Overcoming Obstacles to Variable Retention in Forest Management
Science to Management Forum Proceedings*

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Forum Program and Table of Contents

* **Editor's Note:** Abstracts and Popular Summaries are published "as presented" at the FORREX Science to Management Forum, and have not been peer-reviewed as part of the publication process. Some figures are available in colour in the on-line version of the proceedings at: *http://www.forrex.org/publications/jem/ISS42/vol8_no3_scienceforum.pdf*

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Introduction

In the early 1980s, coastal British Columbia was the focus of a global debate around forest management practices. The use of variable retention became a jurisdictional response to the criticism of past forest management, causing a shift away from the traditional clearcutting systems. With the outbreak of the mountain pine beetle in the Interior, the use of retention systems has now increased significantly across the province. What have the lessons from the Coast taught us as retention moves into the Interior? What does the latest science have to say about what we know and don't know about this approach, and how it works when managing for the various values on the landscape? Where is variable retention an option? Are there barriers (silvicultural, technical, and institutional) to the wider implementation of variable retention?

FORREX, in partnership with the Forest Investment Account–Forest Science Program, the Sustainable Forest Management Network, and the Northern Boreal Research Partnership, presented this Science to Management Forum as a vehicle to explore and discuss how to overcome obstacles to variable retention in British Columbia's forests. For the interest of readers and participants of this Science Forum, the information generated in the Café Process—which asked participants to articulate their vision of what successful implementation of retention would look like—will be summarized and made available in the near future.

Acknowledgements

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PowerPoint presentations from this event (those made available by presenters) are accessible on the Forum Web site at: ***http://www.forrex.org/program/forest/Science_Forum.asp?AreaPkey=18***

Keynote: Business drivers for tree retention

Steve Kozuki[1]

Presentation Abstract

British Columbia has a proud history of forest sector growth which, today, is one of the economic engines of the province's economy. From a business perspective, forest companies wish to make a profit as well as contribute to the well-being of their workers and communities. To achieve this, forest companies think of timber supply in three steps: (1) availability (physical existence of timber); (2) accessibility (potential for harvesting given non-timber constraints); and (3) affordability (operational costs and stumpage relative to the value of the timber). Companies realize that retention practices help to maintain a "social licence" to operate on the land base. They have also used retention to address many of the legislative requirements designed to achieve other values. Customers of wood products are also increasingly looking for some assurance that forest products are being derived from sustainably managed forests and, again, retention has a role to play in assuring the customer. However, even with these external drivers to use the retention system, a number of policy barriers reduce the incentive to use this system, and thus impinge on the accessibility and affordability of the timber supply. Specifically, a lack of operational cost recognition, conflicting definitions of partial cutting within the appraisal manual, and the lack of proven timber supply benefits of this practice make the use of this system questionable from a forest company's perspective. If policies such as these could be modified to enhance incentives, then there would likely be an increase in the use of this system by forest companies on the broader land base.

KEYWORDS: *certification, forest industry, partial cutting, policy barriers, social licence.*

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Popular Summary

Forest dynamics perspective – Challenges in implementing a variable retention strategy: Barriers to progress and tools to help navigate a way forward

Gerry Fraser[1], Brad A. Seely[2], Duncan Cavens[3], Hamish Kimmins[4], and Stephen Sheppard[5]

Presentation Abstract

Variable retention (VR) management, with its focus on retaining a biological legacy within cutblocks, has provided a vehicle for forest product companies to continue to operate in coastal forests where the maintenance of multiple resource values is paramount. While it has shown promise towards this end in the short term, a number of policy and technical barriers impede its employment as a central component of a sustainable forest management program. Unlike clearcutting, the retention of partial overstorey within a cutblock creates openings in which much of the area has regeneration patterns and growth conditions that are substantially influenced by forest edge or retained trees. From a sustainable planning perspective, it is essential that we begin to explore the potential long-term impacts and tradeoffs of VR management for multiple resource values including economic production, wildlife habitat, and viewscape management. As there are few long-term field trials for partial cuts in British Columbia ecosystems, managers must rely in part on credible models to inform policy and to design specific retention strategies. *(continued on next page)*

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Here we present an overview of the key barriers encountered during the development and implementation of Interfor's VR Strategy. In addition, we describe the development and application of a spatially explicit modelling framework, the Local Landscape Ecosystem Management Simulator (LLEMS), designed to assist managers in assessing the long-term impact of alternative VR systems in the context of an adaptive management framework. Demonstrations of the visual model interface and output for dispersed retention alternatives are provided.

KEYWORDS: *adaptive management framework, decision-support tools, value trade-off, visualization.*

Implementation of Variable Retention at Interfor

In 1999, Interfor began to move towards variable retention (VR) management as a central part of their sustainable forest management strategy. In general, VR was defined operationally as a harvesting system in which more than half of an opening created within a cutblock must be located within one tree-height distance from the base of a tree or group of trees (located either inside or outside the cutblock). The formalized goals of Interfor's VR strategy included reducing both the aesthetic and the ecological impact of harvesting by retaining elements of mature forest structure within cutblocks. In 2000, a target of using VR silviculture systems for 50% of all harvesting by 2002 was established. This objective was met and has been maintained to date. A suite of monitoring criteria has subsequently been developed which includes measures of cost implications, safety concerns, timber access, susceptibility to windthrow, and benefits associated with retention patches (Information Guide on Variable Retention [2000] and [2001]; Variable Retention Guide and Definition [2004]; Variable Retention Monitoring Plan [2003]—Interfor internal documents). In 2001, Interfor's Coastal Woodlands were third-party certified under the Sustainable Forestry Initiative (SFI) and the VR strategy was incorporated as part of the company's Sustainable Forest Management Plan (SFMP) and Environmental Management System (EMS).

Over the past 5 years, targets, monitoring procedures, and operational considerations have been under continual review. Through this internal review process, some of the key operational challenges associated with VR management have been identified. These include:

- assuring VR operations are both safe and economically viable while providing environmental and (or) aesthetic benefits;
- determining appropriate stocking standards for multilayered stands;
- assessing the species-specific growth and yield implications of different VR patterns; and
- mapping and tracking retention for appraisal and timber supply review (TSR) purposes.

Balancing Economic Viability with Benefits of Variable Retention

One of the goals of VR harvesting is that the harvested trees are representative of the stand as a whole. In practice, this can be difficult as managers must balance the need for economic viability associated with log value against the perception of "high grading" or selective harvesting, which creates retention patches with significantly different species composition relative to the parent stand. One solution to this problem may be to recognize VR harvesting outside of the timber harvesting land base (THLB) as incremental volume in timber supply reviews at the management-unit level.

Stocking Standards

The determination of stocking standards under multilayered stands, particularly those developed following dispersed retention, is problematic because standards developed for clearcut-based harvesting are not applicable. The retention of overstorey trees has a strong influence on the viability of regeneration through increased competition for growing space, light, and nutrient resources. The degree to which retained stems influence regeneration is dependent on their density, vigour, and spatial distribution. Stocking standards must be adjusted to take these factors into consideration.

Growth and Yield Implications

One of the more challenging issues to cope with as we transition to VR harvesting is the need to project the impact of retention on the long-term productivity of both residual and regenerating trees. By definition, retained stems in VR systems must be retained for at least one rotation. The degree to which regeneration will provide volume for subsequent harvests depends on a number or factors including: the density, vigour, and distribution of retained trees; the species and density of regeneration (planted or naturally regenerated); and the desired rotation length. Spatially explicit growth models capable of representing uneven-aged stands are necessary to support such analyses.

Mapping Retention

In many cases, all retention is not spatially located in site plans. Instead, a percentage of trees or basal area is prescribed to be retained and instructions are given to fallers or equipment operators to implement the prescription. This practice has implications to cutting authority administration and the identification of the THLB in timber supply analyses. Cost-effective methods to describe the quantity of retained stems and their spatial distribution are required that meet both operational and strategic planning needs.

To help cope with some of these issues and to provide support for sustainable planning initiatives, it is essential that we begin to explore the potential long-term impacts and tradeoffs of VR management for multiple resource values including economic production, wildlife habitat, and viewscape management. As there are few long-term field trials for partial cuts in British Columbia ecosystems, managers must rely in part on credible models to inform policy and to design specific retention strategies. In 2002, Interfor entered into a partnership with the Natural Sciences and Engineering Research Council of Canada (NSERC) and the University of British Columbia (UBC) to fund the development of a decision-support tool for the evaluation of VR alternatives.

LLEMS Modelling Framework

Description

The Local Landscape Ecosystem Management Simulator (LLEMS) is an ecologically based, spatially explicit, modelling framework designed to explore the short- and long-term consequences of varying cutblock shapes, orientations, and retention strategies for a series of economic, ecological, and social (e.g., visual) indicators of SFM (see Seely 2005 for more detail). The modelling framework operates at a spatial scale of a large cutblock or group of cutblocks (up to 3000 ha in size). The primary components of LLEMS include an interactive visual management interface and a linked forest growth model. The visual management interface developed by the Collaborative for Advanced Landscape Planning (CALP) lab at UBC allows the user to lay out cutblocks and retention areas in a three-dimensional environment (Figure 1). After a series of spatial management choices are defined, the layout is sent to the growth model. Growth within LLEMS is driven at the pixel-group level (with a minimum resolution of 10 m × 10 m) based on a modified version of the FORECAST model (Kimmins *et al.* 1999). The present capabilities of the model include a representation of the effects of forest edges and dispersed retention on natural regeneration patterns, light availability, and resource partitioning between species and age cohorts. Output from the forest growth model can be viewed as two-dimensional maps including graphs and tables or exported for three-dimensional viewing within the visual forest management interface.

Demonstration: Effect of Dispersed Retention on Growth and Yield

A series of dispersed retention simulations was conducted within the LLEMS modelling framework to demonstrate the application of the model to project the impact of varying levels dispersed retention harvesting on the long-term productivity of retained and regenerating trees (Table 1). The model was set up to represent a CWHvh1 ecosystem type with a site index of approximately 24 m at breast-height-age 50. In addition, to investigate the effect of stand vigour at the time of harvest, two initial stand conditions (old-growth western hemlock [Hw] and western redcedar [Cw], and second-growth HwCw) were used for the simulations. In each simulation, planting density (95% Cw and 5% Sitka spruce) and natural regeneration density (Hw) were assumed to vary with level of retention, with total

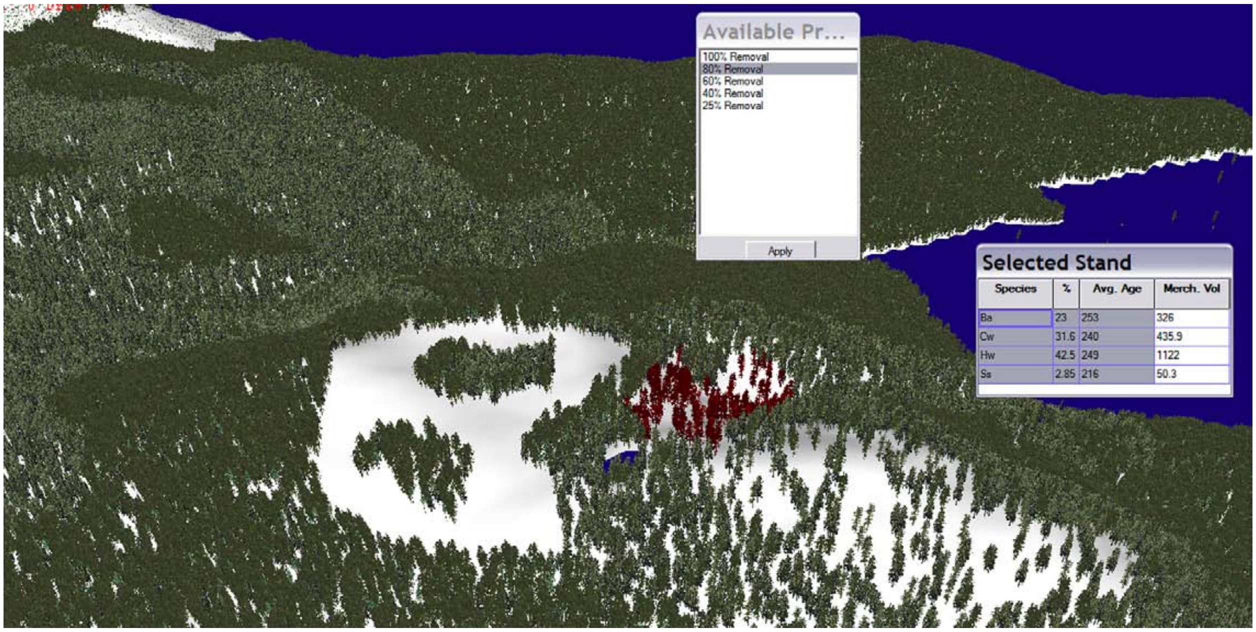

FIGURE 1. A screen capture from the 3-D interactive visual management interface for viewing the landscape and laying out cutblock boundaries and associated retention areas within LLEMS. Examples of aggregate and dispersed retention are shown.

regeneration densities ranging from 1800 to 1200 stems per hectare split evenly between planted and natural regeneration.

TABLE 1. A description of initial stand conditions and dispersed retention levels represented in the modelling scenarios

Initial stand conditions	Retention levels (% of basal area)
Old HwCw (225 yrs)	15, 30, 40, 50
Second growth HwCw (80 yrs)	15, 30, 40, 50

Results from the dispersed retention simulations (Figure 2) indicate the importance of initial stand vigour on the distribution of volume production between new regeneration and retained stems. When starting with a vigorous second-growth stand, the model suggests that growth rates of new regeneration will be marginal for levels of retention greater than 15%, but that volume growth in retained stems will be substantial, accounting for most of the volume accumulation in the future stand. A different pattern emerges in the simulations beginning with an old-growth condition. In this case, volume accumulation in newly regenerating trees can be significant for higher levels of retention. The trade-off in this case is that there is little further volume accumulation in retained trees. The fundamental difference between these scenarios is the rate and degree to which the overstorey canopy recovers and shades regeneration following harvest. Overstorey canopy recovery is relatively quick and complete in the second-growth scenarios where tree vigour is relatively high. In contrast, recovery is relatively slow and incomplete in the old-growth scenarios where retained trees have reduced vigour. Furthermore, the properties and values of the logs generated and available for harvest in the next rotation will vary with initial stand conditions and retention levels.

A more complete assessment of the effects on implementing different types of VR systems on volume production in subsequent rotations requires that results for volume production be weighed against projections of the impacts of specific retention systems on aesthetic and ecological values as part of a multi-value trade-off analysis. This can be done on an individual cutblock basis and (or) at a larger landscape-unit scale. The LLEMS modelling framework provides a tool for conducting such analyses towards the development of sustainable forest management plans. A conceptual representation of multi-value trade-off analysis for dispersed retention systems at the cutblock scale is shown in Figure 3.

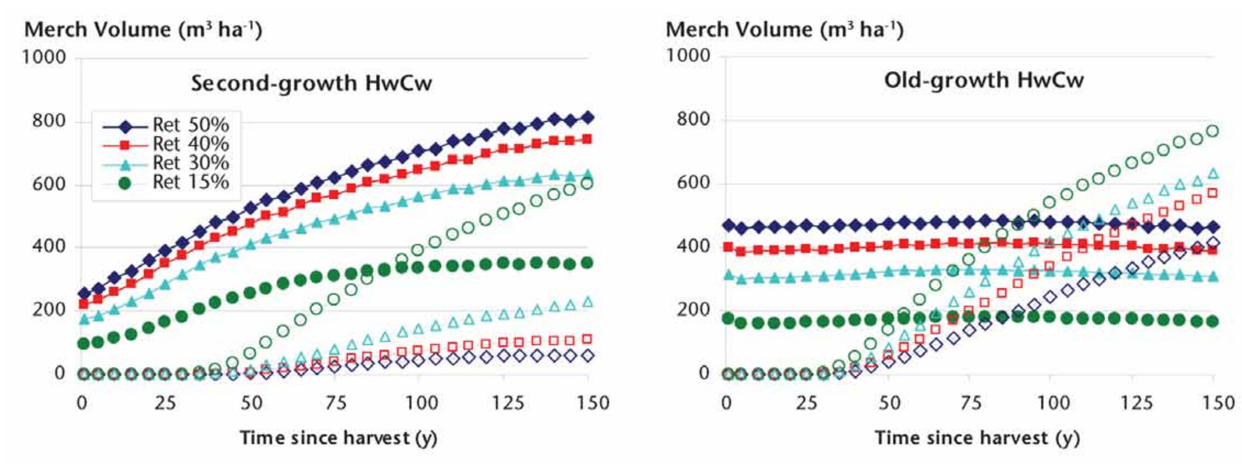

FIGURE 2. Simulated volume accumulation for different levels of dispersed retention starting with a second-growth or old-growth HwCw stand. Open symbols represent total volume accumulation in new regeneration and closed symbols represent volume in retained stems.

