire[2] examined the potential for natural regeneration of jack pine in the Thunder Bay District. He suggested that selected sites on the Spruce River forest management unit could benefit from the ingress of natural regeneration. Recommendations included an emphasis on finer silvicultural stratification to identify suitable sites and to differentiate the treatments they receive. He also recommended that: (i) site preparation should be delayed at least one season to assist tree planters in identifying stems resulting from natural ingress, and (ii) a shift to an area-based method of planting trees be adopted. The need to manage mineral soil exposure was also stressed; less being better to limit the amount of jack pine ingress on a site.

In 1992 the Ontario Independent Forest Audit Committee (Hearnden 1992) completed an examination of forest regeneration success within the province. The objective of the audit was to move beyond the stand establishment stage to examine the actual success of these endeavors. Results of the audit confirmed that while ingress is obviously occurring across northwestern Ontario, a conversion of stand types from softwood-dominated mixedwoods and black spruce types to hardwood, mixedwood, and jack pine types is also occurring. While the study provided a good description of the structure and composition of plantations, it did not attempt to relate these results to the preharvest NWOFEC type, nor did the committee examine the rate at which the ingress occurred onto sites.

From the literature it is apparent that very little is known about the exact rate of ingress onto a site, particularly for species that occur in northwestern Ontario. There is little information on differences in levels of natural ingress on common site types found in northwestern Ontario and described by the NWOFEC. It has been suggested that regeneration assessments should be delayed to allow recognition of ingress that naturally increases the stocking. Would delays in timing of regeneration assessments be appropriate for sites in northwestern Ontario?

A recent study of sites across the northwest region of Ontario should provide data that will address the lack of information on rate and density of ingress.[3] However, due to the age of the plantations in the study the results are applicable only to tree-length harvested sites. Are the results similar for plantations established following full-tree harvesting? The use of full-tree harvesting techniques has increased dramatically in northwestern Ontario (Wiensczyk 1992). There is now concern that full-tree logging, especially in jack pine and black spruce stands, may remove too many cones from cutover areas, thereby reducing the chance of successful levels of subsequent natural regeneration.

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[2] Wiltshire, B. 1992. Understanding the potential for natural jack pine regeneration on the Spruce River Forest. Ont. Min. Nat. Resour., Thunder Bay, ON. Unpublished report. 13 p.

[3] Bowling, C.; Niznowski, G.; Maley, M. Natural regeneration of softwood and hardwood tree species after tree-length harvesting. Ont. Min. Nat. Resour., Northwestern Ontario Science and Technology Unit, Thunder Bay, ON. (In prep.)

The primary objective of this study was to determine if a link exists between selected site types defined by the NWOFEC and the rate and density of ingress occurring on those sites after they have been full-tree harvested. While this study is designed to help predict which NWOFEC site types are likely to have ingress of natural regeneration, it does not attempt to identify the causal factors. Many factors influence the ingress found on any particular site. These include microsite, seed source, cone loading, physical site parameters, pathogens, seed and seedling predators, and vegetative competition.

METHODS

Survey Area Description

The area for the study was defined as the Ontario Ministry of Natural Resources (OMNR) Northwest Region, extending from the Manitoba border east to the Kenogami River in the north central part of the province. In the southern part of the region a narrow strip along the Canada–United States border, from Lake Superior to Manitoba, falls into the Great Lakes–St. Lawrence Forest Region (Rowe 1959). The major conifer species of this region include eastern white pine (*Pinus strobus* L.), red pine (*Pinus resinosa* Ait.), and eastern hemlock (*Tsuga canadensis* [L.] Carr.). Major deciduous tree species include yellow birch (*Betula alleghaniensis* Britt.), sugar maple (*Acer saccharum* L.), and red maple (*Acer rubrum* L.) The remainder and majority of the study area falls into the Boreal Forest Region. The dominant softwood and hardwood species that define this forest include jack pine, black spruce, white spruce (*Picea glauca* [Moench] Voss), balsam fir (*Abies balsamea* [L.] Mill.), tamarack (*Larix laricina* [DuRoi] K. Koch), poplar (*Populus tremuloides* Michx.), and white birch (*Betula papyrifera* Marsh.).

Procedures For Site Selection

The methodology followed that used by Bowling et al.[4] It was decided that a large-scale survey approach was better suited for this study than was a permanent sample plot approach since meaningful results would be difficult to obtain within the restricted time frame of the Northern Ontario Development Agreement (NODA). With the SOARS database as a starting point, plantation records were examined at districts across the Northwest Region so as to compile a short list of survey sites. Candidate stands were selected from district and company records using the following criteria:

1. Ten to 15-year-old full-tree harvested areas, planted to jack pine, red pine, white spruce, or black spruce and without replant, fill plant, or aerial seeding.
2. Three seedbed condition classes (SCC) including: intact/mixed forest floor (SCC1), scalped soil (SCC2), and slash.
3. NWOFEC soil types and preharvest vegetation types (Table 1).

Although the postharvest vegetation type of a site may have technically changed compared to the preharvest condition due to planting, ingress was studied for the preharvest vegetation condition. For example, a red pine plantation located on an area previously classified as a jack pine vegetation type was acceptable for this study and would have been categorized as a jack pine site type. Ecologically similar NWOFEC vegetation types were grouped together into treatment units (TU's) as described by Racey et al. (1989).

Due to the nature of the study, the determination of "naturally" regenerated trees was of primary concern since ingress was not monitored over time. In addition, most seeding that took place was aerial in nature. This resulted in variable tree spacing across the site. Such nonuniform distribution of tree seedlings could easily be confused with natural regeneration. Consequently, seeded sites were not sampled because of the difficulty in distinguishing ingress.

Aerial seeded sites that were later planted were not sampled either because the trees established from the introduced seed were impossible to distinguish from naturally occurring seedlings. Thinned sites were avoided because there was obviously ingress removed from these sites. Some sprayed sites were visited, but these were omitted from the final database because the hardwood data would have been difficult to interpret.

Field Sampling Procedures

Stratification

Although the silvicultural records usually indicated if a site had received any tending, a ground check of each site before sampling allowed for confirmation of record accuracy. The ground check also provided an opportunity to combine knowledge of the site's history gathered from the files (preharvest Forest Resource Inventory [FRI] data and the silviculture card data) with the existing postharvest vegetation community to determine the preharvest NWOFEC vegetation type. Obviously, there was some element of conjecture in this estimation. Residual standing timber was inspected if it was believed to be similar to what had been harvested (most often, lowland areas surrounding the cut block were all that were left, thereby giving a poor representation of what previously existed on

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[4] Ibid.

the site). Where possible, preharvest stand composition was estimated from the study of preharvest photos.

