**EP1162 Discussion Literature outline**

**Proposed headings/themes for the discussion**

1. Introductory statements
2. Tree growth
3. Stand structure
4. Stand basal area and volume
5. Implications for partial harvest silviculture systems in central BC
6. Other considerations for partial cutting in central BC
7. Conclusions

**Proposed points of discussion**

In the introductory statements paragraphs, I suggest we summarize important results from study.

From a silviculture perspective, the success of partial cutting is related to the growth response of residual trees (Thorpe & Thomas, 2007).

# Tree growth

What are the interacting effects of residual basal area, species and tree diameter class on tree growth responses over time and over the entire post-harvest period (27 years)? How did different residual basal area treatments change resource availability to residual trees?

From (Thorpe et al., 2007): treatments dramatically increase the light available to residual trees and likely cause soil temperatures to rise as more sunlight reaches the forest floor. In the cold, wet sites considered in this study, even small increases in soil temperature could have important implications for tree growth. Nutrient flush- ing following harvest may also help to explain the pattern of growth response.

Partial cuts allow for manipulation of light conditions in the understory but it is important to determine how the advance regeneration existing under different levels of suppression may react to different levels of release (Wang et al., 2011).

## Was there a lag effect in growth response? What are some potential causes of a delayed growth response?

When surrounding neighbours are removed, residual trees commonly display enhanced growth, but with a variable time lag following harvest (Thorpe et al., 2007; Thorpe & Thomas, 2007). This pattern has been found in a number of species and treatments, with peak residual-tree growth occurring 6–25 years after harvest (e.g., Youngblood 1991; Groot and Ho¨kka¨ 2000; Latham and Tappeiner 2002; Jones and Thomas 2004).

Residual black spruce trees displayed a sizeable increase in growth following partial harvest. At their peak, radial growth rates were double those found before harvest. The mean observed peak was delayed, occurring 8–9 years after harvest, and the response pattern exhibited a 2-year delay period of no response followed by a 6- to 7-year period of increase after harvest (Thorpe et al., 2007)

We hypothesize that [delayed growth response]S may be caused either by slow acclimation responses or by resource allocation to root and (or) shoot growth during the first 2 years after harvest (Thorpe et al., 2007).

From: (Wang et al., 2011) Typically, smaller trees are less affected by the postrelease stress than larger trees (Boily and Doucet 1991; Murphy et al. 1999), which is also the case in our study. There are, however, observations contradicting the respira- tory stress hypothesis.

individuals restore the root–shoot balance by greater initial investments to root growth to offset the increased transpiration losses associated with the greater light and higher temperature conditions and the relative changes in the photosynthetic versus nutrient uptake capacity following the canopy opening (Kneeshaw et al., 2002)

From (Kneeshaw et al., 2002): stock forests have been adopted in parts of the British Co- lumbia interior dry belt, primarily because shade-tolerant Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) has proven difficult to regenerate in clearcuts, because of high sum- mer temperatures and associated moisture stress (Newsome et al. 1990) and susceptibility to damage from frosts during the growing season (Steen et al. 1990). Furthermore, Douglas-fir is considered to have acceptable release potential for use with partial-cutting systems (Hopwood 1990; Weetman and Vyse 1990). However, a companion species, lodgepole pine (Pinus contorta Dougl. ex Loud.), which also occurs widely in this ecosystem, is generally believed to respond poorly to release.

From: Kneeshaw et al. 2002: Compared with open-grown seedlings, shaded seedlings show a number of acclimations that facilitate their survival in lower light. These acclimations include changes in photo- synthetic and respiratory rates (Björkman 1981; Evans 1987; Sims and Pearcy 1994; Larcher 1995), changes in the spe- cific leaf area (Kellomäki and Oker-Blom 1981; Niinemets and Kull 1995a; Beaudet and Messier 1998), changes in the seedling hydraulic architecture (Sellin 1997), and changes in the shoot and crown architecture (Oker-Blom and Smolander

1988; Niinemets and Kull 1995b). Also, many studies have shown considerable differences between above- and below- ground allocation in sun- and shade-grown seedlings (Messier and Puttonen 1995; Canham et al. 1996). Upon canopy release, the shade-acclimated seedlings need to mod- ify their functions and structure to survive in the new condi- tions.