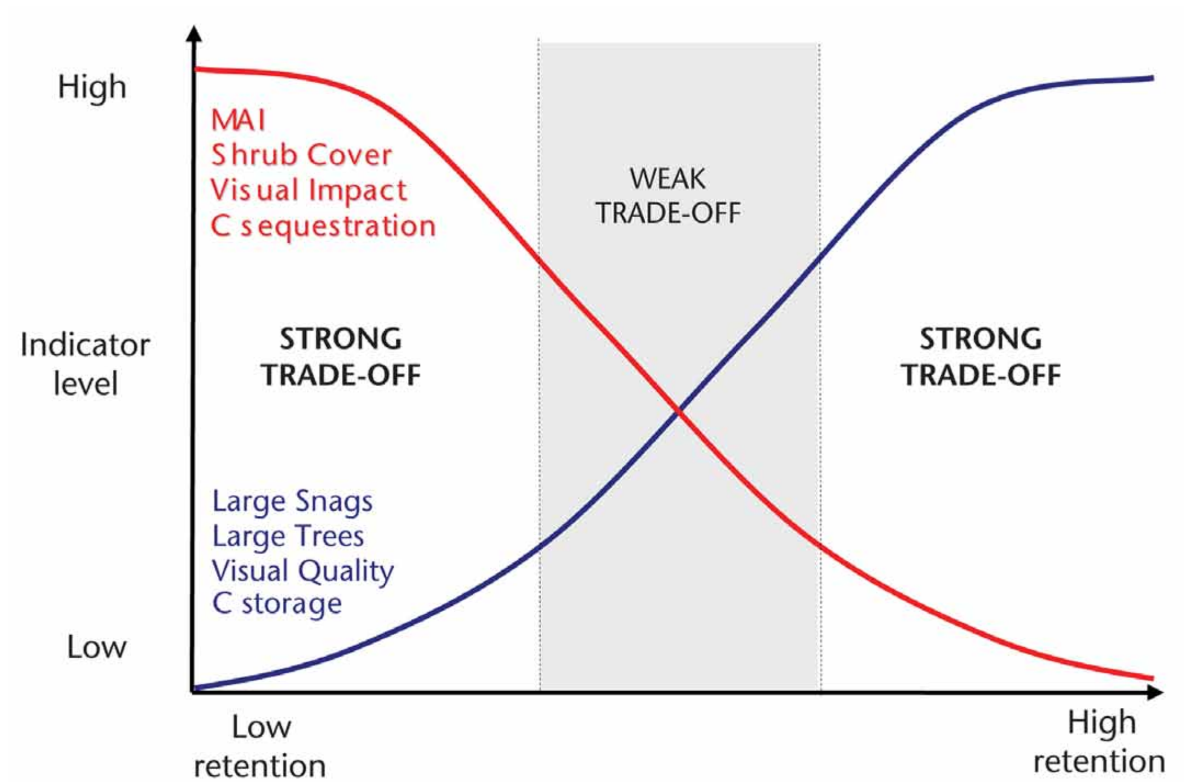

FIGURE 3. A conceptual diagram illustrating a multi-value trade-off analysis for varying levels of dispersed retention at the cutblock scale.

Future Directions

Development of the LLEMS modelling framework is continuing on the following fronts:

- The UBC development team is continuing to work with Interfor towards the implementation of LLEMS as a decision-support tool for forest planners and policy makers.
- The representation of natural regeneration within LLEMS will be evaluated and refined as part of a B.C. Forest Investment Agreement (FIA) funded project to resample a series of permanent sample plots established in 2003 in VR blocks within the North Coast Forest District.
- A generic wildlife habitat submodel is presently under development (funded by the B.C. Forest Science Program) to allow users to construct and quantify habitat suitability indices and associated spatial metrics based on a large number of variables represented within FORECAST/LLEMS.
- New funding has recently been awarded from Natural Resources Canada to develop the LLEMS modelling framework as a tool for evaluating alternative spatial mountain pine beetle (MPB) salvage strategies in Interior British Columbia.

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Abstract

Watershed management perspective – Using site and watershed-level retention for water and terrain conservation

Dave Wilford[1], Robin Pike[2], and Todd Redding[3]

Presentation Abstract

This talk addresses the topic of retention for water and terrain conservation, discussing the benefits and potential consequences (considerations) of a variety of "retention" strategies at both the site and watershed level and in a temporal context. The review initially focusses on the evolution of water- and terrain-related retention practices supported by forest science results. For many years, retention practices for water and terrain conservation have been applied in British Columbia. While initially not labelled, or necessarily recognized, as "retention," a variety of practices at both site (e.g., riparian reserves, partial cutting) and watershed levels (e.g., consideration of "equivalent clearcut area," or ECA) have been used to maintain or improve water quality, quantity, and terrain stability. As forest science has evolved over the last 30 years, so too have many of the retention practices (or at minimum their specific labelling). In British Columbia, research and monitoring have been conducted on the efficacy of riparian reserves in maintaining stream function as well as analysis of the effects of differing harvest levels on water quantity (i.e., peak flows and timing of those peaks). With the pressing issue of the mountain pine beetle outbreak, increased rates of salvage harvesting, and projected cumulative effects, the issue of when and where retention should be used has intensified. Discussion points to be considered when approaching retention and future directions of study conclude this presentation. This talk highlights the importance of recognizing local watershed characteristics and functioning, and the importance of implementing a diversity of retention strategies across the landscape.

KEYWORDS: *cumulative effects, peak flows, riparian reserves, terrain stability, water quality.*

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Conservation perspective – Can variable retention contribute to conservation goals?

Justin Calof[1]

Presentation Abstract

Forest management is constantly attempting to reconcile the conservation goal of maintaining ecosystem function with ongoing forest development. In order to ensure that the biological resources and services that support human well-being are maintained in perpetuity, ecosystem function, in the opinion of many researchers and policy makers, should be the primary goal.

Variable retention may contribute to this broad conservation goal as it can assist in the management of biodiversity, which is a key component of ecosystem function. This short presentation will explore this idea as well as discuss some of the institutional barriers to its implementation.

KEYWORDS: *biodiversity conservation, ecosystem function, forest management, institutional barriers.*

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Calof, J. 2007. Conservation perspective – Can variable retention contribute to conservation goals? *In* Overcoming Obstacles to Variable Retention in Forest Management: Science to Management Forum Proceedings, September 25–27, 2007. *BC Journal of Ecosystems and Management* 8(3):101. URL: ***http://www.forrex.org/publications/jem/ISS42/vol8_no3_scienceforum.pdf***

Abstract

Community forestry perspective – Coming to terms with "hard" and "soft" laws

Marc von der Gonna[1]

Presentation Abstract

The McBride Community Forest is a 60 000-ha area-based tenure. As with many community forests, the McBride licence comes with high expectations from the community itself. Unfortunately for the community of McBride, the tenure also resides in an area that is highly constrained by a variety of other values such as tourism, which has virtually forced the use of the retention system for all forestry operations. In managing the community forest under this reality, we have had to come to terms with "hard laws"—natural laws dictated by Mother Nature and the economics of forestry as a business—and "soft laws"—those that are created by people based on best guesses and subject to change and interpretation. One of the "soft laws" that results in barriers for community forests and the practice of retention is the appraisal system. Making money and getting items through the system in a timely manner have been challenges; however, through political lobbying with the Union of BC Municipalities, we have made some headway, including adjustments to our stumpage rate. Many areas still require flexibility from a community licence perspective—for example, the ability to change site plans as we learn about new things; flexibility of retention levels which conflict with the hard legislative numbers; stocking standards; and re-entry strategies are still outstanding for us. Further work from the community perspective is needed to help us deal with what species we can expect to have in the future as the climate changes, and what growth and yield effects the retention system has on residuals and the understorey.

KEYWORDS: *appraisal system, Community Forest Agreement, McBride.*

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Popular Summary

Timber-focussed evaluation of partial cutting in British Columbia under the Forest and Range Evaluation Program

Patrick Martin[1]

Presentation Abstract

As part of FREP (the Forest and Range Evaluation Program), the B.C. Ministry of Forests and Range is developing methods to evaluate the timber resource, and its silvicultural management, in partially harvested areas. Specifically, the FREP timber evaluation protocols address the following questions:

- To what degree are the conditions observed in partial-cut areas consistent with government's goal to maintain or enhance an economically valuable supply of commercial timber?
- What factors are associated with (might have contributed to) the observed condition?
- What change in management practices might improve the observed condition?

FREP evaluations are intended to provide high quality, reliable, science-based information for the continuous improvement of both policies and practices. Working with the goal stated above, the partial-cut timber evaluation procedures are developed by:

- identifying the dominant factors or conditions that control goal achievement;
- deriving indicators (or measures) for them; and
- establishing reference values (benchmarks) to assist in interpreting the observed levels of the indicators in terms of the degree to which the goal will be achieved.

In this presentation, I describe the indicators that have been developed. In 2006, a pilot evaluation was conducted on areas partially harvested from 2000 to 2002 in one management unit in southeastern British Columbia. Results from this test evaluation will be presented. Existing challenges and opportunities to improve the evaluation procedures will be discussed. The current status of the effort to develop and implement FREP timber-oriented evaluations will be summarized.

KEYWORDS: *effectiveness evaluation, partial harvest, silviculture, timber management.*

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Introduction

When it is used inappropriately, or poorly executed, partial harvesting can reduce the amount and value of timber yields. Improper partial cutting can result in areas stocked with damaged, diseased, slow-growing trees whose low residual volume and value preclude further harvest. However, when partial cutting is well-executed, it can salvage value from beetle-attacked stands, conserve live trees for future harvest, and create conditions that meet biodiversity, visual quality, and habitat objectives. As a result, evaluations of partial cutting practices, policies, and outcomes are urgently required.

In 2006, the Forest and Range Evaluation Program (FREP) began developing methods for evaluating the degree to which the government objectives for timber, as specified under *FRPA* (*Forest and Range Practices Act*), were being met in partial-cut areas. *FRPA*'s Forest Planning and Practices Regulation specifies objectives for timber that relate to delivered wood costs, harvesting licence rights, and maintaining or enhancing an economically valuable supply of commercial timber. The FREP partial-cut timber evaluation protocols focus on the third objective. They evaluate the degree to which stand conditions in partially harvested areas are consistent with the goal to maintain or enhance an economically valuable supply of commercial timber. In 2006, first approximation protocols for both routine and intensive evaluation were developed and then used in a trial evaluation.

This summary outlines the progress made in 2006, briefly describes the 2006 versions of the routine and intensive evaluation procedures, and presents some results from their test application in partial-cut stands in southeastern British Columbia.

Evaluation Methods

Routine evaluation procedures (termed Resource Stewardship Monitoring within FREP) provide rapid, preliminary evaluations. Intensive evaluations provide a more thorough, but also slower and more costly assessment. In 2006, both routine and intensive evaluation procedures were developed to address the following questions:

- To what degree are the conditions observed in partial-cut areas consistent with the goal of maintaining or enhancing an economically valuable supply of commercial timber?
- What factors are associated with (might have contributed to) the observed condition?
- What change in management practices might improve the observed condition?

Development of the partial-cut timber evaluation protocols followed this well-established format for developing outcome-oriented evaluations:

1. obtain a clear statement of the goal,
2. identify the dominant factors or conditions that control goal achievement (Table 1),
3. derive indicators (or measures) for them, and
4. establish benchmarks to help interpret whether observed conditions are consistent with the goal.

In the 2006 version of the routine evaluation procedure, surveyors classify a sample point into one of seven condition classes based on field observations of stocking level, the quantity of poor-quality retained trees, and the ratio of value to volume removal. In addition, surveyors qualitatively assess other factors that could affect the achievement of the timber goal.

In the intensive protocol, sample points are located at random within a population of partially harvested areas. At each sample point, surveyors collect detailed measurements on stumps, live and dead standing trees, and fallen trees. From these measurements, a number of indicators are computed, including stocking level, volume of merchantable dead or down timber, volume of live pine remaining, volume of non-pine harvested, degree of site occupancy by poor-quality trees, and value/volume removal ratio. These variables are compared to relevant benchmark levels (where available). In addition, a stand growth simulator is used to forecast volume development at the sample location and compare it to the volume trends predicted under two management alternatives (clearcut and no harvest). These comparisons provide benchmarks against which the volume trends predicted under current conditions are assessed for degree of consistency with the timber goal.

Study Area

To test the 2006 versions of the evaluation procedures, an evaluation was conducted in partial-cut stands in a forest management unit in southeastern British Columbia. Elevation at the sample locations ranged from 940 to 1700 m, and sample points fell in the IDFdm2, ICHmw1, MSdk, and ESSFdk biogeoclimatic

TABLE 1. Some of the factors assessed by the routine and intensive evaluation protocols

Factor	Consistent with the timber goal when . . .
Dead or down timber	Low amount of standing dead, fallen dead, and fallen live merchantable timber.
Non-pine harvested	Low amount of non-pine timber extracted unless it was threatened (part of BC interior only).
Species harvested under heavy retention	In a mixed species stand under heavy retention, the most valuable species have not been extracted and the area left stocked by overstorey trees of low-value species.
Timber at high risk	Low amount of beetle-susceptible lodgepole pine remaining (BC interior only) and low amount of other retained merchantable timber that is unlikely to survive to the next harvest opportunity.
Growing space occupancy by poor trees	Low level of growing space occupancy by poor-quality, undesirable trees.
Desirable trees free to grow	Crop trees are largely free from interference by non-crop vegetation and other poor-quality trees.
Tree species composition	A diversity of desirable tree species; preferred species are abundant; the more valuable species are abundant.
Planted tree genetic worth	Planted trees are of high genetic worth.
Forest health risk	Low risk of losses to windthrow, root disease, mistletoe, and other forest health agents.
Stocking level	Full site occupancy.
Regeneration delay	Gaps promptly reforested.
Productive area	Forest management practices have not excessively reduced the area that can support tree growth.
Predicted future volume	Future volume trend predicted by stand growth model compares favourably with stand management alternatives

units. Before harvest, the stand types included Douglas-fir mixed stands at lower elevations, pine-dominated stands at middle elevations, and spruce-fir stands at higher elevations. Lodgepole pine, common in many of the stand types, accounted for 46% of the management unit's timber volume. High populations of mountain pine beetle occur in and around the area.

The primary harvesting objectives of the licence-holder are to harvest lodgepole pine to capture value and volume before it deteriorates due to beetle attack, to conserve non-pine trees for future harvest, and to control the spread of the beetle. Much of the partial harvesting involves removing lodgepole pine from mixed species stands with ground-based skidding, but some cable harvesting is used. In many cutblocks, the next harvest is anticipated in 15–30 years.

Results

Survey crews collected intensive evaluation data and made routine evaluation assessments at 25 random sample locations within the population of 677 ha partially harvested from 2000 to 2002 in the management unit.

Surveyors using the routine evaluation procedure classified 22 of 25 sample locations as highly consistent with the timber goal. Among the eight overstorey factors assessed, concerns arose over the growth potential of retained trees, the species diversity in the residual overstorey, the risk of windthrow, and the harvesting of trees not threatened with imminent death. Among the nine understorey factors assessed, concerns arose over tree species diversity and the interference of poor-quality trees with the growth of crop trees.

TABLE 2. Judgements of the degree of consistency with the timber goal in the test evaluation

Indicator type	Indicator	Degree of consistency
Routine	Condition class	High
	Overstorey factors	Medium
	Understorey factors	Medium
Intensive: Current condition	Level of stocking	High
	Volume of merchantable dead or down wood	High
	Volume of pine remaining	High
	Volume of non-pine harvested	Low
	Degree of site occupancy by poor-quality trees	Medium
	Value removal relative to volume removal	High
Intensive: Future condition	Forecast future volume	High

All but one of the intensive evaluation indicators were judged to be at acceptable levels. The indicator "volume of non-pine harvested" was the exception. Given the beetle outbreak and the associated importance of conserving non-pine volume for future harvest, the average of 125 m^3/ha of non-pine species taken during partial cutting was considered inconsistent with the timber goal.

Predicted trends in volume development for the current stands were deemed consistent with the timber goal. Simulations predicted that, over the next 50 years, standing volume would be greatest if the areas were not harvested, although considerable volume would be lost to beetle attack under this management option. When harvested volume was added to standing volume, the observed partial cutting provided the greatest cumulative volume over the next 50 years.

Taken together, the indicators suggest that the current conditions in the partially harvested areas were generally consistent with the timber goal (Table 2). However, the timber goal could be more fully realized by:

- decreasing the harvest of non-pine species;
- increasing the species diversity of (desirable) understorey trees;
- decreasing the frequency of poor-quality trees interfering with the growth of crop trees; and
- when re-harvesting partial-cut areas, prioritizing for overstorey removal those areas with predicted growth rates considerably below that of clearcuts.

Conclusions and Recommendations

The development and pilot application of the evaluation procedures in 2006 led to the following conclusions and recommendations.

Many components of the 2006 first-approximation routine and intensive evaluation procedures require, or provide opportunities for, refinement and development. The routine evaluation method should be completely revised to evaluate conditions over an entire cutblock rather than at a single point within a cutblock. In addition, FREP should consider using forest estate simulation to bring a landscape- or forest-scale perspective to the question of the degree to which current practices will achieve the timber goal.

The trial evaluation experience identified a need to improve some of the field procedures, especially those for determining the species of cut stumps. Better training for field crews is recommended.

The 2006 evaluation protocols, developed for southern Interior stands, should now be tested and revised to make them suitable for application province-wide. Integrating other data sources (e.g., timber cruise, harvest billing, and silviculture information) could also improve the evaluation. Benchmarks and critical values currently used in the evaluation should be reviewed and information assembled to refine and further substantiate them.