Each of the candidate plantations was subdivided as precisely as possible into homogeneous areas of vegetation and soil type. This was done in the office using FRI maps, known NWOFEC plot locations, and air photo interpretation.

Sampling Intensity

Plots were established within each plantation until a precision of ±25 percent of mean total stem density for the dominant SCC was achieved. The total number of plots required to obtain this precision depended on the stocking and density of each plantation. Precision estimates were calculated separately for each SCC within a plantation.

At each site sampling began by establishing a minimum of 11 plots on the dominant seedbed (usually SCC1 [intact/mixed forest floor]). Data from each plot were recorded on a hand-held computer that calculated the mean and standard deviation of total stem density. At this point, if the standard deviation was within 25 percent of the mean and a minimum number of trees were destructively sampled, sampling was considered complete. If, however, the standard deviation was greater than 25 percent of the mean stem density, the required sample size (based on 25 percent of total stem density as the allowable error) was calculated. Once the newly determined number of required plots was known, sampling continued until the additional plots had been established. Again the standard deviation was calculated and compared to the mean stem density. This process continued until a standard deviation within the 25 percent mean had been achieved or until efforts had exhausted an operational maximum of 1 day of surveying the site. On average, 26 plots were established per site.

Sampling For Stand Description Data

To remain within the predetermined sample area and to mitigate edge effects, transects were laid out perpendicular to the direction of site preparation from a random starting point at one edge of the stratum. A series of 4-m^2 circular plots (radius = 1.13 meters) was established every 5 meters along the length of each transect. At each plot, the following were determined:

1. Seedbed condition class (SCC)
    a. Intact/mixed forest floor
    b. Scalped/bare mineral soil exposure
    c. Rock/standing water/slash
2. Number of trees/species/height classes
3. Height and species of tallest tree
4. Percent cover/abundance of competing vegetation by species.

Only the first two seedbed conditions were regarded as acceptable. Although germination can occur on the third seedbed, it represents an unsuitable microsite in the long term. A seedbed condition had to be represented on at least 70 percent of each plot or the plot was rejected. For example, if a plot contained 60 percent intact forest floor and 40 percent mineral soil exposure, it would have been deemed unacceptable and sampling would have been continued at the next plot, 5 meters along the transect.

At each plot with a suitable seedbed condition (i.e., SCC 1 and 2) all the trees within the 4-m plot were tallied using the following height classification:

1. Less than or equal to 0.10 meter
2. 0.11 meter to 1.00 meter
3. 1.01 meters to 3.00 meters
4. 3.01 meters to 8.00 meters
5. 8.01 meters and greater

At this time the tallest tree in the plot was determined and its species recorded. Its height was also measured and any visible damage was documented. Any dead trees that occurred within the plot were also noted by species. While at each plot, the shrub stratum species were listed with a corresponding visual estimation of the percent ground cover for each.

Sampling For Rate of Ingress

When each site was ground checked it was determined which tree species would be destructively sampled to collect rate data. Only those tree species that were predicted to compose at least 20 percent of the stands' stem density at maturation were chosen. Destructive sampling began on the first plot established and continued on every fifth plot. On these plots, stems for the predetermined softwood and hardwood tree species, of all sizes (except for obvious residuals or wolf trees), were felled and a stem disc was taken at the root collar. Destructive sampling continued until a minimum of ten stems of each species had been collected from at least two separate destructive sample plots with the same seedbed condition class. Plots were established until both the density requirement and rate prerequisites were satisfied.

Each disc was appropriately marked by species, plot number, and plantation number. Each plot's collection was bagged separately and kept in cold storage until analysis. To aid in later aging analysis of small trees, the entire plant was collected.

Data Analysis

Stand Description Analysis

Two methods were used to describe density and species composition. Tables of average densities of individual tree species were produced. Stacked column charts, which illustrate the density of each species in each height class, were also created. Kruskal-Wallis H tests (McClave and Dietrich 1988), followed by a nonparametric multiple comparison test (Neter et al. 1990), were used to test for differences in densities of individual species within and among the three treatment units. Mann-Whitney nonparametric tests (Steel and Torrie 1980) were used to test for differences between SCC's on the same treatment unit.

The percentage of plots stocked to each tree species by height class was calculated and averaged for each treatment unit. Differences in stocking among treatment units was tested using a one-way ANOVA. The probability of natural ingress of a species on a given site was calculated as an additional means of describing postharvest SCC's. This was determined by calculating the proportion of sites in each treatment unit that had an occurrence of each species in each height class.

Rate of Ingress Analysis

Previous ingress research has focused primarily on stand structure and composition. Rate of ingress is also important for operational survival assessments that must be completed shortly after artificial establishment has occurred.

The Tree Ring Increment Measuring (TRIM) system[5] was used to count disc rings. Rates of ingress were summarized by species, seedbed condition class, and treatment unit.

Each site was assigned a cutoff age based on the time elapsed since harvest had occurred. Any tree older than this cutoff age would then be defined as advanced regeneration. Using this criterion, advanced growth that had been destructively sampled was easily removed from the database after the TRIM work was complete.

Destructively sampled trees that had obviously been planted were double checked in the office using the TRIM to confirm that their present age was the same as that of the planted stock. The age of planted trees could be determined accurately based on the age of the stock and the time elapsed since they had been planted. With the age of the planted trees known and the use of a removal rule based on the SOARS data (it was determined that the ratio of planted trees to naturals was 4.3 to 1), planted trees were removed from the database.

Theoretically, natural regeneration could continue to enter a site indefinitely. An artificial end point of ingress was defined to restrict the focus of this study to the natural regeneration that occurred during the plantations' early years. The early years are crucial because the ingress that enters a site before crown closure will likely contribute to the stands' dominant canopy at maturity. The end point or "index age" also provided a way to quantitatively express the rate of ingress.

Any ingress that entered a site up to the index age was interpreted as 100 percent of a site's natural regeneration. For example, if the index age is set at 10 years, then the rate of ingress would be based on the first decade of stand development. On a 10-year-old clear-cut site, suppose one-half of the trees were 8 years old and the remaining trees were 6 years old. In this scenario, the first one-half of the tree population entered the site 2 years after harvest; the remaining ingress occurred 4 years after harvest. Relative to the index age, 4 years would indicate that ingress was complete early in the stand's development, i.e., no ingress occurred during the next 6 years.

Although an index age of ten was originally planned, an index age of seven was ultimately chosen. The younger index age was selected because of the recent transition to full-tree harvesting in Ontario's Northwest Region, and the consequent young age of sites available for study. The suitability of a 7-year index age for this study is supported by a recent study.[6] This research suggests that natural ingress of most species is complete between 7 and 8 years after tree-length harvesting in northwestern Ontario, when an index age of ten was used. A one-way ANOVA was completed for each species to test for differences on the three treatment units studied.

