Prince George Forest Region

Forest Resources & Practices Team

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FOREST RESEARCH NOTE

Shelterwood Partial Cutting in Interior White Spruce: Two-year Results of a Case Study at Aleza Lake, BC

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Overview

The Aleza Lake Shelterwood Case Study is a recent introduction of uniform shelterwood methods to interior spruce-subalpine fir forests in central British Columbia. The goal of this operational trial is to test spruce shelterwood prescriptions designed for local conditions, and to monitor and report on post-harvest silvicultural results. Potential risks and operational disadvantages are also being considered and assessed.

Shelterwood methods are of interest to resource managers because they are partial cutting systems that are intermediate between clearcut and selection systems, both in stand structure and complexity of planning (Smith, 1986). We know that shelterwood methods generally are ecologically suited to regeneration of white spruce, based on work in spruce forest in other parts of western and eastern North America.

This case study will provide an initial assessment of the feasibility of shelterwood prescriptions for spruce. It will serve as a baseline for future trials in the region. Some of the early findings reported in this Research Note may provide guidance to silviculturalists and others considering partial-cut prescriptions in spruce-subalpine fir forest types.

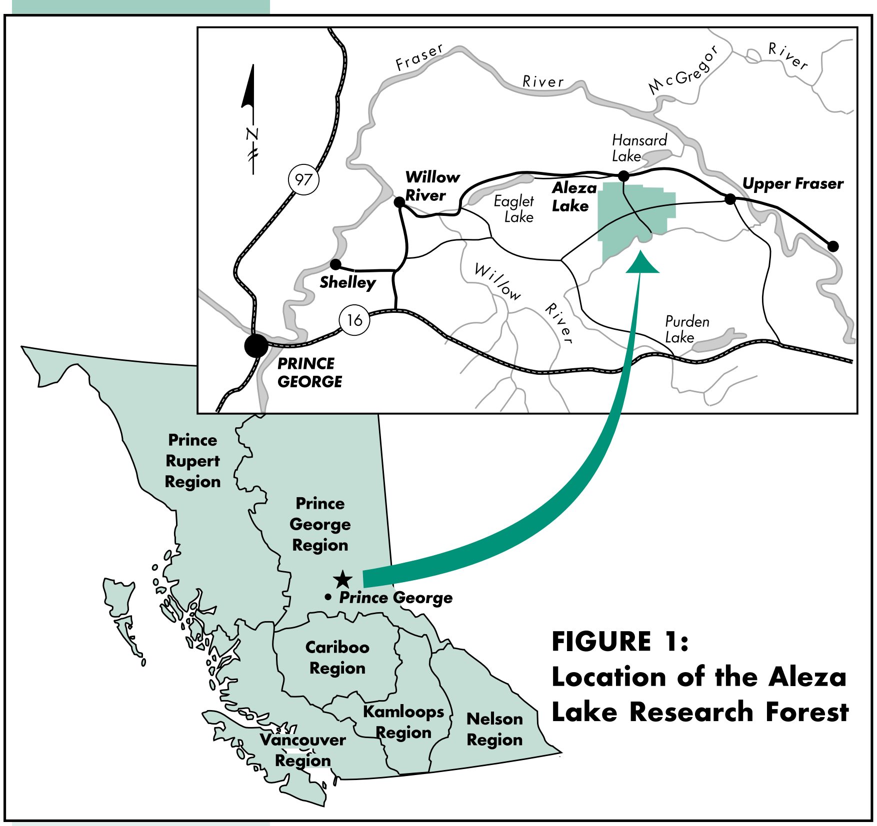


FIGURE 1: Location of the Aleza Lake Research Forest

Background

Increasingly in British Columbia, we are exploring ways to expand the silviculturalist's "tool-kit" of partial-cut silvicultural systems, to meet diverse ecological, silvicultural and social land-use goals for our forests. This tool-kit building is done by testing, refining and customizing various partial cutting methods, to suit the conditions of our local forests, combined with close monitoring to evaluate treatment success.

The shelterwood system is a very promising but often overlooked silvicultural option for partial cutting in British Columbia spruce forests. This is true for many sub-boreal and high elevation interior spruce *(Picea glauca x engelmannii)* - subalpine fir *(Abies lasiocarpa)* stands, especially those spruce forests with a distinctly "even-aged" character. Favourable results in similar spruce-fir forest types across western North America suggest that shelterwood options should be explored more fully in BC. Spruce regeneration under shelterwoods has been successful for spruce-fir forest types in Alaska, Alberta, Saskatchewan, Manitoba and Colorado. (For more information, please see references.)