The evaluation protocols reveal that some aspects of quality and excellence in partial-cut timber management are not incorporated in the typical partial-cut stocking standard. When providing training or guidance documents related to partial-cut stocking standards or to the silvicultural aspects of partial cutting, Ministry staff should endeavour to communicate all of the dimensions of excellence identified in the FREP partial-cut timber-goal evaluations.

With some additional data collection, and establishing sample locations consistent with the appropriate sample design, the measurement protocol can be used to estimate differences among populations, track trends in indicator values over time, or look for associations with auxiliary variables.

Alternative interpretations of *FRPA*'s government objectives for timber are possible and could lead to very different evaluation methods, indicators, and possibly results. Evaluations designed to compare outcomes to a stated goal cannot definitively identify the cause of any observed outcome. Thus, the evaluation cannot conclusively identify to what degree the observed conditions are due to good planning, experienced staff, particular treatments and practices, or good fortune. By itself, the evaluation does not identify the most feasible, cost-effective changes that will further the achievement of the objective. It also cannot determine whether the observed conditions represent the optimal balancing of timber objectives with other management objectives. Rather than claim to be the final arbiter of these debates, the evaluation aims to contribute to these discussions by providing high-quality, defensible estimates of indicators that portray the state of the timber goal.

Ministry and licensee staff, and other interested parties, need to develop some familiarity with FREP evaluations and learn how to use them as part of the broader process of assessing the sustainability, and driving the continual improvement, of forest management in British Columbia.

For additional information on FREP, please refer to the Web site at: ***http://www.for.gov.bc.ca/hfp/frep/index.htm***

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Variable retention yield adjustments in TIPSY

Mario Di Lucca[1] and James W. Goudie[2]

Presentation Abstract

Forest managers in British Columbia are facing a new timber harvesting challenge to address ecological and economic objectives. The variable retention approach to harvesting will provide conservation, ecosystem function, and biological diversity. This new paradigm also meets economic and social objectives by protecting culturally important sites, visual quality, and recreational values. The variable retention growth and yield implications are an important component of long-term timber supply planning. Therefore, the incorporation of a yield adjustment factor into the Table Interpolation for Stand Yields (TIPSY) program will allow forest managers preliminary yield prediction of regenerated or planted managed stands after variable retention harvesting. Further research results will be used to validate the model's prediction capabilities.

KEYWORDS: *variable retention, Table Interpolation for Stand Yields (TIPSY), timber harvesting.*

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Introduction

Forest management in British Columbia is in transition from a traditional forestry management cycle of clearcutting, replanting, and growing forest crops, towards a new timber harvesting paradigm that emphasizes ecological as well as economic objectives. The variable retention approach to harvesting is an adaptive management strategy required to facilitate conservation, ecosystem function, and biological diversity. This approach retains structural diversity characteristics—trees of varying sizes, snags, down woody debris, etc.—from the original stand after harvest, and thereby maintains some of the original forest attributes (Mitchell and Beese 2002; Beese *et al.* 2003). The harvested portion of the stand is then regenerated or replanted following ecological site-specific prescriptions.

The level and spatial retention pattern is very flexible depending upon management objectives and site-specific conditions (Franklin *et al.* 1977). The Scientific Panel first introduced variable retention in British Columbia for Sustainable Forest Practices in Clayoquot Sound (Clayoquot Scientific Panel 1995) to develop new ecosystem management practices for the rainforest ecosystems of Clayoquot Sound of coastal British Columbia. The panel was formed by scientists and First Nations with the purpose of developing a strategy for harvesting old-growth forests while maintaining some of the structural elements of the existing stands. The ecological objectives of this strategy were:

1. to provide immediate after-harvesting habitat for biodiversity;
2. to enrich current and future forests by maintaining some remnant structural features and organisms from the previous stands; and
3. to improve connectivity between cutting units and forest areas. This strategy also meets social objectives by protecting culturally important sites, visual quality, and recreational values.

Based on recommendations from this panel, Weyerhaeuser and other forest products companies adopted variable retention harvesting as standard stand- and forest-level planning in coastal and interior British Columbia forest ecosystems. The potential long-term implications of this new paradigm needed to be addressed; therefore, several research projects were established to investigate, for example, how shading and competition of the retained trees will influence the newly regenerated or planted area of the stand (STEMS 2003). Other technical implementation issues, such as block layout, worker safety, windthrow losses, pest and disease incidence, and economics, were also considered.

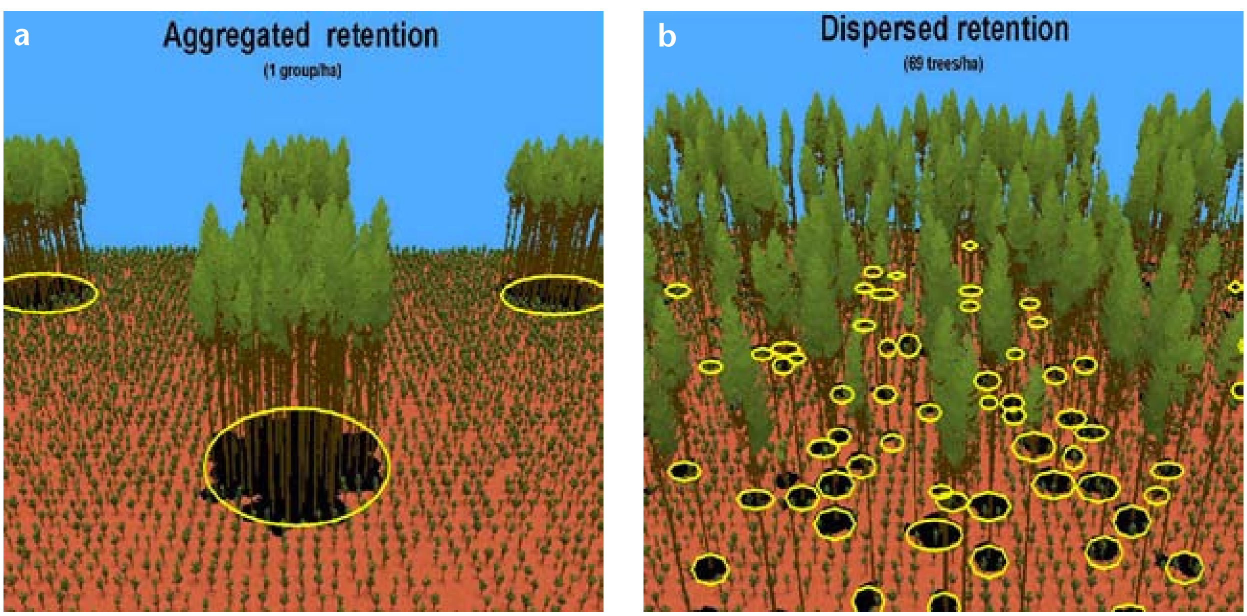

FIGURE 1. TASS images for plantations under 10% retention 10 years after variable retention harvesting for: (a) one aggregated group per hectare; and (b) per hectare.

FIGURE 2. TASS image depicting a variable retention cutblock in the Fraser Timber Supply Area, with cutblock photo insert.

Furthermore, the effects of this strategy on growth and yield and timber supply are unknown because little or no long-term data exist in British Columbia. The acceptance of this approach increased requests for its incorporation into growth and yield computer programs, such as the Table Interpolation for Stand Yields (TIPSY) to allow yield predictions of regenerated managed stands after variable retention harvesting (Mitchell *et al.* 2000; Di Lucca *et al.* 2004). TIPSY is the primary source of yield tables for managed stands used for timber supply analysis in British Columbia. The Tree and Stand Simulator (TASS) (Mitchell 1969, 1975) generated the TIPSY database, and simulated the growth and yield of the retained and regenerated portion of the stand for aggregated and dispersed retention patterns. These generated data were analyzed to develop models that predict variable retention volume adjustment factors (VRAFS), and other variables for simulated managed stands of coastal Douglas-fir, western hemlock, lodgepole pine, and white spruce.

The VRAFS were generated by determining the merchantable volume of the regenerated or planted trees after variable retention harvesting, relative to yields after a traditional clearcut at different harvesting ages, site indices, and retention levels. The yield of the retained trees was not included in the analysis. The retention level is defined as a percentage of the projected crown area retained from the original stand. The edge length and the percentage crown cover are the main drivers in the variable retention adjustment model, therefore ancillary models were developed to predict these variables if they are not available.

The edge length is one of the key factors differentiating variable retention regimes because it numerically accounts for the pattern of the retained trees. Figures 1a and 1b are TASS-generated images representing 10% retention as either aggregated or dispersed trees 10 years after variable retention harvesting and planting. The circles around the retained trees represent the vertical projection of the open crown edges on the ground. In this example, the total edge length ranged from 118 to 910 m/ha for the same number of retained trees.

Edge length is directly related to the ability of the retained trees to occupy growing space and affect the productivity of the regenerated or planted trees in the harvested portion of the stand. Goudie (1999) demonstrated that the volume of the planted stand decreases as the edge length of the retained stand increases.

An Application Example Using TIPSY

Figure 2 depicts an example variable retention cutblock in the Fraser Timber Supply Area of British Columbia that includes 15 retained aggregated groups, including the large riparian strip bisecting the block. GIS analysis of digitized aerial photos provided estimates of a retained crown cover (4.38 ha or 14%), average group size (2920 m^2), and edge length (111 m/ha). Given this information, TIPSY predicts an average VRAF of 0.83 over the life of the new stand, or a 17% reduction from a clearcut stand yield. If the edge is unknown, TIPSY can also estimate the edge length and corresponding volume adjustment factor from crown cover percentage and average group size. The yield impact on the regeneration increases as the dispersion of the retained trees increases because the residual trees can occupy growing space more efficiently due to less residual tree-to-tree competition.

Conclusions

Forest managers in British Columbia are facing a new timber harvesting challenge to address ecological and economic objectives. The variable retention approach to harvesting will provide conservation, ecosystem function, and biological diversity. This new paradigm also meets economic and social objectives by protecting culturally important sites, visual quality, and recreational values. The variable retention growth and yield implications are an important component of long-term timber supply planning. Therefore, the incorporation of a yield adjustment factor into the Table Interpolation for Stand Yields program will allow forest managers preliminary yield prediction of regenerated or planted managed stands after variable retention harvesting. Further research results will be used to validate the model's prediction capabilities.

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Popular Summary

Lessons learned from observations of mortality of residual trees following variable retention in west-central Alberta

Kevin D. Bladon[1], Uldis Silins[2], Victor J. Lieffers[3], and Simon M. Landhäusser[4]

Presentation Abstract

Variable retention (VR) harvesting leaves single or small groups of trees in cutover areas, with the assumption that residual trees will benefit from reduced competition and conditions that are more open. Additionally, VR harvesting has been proposed as a silvicultural practice to maintain biodiversity and ecosystem integrity. However, there may be decreases in growth or higher rates of mortality of residual trees immediately following VR. The objectives of this study were to quantify the mortality rates of white spruce, trembling aspen, balsam poplar, and paper birch residuals in boreal mixedwood cutovers in west-central Alberta. This study also examined the microclimate immediately after VR harvesting, and investigated the differential species responses in transpiration. Mortality rates in VR plots were 2.5- to 4-fold greater than in uncut control plots for all species. The majority of hardwoods died as snags (~70–90%), while most spruce died from windthrow (80%). Increased wind speed around the canopy of residual trees, one month after VR harvesting, produced large increases in atmospheric moisture demand compared to undisturbed forest canopies. Although aspen responses were confounded by attacks of large aspen tortrix, poplar and birch clearly showed signs of atmospheric moisture stress, while spruce responded positively to increased evaporative demand after VR. Species susceptibility to atmospheric moisture stress due to increased evaporative demand can be ranked as: poplar > birch > spruce.

KEYWORDS: Betula papyrifera*, mixedwood forests, mortality,* Picea glauca*,* Populus balsamifera*, variable retention.*

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Objectives

Our objectives were to quantify the mortality of residual trees for trembling aspen, balsam poplar, paper birch, and white spruce 5 years following variable retention (VR) cuts in boreal mixedwood stands, and compare these to natural mortality rates in similar undisturbed stands. Further, we identified the nature of their mortality (e.g. windthrow, standing dead) and investigated whether mortality of residual trees could be related to variables such as crown class, diameter-at-breast-height (DBH), tree height, slenderness coefficient (height/DBH), and logging damage to the lower bole.

An additional study examined the microclimate immediately after VR harvesting, and investigated the differential species responses in whole-tree water use to this change. The objective was to describe and compare tree sap flow and transpiration responses to microclimate change associated with VR for the typical retention species in boreal mixedwood stands.

Methods

Initial surveys for the mortality study were conducted one year after VR harvesting of boreal mixedwood sites near Drayton Valley and Rocky Mountain House, Alberta, Canada, in the Lower Foothills Natural Subregion. In May 2001, one sampling plot (~100 m radius) was established within each of sixty 1-year-old variable retention cutblocks (~10% retention). If present, one healthy residual tree from each species (trembling aspen, balsam poplar, paper birch, and white spruce) and each crown class (dominant, co-dominant, understorey) was chosen within each plot. Trees displaying signs of pathogens, insect defoliation, crown dieback, or stem form defects were not included. A total of 471 residual trees, or approximately 40 trees from each species and crown class were surveyed. Tree condition was re-evaluated 4 years later, in May 2005, to assess mortality rates and the nature of mortality of dispersed residual trees shortly after VR harvest.

A complementary study was approached similarly to a "paired basin" watershed experiment, (before/after, control/treatment) to evaluate the change in micro-climate and tree water relations between a boreal mixedwood, VR harvested stand, and an adjacent, unharvested control stand. Constant-heat sap flow sensors (Granier 1985) were installed in the stems of three co-dominant (CD) trees from each species (trembling aspen, balsam poplar, paper birch, and white spruce) to monitor transpiration. Climate stations were established before harvest at the centre of both the control and treatment sites to measure air temperature (T_a), relative humidity (RH), net radiation (Q^*; W/m^2), wind speed (u; m/s), wind direction, volumetric water content (θv), and precipitation.

Results

- Species ranking of the annual mortality rates in the VR plots were: poplar (10.2%) > birch (8.7%) > aspen (6.1%) > spruce (2.9%)
- Annual mortality rates in the VR plots were 2.5- to 4-times greater than in natural stands (Figure 1)
- The majority of hardwoods died as snags (~70–90%), while most spruce died due to windthrow (80%)
- A nearly 3-fold increase in potential evapo-transpiration (ET_P) in the VR site (Figure 2)
- A 2.8-fold increase in wind speed (u) along with subsidiary increases in net radiation (Q^*) and vapour pressure deficit (D) after harvesting
- Soil volumetric moisture content (θv) also increased in the VR site
- After partial harvesting, transpiration per unit leaf area (Q_l) in all three species began earlier in the morning and extended later in the day in VR trees than control trees (Figure 3)

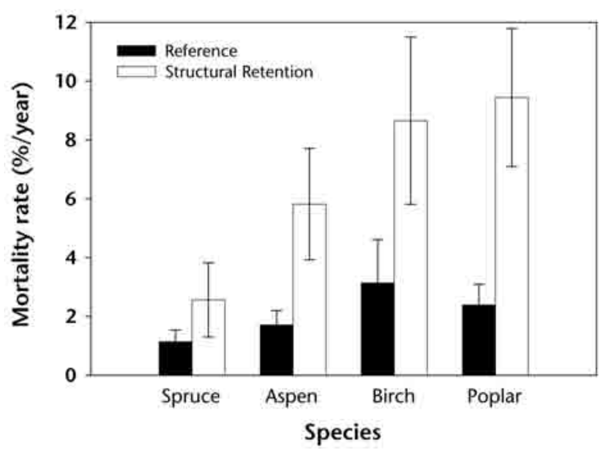

FIGURE 1. Mean annual mortality rates (± 95% confidence intervals) from reference and variable retention plots for white spruce, trembling aspen, paper birch, and balsam poplar (Bladon *et al.* [2008]).

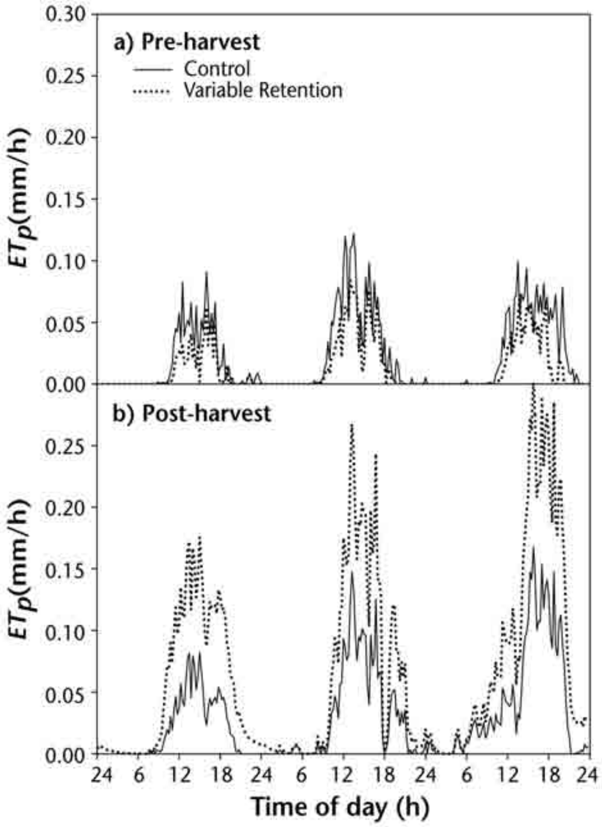

FIGURE 2. Typical 3-day pattern of potential evapotranspiration (ET_P) in the reference and variable retention sites, determined from the Penman combination equation for free-water evaporation: (a) pre-harvest (6–8 July 2003); and (b) post-harvest (15–17 July 2003) (Bladon *et al.* 2006).