A second method used to describe the rate of ingress involved graphically illustrating, by cumulative frequency, the rate of ingress across the time period from harvest to the index age. Rate graphs were developed for each treatment unit and seedbed condition class.

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[5] Miller, R.J. 1991. Stem analysis module for MS-DOS computers. Ont. Min. Nat. Resour., Ontario Forest Research Institute, Sault Ste. Marie, ON. Unpublished report. 9 p.

[6] Bowling, C.; Niznowski, G.; Maley, M. Natural regeneration of softwood and hardwood tree species after tree-length harvesting. Ont. Min. Nat. Resour., Northwestern Ontario Science and Technology Unit, Thunder Bay, ON. (In prep.)

RESULTS

Description of Sampling Sites

A total of 64 different planted areas were visited over the 2-year duration of this study. Before a site was sampled, the amount of mineral soil exposure was examined to determine if the two acceptable seedbed conditions were present in sufficient quantity to sample both. As a result of plantations sampled with multiple seedbed conditions, 71 different sites were surveyed.

Full-tree harvesting came into common practice at different times across Ontario's Northwestern Region. Due to the use of plantation age as a primary criterion for site selection, this resulted in a nonuniform sampling intensity across the various districts.

The concentration of sampled sites was highest in the Dryden and Thunder Bay districts, intermediate in the vicinity of Geraldton and Sioux Lookout, and lowest around Red Lake and Nipigon. Suitable sites were not found in either the Kenora or Fort Frances districts because of the lack of full-tree harvesting in these areas.

Almost two-thirds of the sample sites were classified as Treatment Unit E prior to harvest (Table 1 and Figure 1). Treatment Unit F accounted for approximately one-quarter of the sites while slightly more than one-tenth of the sites were classified as Treatment Unit G.

The majority (83 percent) of the sites occurred on Seedbed Condition Class 1 (SCC1), representing an intact/mixed forest floor condition (Table 2). Mean age of the sample sites was slightly greater than 10 years. Time since harvest ranged from 7 to 15 years. (Table 3).

Stand Structure and Species Composition

General Overview

Of 1 680 plots established over 2 years, only 5 percent had no trees (Table 4). This absence of trees may have been due to a lack of ingress or mortality of planted stock. Approximately three-quarters of the plots had at least one naturally regenerated black spruce or jack pine tree over 1 meter in height (Stocking Categories 3 and 4 combined).

Density by Height Class

Figures 2 to 6 present the relationship between height class, tree species, and density for the different seedbed condition–treatment unit combinations studied. The majority of ingress occurred in the third height class (1.0–3.0 meters) for most combinations. With an average age of 10 years for the sample sites, these results suggest that, on average, natural regeneration will be approximately 2 m tall 10 years after full-tree harvesting. The fourth height class also had a large number of stems, but usually stems were completely absent from the tallest height class.

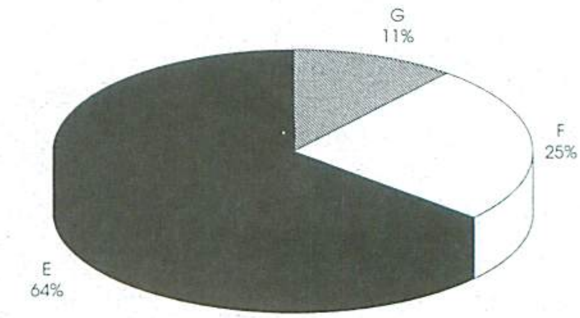


Figure 1. Preharvest treatment unit classification of sites sampled for ingress of naturals after full-tree harvesting.

On most sites, jack pine and white birch dominated the taller height classes. On Treatment Unit F, with exposed mineral soil seedbeds, jack pine dominated all height classes. The larger amounts of black spruce on Treatment Unit E are also evident in Figures 2 and 3, although the dominance of jack pine on these sites is apparent. The only instance with the greatest density occurring in the second height class was on Treatment Unit E sites with mineral soil seedbeds. This combination is dominated by black spruce, and its relatively slow initial height growth (compared to the other three species) explains why this second height class has the greatest density. Treatment Unit G had the highest total density for Height Classes 3, 4, and 5 combined; perhaps a reflection of the relatively higher productivity associated with Treatment Unit G compared to Treatment Units F and E.

Probability of Occurrence

The probability of occurrence of each tree species on the sampled sites was summarized for each treatment unit and seedbed condition class (Table 5). To approximate seedlings and saplings, the five height classes were collapsed into two broader ranges: (i) those trees less than or equal to 1.0 meter, and (ii) those trees greater than 1.0 meter. Jack pine, the most common tree species, occurred on slightly more than two-thirds of the sites. The other three main species—black spruce, poplar, and white birch—were present at about the same extent across the treatment units; each occurred on approximately 75 percent of the sites.

Density and Structure Analysis

Within Treatment Units

Densities of the four dominant species on the five treatment unit–seedbed class combinations were calculated for the two height class ranges, namely saplings (trees > 1.0 m high) and seedlings (trees ≤1.0 m high).

Saplings

For each treatment unit–SCC combination, the mean density in the sapling height class at the time of sampling has been calculated (Table 6). The densities shown represent conditions for a range of plantation ages between 7 and 15 years.

On Treatment Unit F, jack pine sapling density significantly exceeded that of all other species on both SCC1 and SCC2 (5 512 and 7 815 saplings/hectare, respectively). In contrast, jack pine on Treatment Unit G and Treatment Unit E with intact mixed forest floor (SCC1) also averaged the greatest density, but did not differ significantly from the second and third most frequent species. On Treatment Unit E with mineral soil exposure (SCC2) there was no significant difference in density across all species.

Seedlings

Only two combinations of treatment unit and seedbed condition class produced significant differences in seedling density (Table 7). Treatment Unit F on SCC2 had significantly more jack pine than poplar seedlings. Treatment Unit E on SCC1 supported significantly more black spruce than poplar seedlings (3 388 and 598 seedlings/hectare, respectively). The rank of average seedling density for each species mirrored that of the sapling height class on Treatment Unit F found on exposed mineral soil seedbeds, i.e., dominated by jack pine, followed by black spruce, white birch, and then poplar. Treatment Unit E, with an intact forest floor, had the highest average density of black spruce seedlings (3 388/ha), although it did not differ significantly from white birch (3 022/ha). Jack pine seedlings were clearly not as dominant on this condition as were jack pine saplings. Jack pine seedlings represented 19 percent of total seedling density across all species, but 46 percent of total sapling density.

