Quantifying growth of spruce saplings in spruce-birch stands under different environmental conditions in the Sub-Boreal Spruce Zone

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Project Description
This report presents some preliminary findings of a study examining the dynamics in mixed deciduous-coniferous species stands (hereafter, mixedwoods) under different environmental conditions to clarify the interactions between environment and density-dependent, competitive relations in mixedwood stands in the Sub-Boreal Spruce (SBS) zone. A key underlying assumption of this study is that the relationships between deciduous-tree density and growth of conifer crop trees in mixedwood stands differ across key environmental gradients (e.g., slope aspect, elevation, continentality). These relations should be predictable due to links between environmental and physiological growth determinants. The findings of this study will provide the basis to refine the research objectives for the next phase of research that will target the development of a general model to predict site-specific conifer performance in mixed stands in the SBS zone.

Scientific Background
Mixedwood are a common and naturally occurring forest type in sub-boreal and boreal regions of British Columbia, with about 35% of the productive forest area in B.C. composed of different mixedwood associations (3). Recent studies suggest that mixedwood stands offer a wide range of ecological and regeneration benefits, including the reduction of disease/insect pests, enhancements in biodiversity/wildlife habitat, improvements in soil properties and site conditions, greater site productivity and decreased frost damage of conifer seedlings (e.g., 4, 17, 20).

With a growing interest in managing mixedwood forests in B.C. has come the realization that these stands are inherently more complex than single- or mixed-species conifer forests (20), as the mixedwood components have distinct growth patterns and ecological tolerances (7, 18). The use of free-growing standards in these complex stands to predict the operational/production implications of density-dependent relations between deciduous and coniferous species has proven particularly difficult. It is well established that the regeneration and growth potential of understory conifer crop trees in mixedwood stands is strongly influenced by the density of deciduous tree competitors (e.g., 4, 8, 13, 15, 19). However, Lieffers et al. (14) found that current free-growing standards, such as those used in Alberta and British Columbia, failed to reasonably characterize competitive interactions related to light and soil resources among deciduous and coniferous species in mixedwood stands.

Further, density-dependent relations may vary across the range of environmental conditions where mixedwood stands occur (7). Cold soil and air temperatures, generally associated with increasing elevation/latitude and northern slope aspects in Northern ecosystems, are known to be key limiting factors in tree growth and reproduction (12, 21, 23). Deciduous and coniferous species appear to respond uniquely to different temperature conditions, likely altering their relative competitiveness across temperature gradients (e.g., higher latitudes/elevations, more northerly slope aspects) (5, 7, 10, 11, 12, 21, 22).

Consequently, there remains much uncertainty about density-management practices in mixedwood stands across the range of conditions where they are found. Many licensees have resorted to expensive practices intended to release conifer crop trees from growth limitations created by deciduous species (20, 24), ensuring that crop trees reach free-growing status within the required time period (2). Clarifying the ecological interactions in these complex stands is a key step in identifying their best-management practices, which would promote the restoration of mixedwood stands within their natural ranges while limiting the detrimental effects of deciduous competition with conifer crop trees. This result could enhance sustainable-management efforts while offering potential cost reductions to forest licensees.

Key questions need to be addressed before we can begin to improve our density-management practices in mixedwood stands. Can we identify condition-specific levels of “tolerable” deciduous cover that will not severely impede conifer crop-tree growth? What are the environmental determinants of competitive relations under different conditions? Can critical competition thresholds be modeled based on key environmental or geographical
factors (e.g., mean annual temperature, slope aspect, latitude and elevation)?

**Study Methods**

To address these core management questions about mixedwood stands in the SBS zone, this study quantified differences in tree stem-volume increments among spruce saplings growing under variable densities of birch cover (i.e., competitive relations) on north- and south-facing slopes at the Sinclair Mills research site (SMRS) located about 100 km northeast of Prince George (Lat: 54°01′ N; Long: 121°41′ W). While several environmental gradients may alter mixedwood dynamics (e.g., elevation, latitude, continentality), we initially targeted slope aspect (i.e., cold vs. warm site) due to its universal landscape association. SMRS is located in the SBSvk01 subzone (16) at about 700 m elevation. The site was harvested in the winter of 1987-88 and broadcast burned in June 1988. In 1989, 77.7 ha were planted with interior spruce (2+1 PBR, seedlot 29164) at 2.5 m spacing (which should minimize response differences due to genetic variation). In July 1996, 24.1 ha of the plantation were treated with glyphosate by aerial application to remove competing paper birch (*Betula papyrifera* Marsh.) The remaining portion of the block was not treated, and a mixed birch-spruce stand has developed.