- Mean maximum sap flow rates per leaf area ($Q_{l\text{–}max}$) during midday were:
  - 2.5-times greater for spruce in the VR site than in the control trees
  - 1.6-times higher for birch in the VR site than in the control trees
  - only marginally greater for poplar in the VR site than in the control
- Species susceptibility to atmospheric moisture-stress due to increased ET_P following VR harvesting can be ranked as: balsam poplar > paper birch > white spruce

Conclusions

Our results indicate that the mortality rate of hardwood species retained following VR harvesting could increase by as much as four times the natural mortality rate in the first several years following disturbance. If the primary objectives of VR harvesting are to provide critical habitat elements, ameliorate microclimate change, enhance connectivity for movement of organisms, or to sustain basic ecosystem functions (Franklin *et al.* 1997), then we recommend caution in applying VR in dry regions, as high mortality rates could be a problem. However, if snag creation is a priority, our results indicate that retention of isolated hardwood trees is more likely to provide this necessary ecological function (69.4–92.7% of dead trees were found standing), rather than conifers (< 20% of dead trees were standing). Conversely, large spruce trees, particularly those showing stem damage from the

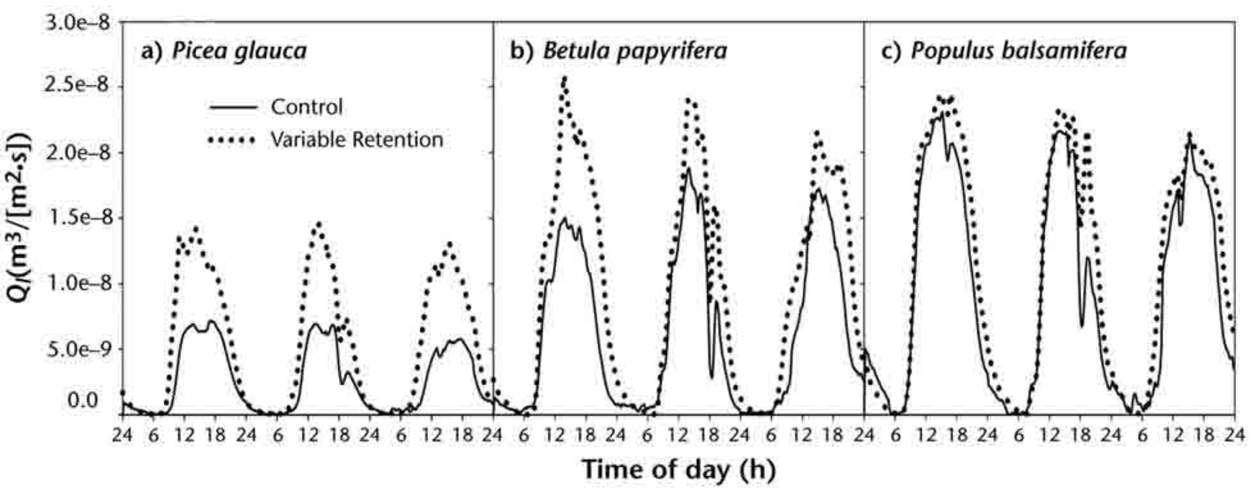

FIGURE 3. Typical pattern of mean transpiration rate per unit leaf area per tree (Q_l) on three clear days following partial harvest: (a) *Picea glauca*; (b) *Betula papyrifera*; and (c) *Populus balsamifera* from the control (solid line) and structural retention (dashed line) sites (Bladon *et al.* 2006).

logging, were more susceptible to windthrow. Leaving small, undamaged spruce is more likely to result in living trees.

The increased wind speeds of VR cuts appears to be problematic, both for windthrow of the conifers and the stress related to increased evaporative demand in the hardwoods. Our observations of heavy crown dieback among the hardwood species prior to mortality suggests that the majority of hardwood mortality could be related to xylem dysfunction (Sperry *et al.* 1994) from the abrupt increase in evaporative demand that occurs after VR harvesting (Bladon *et al.* 2006). Thus, poplar and birch residual trees may suffer extensive dieback and mortality unless they are capable of adapting within a couple years after harvesting. We believe that only those trees with sufficient root or twig xylem conductivity to meet the greater evaporative demand will respond favourably to VR harvesting. Additional research is necessary to determine whether it is possible to identify trees at the time of harvest that are most likely to adapt well to the abrupt change in microclimate.

In conclusion, we suggest that managers should use strategies to reduce wind around residual trees. If living trees are an objective, leaving residuals in clusters, near stand edges or in sheltered landscape positions may reduce mortality. For white spruce, we feel that as long as they are windfirm, most trees should benefit from reduced competition and more open growing conditions after partial harvesting. However, it may also be necessary to retain greater numbers of trees to ensure that the values of living, mature trees are sustained in regions where residual mortality could be high.

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Popular Summary

Spatial dynamics of residual-tree mortality following structural retention harvests in the black spruce boreal forest

Hilary C. Thorpe[1], John P. Caspersen[2], and Sean C. Thomas[3]

Presentation Abstract

The use of alternative silvicultural practices such as partial harvesting has been increasing in recent years in the boreal forest. Such practices aim to balance ecological and economic forest management goals, but little is known about how treated stands will perform over the long term. Of critical concern is the potential for elevated rates of post-harvest tree mortality. We quantified the rate and time course of post-harvest mortality across a chronosequence of harvested stands in the black spruce boreal forest of northeastern Ontario. Tree mortality peaked in the first year following harvest at a rate greater than 10 times the pre-harvest level. Mortality subsequently declined and was below pre-harvest rates within a decade of harvest. Windthrow was an important cause of mortality, but in contrast to previous studies, nearly half of all encountered dead trees remained standing. Both windthrow and standing death risk increased steeply with skid trail proximity. Windthrow risk was further increased by low local retention and increasing tree size. Crowded residual trees were at increased risk of standing death. These findings represent an important step towards developing quantitative models that more accurately predict forest structural and dynamic characteristics in partially harvested stands.

KEYWORDS: *dendrochronology, partial harvest, post-harvest mortality, stand dynamics, windthrow.*

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Introduction

Partially harvested stands are likely to maintain natural forest structure and function more successfully than do conventional clearcuts. In the eastern Canadian boreal forest, historical fire cycles are generally long (> 100 years) and traditional forest management activities have depopulated landscapes of old stands and their associated biodiversity (Bergeron *et al.* 2001). Partial harvesting may provide a silvicultural approach that maintains adequate levels of biodiversity and ecological function while satisfying timber production demands (Harvey *et al.* 2002). A major concern for proponents of partial harvesting is the potential for elevated rates of post-harvest mortality, which represent losses both of timber and live-tree habitat (Thorpe and Thomas 2007). However, few studies have rigorously quantified the level of, or mechanisms driving, post-harvest mortality after partial cutting. Detailed information on rates of mortality is required to make accurate predictions about post-harvest stand development over the long term. Such predictions are needed in order to evaluate the viability of partial harvesting in the boreal forest.

In this study, we used a dendrochronological approach to determine the rate, time course, and causes of post-harvest mortality across a decade-long chronosequence of partially harvested stands in the boreal forest of northeastern Ontario, Canada.

FIGURE 1. Harvest with advance regeneration protection (HARP) operations in a black spruce stand in northeastern Ontario. Photo courtesy of Abitibi Consolidated Inc.

Methods

We collected data for this study in the Lake Abitibi Model Forest (LAMF), a 1.1million ha land base in northeastern Ontario. All sites were harvested with the protection of advance regeneration (HARP) (Figure 1), a partial-harvest method now widely practised in the uneven-aged peatland black spruce stands of the eastern Canadian boreal forest. Such stands are widespread across the claybelt region of Ontario and Quebec, where fire cycles are generally long (see Bergeron *et al.* 2001).

We established a chronosequence of sampling sites harvested from 1995 to 2004, with each year represented by two cutblocks. In each block, we established three 20-m radius plots in which we measured and mapped all stems greater than 5 cm DBH including live and dead residual trees and stumps. We took disc samples from dead residual trees to determine their year of death using dendrochronological methods.

We used maximum likelihood methods to predict probability of post-harvest mortality via windthrow and standing death as a function of tree size, post-harvest local basal area, skid trail proximity, and time since harvest. Post-harvest local basal area was calculated as the basal area (m^2/ha) of live and dead residual trees located within 7.35 m of a target tree. This distance was based on an estimated parameter that represents the scale over which residual tree "neighbours" influenced the probability of mortality for any target tree. Skid trail proximity was calculated in a similar manner: the number of stumps located in skid trails that were found within 1.5 m of a target tree. This distance was also based on an estimated parameter.

Results

On average, residual-tree mortality was elevated 10 times above pre-harvest levels in the first year after harvest. These rates declined exponentially, returning to pre-harvest levels within a decade (Figure 2). Proximity to skid trails was the most important predictor of post-harvest mortality, both via standing death and windthrow. Exposed residual trees (trees with low local post-harvest basal areas) were at increased risk of windthrow, while crowded residual trees (trees with high local post-harvest basal areas) were more likely to die standing. Larger trees were also at increased risk of windthrow.

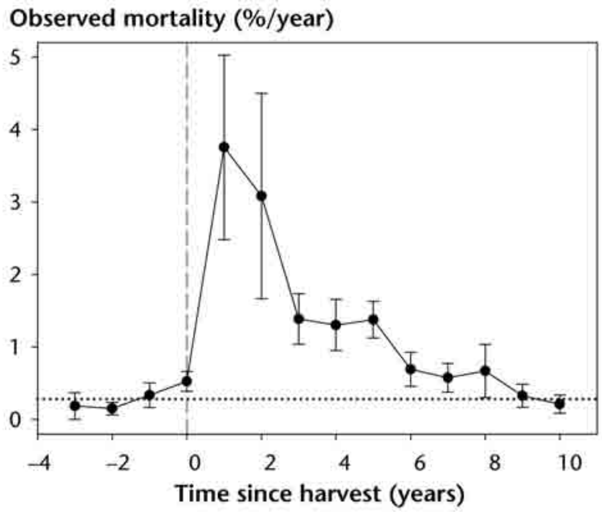

FIGURE 2. Mean observed annual mortality (±SE) before and after partial harvest. Dashed vertical line indicates harvest event. Dotted line indicates estimated pre-harvest background mortality rate.

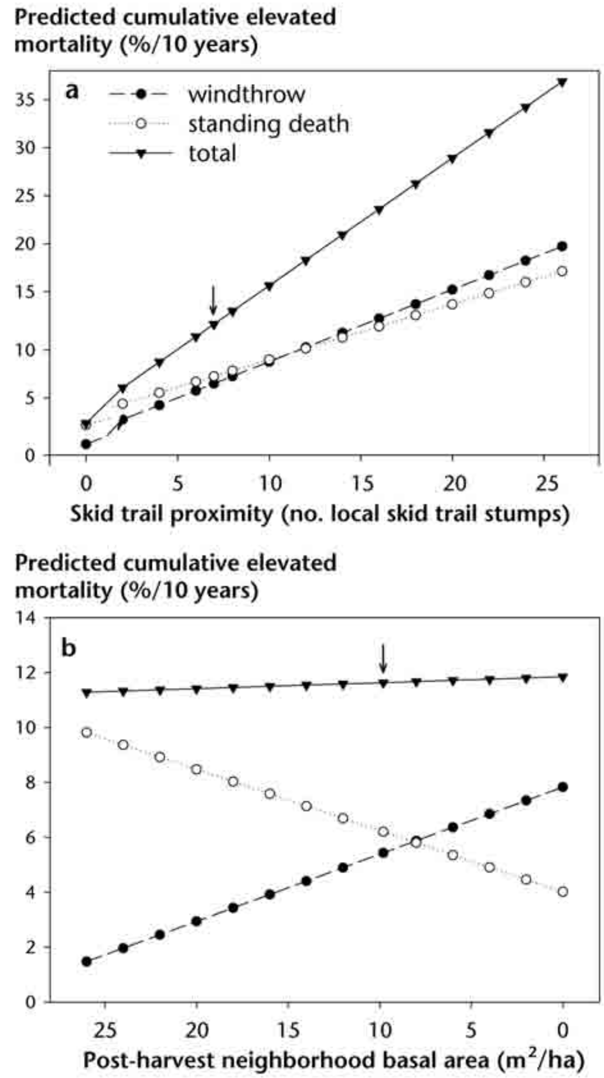

FIGURE 3. Predicted cumulative mortality in the first decade following partial harvesting across (a) the observed range of skidding impacts and (b) retention rates. Arrows indicate average observed condition.

On a cumulative basis, more than 10% of residual trees died in the first decade after harvest as a result of elevated post-harvest mortality. However, there was wide variation in cumulative mortality rates among sites. In a number of plots, virtually no post-harvest mortality was observed, while rates of greater than 30% were recorded in other sites. Skidding impacts had the most important influence on cumulative mortality. Where skidding intensity was low, the expected cumulative mortality rate was less than 5%. At peak skidding intensity, more than 35% of residual trees were expected to die in the first decade after harvest (Figure 3a). Retention rates, in contrast, had little influence on predicted cumulative mortality. At a given skidding intensity, standing death and windthrow compensated for each other: where the local retention rate was high, standing death increased, while windthrow peaked at low rates of local retention (Figure 3b).

Implications for Management

Alternative silvicultural practices such as variable retention and partial harvesting aim to create managed stands that are more similar to those disturbed by natural agents such as windstorms and wildfire. Following natural disturbances, residual live trees provide habitat, contribute to nutrient cycling, and reduce erosion (Franklin *et al.* 1997). Presumably, live trees left in partially harvested stands contribute similarly to ecological function. Such function will be compromised where post-harvest mortality rates are high, and thus efforts should be made to reduce losses of residual trees.

For sites such as those examined in this study, attempts to minimize post-harvest mortality should focus on reducing skidding impacts. Our results indicate that, at the average observed rate of retention, a 50% reduction in the coverage of skid trails would decrease the cumulative rate of mortality by 40%. Reducing skidding impacts would require wider partial cut strips and use of smaller harvesting machinery.

The results of this study represent an important step towards developing more accurate yield models. Previous work showed that black spruce trees display large positive growth responses to partial harvest (Thorpe *et al.* 2007), and thus spatially explicit simulation models are necessary to explore the long-term implications of partial harvesting in the boreal forest. Results from such models are required to assess the viability of these and other novel silvicultural practices to provide adequate ecological function or timber production over the long term.

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Popular Summary

Forest birds and retention levels

David Huggard[1]

Presentation Abstract

I used a meta-analysis of 69 forest bird species in 51 North American studies to examine the relationship between bird abundances and forest tree retention level, and whether this relationship differs by season, forest type (coniferous versus deciduous), location (coastal, Interior, and boreal conifers; eastern and boreal deciduous) and retention type (uniform versus aggregated). Season, forest type, and location affect relationships for some species; retention type is rarely important.

Roughly one-third of forest bird species respond positively or neutrally to all levels of forest harvesting. Another large set of species shows positive or neutral responses, except when retention drops to low levels (< ~15%). Among more sensitive species, which make up approximately one-half of those studied, about one-third show abundances more than proportional to retention level (i.e., 20% retention retains > 20% of uncut abundances of these species). Another one-third of sensitive species show abundances proportional to retention level. Only a few species in particular forest types show abundances less than proportional to retention levels. A final group shows sigmoidal or "soft threshold" responses, in which abundances drop relatively rapidly below a certain retention level (often in the range of 30–40%). No sharp thresholds were seen. Pooling all species, total abundances peak at medium retention levels, but community similarity to uncut forest declines continuously with declining retention, with a more abrupt decline below 15% retention.

Retention at operational levels of 15–20% benefits many forest species, but higher levels (30–40%) are required for some more sensitive species. The most sensitive species would benefit more from allocating the retention to larger uncut reserves.

KEYWORDS: *birds, forest birds, meta-analysis, partial retention, synthesis, variable retention.*

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Huggard, D. 2007. Forest birds and retention levels. *In* Overcoming Obstacles to Variable Retention in Forest Management: Science to Management Forum Proceedings, September 25–27, 2007. *BC Journal of Ecosystems and Management* 8(3):120–124. URL: ***http://www.forrex.org/publications/jem/ISS42/vol8_no3_scienceforum.pdf***

Introduction

The relationship between the abundance of animal species and percent retention in variable retention (VR) cutblocks is important information for deciding on VR retention levels. If there was a sharp threshold in this "response curve"—a retention level below which species decline suddenly—this would provide a clear target on a desirable minimum retention level for maintaining the species. However, thresholds are expected to be rare in nature, or at least very soft (Lindenmayer and Luck 2005).