Across Treatment Units

Density differences across treatment units were also tested (Table 8). Densities of jack pine showed no significant differences among treatment units. Black spruce seedlings were significantly more frequent on Treatment Unit E (3 971 seedlings/hectare) than on either Treatment Unit F (1 151 seedlings/hectare) or Treatment Unit G (1 192 seedlings/hectare) on SCC1. Black spruce sapling densities were significantly less on Treatment Unit G than on Treatment Unit E, but did not differ significantly from Treatment Unit F on SCC1. Total density of black spruce stems was significantly greater on Treatment Unit E compared to Treatment Unit F and Treatment Unit G on SCC1, with 5 868, 1 969, and 1 350 seedlings/hectare, respectively. No significant differences occurred among the densities of poplar seedlings on SCC1 across the three treatment units. In contrast, Treatment Unit G on SCC1 had a significantly higher density of poplar saplings than did Treatment Unit F and Treatment Unit E, with 2 538, 1 135, and 1 211 seedlings/hectare, respectively. Treatment Unit E had the highest white birch densities and no significant differences were found across the three treatment units for either the seedling, sapling, or total density variables.

Differences in species density attributable to seedbed condition can only be discussed in terms of Treatment Unit E and Treatment Unit F because only one seedbed condition class was sampled for Treatment Unit G. On Treatment Unit F, average densities were less on mineral soil exposed seedbeds than on intact forest floor conditions for all species except jack pine. The jack pine showed an opposite trend in both height classes. Mineral soil exposure significantly reduced black spruce and poplar seedling density, poplar sapling density, and total black spruce density. On Treatment Unit E, exposed mineral soil significantly reduced jack pine seedling density but had no effect on any other species.

Combining Probability of Occurrence and Density

Combined results of the probability of occurrence and density calculations are presented for SCC1 across the three treatment units (*see* Table 8). These data show that jack pine saplings have an extremely high probability (X) of existing on Treatment Unit G and that the associated density is likely to be high (H). In comparison, black spruce saplings have only a moderate probability (M) of occurring on Treatment Unit G and a low associated density (L) (800 stems per hectare).

Stocking

A summary of the percentage of plots stocked to each species by height class and treatment unit is given in Table 9 for both seedbed condition classes combined.

Both height classes of spruce were found to be significantly higher stocked on Treatment Unit E (the black spruce dominated TU) than on either Treatment Unit F or Treatment Unit G (TUs dominated by jack pine). On all three treatment units the jack pine seedlings were consistently lower stocked than were the saplings. This indicates that 10 years (average) after full-tree harvesting most jack pine are at least one meter tall and that very little young (small) jack pine are present. However, no significant differences existed across any of the treatment units for either height class of jack pine. On Treatment Unit G poplar saplings were stocked significantly higher (57 percent) than on Treatment Unit E (24 percent) or on Treatment Unit F (22 percent).

Rate of Ingress

While, in the previous section, two sites may appear similar in terms of stand structure and composition, the dynamics involved in the arrival of those stems may be entirely different on those sites. On average, across all species, ingress was completed most rapidly on Treatment Unit F. Treatment Unit E was the second quickest to achieve maximum ingress, while ingress was slowest to achieve completion on Treatment Unit G. However, no significant differences were detected in the time it took for any treatment unit to receive all of its ingress (Table 10).

On average it took 5.5 ±1.6 years to achieve maximum ingress on the sites surveyed. For no species or treatment unit was ingress onto a site completed before at least 4 years.

Figures 7 to 11 illustrate the average rate of ingress for each treatment unit–seedbed condition combination. On Treatment Unit E, found on intact forest floor, jack pine entered the sites quite quickly while white birch was usually the slowest species to complete its ingress. These results can be confirmed by cross-checking with Table 10, in which it will be seen that complete ingress of jack pine is quickest at an average of 5.48 years; white birch arrives over the longest period at 5.93 years.

DISCUSSION

Stand Structure and Species Composition

Results from this study suggest that ingress of naturals after full-tree harvesting depends on the preharvest vegetation community. Regardless of site type, all sites experienced high levels of ingress.

One unexpected result was the relatively large amount of white birch regeneration. The tendency for white birch to be more prevalent than poplar on the study sites may be due to the high levels of birch residuals that were often left standing on the sites. The high densities of birch may also be a result of the forest floor remaining relatively undisturbed, thereby discouraging poplar suckering.

As anticipated, jack pine was the most common species occurring on the sites. Most likely, this was because it made a major contribution to the preharvest stands and is an aggressive pioneer species.

Jack pine saplings dominated the jack pine/feathermoss sites (TU F) 10 years after full-tree harvesting. Black spruce and white birch seedlings were more prominent than seedlings of other species on Treatment Unit E (black spruce mixedwoods). As well, black spruce stocking was higher on Treatment Unit E. Poplar saplings were highly stocked on Treatment Unit G (jack pine/shrub rich sites). All of these patterns suggest that treatment units return to their preharvest tree species composition, although absolute proportions of each species on the sites may be different.

Seedlings accounted for the majority of stems found on Treatment Unit E. This could be due to a greater amount of black spruce, which takes a longer time to develop into saplings. There is a chance that eventually the seedlings will contribute significantly to the final stand composition because this height class is composed primarily of relatively larger trees. Spruce seedlings on Treatment Unit E may eventually increase the final spruce component on mature sites. If this occurs, the spruce dominance or codominance on these sites would be maintained.

The large variation in actual densities may be accounted for by a number of factors. Treatment units are a coarse definition of a site type, so the different composition of the preharvest stands will influence what natural regeneration ultimately returns to the site. The age of harvested stands may have varied and this could have affected cone loading and thus the amount of seed available for natural regeneration. The average stem densities represent conditions for a range of stand ages, and there will be an inherent level of variation in stem density for maturing stands.

Jack pine was more abundant, but not significantly so, on exposed mineral soil on Treatment Unit F; otherwise, stem density was lower on this site combination for all other species (significantly so for poplar). Numbers of jack pine seedlings were significantly less on Treatment Unit E sites with exposed mineral soil than on similar sites with intact or mixed forest floor. On Treatment Unit E, black spruce tended to have higher densities on sites with exposed mineral soil. Although the dominant conifer's stem density increased with mineral soil exposure on both sites, perhaps competing vegetation also intensified on the disturbed forest floor. This would hinder the germination of even more conifer stems.

Results for the full-tree harvested sites are very similar to that reported for tree-length harvested sites. For example, the same trend was observed for both studies with respect to the probability of a tree species occurring on a site. Jack pine was the most commonly occurring species after both types of harvesting; black spruce, poplar, and white birch were encountered less often. Jack pine densities were the highest of any species after either type of harvesting. White birch experienced the second highest densities overall after full-tree harvesting, while poplar had the second highest densities after tree-length harvesting. Total stem density was roughly comparable between the two types of harvesting on equivalent sites. However, white birch occurred at higher densities following full-tree harvesting. Similar stand structures were observed after both methods of harvesting. Treatment Unit E contained the greatest proportion of seedlings (approximately 50 percent of the total stems after full-tree harvest compared to approximately 40 percent following tree-length harvest). Although fewer stems were classified as seedlings on the tree-length harvested sites, the average age of the sites was older. This allowed a greater opportunity for those stems to advance to the sapling height class. After both methods of harvesting, the density of jack pine saplings on Treatment Unit F was higher when encountered on exposed mineral soil. This same trend was observed for black spruce on Treatment Unit E.