Height growth was re- stored only after considerable root growth had taken place. This tends to suggest that aboveground reductions in growth rate are not caused by decreasing productivity, but are in- stead a result of allocational changes in seedlings (Kneeshaw et al., 2002)

Observed periods of reduced height growth (growth shock) in seedlings and saplings following overstory re- moval appear to be linked to moisture-related stress (Kneeshaw et al 2002). observation that understory seedlings are limited because of insufficient capacity to take up and trans- port water (Kneeshaw et al. 2002). Therefore, these smaller trees might allocate more resrouces to root response after canopy opening in order to capitalize on increased soil moisture availability and to restore a functional balance between above- and below-ground systems (Kneeshaw et al. 2002).

From: Kneeshaw et al. 2002: It is speculated that changes in growth allocation patterns from aboveground tis- sues to belowground tissues should vary with climate and degree of overstory removal. Delays in aboveground growth response should be longer in drier sites and stands with greater overstory removal than in moister sites or those har- vested using partial cutting techniques. Forest

## Is growth accelerating in certain tree sizes? Have other studies identified that post-treatment growth response is stronger in certain size/ages?

Younger trees are likely to display larger growth increases than old trees, while larger trees may reach faster growth rates than their smaller coun terparts (Thorpe et al., 2007; Thorpe & Thomas, 2007). Suppression may also affect individuals’ ability to respond to harvest, and thus, slow preharvest growth rates may be associated with more modest growth increases.

Suppressed trees are likely to be smaller ones, therefore, one might expect that larger trees would release faster (my thought).

(Thorpe et al., 2007) found that Tree age had a strong influence on the magnitude of predicted responses . Older trees displayed modest growth responses compared with their younger counterparts, and very old trees (>200 years old) showed little or no positive growth response to harvest.

The intermediate trees responded best to a partial cut, while small trees responded well to a complete over- story removal, which caused growth losses in large trees and, to a lesser extent, in intermediate trees (Wang et al., 2011).

Many studies have demonstrated the significance of tree size in predicting variation in growth (e.g., Canham et al. 2004; Jones and Thomas 2004) but size was not an important pre- dictor of growth in the present study. This is likely due in part to the small range of residual-tree sizes, but tree age does appear to be a much stronger predictor of growth in this system (Thorpe et al., 2007).

From: Kneeshaw et al. 2002: partial canopy removal normally influences light more than temperature levels (Larcher 1995), which should lead to an increase in the seedling carbon balance. However, if acclimation to shade prevents the seedling from fully re- sponding to increased light (e.g., low light saturation, insuf- ficient water uptake and transport capacity, pigment injury) and if the respiration rates are simultaneously increased (in- creased repair demand, higher temperatures), seedlings may experience or approach a negative carbon balance as sug- gested by Staebler (1954). If this were true, larger individuals with greater non-photosynthetic biomass would be expected to respond more slowly to openings than would smaller indi- viduals.

We, however, observed no pre- and post-harvest differences in growth between size classes in terms of relative growth. However, temporally the larger individuals experi- ence a greater growth shock in the first post-harvest growing period than do the smaller individuals (Kneeshaw et al., 2002)

Studies examining the release of advance regeneration have observed conflicting patterns in trees at different developmental stages. Superior release responses in advance regeneration were observed in smaller trees (Givnish 1988; Oliver and Larson 1996; Claveau et al. 2002), larger trees (McCaughey and Schmidt 1982; Peterson and Pickett 1995; Webb and Scanga 2001), younger trees (Oliver and Stephens 1977; Ferguson and Adams 1980; Helms and Standiford 1985), or without any age dependence (Johnstone 1978; Boily and Doucet 1993; Puttonen and Vyse 1998).