Even without clear thresholds, knowing the form of a species' response curve can help guide decisions about retention levels and how to allocate a particular amount of retention. For example, a species that is moderately sensitive to forest harvesting might show a response curve to VR retention that is "above proportional." Twenty percent retention, for example, might retain the species at 50% of its abundance in uncut forest. In this case, 20% stand-level retention using VR would retain more of the species across a landscape than retaining 20% of the landscape in larger reserves and clearcutting the rest. Conversely, a species with a "below proportional" response curve would be at disproportionately low abundance in VR stands—for example, 5% of uncut abundances with 20% retention. In this case, the retained trees would be better allocated to larger landscape-level reserves rather than "diluted" across VR stands. Establishing the form of a species' response curve to retention levels is therefore key to assessing the biological effectiveness of VR retention levels (Kremsater *et al.* 2003).

Measuring responses to retention levels is often difficult for individual studies. A wide range of retention levels is rarely available in one study area, and a large effort would be required to sample many species across many stands. With well-studied groups like birds, however, there are already dozens of studies that collectively form a large sample of stands across the full range of retention levels. The goal of this study was to combine the results of the many published studies of birds in partial retention systems, to define how the abundance of each species responds to retention level. For the more common bird species that occurred in many studies, this synthesis also examined whether response curves differed by retention type (group versus uniform retention or removal), and among different forest types and locations.

Methods

Studies were included in the synthesis if they presented counts of individual bird species in at least one partially harvested treatment and in uncut forest. The uncut forest was needed because all values were standardized as a percentage of abundances in uncut forest. Fifty-one published studies met the criteria, with 69 bird species represented at five or more retention levels. Results from different studies for a particular species were combined in a model selection analysis, with a wide variety of possible forms for the response curve. Each treatment from each study formed a data point, statistically weighted by the precision of the reported result. Confidence intervals on the resulting response curves were estimated using bootstrapping.

Where the available data permitted, comparisons were made of response curves in: (1) summer versus winter; (2) uniform versus group VR or removal; (3) coniferous versus deciduous forest; (4) the interaction of (2) and (3) (whether differences between VR type were the same in conifers and deciduous stands); (5) Interior, boreal, and coastal conifers; (6) eastern and boreal mixedwood deciduous; and (7) drier versus wetter or higher areas within Interior conifer forests and within coastal forests.

Results

Of the factors that may affect response curves, some frequently affected bird response to VR levels, while others had few effects.

- Seasonal: Only one of six species with summer and winter data showed different seasonal response curves.
- VR type: VR type had an effect on the response curves for only two of the 42 species examined.
- Conifer versus deciduous: Twelve of 25 species showed differences in response curves between forest types, with nine species more sensitive to harvesting in deciduous stands.
- Coast versus Interior: Eight of 20 species showed different responses in the two areas, with five of these species more sensitive to harvesting on the coast.
- Climate: Reponses did not differ in wetter versus drier coastal forests, but in the Interior, 12 of 20 species showed different responses in wetter versus drier forest types.

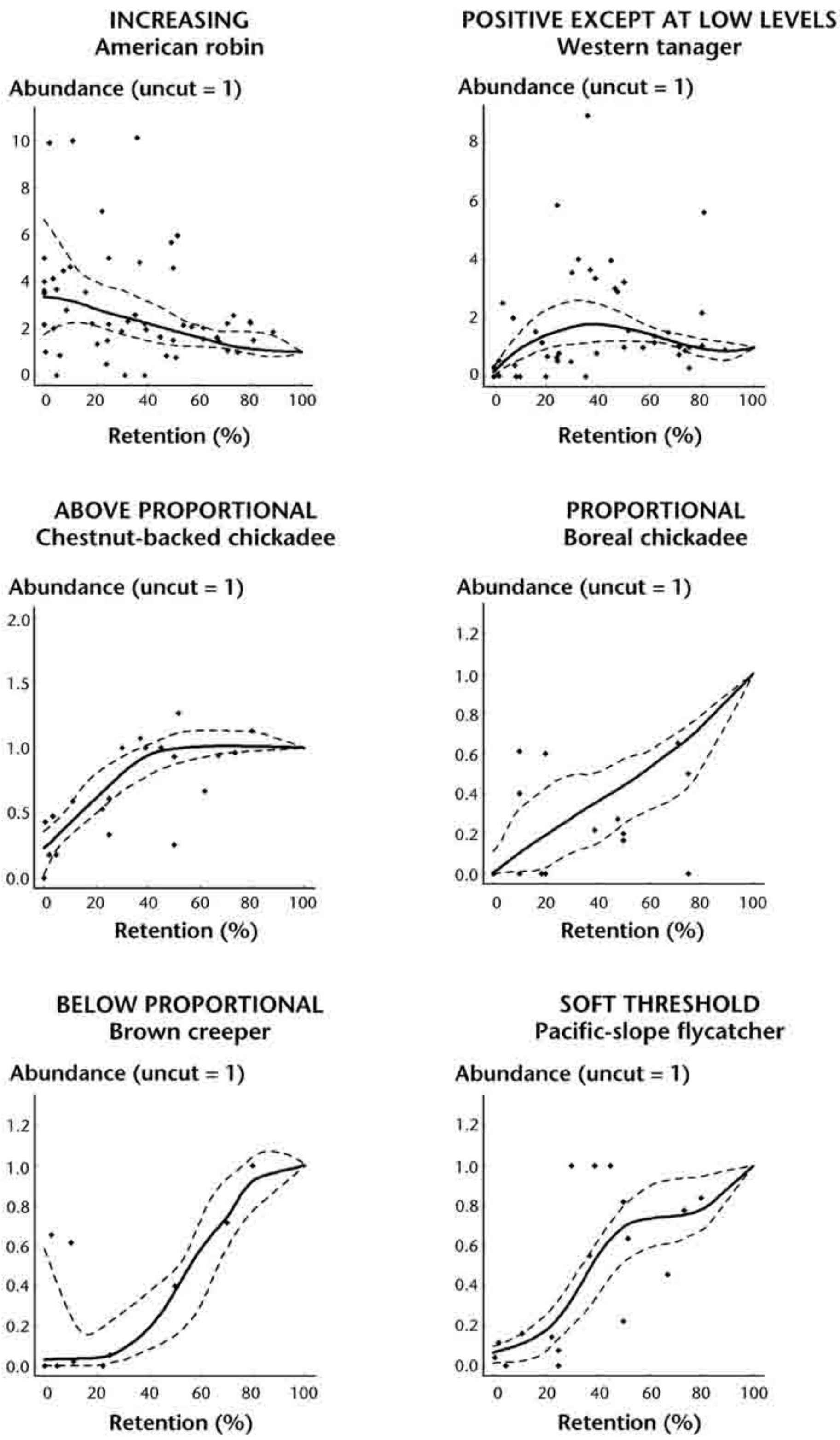

FIGURE 1. Examples of six types of response curves of bird abundance (relative to uncut = 1) to retention level in partial-retention harvest treatments. Dotted lines are bootstrapped 95% confidence intervals. Data points weighted by precision (not shown).

About one-third of the species showed positive or neutral responses to lower levels of retention. That is, abundances in the VR blocks were as high or higher than in the uncut forest. Examples included widespread species like American robins and dark-eyed juncos, and wide-ranging species like gray jays, Steller's jays, and northern flickers. Another common pattern was a neutral or positive response to harvesting, except for a decline at the lowest retention levels (< 10–15%). Black-capped chickadees and western tanagers were examples of species showing this pattern.

Among forest species that declined with harvesting, about one-third showed response curves that were more than proportional to retention level. For example, 20% retention in VR stands retained chestnut-backed chickadees at 50–70% of their abundance in uncut stands. Another third had abundances proportional to retention level. Twenty percent retention in a VR stand would support these species at approximately 20% of their abundance in uncut forest. Examples include golden-crowned kinglets, red crossbills, and pileated woodpeckers.

Relatively few species showed response curves that were less than proportional. Brown creepers were the most sensitive of these species. Twenty percent retention retained almost no creepers, with substantial numbers only appearing in stands with greater than 40–50% retention. For other species, the less-than-proportional response occurred only in particular forest types, such as for golden-crowned kinglets in deciduous forest or overbirds in boreal mixedwood.

A final pattern was a soft threshold response, in which abundances were near uncut levels down to some retention level, then declined fairly rapidly to low levels at the lower end of the retention scale. For some species, such as Pacific-slope flycatcher, the relatively rapid decline occurred between 40% and 20% retention, while for others, such as Townsend's warbler, the decline occurred between 20% and 10% retention. There were no well-defined sharp thresholds seen in the available data.

Combining results for all species, total abundance of birds increased moderately as retention levels dropped, to a peak abundance at about 50% retention. Abundances then declined gently at lower retention levels, so that stands with less than 10% retention had fewer birds than uncut stands. However, the similarity of the species composition to the bird community in uncut forest declined continuously with decreasing retention, with a more rapid decline below 15% retention. The rapid decline in community similarity below 15% retention reflects the decline of many forest species, including those less sensitive to harvesting, and the increase of a few widespread generalists that prefer open areas.

Discussion

Synthesis of existing studies is an efficient way to develop important relationships for well-studied groups like birds (Arnqvist and Wooster 1995). Despite occasionally conflicting conclusions and recommendations from individual studies, the patterns seen when many studies are combined often correspond well with the natural history of the different species, and provide a more robust, general basis for management decisions. The broad patterns can also be used to complement local monitoring programs. They are particularly useful for the less common species, where even intensive local monitoring is likely to produce uncertain results.

The synthesis did not show any hard thresholds that could be used to set clear targets for retention levels, but two retention levels stand out as important for many bird species. Retention levels of more than 15–20% retain many of the forest species that are less sensitive to harvesting at abundances similar to uncut forest, or only moderately reduced. Many species decline more rapidly in abundance below this level. Community similarity with uncut forest also shows a more rapid decline below 15% retention. This level is similar to retention levels used operationally in parts of British Columbia. However, a higher retention level of 35–40% is important for some more sensitive species. Several species with "soft" thresholds decline more rapidly when retention falls below this level. This was also the level at which the most sensitive species, such as brown creepers, started to use the stands.

Retention levels of ~20% are a practical goal for many operational blocks, and will make a substantial contribution to maintaining forest birds. Some higher retention blocks should also be used to support more sensitive species, even if this means reducing retention in other blocks. Variable retention type (uniform versus group) did not have strong effects on birds' response to retention levels, although available studies did not allow very solid comparisons of the types (and birds may be less sensitive to pattern than less mobile organisms). The most sensitive bird species, however, are unlikely to be maintained by VR with operationally practical levels of retention. Larger reserves are needed to maintain these species on the landscape.

Details of the synthesis methods, response curves for all species, and more discussion, including caveats, are in Huggard (2006).

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Popular Summary

Variable retention in a sub-boreal landscape: Is it worth the hassle?

J. Douglas Steventon[1,3] and Dave Daust[2,3]

Presentation Abstract

Stand-level studies have shown partial cutting (typically 30–70% canopy retention) maintains habitat for many species using mature forest. We used simulation modelling to examine the potential magnitude of such benefits if a shift to 30% of harvest volume from clearcutting to partial cutting was implemented in the Nadina Forest District, in the context of mountain pine beetle attack, salvage harvesting, and climate change. We projected future landscape conditions by applying 140-year harvest trajectories from Timber Supply Review simulations to four retention scenarios: (1) "status quo" of no retention beyond conventional wildlife-tree-patch requirements; (2) retention of understorey conifers; (3) retention of 30–70% of live overstorey; and (4) both understorey and overstorey retention.

We then assessed the ability of projected landscapes to support wildlife species "profiles" representing territory size requirement and strength of association with mid- to old-seral forests. We focussed on species generally associated with mid- to old-seral forests and constrained in their use of space by territoriality (e.g., marten). For each landscape, we estimated the number and quality of potential territories, and dispersal connectivity among territories. We also projected mature-forest bird community similarity.

Retention strategies led to substantive increases (10–38%) in long-term territory abundance and bird community similarity. Depending on species profile, overstorey retention had the greatest long-term effect: ~5–26% above status quo for territory abundance, and 0–7% with understorey retention alone. Connectivity differences were more equivocal. Increased territory abundance in turn made populations more resilient to increased future disturbance risk from changing climate.

KEYWORDS: *climate change, mountain pine beetle, partial cutting, sub-boreal landscapes, variable retention, wildlife habitat.*

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Background

Overstorey retention via partial cutting has been proposed to maintain mature-forest habitat for wildlife while allowing extraction of timber (e.g., Waterhouse *et al.* 2007). We used simulation modelling to explore the potential magnitude of such benefits if a shift of 30% of harvest volume from clearcutting to partial cutting was implemented in the Nadina Forest District. This was applied in the context of extensive mountain pine beetle attack, accelerated salvage harvesting, and disturbance risk from climate change.

For a net gain at the landscape scale, the stand-level habitat benefit must be, on average, greater than the stand-level canopy proportion retained. Otherwise, the benefits would be offset by increased area harvested or more frequent harvest entries. The response to percentage retention, however, varies among species (Huggard 2006), which argues for maintaining a variety of retention levels.

A second type of retention we consider is protection of advanced regeneration or understorey. Presence of understorey provides structural diversity within mature forests, and aids recovery from overstorey removal or mortality. Currently, such understorey is usually removed in favour of regeneration by planting.

Wide-ranging territorial species that favour mature forest may be particularly sensitive to habitat loss; they need to integrate sufficient area of suitable habitat to create effective territories (e.g., marten; Hargis *et al.* 1999). Sparse habitat may be offset by expanded territory size, but size is limited by energetic cost. If sparse habitat in turn leads to widely dispersed territories, dispersal among territories may also be affected. A greater amount of habitat on the landscape, as from application of retention, could allow greater flexibility in the spatial use of habitat.

Using simulation experiments, we explored some district-scale implications through time (140 years) of the above assumptions.

Landscape Model

We used the SELES (Spatially Explicit Landscape Event Simulator) domain language and simulation engine (Fall and Fall 2001). We started with maps of the current condition of the study area (circa 2000), including biogeoclimatic subzones, forest age, site index, etc. There were no maps of understorey structure; thus, we applied hypothetical maps using the proportions reported by Coates *et al.* (2006).

We then simulated the predicted spread of beetle-attack, and applied timber harvesting "rules" representing management strategies. Harvest targets, in clearcut equivalent hectares, were set consistent with B.C. Ministry of Forests and Range Timber Supply Review projections, including increased harvesting to address the beetle infestation.

We simulated four harvesting policies.

1. Clearcut and plant: Harvesting removes all trees except for wildlife tree patches and establishes a new stand of age zero, assuming planting.
2. Clearcut and retain understorey: Same as (1), but retains understorey conifers if present. Stand age reflects the clearcut-equivalent-age (Coates *et al.* 2006) of advanced regeneration (0 to 60 yrs).
3. Partial cut and plant: 30% of the target harvest volume was applied as partial cutting, and the remaining 70% as clearcutting. For each partial cut harvest block, an overstorey retention target was chosen from the range of 30–70%. Harvestable volume had to exceed 30% prior to entry. The harvested portion of the stand was re-established to age zero, assuming planting.
4. Partial cut and retain understorey: Same as (3), but also retained understorey.

We repeated the scenarios with stochastic natural disturbance at 30% and 50% of mean estimated historic rates (Steventon 2001). For each rate, we also simulated the spread of higher disturbance subzones into lower disturbance subzones as predicted with climate change. Disturbance events removed 90% of the stand-level overstorey in patches ranging from 20 to 2000 ha. Each disturbance scenario was repeated five times to account for variability.

Wildlife Response Model

The first step was to assign every 1-ha cell on the landscape a score from 0 to 1 representing potential habitat value. The landscape model tracked two live-tree canopy layers (overstorey and understorey). The base habitat value of each layer followed a sigmoidal relationship with stand age of the form $[1-\exp(-10(\text{age}/\text{opt\_age})^5)]$, where age is the time since disturbance and opt_age is the age after which there is no further improvement in habitat recovery (60, 120, or 180 years). The effective "ages"of both tree layers were adjusted by site index (productive sites recovered more quickly as habitat).

For beetle-killed stands or with partial cutting, the base habitat value was adjusted for the proportion of remaining live overstorey. First, we applied the bird community similarity response curve of Huggard (2006, Figure 7b). We considered this a "coarse-filter" indicator, integrating a number of species response profiles to retention level. Second, we applied the sigmoidal relationship $[\exp(-8(p^{2.5})]$ where 1–p is the proportion of the canopy retained. This represented species where, as overstorey was removed, habitat value initially remained high, followed by an exponential decline with continued removal. We also assumed that beetle-killed trees contribute to habitat value for a short period. The value of beetle-killed trees declined exponentially through time $[\exp(-7.5(\text{years}/20)^5)]$ approaching 0 after 20 years.

The same equations used to determine the habitat value of the overstorey were applied to the understorey. The final raster cell score was the sum of the live overstorey, dead overstorey, and understorey values (to the maximum score of 1).

We then delineated potential territories for the sigmoidal habitat response profile, applying three minimum territory sizes (25, 250, and 2500 ha). Territories could expand up to three times the minimum size to capture sufficient resources, with final territory quality calculated as the inverse of territory size assuming larger territories entail a higher energetic cost. We report territory numbers weighted by the quality score.

We assessed dispersal connectivity among territories using a landscape graph approach similar to O'Brien *et al.* (2006) that estimated the proportion of territories within dispersal range (adjusted for movement cost, and probability of dispersing various distances).