Regardless of what tree species was planted on the sampled sites after full-tree harvesting, given enough time nature dictated the composition and structure of the stand that developed. Neither barren sites nor monocultures were encountered. All four main species were found on the majority of the sites. This also tended to be the case after tree-length harvesting.

Stem clumping was observed on many study sites. Clumping can be loosely defined as a high number of trees growing in a small area. Unfortunately, no mechanism was used to explicitly record the amount or severity of clumping. Sites that had clumping were characterized by high densities associated with relatively low levels of stocking. Clumping occurred most often with jack pine, particularly on Treatment Unit E, and with white birch on Treatment Unit F. Clumping was anticipated with jack pine natural regeneration because all of the seed from a cone that falls on a suitable seedbed may potentially germinate. Nature is not "concerned" with creating a well-spaced stand.

Depending on the objectives for a stand, tending may be necessary on the majority of the study sites visited. If the stands are to be managed for timber production, they should benefit from thinning. However, if the stand is designed for pulpwood production, then maximum biomass on the site may be the objective. As this would likely by accompanied by a short rotation age, thinning may not be necessary. Due to the erratic spacing and clumping of the natural regeneration on most cutovers, planted trees helped to improve stocking. Unfortunately, natural regeneration often occurred close to the planted trees and this created an undesirable crowding condition. The problem then becomes one of being unable to predict where natural regeneration will occur. However, rather than attempting to predict this, it may be more reasonable to delay planting so that natural regeneration can be allowed to enter the site. Planting could then be avoided.

To a large extent the stand composition emerging as a result of natural regeneration approximately 10 years after harvest resembled the preharvest vegetation community on the site. Thus, a wholesale shift in vegetation communities did not occur on the study sites.

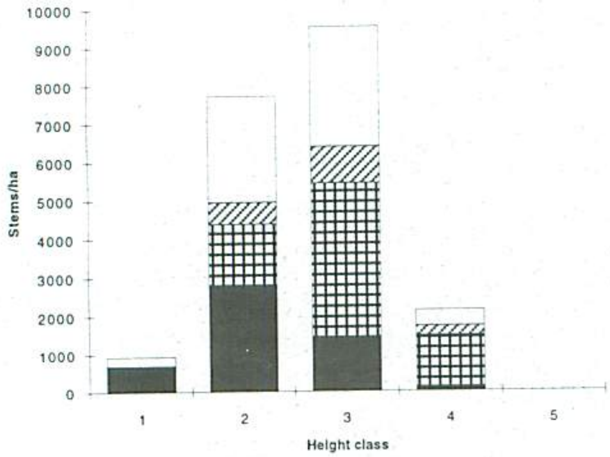
At first glance, it may appear that some stand conversion to mixedwood may have occurred, particularly on the spruce-dominated sites that had a high density of poplar and white birch. Since all of the treatment units include conifer-dominated mixedwood NWOFEC vegetation types in their definition, it is difficult to distinguish if indeed there was a shift to an increased hardwood component on the study sites. Perhaps a large number of the study sites previously supported these mixedwood vegetation types, thereby accounting for the higher levels of hardwoods. However, a conversion to a more hardwood-dominated mixedwood would be likely since poplar, birch, and jack pine are considered to be more aggressive, earlier successional species than is black spruce.

Rate Analysis

While the density and species composition components of this study represent a "snapshot" of conditions existing on plantations 7 to 14 years after harvest, the rate component sought to answer different questions: How fast did the ingress occur on a given site? Was the rate of such ingress related to NWOFEC site types? The implications of rate of ingress could dramatically alter the assessment of a site and thus any subsequent prescriptions. For instance, depending on the NWOFEC type, a site may not be accurately judged for success 5 years after harvest because ingress may continue to enter the stand throughout its first decade of growth. To interpret the rate of ingress relative to the index age it is important to remember that the higher the number the longer ingress continued to arrive on a site since harvest. Therefore, a small number in relation to the index age would indicate that ingress occurred on a site for only a short time after harvest.

Although a trend existed among species at the rate they entered the treatment units, differences were not statistically significant. As an example, Treatment Unit F (jack pine/feathermoss) was the quickest site to complete ingress for all species on both the full-tree and tree-length harvested sites. The ingress of naturals on Treatment Unit E progressed more rapidly than on Treatment Unit G after full-tree harvesting, but the reverse was true on tree-length harvested sites.

The average age for which ingress was complete across the treatment units was 5.5 years, based on an index age of seven. However, is seven an appropriate index age? From the literature it would seem inevitable that ingress will occur beyond the seventh year. Ingress did, in fact, continue beyond 5 years on most sites; however, it was not captured in this study due to the relatively young index age



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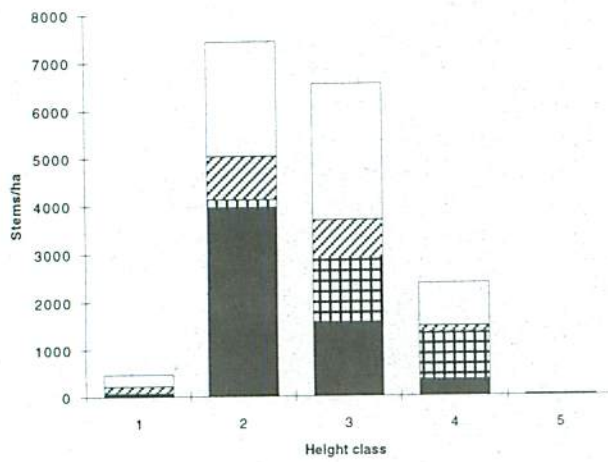

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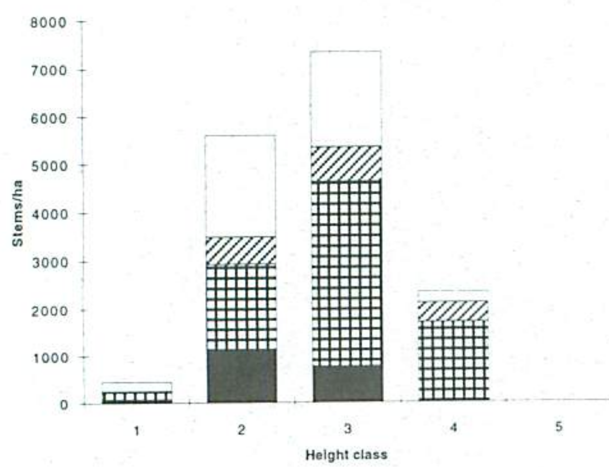