An extensive literature review on this topic (Coates et *31*, 1994, p.100) indicates that shelterwood systems may be one of the most efficient options for achieving natural regeneration of interior spruce. Also, shelterwood systems can include planting; although we have only recent experience with planting of spruce under this system, the well-known shade tolerance of spruce suggests good potential for success of underplanted regeneration. Planting spruce under a shelterwood canopy could be used to ensure quick establishment of spruce regeneration while maintaining other benefits such as aesthetic qualities, volume growth on shelterwood overstory trees, and the ecological and structural diversity of a two-aged stand.

Several sources provide initial guidance for shelterwood prescriptions in our spruce forest types: Zasada (1972) provides recommendations for implementing the shelterwood system in Alaskan spruce forest. Glew (1963) and Weetman and Vyse (1990, p. 127) indicate this system may be a feasible option for thrifty-mature forest types in the Sub-Boreal Spruce biogeoclimatic (SBS) zone of Interior BC. Alexander (1987) detailed a range of shelterwood cutting scenarios for high elevation spruce-fir forests in the central and southern Rocky Mountains in the western US. Day (1970) achieved successful natural regeneration after scarification and a shelterwood cut in a high-elevation spruce-fir stand in Alberta. Youngblood and Zasada (1991) reported on the long-term results of a successful trial of shelterwoods on flood plains in central Alaska; here, there was minimal wind damage along with successful natural regeneration and overstory removal on snowpack, 14 years after the initial establishment cut.

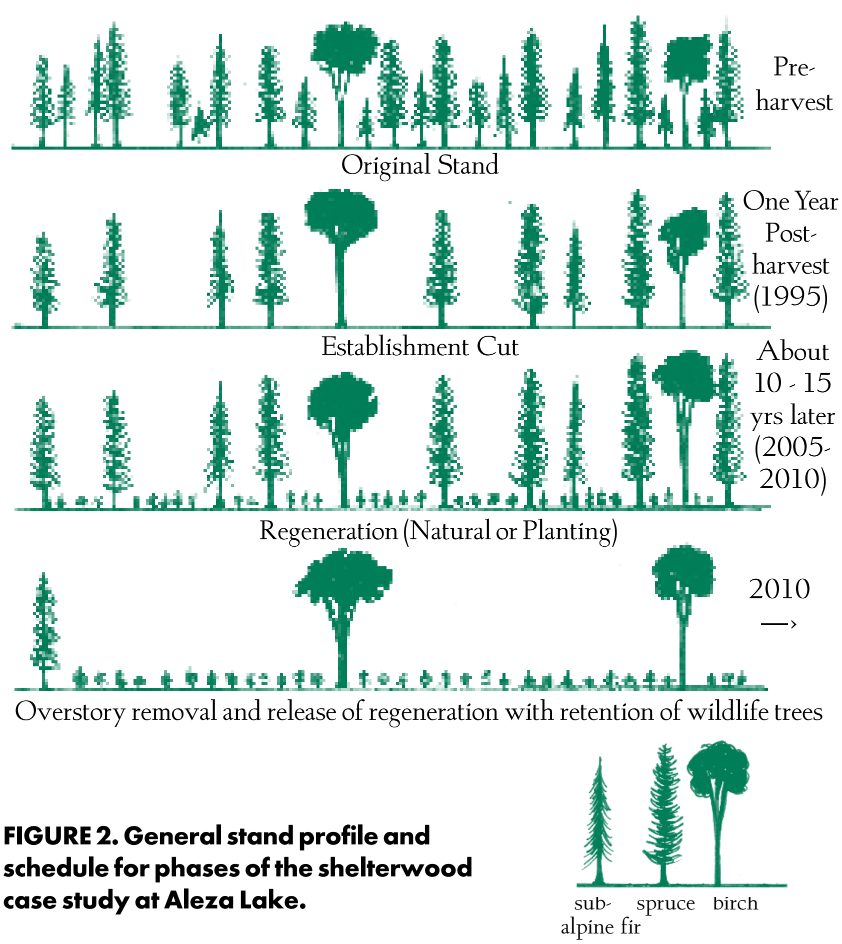


FIGURE 2. General stand profile and schedule for phases of the shelterwood case study at Aleza Lake.