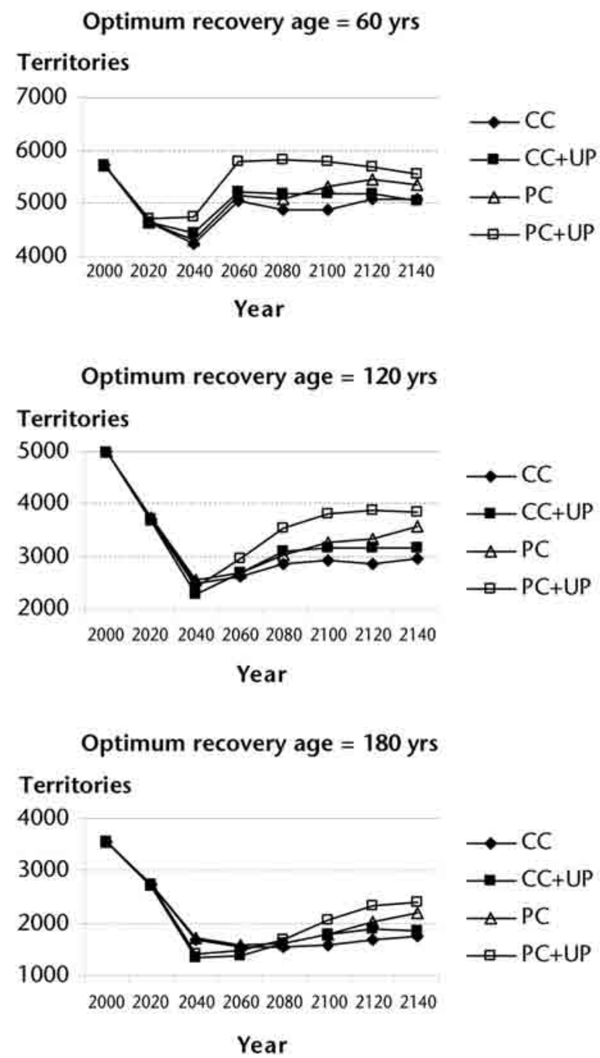

FIGURE 1. Predicted territory abundance by management strategy (CC = clearcutting only; CC+UP = clearcutting with understorey protection; PC = partial cutting; PC+UP = partial cutting and understorey protection) for three habitat recovery assumptions (optimum recovery ages of 60, 120, and 180 years).

Results

The predicted number of territories decreased in proportion to territory size (i.e., minimum). Territory size did not interact with harvesting policy, thus we only report on the 250-ha territory scale (approximating female marten).

In the absence of future natural disturbance, partial cutting in combination with understorey retention was the most effective habitat strategy (Figure 1). It facilitated a more rapid and higher recovery from the beetle mortality and salvage era. At the end of the simulation period, it provided 10–38% (depending on habitat recovery assumptions) more potential territories than did "status quo" clearcutting. Understorey retention alone provided a 0–7% increase, partial cutting a 5–26% increase. The influence of understorey retention was greatest in the mid-term, while the influence of overstorey retention was greatest later in the simulations. Connectivity among territories did not show any strong differences among the scenarios. Bird community similarity showed patterns of response similar to territory abundance.

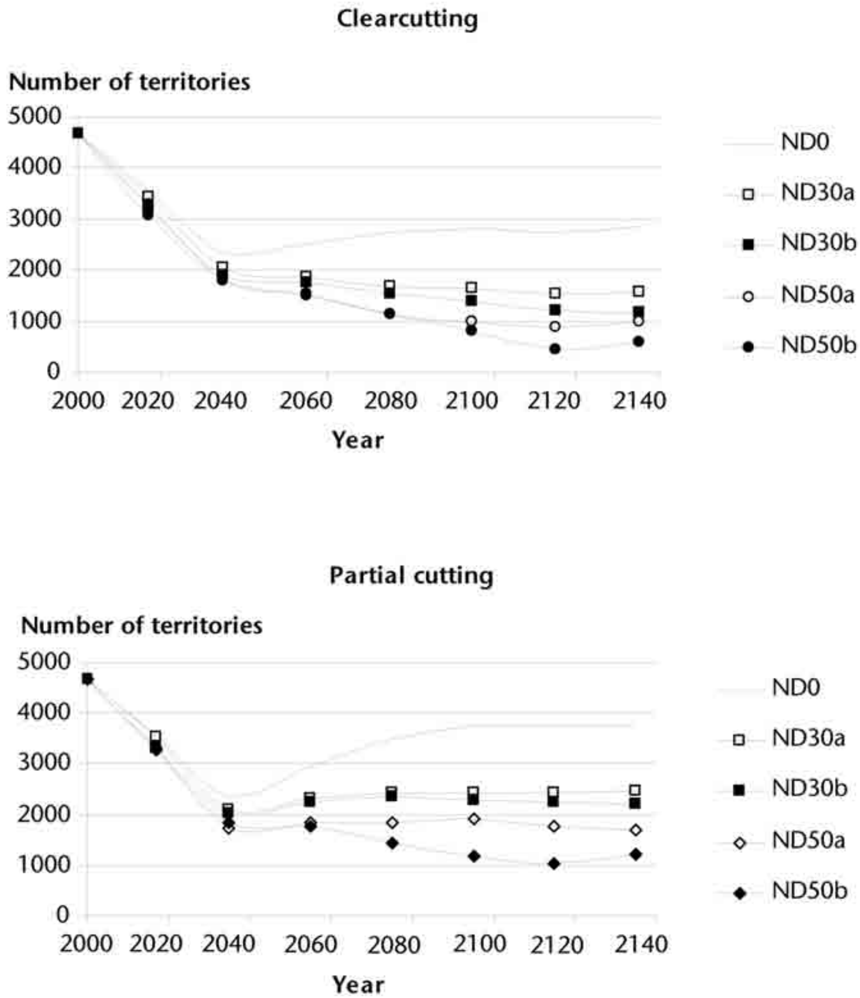

FIGURE 2. Total number of territories for clearcutting and partial cutting policies with varying rates of natural disturbance: ND means natural disturbance and is followed by the rate (%); "a" means no subzone spread; "b" means subzone spread. Optimum recovery age of 120 years.

With the addition of future natural disturbance, the relative benefits of retention followed the same general pattern as above. Partial cutting in combination with understorey retention remained the most effective habitat strategy. At the end of year 2075 (prior to significant harvest deficits that complicate interpretation), it provided about the same absolute increase in territory abundance (ranging from 715 to 826 territories) for all but the most extreme disturbance scenario (ND50b). This absolute increase translated into higher percentage increases over clearcutting (from 28 to 64% depending on disturbance rate). Again, bird community similarity showed similar patterns of response as territory abundance.

Natural disturbance caused similar proportional declines in territory abundance for all harvest policies (Figure 2). Territories reached a minimum shortly after the beetle outbreak and related salvage (at about 2035). With minimal post-beetle disturbance (ND0), habitat increased until about 2075 and then stabilized. Increased future disturbance coupled with harvesting brought habitat abundance to lower equilibriums, never recovering to levels found before the beetle outbreak.

In addition to reducing old forest habitat, increased natural disturbance rates reduced the area harvested. Partial cutting without understorey retention led to the highest harvest deficits in all scenarios. In most cases, policies that retained understorey had the lowest deficits. Shortfalls in harvest usually became apparent after 2075.

Discussion

We are continuing to refine both the landscape dynamics model and the breadth of our wildlife response assumptions. While we believe the pattern of model outcomes we present to be robust, the results should be considered preliminary. Retention strategies substantially improved habitat outcomes in all scenarios. However, there has been resistance to partial cutting in the central/northern interior of British Columbia. This resistance likely stems from questions around perceived loss of timber production, and increased cost and complexity.

If variable retention treatments can realize similar timber productivity over time as do clearcuts, then habitat benefits accrue without reducing timber supply. Silviculturists, however, are still debating the volume production implications of partial cutting versus clearcutting. In our future disturbance scenarios, partial cutting resulted in higher harvest deficits due to constraints on area available (not productivity). Modifying our harvest rules to allow more flexibility in harvesting rate and strategy among time periods could reduce the deficit, and needs to be better explored. The increased cost of partial cutting, however, is likely the main short-term impediment to application.

Potential negative conservation effects of partial cutting are increased road density and reductions in snag abundance. The magnitude and significance of these effects, however, is dependent on many factors (Bütler *et al.* 2004; Delong *et al.* 2004).

Overall, we conclude that empirical evidence and simulation experiments support the conservation value of variable retention as part of a landscape strategy in sub-boreal forests. In earlier simulation experiments we found the only other effective conservation tool was reduced mid- to long-term harvest rates. However, if variable retention is to be useful at a population scale and not just an interesting curiosity, it will have to be applied thoughtfully and over a substantive portion of the harvested land base. We suggest starting in targeted watersheds to allow testing of landscape-scale predictions.

Acknowledgements

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Abstract

Leave-tree mortality: Rationale for using a variety of approaches to maximize long-term success of mature Douglas-fir residual trees following harvesting

Bruce J. Rogers[1] and Chris D. Hawkins[2]

Presentation Abstract

Variable levels of mortality have been observed shortly after logging for single mature Douglas-fir leave-trees retained in dispersed patterns on cutblocks in the Sub-Boreal Spruce zone of central British Columbia. Innovative approaches to stand-level retention practices may be necessary to meet long-term strategic objectives. Douglas-fir are at the northern extent of their range in North America in central British Columbia, occur in a patchy distribution primarily on warmer aspects across the landscape, are long-lived, and thus, in relation to other conifer species, provide vertical structure with unique habitat values. These values are recognized by government, and current policy addresses its importance, especially its contribution to critical ungulate winter range for mule deer. However, much of the Douglas-fir occurs as a secondary component in lodgepole pine-leading stands that are currently targeted for salvage harvesting after mountain pine beetle attack. As a result, more single mature tree retention is taking place on the landscape. Recent research has shown that mature trees retained in single dispersed patterns following harvest are under greater water stress compared to pre-harvest conditions, and are thus at higher risk for mortality. If Douglas-fir leave-tree mortality occurs shortly after harvest, this silviculture system fails to meet the long-term objective of providing live vertical structure through ensuing stand development. To maximize survival of leave-trees, patch retention is recommended to maintain the microenvironment around the leave trees. Conversely, if management objectives include recruiting standing and downed deadwood of large size soon after harvest, the single-tree dispersed method of retention may provide predictable recruitment.

Editor's Note: This presentation was based on the article "Examining mature Interior Douglas-fir single tree retention" which was published in *LINK* Volume 8, Issue 3 (see ***http://www.forrex.org/publications/link/ISS44/vol8_no3_art4.pdf***).

KEYWORDS: *Douglas-fir, leave-tree, mortality, residual, retention, stress.*

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Popular Summary

Dispersed retention in the Coast–Interior transition: Stand structure and regeneration 15 years after harvest

Brian D'Anjou[1]

Presentation Abstract

A trial evaluated dispersed tree retention near Boston Bar, B.C. (IDFww), in part for improving regeneration success. Five treatments were applied to a mature Douglas-fir forest to yield a range of understorey shading: three densities of dispersed retention, a clearcut, and an unlogged control. Treatments were repeated in two neighbouring blocks with distinctly different site conditions. Windthrow and subsequent Douglas-fir bark beetle attack reduced retention densities primarily in the upper block. Wildfire in year 5 killed dispersed trees in both blocks. By year 15, dispersed tree densities ranged between 18% and 63% of post-harvest levels and beetle attack appears chronic. Remaining dispersed trees show epicormic branch development, and enhanced diameter and reduced height growth compared with control trees. Post-harvest natural regeneration densities met stocking objectives in higher retention treatments of the upper block by year 4; little regeneration established in the lower block. Post-fire regeneration densities exceeded pre-burn densities in both blocks and ingress continues. Free-growing height objectives (minimum height of 1.5 m) were easily met in the clearcuts by the tenth year after the fire. Subsequent management of the understorey regeneration requires setting clear target stand objectives for each treatment. Dispersed retention provided snags and coarse woody debris—biological legacies important for meeting broader biodiversity objectives—but bark beetle continues to reduce residual densities. Aggregated retention may be more suited to specific site conditions while meeting regeneration and biodiversity objectives.

KEYWORDS: *dispersed retention, IDF, seed tree, shelterwood, wind damage.*

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Introduction

With the increasing appreciation of the ecological complexity of forests, and heightened recognition of other resource values, the need for establishment and evaluation of non-clearcutting silviculture systems developed. Interested organizations in the Vancouver Region collaborated and identified four priority forest types where alternative silvicultural systems should be established and studied in the region. The Coast–Interior transition zone (IDFww and CWHds1) was one of those types. While the IDFww represents the wettest and mildest part of the zone, severe water deficits combined with planting stock limitations can result in low plantation survival. Silviculture systems for improving regeneration success by moderating understorey climate and (or) enhancing natural regeneration development (e.g., shelterwoods) are well documented and used on similar sites in Washington and Oregon (Williamson 1973; Seidel 1983).

Staff from B.C. Ministry of Forests Region and Chilliwack District, Fletcher Challenge, and Forest Engineering Research Institute of Canada collaborated to demonstrate seed tree and shelterwood systems in two neighbouring blocks near Boston Bar, B.C. It was recognized that tree retention as prescribed may permit meeting wider biodiversity objectives, including providing biological legacies such as large-diameter trees, snags, and downed wood components, structural attributes that are typically absent or in low abundance after clearcutting. After harvesting in 1991, residual tree and regeneration (natural and planted) development were monitored and results reported four years after harvest (D'Anjou 1998). A wildfire that started kilometres away swept through the study site in late summer of 1995. The project became dormant until research funds (FIA) were awarded in 2005 (15th year after harvest) to document residual stand and regeneration development.

Study Site

A site east of Boston Bar (IDFww) at the confluence of East Anderson River and Utzlius Creek was chosen. The study site, 40 ha in size, included an upper flat block and a lower steep block. Douglas-fir (*Pseudotsuga menziesii*), 110–140 years of age, dominated both blocks with a diameter distribution representing an inverse J-curve. The lower block had greater volume than the upper block (449 versus 391 m^3/ha); lower volume in the upper block was partly attributed to mortality from spruce budworm (*Choristoneura occidentalis*) attack and *Phellinus pini* stem rot opening the overstorey crown enough for Douglas-fir to regenerate.

Harvest Treatment Design

Five harvest treatments were developed as a group to yield a range of understorey light levels by controlling residual overstorey densities ranging between 0% light (unlogged control) and 100% light (clearcut). Design of the three other intermediate treatments utilized literature on seed tree and shelterwood systems conducted in Pacific Northwest states and correspondence with those experienced in shelterwood management. The heaviest retention level of the three intermediate treatments, "Shelterwood Light Removal" (SLR) with 50% residual basal area, was selected as an upper limit of retention suggested for satisfactory regeneration due to soil moisture competition (Williamson 1973). A second shelterwood treatment, "Shelterwood Heavy Removal" (SHR), with 25% residual basal area was selected as the lower limit meeting the definition of a shelterwood (Smith 1962). The final treatment, "Seed Tree" (ST), prescribed retention of 15–20 trees per hectare, would retain trees as a seed source rather than a source of shade. Tree marking guidelines utilized relationships for estimating ground shade cast in western Oregon based on residual basal area and quadratic average stem diameter (Williamson 1973). Inter-tree spacing was determined by translating basal area to stand densities, permitting field guidance for residual tree selection. Trees selected for retention (dominant or co-dominant, good form and free of defects, free of insect and diseases, and evenly spaced although tree quality took precedence over spacing) were painted.

Experimental Design

The trial was designed as a randomized complete block design, with all five treatments (clearcut [CC], seed tree [ST], shelterwood heavy removal [SHR], shelterwood light removal [SLR], and unlogged control) applied within both upper and lower blocks. Upper block treatments occupied on average 5.5 ha; lower block treatments averaged 4 ha in area. Lower block treatments were harvested with hand-felling and cable yarding; upper block harvest utilized mainly a feller-buncher with ground-based yarding.

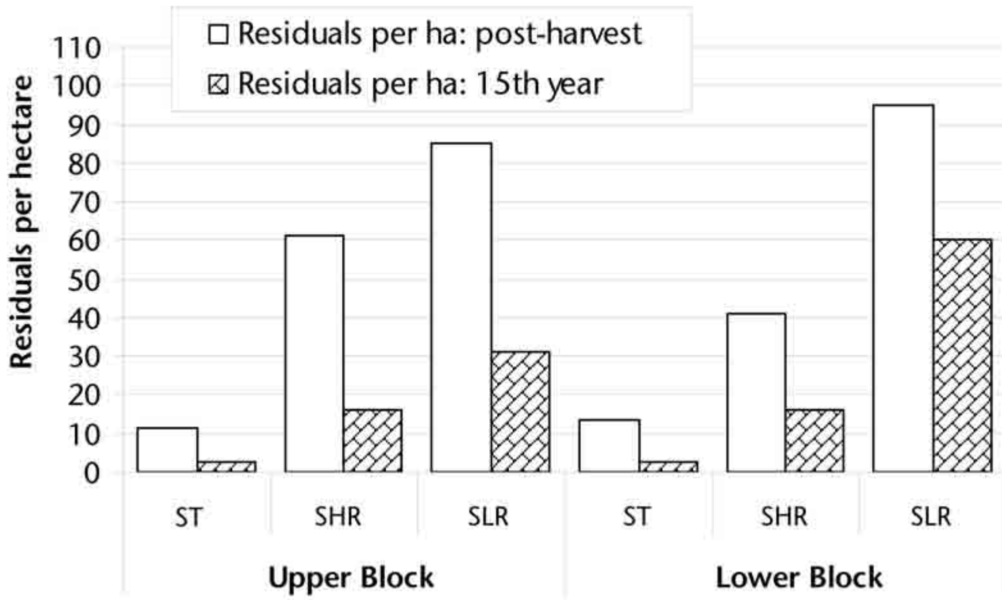

FIGURE 1. Residual tree densities in ST, SHR, and SLR treatments: post-harvest and 15 years after harvest.