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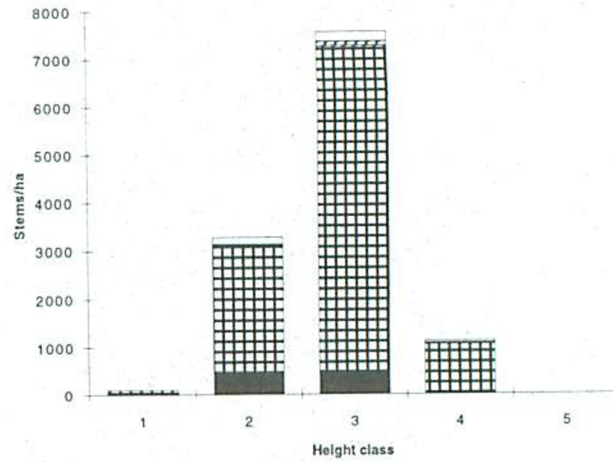

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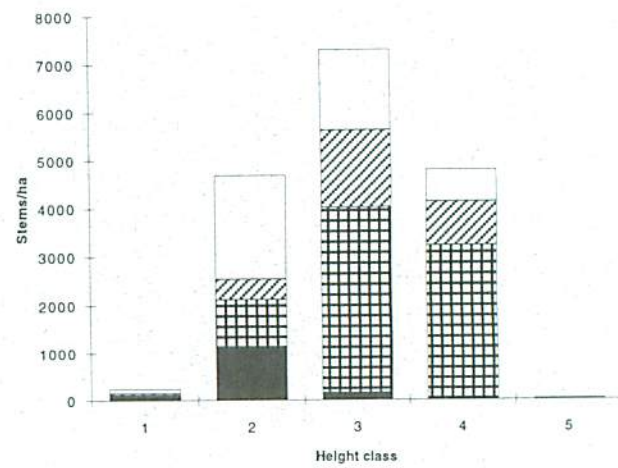

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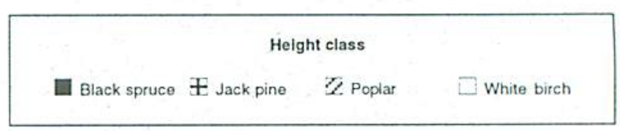


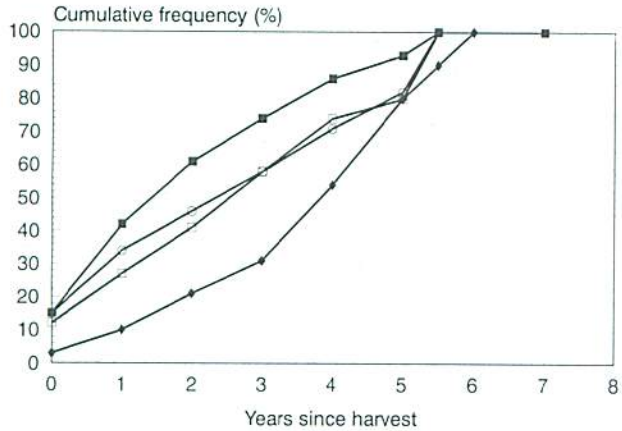
Figure 2. Stand Structure and Composition Treatment Unit E, Seed Bed Condition Class 1.

Figure 3. Stand Structure and Composition Treatment Unit E, Seedbed Condition Class 2.

Figure 4. Structure and Composition Treatment Unit F, Seedbed Condition Class 1.

Figure 5. Stand Structure and Composition Treatment Unit F, Seedbed Condition Class 2.

Figure 6. Stand Structure and Composition Treatment Unit G, Seedbed Condition Class 1.



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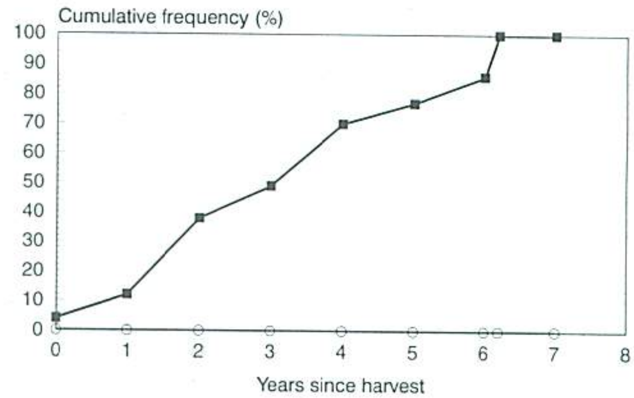

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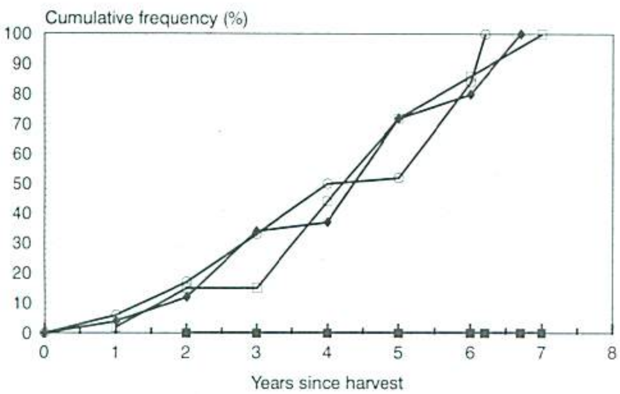

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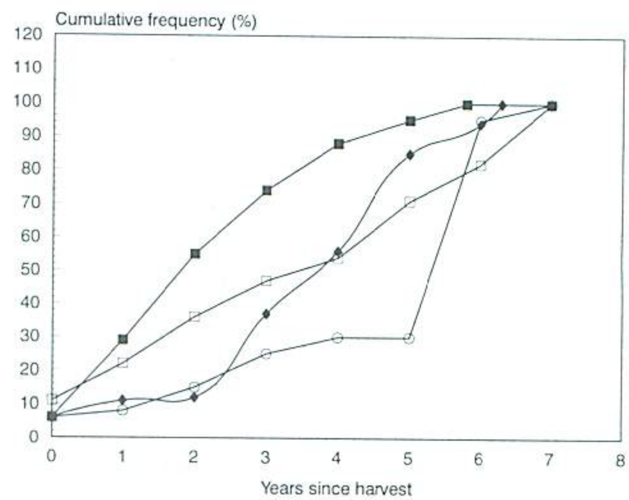