Natural regeneration methods for spruce have also been used in conjunction with partial cutting more locally. In the late 1950's and early 1960's, the BC Ministry of Forests routinely prescribed seedbed scarification with tractor-mounted brush blades to promote natural regeneration in selection-cut and strip-logged areas in the Fort George (now Prince George) district. The results of these kinds of treatments generally demonstrate that successful natural spruce regeneration is frequently possible on SBS sites with adequate seed supply and seedbed conditions (Arlidge, 1967). In comparison, other partial-cut stands of similar vintage which were winter-logged with no seedbed preparation have little established spruce regeneration.

However, perceived risks of shelterwoods from an operational or economic perspective (compared to clearcutting) include: likely higher harvesting costs at least in the initial phases, potential damage to residual trees during the regeneration cut, a presumed higher risk of blowdown and bark beetle attack, damage to young seedlings when the residual mature trees are removed, and more difficult site preparation compared to clearcutting (Coates *et al.* , 1994).

The spruce shelterwood case study at Aleza Lake is an attempt to learn from past successes and mistakes. We hope to successfully apply our knowledge of partial cutting systems in spruce-fir forests using modern silvicultural tools, (e.g. the Biogeoclimatic Ecosystem Classifications (BEC), windthrow management principles (Stathers *et al.*, 1994) and artificial regeneration options).

Shelterwood Systems Defined

Shelterwoods are one of six major categories of silvicultural systems recognized in BC. (A silvicultural system is a program of treatments applied throughout the life of a forest stand. These treatments are designed to achieve specific stand level objectives based on integrated resource management goals. Silviculture includes harvesting, regeneration and stand tending.)

Under a shelterwood silvicultural system, some mature trees are removed in a series of separate cuts. The purpose is to regenerate a new, even-aged stand under the *shelter* of remaining "leave" trees. The new growth may result from planting, natural regeneration from seed, or established advance regeneration from the pre-harvest stand.

There may be up to three cut phases in the shelterwood system (Figure 2). The ***preparatory cut*** improves the vigour, health and windfirmness of a stand, where necessary (the preparatory cut was not required in the Aleza Lake study). The ***establishment cut*** provides growing space and improved light for regeneration. ***Overstory removal cuts*** remove some or all of the final overstory once regeneration is satisfactorily established.

In **uniform shelterwoods**, individual leave-trees are distributed quite uniformly throughout a site to a prescribed density. Usually the smaller and poor-quality trees in lower crown classes are removed. The more windfirm dominant and upper co-dominant trees of desirable form, vigour and seed production potential are retained until a final overstory removal.

In **irregular shelterwoods**, mature leave-trees are retained long past the time needed for successful regeneration (e.g. from 20% of the rotation to several rotation periods).

For more discussion of shelterwoods or other silvicultural system options, please refer to the *Silvicultural Systems Guidebook (1995).*

Case Study Objectives

This trial was designed to demonstrate and evaluate spruce shelterwood prescription options in a mature stand on a sub-hygric (moist, well-drained) site in the wet cool Sub-Boreal Spruce (SBSwk1) subzone.
We are examining the effects of shelterwood cuttings in a spruce stand on windfirmness of leave-trees, leave-tree growth and vigour, and spruce regeneration success. Natural and planted spruce seedling development will be evaluated in terms of short-term and long-term growth, species composition, and stocking, both before and after final overstory removal.

Site Description and Study Methods

The study site is located in the Aleza Lake Research Forest, an 8,000 hectare research area located 60 kilometres east of Prince George, BC. (Figure 1). It is within the Willow Wet Cool Sub-Boreal Spruce (SBSwk1) biogeoclimatic subzone.

The shelterwood trial covers 17.7 hectares of moderately well-drained sandy loam upland soils with rooting depths of about 35 to 50 cm. Slopes on the gently rolling site range from 5 to 20%. Approximately 4 to 5 hectares of a similar, adjacent stand was set aside as an uncut control.

Historically, the stand was horse-logged 70 years ago in the winter of 1926/27. This 1920's logging was a "diameter-limit cut", removing most trees larger than about 25 to 30 centimetres diameter at breast height (dbh). It created a residual stand of hybrid spruce and subalpine fir. In 1993, trees in the stand ranged in age from 78 to 200 years, with an average age of 126 years.