Results

Stand Structure

Residual tree densities 15 years after harvest ranged between 3 stems per hectare (Upper ST) and 60 stems per hectare (Lower SLR) (Figure 1), representing between 18% and 63% of post-harvest densities, with a greater percentage remaining in treatments with higher post-harvest densities. Wind damage, bark beetle, and fire were agents identified as reducing residual stand structure.

Wind damage began 1 month after harvest in the upper block and by the late fall totalled 60 trees, mainly in the ST and SHR treatments; lower wind damage in the upper SLR was attributed to the neighbouring unlogged control providing some protection from the southerly winds. Windthrow in the lower block was limited to one tree. Subsequent wind damage was minimal until a spring survey in 1995 found 111 damaged trees, most in the upper block concentrated in the SHR treatment. Fifteenth-year sampling found the first substantial wind damage in the lower block principally in the form of stem break rather than the root-failure as in the upper block. Broken tops varied in stage of decomposition, suggesting chronic wind damage rather than a single-year event. Wind damage in the controls and lower block wildlife corridor has been minor.

Douglas-fir bark beetle (*Dendroctonus pseudotsugae*) attacked trees in the upper block in the second year after harvest, but evidence suggested that some trees were attacked the previous year. Lack of beetle attack in the lower block suggests beetle attack was related to windthrow. Attacked trees were felled and horse-skidded out along with blown down trees to minimize the number of emerging beetles. Bark beetle attacks continued during the following 2 years. Recent tree mortality was related to bark beetle activity suggesting a continuing influence on remaining stand attributes.

Fire swept through both blocks in September 1995 and site inspection revealed a predominantly ground fire consumed most vegetation and smaller woody material. The fire killed more overstorey trees in the upper block than in the lower block. (Note: The IDFww is classified as a Natural Disturbance Type 4 ecosystem with frequent stand-maintaining fires and a surface fire return period of 4–50 years.) Aerial views suggested a change in fire behaviour from a crown fire in the neighbouring unlogged forest to predominantly ground fire when it hit the partial cut treatments (Green and Blackwell, pers. comm.).

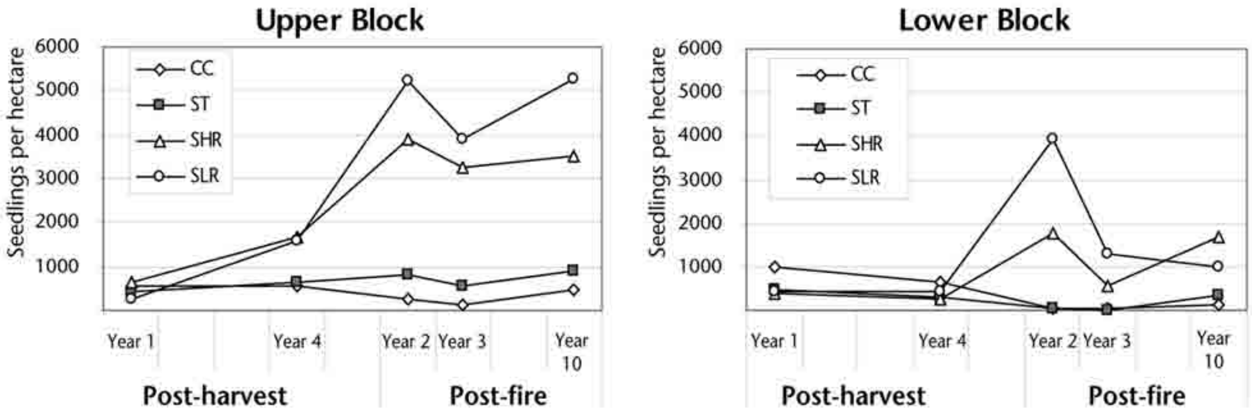

FIGURE 2. Natural regeneration densities (seedlings per hectare) by year after harvest and year after fire.

Regeneration

Natural

Some advanced Douglas-fir regeneration survived harvest activities in each upper block treatment, ranging from 25 (SLR) to 100 stems per hectare (CC). Post-harvest natural regeneration development differed substantially between the two blocks. Abundant 1990 seed fall resulted in regeneration in treatments of both blocks; subsequent regeneration developed primarily in the upper block (Figure 2). Natural regeneration densities were higher in the shelterwood harvests and met minimum stocking standards (500 seedlings per hectare, minimum of 2 m between seedlings) by the fourth year after harvesting. Factors limiting natural regeneration in the lower block, despite seed-fall levels comparable to the upper block, are unknown although differences in soil substrate and increased isolation due to slope were suggested during tours.

Densities of regeneration surviving the fire in the upper block ranged from 76 to 303 seedlings per hectare. In the lower block, only the SHR (68 seedlings per hectare) contained survivors. Post-fire natural regeneration densities in the third and tenth year after fire exceeded the post-harvest densities in both blocks, suggesting regeneration establishment benefits from burning. The trend of greater natural regeneration establishment in the upper block remained in place after the fire. Estimates of the natural regeneration ages suggest ingress had been continuous since the fire.

Planted

After harvest, planted Douglas-fir (1+0 PSB 415) stem caliper growth, and to a lesser extent height growth, was reduced beneath the heavier overstoreys. Third-year height/stem caliper ratios increased under the heavier overstoreys. Average survival was higher in the partially cut stands and higher in the lower block. Several operational plantings have taken place since the fire with no single planting common to all treatments and both blocks.

Conclusions

Classical silvicultural systems (seed tree and shelterwood), recognized for enhancing regeneration development, were established in two neighbouring blocks in the Coast–Interior transition. Both shelterwood systems provided conditions suitable for natural regeneration establishment to meet minimum stocking levels, although early results suggest reduced growth beneath the higher-retention densities. Seed tree treatments provided some increase in natural regeneration establishment over that in the clearcut, but the benefits may not be operationally relevant. Whether residual stands, which include relatively abundant snags and downed woody material, could potentially meet other management goals will depend on long-term stand development and desired density of surviving residual trees.

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Popular Summary

Determining the impact of the retention system on the productivity and cost of forest harvesting operations

Mihai Pavel[1]

Presentation Abstract

As the retention system becomes more common in British Columbia, assessing the influence of the silviculture prescription on the productivities and costs of harvest operations also becomes important for appraisal and planning purposes. Most practitioners hold the view that harvesting costs under partial-cut prescriptions are higher than in traditional clearcutting operations, but little objective proof has been provided so far. Quantifying the influence of silviculture prescriptions alone is a complex task, as it is obscured by stand, site, and operation descriptors. In general, a direct comparison of traditional and partial-cut operations is difficult (even impossible) because harvesting productivities and costs are influenced by many numerical and non-numerical factors.

In this study, a quantitative assessment of 23 loader-forwarder operations (studies of the Forest Engineering Research Institute of Canada [FERIC]) was conducted using Artificial Neural Networks (ANN). Operations were described by 11 numerical and categorical (non-numerical) attributes that describe the stand, site, harvesting system, and the prescription. The ANN successfully identified the influence of prescription and allowed computation of alternate productivities for the harvest operations: that is, productivities in studies of partial-cut operations estimated as if the sites had been clearcut, and productivities on clearcut sites estimated as if they were harvested under a specific partial-cut prescription. These results thus allow computation of incremental costs due to the silviculture prescription on a case-by-case basis, based on assumed utilization rates and costs of various harvesting machines.

KEYWORDS: *Artificial Neural Networks, harvest operations, productivity and cost, retention, silviculture prescription.*

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Pavel, M. 2007. Determining the impact of the retention system on the productivity and cost of forest harvesting operations. *In* Overcoming Obstacles to Variable Retention in Forest Management: Science to Management Forum Proceedings, September 25–27, 2007. *BC Journal of Ecosystems and Management* 8(3):136–139. URL: ***http://www.forrex.org/publications/jem/ISS42/vol8_no3_scienceforum.pdf***

Introduction

The introduction of the retention silviculture system in British Columbia has created a need to assess its impact on productivity and cost of forest operations. This need is driven by two reasons:

1. for planning purposes, to assess the expected performance (productivity and cost) of harvesting machines in retention blocks, and
2. for appraisal purposes, for a correct determination of the stumpage allowance to be applied in conjunction with the retention system.

Qualitatively, it is relatively easy to demonstrate that the application of the retention system reduces machine productivities and increases costs of harvest operations. However, a quantitative assessment is more difficult: isolating the influence of the silviculture prescription is challenging because many stand, site, and operation variables of both a numerical and non-numerical type influence harvesting productivity.

This study aimed at quantifying the influence of the silviculture prescription for loader-forwarding operations by using an Artificial Neural Network (ANN). ANNs are information-processing systems that have certain performance characteristics in common with biological neural networks, and have been developed as generalizations of mathematical models of human cognition and neural biology. They form a vast scientific domain and numerous types of ANN have been developed to address various types of problems (Bishop 1995).

Data Used

The data used in this research consisted of 23 studies of loader-forwarding operations conducted by FERIC (now FPInnovations, FERIC Division) in coastal British Columbia. Twelve studies were retention blocks, and 11 were clearcuts. Each operation was described by 11 numerical and class-type (non-numerical) attributes that depict the stand, site, harvesting system, and the prescription as described below:

- site descriptors: average slope, site bearing capacity, natural obstacles
- stand descriptors: stand density, piece size
- operation: machine size, influence of falling
- prescription: number of patches left, percentage of patches of the harvest area, number of single trees left per hectare, extraction distance

The criterion variable is productivity in cubic metres per productive machine hour (m^3/PMH).

Since all these were previous FERIC studies, data were collected and presented in a consistent manner. Supplementary data were obtained through direct discussions with the authors of these studies.

Methods

As the data available were both numeric and class-type, they were coded using the "1-of-c" coding method (Bishop 1995), which is similar to the "dummy" variables in statistics. In this study, the Cascade Correlation neural network (Fahlman and Lebiere 1990) was used based on the implementation described in Zell (1999) and Fisher *et al.* (2001).

For the analysis, the dataset was split into two subsets (one to train the ANN and one to test it) in a ratio of approximately 2/3 to 1/3 (i.e., 16 observations were used to train the ANN and 7 observations were used to test it). As a final check on the quality of the prediction, the ANN was used to calculate theoretical productivities for all retention blocks as if they were clearcut. Also, a theoretical retention prescription was defined as the average of all retention blocks. Theoretical productivities were also calculated for the clearcut blocks as if they were harvested under this (retention) prescription.

Results and Discussion

After training the ANN, results obtained with the testing dataset indicated that the model performed well. Differences between actual and predicted productivities ranged from 0 to 8 m^3/PMH. The bias (computed as the average of differences between predicted and actual productivities) was 2.9 m^3/PMH, and in general, there was a good fit between actual and predicted productivities.

Productivities of partial-cut operations estimated as if the sites had been clearcut, and productivities on clearcut sites estimated as if they were harvested under a hypothetical partial-cut prescription, are presented in Figure 1. This shows that for retention sites, changes in productivity can range from 0% to 200%. For clearcuts, the application of the prescription selected may have no influence in some cases, or may reduce productivity to about 65% (of the actual productivity).

The cost of loader-forwarding is influenced by numerous factors, such as machine size and utilization,

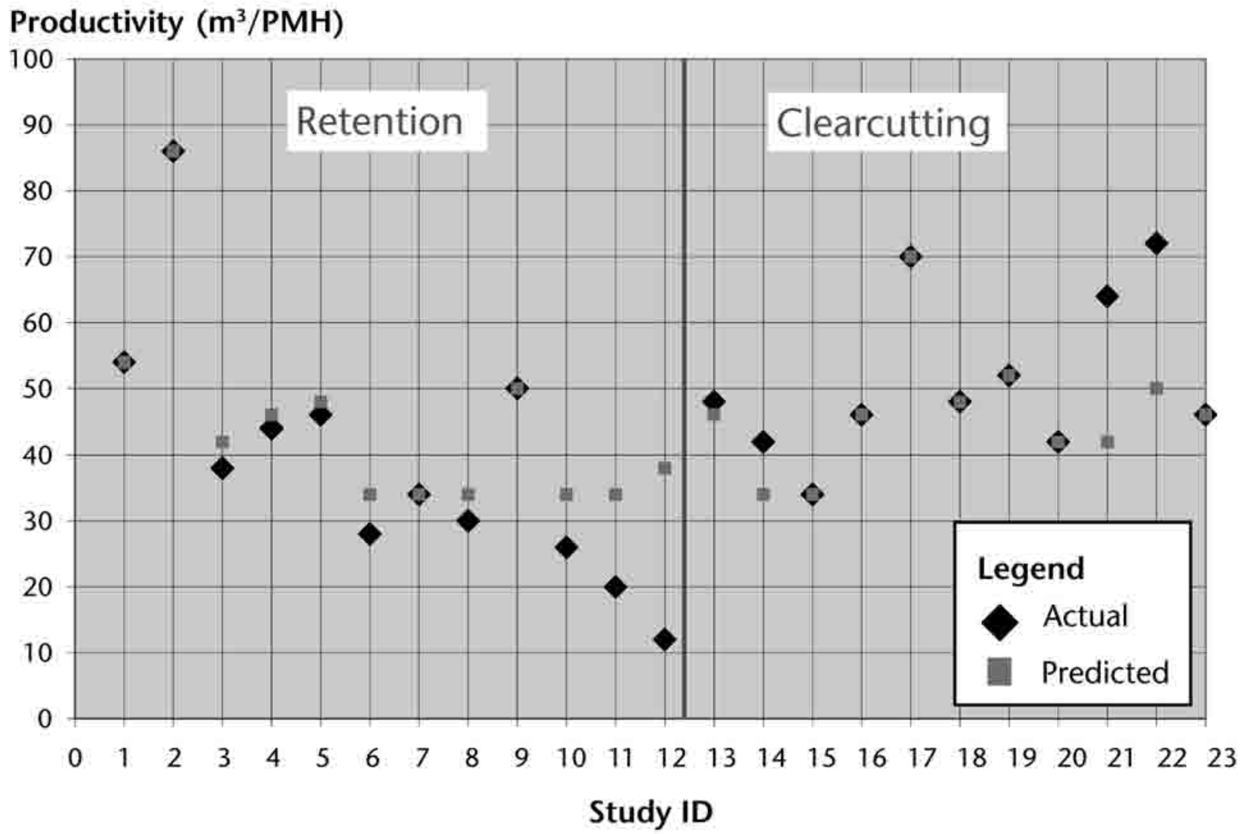

FIGURE 1. Estimated impact of retention and clearcutting prescriptions on productivity.

and volume of piece size moved, and in general ranges from \$3 to \$5 per cubic metre (Pavel 2006). Therefore, data in Figure 1 suggest that in the retention operations, incremental costs of up to \$6–10 per cubic metre (for the extraction phase only) were produced compared to a clearcut. The results presented in this study allow computation of incremental costs due to the silviculture prescription on a case-by-case basis: by using utilization rates and costs for specific harvesting machines and operations, the harvesting costs (in $\$/m^3$) can be computed.

Conclusions and Recommendations

Results of this study provided quantitative proof about the influence of retention in loader-forwarding operations. However, given its complexity, the method used in this study has little practical applicability. For practical applications, development of productivity charts (nomograms) may be a feasible alternative. The charts can be developed by selecting certain site and stand parameters (that are representative for a certain geographic area) and by varying the parameters that define the prescription (i.e., number of patches and their area, and the number of individual trees). This representation can provide foresters and planners with a reasonable estimate of the potential influence of the prescription on harvest operations.

FPInnovations, FERIC Division is currently considering conducting similar analyses for other harvesting phases (e.g., falling, yarding) and also for the Interior of British Columbia.

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Popular Summary

Shelterwood silvicultural systems to address integrated resource management issues in the Kootenays: Year 10 update

Teresa Newsome[1], Michaela Waterhouse[2], and André Arsenault[3]

Poster Abstract

In 1993 in the Kootenay region, a shelterwood trial (EP1186) was initiated because a significant percentage of the land base was being harvested with partial retention systems to meet guidelines for visual, ungulate habitat, and other values. There continue to be serious management questions about the productivity (tree growth and yield), regeneration, and future health of these forests where mature stems have been retained, especially as a large portion of the area is infected with root diseases such as *Armillaria ostoyae* and *Inonotus tomentosus*. Partial harvesting is thought to accelerate the spread of root disease by leaving stumps, which provide a food source for the fungus. More recently, there is an opportunity to use these shelterwood silvicultural systems trials to evaluate management options for stands affected by mountain pine beetle. It is not known how complex stands will respond to selective removal of pine trees. Pine species (lodgepole, white, ponderosa) are a common component of mixed stands in many biogeoclimatic subzones. The death and (or) removal (through salvage) of pine will affect stand development and consequently long-term timber supply. Results from this trial (in place now for 10 years) will provide guidance as to level of harvest, and predict regeneration and residual overstorey response.