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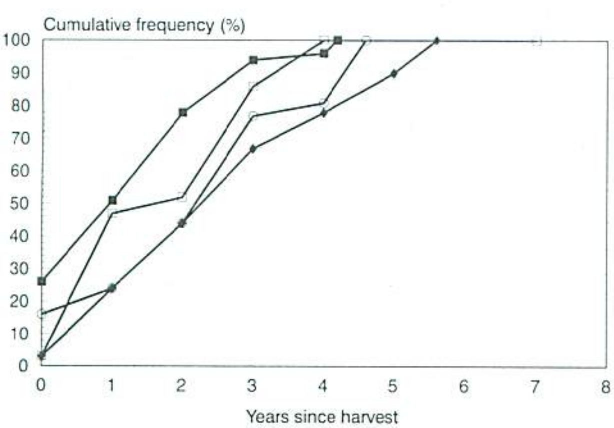

Figure 9

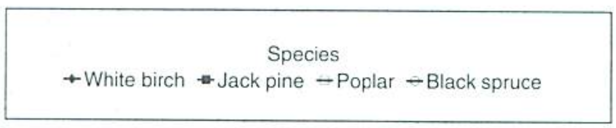

Figure 7. Cumulative natural ingress for Treatment Unit E, Seedbed Condition Class 1.

Figure 8. Cumulative natural ingress for Treatment Unit E, Seedbed Condition Class 2.

Figure 9. Cumulative natural ingress for Treatment Unit F, Seedbed Condition Class 1.

Figure 10. Cumulative natural ingress for Treatment Unit F, Seedbed Condition Class 2.

Figure 11. Cumulative natural ingress for Treatment Unit G, Seedbed Condition Class 1.

Table 1. Vegetation and soil type criteria for study site selection.

NWOFEC treatment units	Dominant tree species	NWOFEC vegetation types
E	Black spruce–jack pine	19, 20, 31, 32, 33
F	Jack pine	18 and 29
G	Jack pine	17 and 28
NWOFEC soil unit	Soil description	NWOFEC soil types
SU-1	Shallow	SS1, SS2, SS3, SS4
SU-2	Sandy	S1, S2, S7, SS5
SU-3	Coarse loamy	S3, S8, SS6, SS8
SU-4	Fine loamy/clayey	S5, S6, S10, SS7

Table 2. Number of sites sampled by treatment unit and seedbed condition class (SCC).

Treatment unit	SCC 1*	SCC 2**	Total
E	38	7	45
F	13	5	18
G	8	0	8
Total	59	12	71

* SCC 1 = intact/mixed forest floor.

** SCC2 = mineral soil.

Table 3. Age-class distribution of sites studied for ingress of natural regeneration after full-tree harvesting.

	Growing seasons since harvest								
	7	8	9	10	11	12	13	14	15	Total
No. of sites	10	9	2	16	5	22	0	5	2	71

Table 4. Distribution of 4-m^2 plots by stocking category.

Stocking category	Percentage of total	Number of plots
1. No trees occurred.	5	87
2. Any tree species may have occurred but none exceeded 1 meter in height.	10	166
3. Any tree species may have occurred, but at least one must be black spruce or jack pine over 1 meter and no hardwoods over 1 meter occurred.	43	730
4. Any tree species may have occurred, but at least one must be black spruce or jack pine over 1 meter and at least one hardwood species over 1 meter occurred.	31	525
5. Any tree species may have occurred, but at least one must be a hardwood over 1 meter and no softwoods over 1 meter occurred.	7	124
6. Any tree species may have occurred, but at least one other conifer* over 1 meter was present.	3	48
	100	1 680

*Conifer = balsam fir, cedar, larch, red pine, or white pine.

Table 5. Probability of occurrence (expressed as a percentage of the number of plantations [n] of each species by treatment unit [TU], height class [m], and seedbed condition class [SCC]).

			Species and height class*							
			Pj		Sb		Po		Bw	
TU	n	SCC	≤1.0	>1.0	≤1.0	>1.0	≤1.0	>1.0	≤1.0	>1.0
			(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
E	38	1	71	89	100	87	84	76	82	68
	7	2	29	100	100	86	43	71	71	57
F	13	1	92	100	54	61	77	85	54	54
	5	2	100	100	40	40	20	40	60	40
G	8	1	100	100	75	50	100	100	75	88

* Pj = jack pine, Sb = black spruce, Po = poplar, and Bw = white birch.

Table 6. Mean density (stems/hectare) of natural regeneration occurring in the sapling height class (>1.0 m) by treatment unit (TU), species*, and seedbed condition class (SCC)**.

TU	G	SD***	F	SD	F	SD	E	SD	E	SD
SCC	1 (8)		1 (13)		2 (5)		1 (38)		2 (7)	
Pj	7067 a	±4151	5512 a	±4450	7815 a	±4003	5355 a	±7927	2342 a	±1522
Sb	159 b	±316	819 b	±1217	499 b	±1035	1538 ab	±1257	1897 a	±1646
Po	2538 ab	±1633	1135 b	±1817	123 b	±203	1211 b	±2110	949 a	±1518
Bw	2337 ab	±2158	2225 b	±3245	248 b	±340	3552 ab	±4696	3751 a	±3967

*Pj = jack, pine, Sb = black spruce, Po = poplar, and Bw = white birch.

**Letters next to density values correspond to nonparametric multiple comparison test (*from* Neter et al. 1990) on ranks of the species. For each TU, species with the same letter are not significantly different (p = 0.05). The number of plantations sampled is provided in brackets.

***SD = standard deviation.

Table 7. Mean density (stems/hectare) of natural regeneration occurring for each species by treatment unit (TU), height class (m), and seedbed condition class (SCC).+*

		Pj**			Sb**			Po**			Bw**			
TU	SCC	1.0m	>1.0m	Total	1.0m	>1.0m	Total	1.0m	>1.0m	Total	1.0m	>1.0m	Total	TOTAL
G	1(8)	1078a	7067a	8145a	1192b	159b	1350b	422a	2538a	2961a	2228a	2337a	4565a	17021
	SD	±748	±4151	±4073	±2511	±316	±2819	±261	±1633	±1616	±3641	±2158	±5179	±2906
F	1(13)	2006a	5512a	7518a	1151b	819ab	1969b	578a	1135b	1713a	2316a	2225a	4542a	15742
	SD	±2121	±4450	±5283	±2566	±1217	±3654	±724	±1817	±2113	±4327	±3245	±7230	±2709
F	2(5)	2713a	7815a	10528a	490a	499a	989a	29b	123a	153a	143a	248a	391a	12060
	SD	±2121	±4003	±4803	±693	±1035	±1483	±66	±203	±218	±153	±340	±415	±5021
E	1(38)	1641a	5355a	6996a	3388a	1538a	4925a	598a	1211 b	1809a	3021a	3552a	6573a	20304
	SD	±2121	±7927	±9856	±3832	±1257	±4031	±799	±2110	±2621	±3743	±4696	±7846	±2354
E	2(7)	222b	2342a	2563a	3971a	1897a	5868a	1056a	949a	2006a	2655a	3751a	6407a	16844
	SD	±493	±1522	±1983	±3107	±1646	±4377	±1935	±1518	±3072	±3220	±3967	±6340	±2247

+ Letters next to density values correspond to nonparametric multiple comparison test (*from* Neter et al. 1990) on ranks of the species. For each species, TU's with the same letter are not significantly different (p = 0.05).