In November 2002, sample spruce trees were identified and GPS mapped across a wide range of birch cover densities (from fully open to fully covered at high densities) on north-facing (320° to 40°) and south-facing (140° to 220°) slope aspects. Thirty sample plots per slope aspect (single spruce sapling and associated birch cover trees within 6 m fixed radius) were established. Manual band dendrometers (described below) were installed on a sample conifer tree in each plot, and baseline measurements on all spruce saplings (i.e., height, diameter breast height, stem basal diameter) were conducted.

The following methods were validated during a pilot study at a B.C. Ministry of Forests research site near Prince George during the summer of 2002 (i.e., Spey Creek). Using manual band dendrometers (Figure 1, Agricultural Electronics Corporation, Tucson, AZ) capable of resolving stem diameter growth increments as small as 1.6 μm, we measured weekly basal diameter increments of sample trees throughout the growing season (late April to late October 2004, depending upon weather). Weekly height measurements for each sample tree were conducted until budset using a telescoping height pole. Weekly changes in stem volume were calculated for each sample conifer tree using the equation: \( \text{stem volume} = \frac{1}{3}(\pi r^2 h) \), where \( r \) is the stem basal radius and \( h \) is the stem height (25).

![High-resolution manual dendrometer bands were used to measure small diameter growth increments in sample spruce saplings.](image)

Deciduous competition was quantified by measuring the stem densities and basal areas of birch trees within fixed-radius plots around all sample conifer crop trees (14, 26). For competing birch trees within a 6 m radius of each target spruce sapling, stem density, height, basal diameter and distance from the spruce sapling was measured, grouping birch stems by quadrants oriented northeast (1-90°), southeast (91-180°), southwest (181-270°) and northwest (271-360°). These plot measurements allowed us to assess the relative influence of deciduous competition on conifer crop-tree growth (using stem density and basal area) based on distance and orientation of birch trees from target spruce samplings.
Preliminary Results, Discussion and Management Implications

Some studies have observed negative correlations between conifer crop-tree growth and the density of competing deciduous trees in mixedwood stands (e.g., 8, 14, 26). Yet, preliminary findings from the first year of this study indicate that competitive relations between coniferous and deciduous components in mixedwood stands may be quite distinct on opposing slope aspects in the SBS zone. On south-facing slope aspects (i.e., warmer), we found no relation between conifer crop-tree growth and the density of competing birch over the growing season (Figure 2). It appeared that seasonal trends cancelled each other out, as growth * birch-density relations were negatively correlated in the early growing season and positively correlated in the later growing season (not shown).

Conversely, on north-facing slope aspects (i.e., colder) we found strong negative correlations between conifer growth and density of birch trees over the whole growing season and in each seasonal period. Such dramatic differences in competitive relations may significantly impact operational strategies for assessing and managing free-growing status in mixedwood stands under different conditions.

These findings should provide immediate qualitative information to end users about the management of mixedwood stands under different landscape conditions. For instance, preliminary findings indicate that the levels of competition management required in mixedwood stands appear to vary considerably on north- and south-facing slope aspects in the SBS zone. Specifically, it seems that more intensive control of competing deciduous vegetation is required on north-facing slope aspects in the SBS zone, if acceptable crop-tree growth is to be achieved. These findings will be of considerable interest to forest licensees, as they may transfer into direct cost savings.

Further, this study suggests that it may be fairly straightforward to model competitive variation on opposing aspects in the SBS zone. It will be necessary to first establish the mechanistic causes for the observed variation in density-dependent relations between opposing slope aspects. In the upcoming year, the primary focus of this continuing study (funding approved through FSP grant) will shift to explaining variation in condition-specific trends based upon key microenvironmental factors (e.g., air and soil temperature, soil moisture), which should be strongly influenced by slope aspect (9, 1). In November of 2003, we installed environmental monitoring equipment (Onset Computer Corp, Bourne, MA, USA) to measure air/soil temperature, soil moisture and ambient light in a sub-sample of plots on both north- and south-facing slope aspects.

Findings from this and subsequent studies should provide a basis to refine the research objectives for a second phase of research, which will entail the development of a general model that could be used to predict conifer performance in mixed stands in the SBS zone.

Figure 2: Relative growth rate (cm$^3$ stem growth increment for growing season per cm$^3$ initial stem volume) of sample spruce saplings on north- and south-facing slope aspects as a function of basal area of competing birch trees within a 3.99 m radius of the spruce saplings.
Literature Cited

7) Green, D.S. In Review. For. Chron.