FromGriesbauer and Green 2006: The age and size distribution within the advance-regeneration cohort may vary widely in any given stand, resulting in non-uniform release responses following mpb attack. Consequently, some stands developing from advance regeneration following mpb attack may be characterized by structures and distributions that become increas- ingly complex and uneven-sized over time.

## How did spruce and fir respond to release in this study? Do silvical characteristics explain differences between species?

If there aren’t any differences between species, perhaps this reflects that these species are similar in terms of growth strategies/

From (Kneeshaw et al., 2002) Furthermore, Douglas-fir is considered to have acceptable release potential for use with partial-cutting systems (Hopwood 1990; Weetman and Vyse 1990). However, a companion species, lodgepole pine (Pinus contorta Dougl. ex Loud.), which also occurs widely in this ecosystem, is generally believed to respond poorly to release.

Strong release responses (i.e., large growth increases) have been observed in more shade-tolerant species, such as spruce and subalpine fir, following windstorm or insect disturbance (Groot 1984; Doucet 1988; McCaughey and Ferguson 1988), even after pro- longed suppression (Alexander 1984; Kneeshaw et al. 1998; Antos et al. 2000).

Understorey subalpine fir and spruce were found to release well following a spruce bark-beetle epidemic with sustained growth for over 40 years, possibly up to 100 years in some cases (Veblen et al. 1991). True firs generally release faster following light changes than co-occurring species such as spruce (Doucet and Boily 1995); in some studies, however, species such as spruce have been shown to exhibit more sustained release (McCaughey and Schmidt 1982; Boily and Doucet 1993).

Conversely, shade-intolerant species (where present in the advance-regeneration cohort) will likely exhibit relatively poorer release responses compared to shade-tolerant species following mpb attack due to their more fixed crown physiology and structure (Messier et al. 1999; Williams et al. 1999) and more lingering effects of prolonged suppression (Gavrikov and Sekretenko 1996; Wright et al. 2000; Kneeshaw et al. 2002). If man- agement targets seek to utilize shade-intolerant advance regeneration to form future tree crops on some sites, it will be critical for forest managers to assess the potential of these trees to release and achieve adequate growth

## What are some other sources of variation in tree growth that could be considered in future studies? Stem mapping, radial growth response can provide annually resolved growth responses.

Differences in the magnitude of individual-tree growth responses not ex- plained by tree age may be attributable to spatial variation in postharvest stand structures; such factors could account for a substantial fraction of the unexplained variation in the observed (Thorpe et al., 2007).

# Stand structure

How did tree density change over time, and among treatment units and species?

Were there patterns of mortality in the study?

How did the diameter class distribution change over time, by treatment unit?

3. **Stand basal area and volume**

What are the differences in basal area/volume increment over time (periodic and entire period) among treatment units?

Was there a lag effect in stand basal area/volume? Can this be explained by tree-level growth responses discussed previously?

Can we identify primary sources of basal area/volume increment from diameter classes and species? In other words, did most of the basal area increment come from trees of a certain size or species?

4. **Implications for partial harvest silviculture systems in central BC**

Can we make any future projections about stand volume, structure and composition among treatments? Will treatment units converge over time? When?

Can we infer implications to total stand volume from partial cutting?

Will partial harvest in central BC spruce-fir stands inevitably result in stand conversion to fir-leading if spruce are targeted for harvest?

How can our results inform the use of partial cutting to achieve different management objectives (e.g., timber production, shelterwood, bark beetle salvage, structural diversity)

5. **Other considerations of partial harvest silviculture systems in central BC**

Increasing interest in these types of silviculture systems to salvage bark beetle-killed trees while protecting residual live trees for mid-term timber supply, wildlife habitat, carbon, etc…

Blowdown is a key stand-level consideration in designing these systems. Very little blowdown in this study – can we relate this to elements of the system design (e.g., block configuration).

6. **Conclusions**