* Number of plantations sampled in brackets.

** Pj = jack pine, Sb = black spruce, Po = poplar, and Bw = white birch.

Table 8. Probability of occurrence and associated density for ingress of naturals after full-tree harvesting.*

		Pj**		Sb**		Po**		Bw**	
		Height class (m)							
TU	SCC	1.0	>1.0	1.0	>1.0	1.0	>1.0	1.0	>1.0
E	1 (38)	H–M	X–H	X–M	X–M	X–L	X–M	X–H	H–H
F	1 (13)	X–M	X–H	H–M	H–M	X–L	X–M	H–H	H–G
G	1 (8)	X–M	X–H	H–M	M–L	X–L	X–H	H–H	X–H

* Each pair of letters represents: probability class (%)–density class (stems/hectare)
L = Low; M = Moderate; H = High; X = eXtremely high
Probability classes (%) are : L = 25, M = 26–50, H = 51–75, x ≥ 76.
Density classes (stems/hectare) are L = 800; M = 801–2100; H ≥ 2101
** PJ = jack pine, Sb = black spruce, Po = poplar, and Bw = white birch.

Table 9. Proportion of plots stocked in each treatment unit (TU) with natural regeneration by species and height class; both seedbed condition classes combined.$^{+}$

		Treatment Unit E		Treatment Unit F		Treatment Unit G	
Species*	Height class (m)	Average (%)	SD** (%)	Average (%)	SD (%)	Average (%)	SD (%)
Pj	≤1.0	23 a	15	36 a	20	30 a	20
	>1.0	73 a	22	94 a	29	100 a	36
Sb	≤1.0	50 a	28	19 b	11	22 b	9
	>1.0	43 a	21	22 b	11	10 b	3
Po	≤1.0	17 a	10	14 a	9	13 a	9
	>1.0	24 a	9	22 a	7	57 a	16
Bw	≤1.0	37 a	19	26 a	12	31 a	18
	>1.0	41 a	16	34 a	13	45 a	15

\+ Letters next to density values correspond to Bonferroni multiple comparison test on ranks of the species. For each species, TU's with the same letter are not significantly different (p = 0.05).
* Pj = jack pine, Sb = black spruce, Po = poplar, and Bw = white birch.
**SD = standard deviation.

Table 10. Years to reach 100 percent ingress (based on index age of 7) after full-tree harvesting for selected species on three treatment units (TU), by seedbed condition class (SCC).

TU	G	F	F	E	E
SCC	*1*	*1*	*2*	*1*	*2*
Pj*	5.77 a	4.18 a	6.15 a	5.48 a	–
Sb*	6.95 a	4.75 a	–	5.72 a	6.20 a
Po*	6.90 a	4.00 a	–	5.66 a	7.00 a
Bw*	6.28 a	5.65 a	–	5.93 a	6.70 a

\+ Letters next to density values correspond to Bonferroni multiple comparison test on ranks of the species. For each species, TU's with the same letter are not significantly different (p = 0.05).
* Pj = jack pine, Sb = black spruce, Po = poplar, and Bw = white birch.

chosen. How much longer ingress actually lasts on average is open to speculation. It would seem plausible, however, that it does indeed continue at least until the end of the first decade of stand development.

Due to the sample methodology, no information was collected on tree mortality that occurred during the first 10 years of stand development. Although lack of mortality data is not a major concern, without it the exact nature of each stems' arrival onto a site remains unknown. For example, consider a rate graph that indicates 80 percent of the ingress had arrived on a site 4 years after harvest. These stems may appear to have entered the stand consistently over time, but an unknown amount of mortality accompanied that ingress over the same period.

It appears that ingress tended to either be complete or on the decline 7 years after full-tree harvest took place. While it is inevitable that some ingress will continue onto these sites after the first 7 years, it is perhaps more important to consider the implications of the additional trees rather than the amounts alone. Seven years after harvest competing vegetation is well established on the cutovers, as is a large number of naturally regenerated trees. At some point in the future the contribution of subsequent ingress will be little more than a biological phenomenon rather than a meaningful contribution to the final stand's makeup. When ingress' contribution becomes diminished is difficult to predict, but on the sites that were studied crown closure would be occurring in the foreseeable future if it had not already occurred. Certainly, beyond crown closure, ingress will have questionable relevance in any discussion of the final stand's dominant canopy. Since an average of 2 years elapsed between harvest and planting, the majority of study sites would have been assessed for a fifth-year stocking survey at 7 years after harvest; probably adequate time to capture most of the stems that will appear on the site.

CONCLUSION

Although some sort of artificial regeneration must often be relied upon to successfully regenerate sites, natural regeneration did make an enormous contribution to the site types investigated. However, natural regeneration must not be seen as a panacea to compensate for the reduced levels of funding available for forest renewal.

Establishing trees before competition overtakes a site's available growing potential must be balanced by consideration given to the level of ingress the site will attain and when it will arrive. Perhaps areas could be left unplanted for a longer period after harvest if competition levels remained reasonably low. This would allow ingress time to establish itself naturally. The feasibility of fill-in planting should be investigated for these site types.

Jack pine/feathermoss (Treatment Unit F) sites present the best potential to attain sufficient levels of ingress for successful regeneration. Leaving Treatment Unit F sites for natural regeneration may be particularly appealing, because trends suggest that ingress is completed early on this site type.

It is recommended that black spruce–jack pine /feathermoss (Treatment Unit E) sites be planted with black spruce if it is desired as a dominant species for mature stands. Competition control for hardwood tree species would probably be required most often on jack pine/shrub rich sites (Treatment Unit G).

Certainly, some sort of recognition of ingress as an ecological process should be made for setting stocking standards. However, because an average of almost 2 years elapsed before harvested sites were planted, a typical fifth-year assessment would generally occur at 7 years after harvest and would capture most of a site's ingress. A fifth-year stocking survey done after harvest on a site left for natural regeneration would appear to be premature, particularly on Treatment Unit E and Treatment Unit G sites. Therefore, it would be prudent to delay a stocking survey until the seventh year after harvest for areas left for natural regeneration.

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