TABLE 1: Acceptability Criteria for Leave Trees, Aleza Shelterwood Case Study

Preferred and Acceptable Leave-Trees were chosen based on the following characteristics:

- dominant or upper codominant crown positions;
- greater than 37 cm in diameter at breast height;
- good taper and height/diameter ratios of 50 to 70;
- a Live Crown Ratio of 40% or more;
- well rooted in deep soil with little evidence of historic windthrow nearby, and;
- good vigour and without defect in the lower 2/3 of the stem.

TABLE 2: Pre-harvest and Post-harvest stand statistics

	All Trees				Overstory Trees (trees › 37 dbh)			
	Pre-Harvest	*Removed*	*Post-Harvest*	*% Harvested*	*Pre-Harvest*	*Removed*	*Post-Harvest*	*% Harvested*
Stems per hectare	436	336	100	77%	165	75	90	45%
Basal area m^2/ha	46	27	19	59%	29	11	18	37%
Merchantable volume (m^3/ha)	400	230	170	58%	267	107	160	40%

Upland sites supported a net merchantable volume of 400 m3/ha and an average canopy height of 25 to 37 metres in 1993. Mean annual net merchantable volume increment in the 68 years since horse-logging was about 4.5 to 6.0 m^3/ha per year, based on long-term plots in nearby stands.

The pre-harvest stand contained many upland areas with well spaced, mature spruce and other species of good vigour and 40 to 50% live crown. The pre-harvest timber cruise indicated these made up 20m^2/ha basal area and 100 stems/ha. Leave-tree acceptability criteria (Table 1) were designed to select leave-trees of high quality and relatively low windthrow hazard. This "target stand" of 18 to 20 m^2/ha basal area and 90 to 100 stems/ha approximates targets recommended in the literature (Zasada 1972, Youngblood and Zasada, 1991, Alexander, 1987). Windthrow issues were also considered during initial cutblock planning, when some wetter, windthrow prone areas of *Spruce-Equisetum* site types were identified and deleted from the original candidate area. These wet sites were found to be poorly drained, heavy-clay soils with only shallow rooting.

Target Stand Conditions

The objective of the shelterwood establishment cut is to protect high quality, vigorous windfirm overstory trees and to remove poorer quality, less windfirm trees in the smaller, codominant tree classes. The overall stand basal area was reduced to approximately 40% of the pre-harvest level. However, most of the volume removal was a "thinning from below", focused on smaller and/or poor quality tree classes (Figure 3). About 60% of trees larger than 37 cm dbh (that is, the main canopy trees) were protected during harvesting. (Table 2)

The prescription improved the spruce component in the shelterwood stand. The post-harvest stand contains 62% spruce (by stems/ha) compared to 50% in the uncut stand. Keeping the most vigorous, highest quality trees of the original stand is an opposite result compared to past "high-grading" logging methods which usually logged out the largest and most valuable spruce trees, leaving behind many smaller damaged trees. The shelterwood overstory leave-trees will be available for harvest once developing young trees reach a certain age or height.

Site Preparation

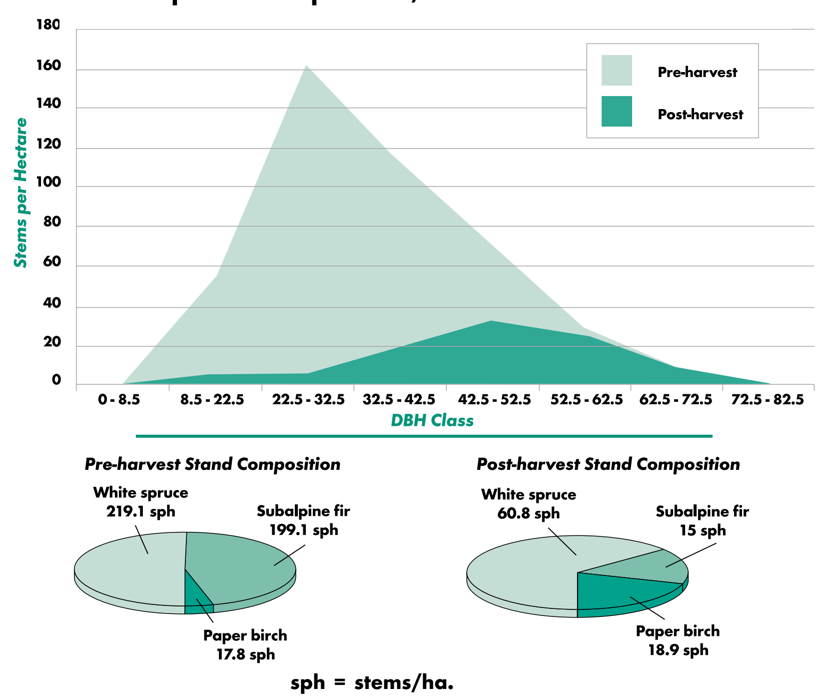
Pre-harvest seedbed scarification (site preparation) was prescribed for 3 treatment units totalling 9 hectares in area. An additional 3 treatment units totalling 9 hectares were left unprepared for "raw" underplanting of spruce.

Scarification to a maximum depth of 5 centimetres, was completed by mid August, 1993 to ensure that the seedbed was receptive to natural regeneration before seedfall in September. (1993 was an excellent seed crop year in this area.) This work was done with a Caterpillar D4 hi-drive mounted with a brush blade on dry soils and was closely supervised to minimize detrimental soil disturbance. Mineral soil exposure achieved was approximately 35%.

A three metre radius no-work buffer zone was prescribed around all designated leave-trees. However, use of the buffer zone was not as effective as expected in preventing root damage during scarification. The buffer width size should be increased by perhaps 50% (4 to 5 metre radius) in future applications.

To monitor seedfall immediately after the scarification was complete, fifteen 35 centimetre diameter seedfall traps were placed systematically within each of the three seedbed scarification units (45 seedtraps in total). Seedfall collection continued each autumn, and was completed in October 1995.

FIGURE 3: Pre- and Post-Harvest Diameter Classes and Species Composition, Aleza Shelterwood



The Establishment Cut

The site was winter harvested in January, 1995 under Cutting Permit 420 by the forest licensee Northwood Pulp and Timber Ltd., on a 50 centimetre snow-pack and frozen ground. The trees were hand-felled and skidded to landings with small tracked skidders. Where necessary, rub-trees were used to minimize damage to designated leave-trees.

Results and Observations to Date

Pre-Harvest Stand Marking Logistics

About one year before harvesting, the stand was "marked-to-leave" (leave trees marked with blue paint) to a target density of 90 to 100 stems per hectare ($18m^2$/basal area) over 17.7 hectares. This operation included a detailed stand walk-through and marking of 1600 to 1800 trees, taking a two person crew 7.25 days to complete. Marking included two passes through the stand. The first pass was to identify and mark the most preferred or most obvious leave trees up to the target basal area if possible. The second pass (usually briefer) checked the first-pass marking results and marked additional acceptable leave-trees necessary to bring marked leave-tree stand densities up to the planned target. Leave trees were identified using preset acceptability criteria (Table 1).

Including all quality control measures, overall marking efficiency was about 2.5 hectares per day. At a hypothetical 2 person crew cost of $600 per field day, per hectare marking costs are about $240 per hectare, for this cutblock. Marking speed and efficiency would likely increase and costs decrease as experience is gained. Per hectare marking costs will vary of course with the prescribed number of trees to mark (to cut or leave), access, complexity of a prescription, and labour costs.

Logging damage

Post harvest assessment of leave-tree damage (which actually includes damage due to skidding and site preparation activities) indicates that 12% of leave-trees had significant bark (cambial) scars greater than 100 cm^2 in area on the lower bole of the tree. Most of this bole damage involved surface stripping of bark only, most frequently along main skid trials; 1% of shelterwood leave-trees had further gouging of sapwood. Recovery and rate of healing-over of cambial scars on the leave trees will be assessed as the trial progresses, up to final overstory removal. Damage rates observed in this case study may decrease in future applications as more experience is gained.

The Aleza shelterwood study area, one year after the initial establishment cut (March, 1996).

Post Harvest Mortality

Wind: Minimal windthrow (or "blowdown") has been observed in the shelterwood in the two years following logging (20 stems lost to windthrow out of 1800 total stems). Due to small sample sizes we have not yet been able to identify any distinct trends in windthrow damage by species or size class. In general though, most of the windfallen trees to date have been smaller codominant trees and trees with internal butt-rots. Observations will continue to attempt to identify long-term damage trends if any emerge.

During the period from March 1995 to October 1996, the wind monitoring station located 1.5 kilometres away, has recorded 5 separate wind events with gusts exceeding 20 metres/second (72 km/hour). The highest gust speed recorded since shelterwood harvest has been 23.59 metres/second (85 kilometres/hour).

Mortality of Standing Trees: Standing mortality of leave trees has been a more significant impact on the residual shelterwood stand than wind damage. 5.2% of the leave trees (95 trees out of the total population of 1800 trees) died or were moribund in the 12 months following the 1995 harvest. These were salvage logged in the winter of 1995/96. In 1996, an additional 1.4% of the original leave trees died. The scattered 1996 mortality was not salvaged and monitoring of future trends will continue in 1997 and 1998.

Whether the mortality is due to the usual explanation for such a phenomenon - spruce beetles (*Dendroctonus rufipennis*) - is not at all certain in this case. General observations of the cambium (underbark) of both standing green mortality and occasional blowdown indicated that spruce beetle was in fact infrequent in these trees, and perhaps not necessarily a causal agent for post-harvest mortality. Also, root rots have not been observed in the area to date. So far, over the past two growing seasons (1995, 1996), the mortality trend has decreased dramatically. Visual inspections of the crowns of live remaining leave-trees, suggests that trees are recovering gradually and adjusting to the partial-cut conditions. An alternative explanation for the pattern of mortality is that the partial cutting stressed some leave-trees in 1995 following harvesting, but that the remaining trees are adjusting successfully to the new stand conditions over time.

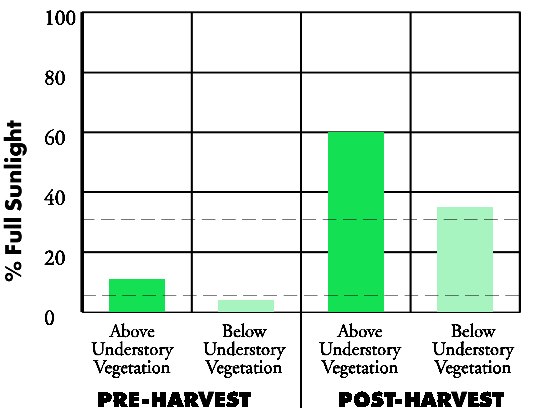
Regeneration

Cone assessments in early summer 1993 predicted a very good spruce seed crop and those expectations were fulfilled with over *32 million* seeds/ha, or 3200 seeds per m^2 (5.2 million seeds/ha and 520 seeds/m^2 for sub-alpine fir) collected during an eight week sampling period. Viability was assessed using standard procedures. Laboratory germination tests for 1993 seed crop indicated 52% viability for spruce (percent of seeds able to germinate) and 25% viability for sub-alpine fir.

Actual field germination success of this large seed crop was assessed in 1994, one year after seedfall using random fixed-area 0.5 m^2 plots. An average of about 1.7 million spruce and 0.2 million subalpine fir germinants/ha were counted on the scarified areas. Following harvesting in winter 1994/95 and one growing season, the October 1995 seedling count found 270,000 spruce, 40,000 subalpine fir and 30,000 paper birch germinants/ ha. The seedling density will be reassessed 3 years after harvest, in fall 1997. To date, white spruce makes up 79.4 percent of natural seedlings per hectare.

The entire shelterwood trial (except areas which are naturally regenerated only) was planted in May 1996 to a prescribed 2000 stems per hectare of spruce.

FIGURE 4. Comparison of pre- and post-harvest light levels below the canopy.



Understory light conditions

Understory light in the study area was measured before and after harvest along three fixed transects totalling 1000 metres. Photosynthetically active radiation (PAR) was measured above and below potentially competing vegetation at random points along each transect using a Decagon Ceptometer. 100 percent "full sunlight" was measured in an adjacent 20 hectare clearcut opening.

Before harvest, PAR measurements in the uncut stand averaged about 11% of full sunlight beneath the canopy, and about 4% of full sunlight beneath the shrub and herb vegetation. Following the shelterwood cut these light measurements increased to about 61% of full sunlight in the understory and 36% of full sunlight beneath vegetation (Figure 4).

First and second year post-harvest light levels in the shelterwood, both above and below understory vegetation are above the "light saturation point" (approximately 30% full sunlight) for maximum photosynthesis in white spruce. (Coates *et al*, 1994)

Future Work

Ongoing and future assessments of this pilot shelterwood study will continue to assess regeneration (both natural and planted), windthrow and mortality rates of the residual stand, and growth increments of the residual trees.

The research findings will be reported at regular intervals as results and analyses are available.

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