KEYWORDS: *regeneration, root disease, shelterwood.*

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Newsome, T., M. Waterhouse, and A. Arsenault. 2007. Shelterwood silvicultural systems to address integrated resource management issues in the Kootenays: Year 10 update. *In* Overcoming Obstacles to Variable Retention in Forest Management: Science to Management Forum Proceedings, September 25–27, 2007. *BC Journal of Ecosystems and Management* 8(3):140–143. URL: ***http://www.forrex.org/publications/jem/ISS42/vol8_no3_scienceforum.pdf***

Introduction

In 1993 in the Kootenay region, a shelterwood trial (EP1186) was initiated because a significant percentage of the land base was being harvested with partial retention systems to meet guidelines for visual, ungulate habitat, and other values. There continue to be serious management questions about the productivity (tree growth and yield), regeneration, and future health of these forests, especially as a large portion of the area is infected with root diseases such as *Armillaria ostoyae* and *Inonotus tomentosus*. These diseases affect both forest harvesting and regenerating management practices. Partial harvesting is thought to accelerate the spread of root disease by leaving stumps, which provide a food source for the fungus.

There is also an opportunity to use these shelterwood silvicultural systems trials to evaluate management options for stands currently affected by the mountain pine beetle outbreak. It is not known how complex stands will respond to selective removal of pine trees. Pine (lodgepole, white, ponderosa) is a common component of mixed stands in many biogeoclimatic subzones throughout the Southern Interior. The death and (or) removal (through salvage) of pine will affect stand development and consequently long-term timber supply. Results from this trial (in place now for 10 years) will provide guidance as to level of harvest, and predict regeneration and residual overstorey response.

The study was set up on two trial sites: Mount Seven (ICHmk1), and Ice Road (ICHmw2). There are four levels of basal area and two types of harvesting: conventional and whole-tree push-over logging. Pushover logging was selected to reduce the spread of root disease. Data on the response of residual trees and regeneration was collected 5 years post-harvest, and Delong *et al.* (2005) found that the growth rate increased as the level of canopy openness increased, but did not vary among species of different shade tolerance. The root removal treatment, by contrast, had no effect on seedling survival after 5 years.

Subsequently, the tenth year data was collected in 2004 and 2005 on the residual trees, planted stock, natural regeneration, and vegetation. This summary provides some highlights from the tenth-year data collection. Technical reports and journal articles on various aspects of the trial are being prepared over the next 3 years.

Objectives

1. Evaluate the impact of various levels of basal area retention on the survival and growth of natural and planted regeneration.
2. Describe the regeneration options for partially cut stands under various levels of retention.
3. Investigate the effects of microenvironment (light, frost), understorey vegetation, and soil properties on the survival and growth of natural and planted regeneration.
4. Evaluate the early growth and yield implications based on residuals and new regeneration.
5. Compare the success of conventional harvesting with pushover harvesting in ameliorating the effects of Tomentosus and Armillaria root diseases on seedling survival and growth.
6. Develop and refine stocking standards and free growing guidelines in partially harvested stands.
7. Provide information to model stand development through time and its implication for long-term timber supply.

Trial Description and Design

There are two installations: Mount Seven near Golden, B.C. in the ICHmk1, and Ice Road near Nakusp, B.C. in the ICHmw2. The Mount Seven site is infected with Tomentosus while the Ice Road site is infected with Armillaria. The trial design on each site is a completely randomized factorial (CRD) (Figure 1). This includes seven treatments established in a 2 × 3 factorial with controls (no-harvest). Each 1-ha treatment unit is replicated twice on site. The first factor in the experimental design is harvesting method (hand falling and pushover falling). The second factor includes three levels of basal area retention: none (clearcut); light (~25% overstorey retained); and heavy (~50% overstorey retained). Separate controls were assigned to the hand and pushover falling treatments for a total of four 1-ha controls per site. Within each 1-ha treatment unit, 16 subplots were established on a 20 × 20-m grid for a total of 256 per site.

Harvesting was completed on the Mount Seven site in 1995 and on the Ice Road site in 1996. The residual basal area (m^2/ha) immediately after harvest at Ice Road was 0, 12.8, 23.6, 46.7, and at Mount Seven was 0, 14.1, 24.6, 53.7, on the clearcut, light retention, heavy retention, and uncut treatments, respectively.

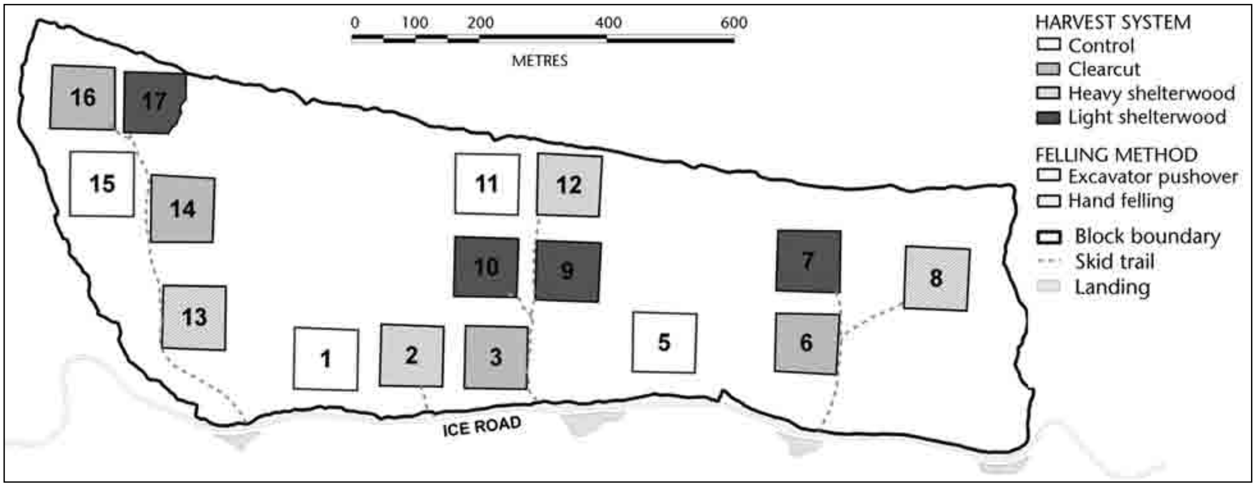

FIGURE 1. Layout of the Ice Road installation.

Highlights of Some Results from the Tenth-year Measurement

The variables that were measured include: planted seedlings (survival and growth), advanced natural regeneration at the time of harvest (survival and growth), natural regeneration ingress (density), stand structure (growth and yield plots), vegetation, light, and tree fall.

Vegetation: Cover changes were found for many species. Those that would be serious competitors for conifer growth were birch, thimbleberry, and fireweed on both sites, and these increased in all treatments compared to the control; however, the greatest increase was found in the clearcut treatment. The diversity of vascular plant species was significantly higher in harvested areas responding to available light. No species were restricted to unlogged stands; however, older shrubs of rocky mountain maple were significantly reduced. Retaining these older shrubs in cutblocks is important to maintain habitat for epiphytic cyanolichens in harvested stands.

Root Disease: Seedling death due to infection from Armillaria was found in both the light retention and the clearcut treatments at the Ice Road site. Preliminary results suggest that there was no difference between the hand-felled and the pushover logging. More detailed root disease studies will be conducted over the next 3 years to provide more definitive results. There is no sign yet of Tomentosus affecting seedling performance on the Mount Seven site.

Stand Growth: Even though stand composition was quite different, changes in the residual overstorey volume 10 years post-harvest were similar at both sites. The uncut treatments increased by ~75 m^3/ha, the heavy retention by ~43 m^3/ha, and the light retention by ~30 m^3/ha. On both sites, the light retention was significantly lower than the uncut, and the heavy retention was not significantly different from either the uncut or the light retention.

Planted Stock Survival: Western larch and Douglas-fir were planted on both sites. Due to ecological differences between sites, western redcedar was planted at the Ice Road site and interior spruce at the Mount Seven site. In both cases, these latter two more shade-tolerant species had the highest survival (over 90%), whereas the less shade-tolerant Douglas-fir and western larch had lower rates. On the Ice Road site, survival of western larch was particularly low at 50% on the clearcut treatment, decreasing to only 12% in the heavy retention treatment. All other survival rates were over 50%. Western larch was the only species that showed some differences in survival between retention levels.

Planted Stock Height Growth: At both sites, Douglas-fir seedling 10-year height growth was significantly reduced by leaving any amount of residual overstorey. This trend was also true for western larch and spruce planted at Mount Seven. Conversely, at Ice Road, western redcedar seedling height growth did not differ significantly between the light retention and clearcut treatments, and there were no differences observed in the height growth of larch across all retention levels. Overall larch performance was poor on the Ice Road site.

Conclusion

Shelterwoods can create conditions that facilitate the growth and performance of a number of species. They also promote utilization of a variety of tree species as a result of the different entry periods. Initial entries remove seral species such as pine and broadleaves before they deteriorate. Leave trees, of the appropriate species and vigour, will produce larger and more valuable timber. In most cases, final removal of the overstorey will be necessary to maximize growth of the understorey regeneration. In the long term, a range of tree species across the landscape can mitigate (economically and biologically) natural disasters such as the current mountain pine beetle epidemic.

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Popular Summary

Harvesting mountain pine beetle-killed pine while protecting advanced regeneration

Grant Nishio[1]

Poster Abstract

The current mountain pine beetle (MPB) outbreak in British Columbia will cause a shortage in the mid-term (15–50 years from the present) wood supply. In mixed stands containing sufficient non-pine overstorey and understorey, harvesting only MPB-killed pine while protecting the advanced regeneration and non-pine species can potentially reduce the time to a harvestable stand compared to a standard clearcut and plant strategy, and thereby reduce the forecasted shortage. In 2006, the B.C. Ministry of Forests and Range commissioned FPInnovations, FERIC Division, to carry out a research project to examine retention harvesting in MPB-attacked stands in the Northern Interior Forest Region. The objectives are to investigate the cost and productivity of different combinations of harvesting equipment suitable to harvest MPB-killed trees while protecting the secondary structure. Preliminary analyses of five case studies in year 1 of the 3-year project include cost and productivity, pre- and post-harvest stocking assessments, and trail disturbance. The residual stands are evaluated for tree damage, site disturbance, and advanced regeneration. Factors affecting the residual stand and success of the treatment include pre-harvest stand attributes, pre-harvest planning, equipment type, and operator experience/attitude. In general, there is an inverse relationship between productivity and level of residual tree protection. However, it is important to realize that the higher cost of retention harvesting now allows development of a stand that will be harvestable in the near future and contribute to the mid-term timber supply. The second year of the study is being funded by the Forest Science Program.

KEYWORDS: *cost and productivity, harvesting equipment, mountain pine beetle, retention harvesting, secondary structure, understorey protection.*

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Introduction

FPInnovations, FERIC Division is carrying out a research project to examine retention harvesting in mountain pine beetle (MPB) attacked stands in the northern interior of British Columbia. The purpose of this project is to address the issue of the predicted mid-term wood supply shortage. Harvesting MPB stands while protecting non-pine trees and understorey (secondary structure) can potentially accelerate the harvestable age of a partial-harvested stand several years ahead of a standard clearcut and plant strategy. This project is a series of trials studying different combinations of harvesting equipment to harvest pine trees while protecting the secondary structure. Ongoing analyses include productivity and costing analyses, pre- and post-harvest stocking assessments, total trail area (and trail disturbance level) assessments, and residual stand characteristics (basal area, species, size distribution, etc.). The results are used to indicate the different levels of productivity and residual tree protection achieved with different equipment combinations, stand types, and harvesting methodologies. Field trials have been focussed in the Prince George area so far, but will expand to include other areas as deemed necessary. Project development is ongoing and has included modifications to improve sampling information, field procedures, harvesting plans, block selection, and acquisition of study blocks.

Methodology

To date, the project has completed five trials using a variety of equipment combinations including hand-faller/hoe/forwarder, hand-faller/line skidder, feller-buncher/grapple skidder, and feller-buncher/dangle-head processor/forwarder. Two of the trials produced short logs using cut-to-length methods, and three trials produced full-length logs. Measurements included pre- and post-harvest sampling with permanent sample plots (PSPs), installation of electronic data-loggers (MultiDATs) on all harvesting equipment, and detailed timing of all harvesting activities. Treatment blocks were separated into trail and non-trail areas that were identified and measured differently. Permanent sample plots were located in the non-trail areas in a systematic grid pattern on strip lines spaced 100 m apart. The sample plots included variable radius (VR) plots for trees greater than 12.5 DBH, and 3.99 m radius fixed-area plots for all trees including trees less than 12.5 cm DBH. "Well-spaced trees" less than 12.5 cm DBH were recorded in the fixed area plots and block tree volumes were estimated from VR plots for trees greater than 12.5 cm DBH (Lemay and Marshall 1990).

Permanent sample plot locations were marked with metal markers and GPS co-ordinates were recorded. All PSPs were sampled before and after harvesting and will be sampled again in the following years of the study. Several variables representing tree damage/mortality status, species, height, DBH, etc. were recorded. The differences between pre-harvest and post-harvest measurements were used to calculate the amount of retention and the type and level of tree damage resulting from the harvesting treatment. Measurements in the following years can be used to determine the post-harvest effects of exposure (windthrow, mortality, etc.).

Pre-harvest plot tree variables include species, size, density, and basal area. These values are compared to the post-harvest measurements to calculate the species distribution, tree volumes, and tree sizes that were successfully retained after the harvesting treatment. Post-harvest plot trees were examined for damage including type and severity (British Columbia Ministry of Forests 1997; Glode and Sikstrom 2001) and mortality. These values indicated the level of residual tree protection that was accomplished by the harvesting treatment and the potential contribution to the mid-term timber supply. Other measurements focussed on site conditions (soil texture, topography, proximity to trail, etc.).

Pre- and post-harvest stocking assessments were done using the "Deviation From Potential" (DFP) method developed by Martin *et al.* (2005). The DFP method incorporates basal area information from VR plots and understorey information from 3.99 m radius fixed-area plots to arrive at a DFP value. The DFP value is a proportional estimation of the stand volume produced as compared to a fully stocked clearcut plantation. Only non-pine species were recorded in both VR and fixed-area plots. Overstorey trees (> 12.5 cm DBH) and understorey trees (< 12.5 cm DBH) were measured to assess the regeneration potential of the residual (partially harvested) stand. The measurements taken before and after harvesting allowed pre- and post-harvest stocking assessment and estimations of tree damage caused by harvesting. The DFP values will be used to compare the potential timber supply if the stand was not harvested to the potential volume of the harvested residual stand. To further ensure stand stocking was assessed for its potential to contribute to the mid-term wood supply, only understorey trees taller than 1.3 m were included as "well-spaced" trees in the post-harvest stocking calculations (the assumption being that trees must be at least 1.3 m tall to reach a harvestable size by the mid-term time period).

Total trail area was calculated by measuring the length of all trails using both GPS and hip chain, and trail width every 50 m of trail length. Soil disturbance on trails was recorded at the 50 m intervals to determine the level of trail disturbance. The product of mean trail width and total trail length was used to calculate total trail area. Trail area divided by block area provided the proportion of trail to block area. The trail soil disturbance measurements indicated the degree of disturbance the trails represented. Two 25-m transect lines emanating from plot centres were used to determine site disturbance at the block level.

Harvesting productivities and costs were determined using shift-level and detailed timing study methods. Harvesting costs were calculated using FERIC's standard machine costing methodology. MultiDAT data-loggers electronically record equipment operating times and work stop times to provide the shift level timing information. Hand-held data-loggers were used to record the breakdown of work cycle elements.

Preliminary Study Results and Future Trials

Data processing and analyses are ongoing. Preliminary analyses that have been completed include total trail area/disturbance (Table 1) and harvesting productivity (Table 2). Ongoing analyses yet to be completed include mapping trail locations using GPS data and determining levels of post-harvest tree damage. Factors that affect the level of tree protection include equipment size and type, operator experience/attitude, pre-harvest planning (i.e., trail layout), and pre-harvest stand attributes. Equipment size and type created limitations in the ability to protect the surrounding secondary structure while selectively removing MPB-attacked pine trees. Larger machines required larger trail and work areas. Smaller machines (including zero-tail swing feller-buncher) required less trail and work areas and allowed a greater level of finesse when accessing trees. Operator skill and previous experience, and a clear

TABLE 1. Trail area and trail soil disturbance

Trial no.	Equipment combination	Trail/block area (%)	Road/block area (%)	Disturbed mineral soil on trails (%)	Disturbed mineral soil on roads (%)	Length of trail per ha (m/ha)	Length of road per hea (m/ha)
1	Hand-faller/ hoe forwarder	3		16		93	
2	Feller-buncher/ grapple skidder	19		2		377	
3	Feller-buncher/ forwarder/processor	22	6	9	100	589	77

TABLE 2. Productivities for the different equipment combinations

Trial no.	Equipment type	Harvested volume (m^3)	PMH[a]	Productivity per PMH (m^3/PMH)	SMH[b]	Productivity per SMH (m^3/SMH)	Utilization PMH/SMH (%)
1	Hand faller	1330	130.0	10.2	180.0	7.4	72
1	Hoe	1330	88.2	5.1	270.0	4.9	33
1	Forwarder	1330	41.3	32.2	126.0	10.6	33
2	Feller-buncher	4746	150.1	31.6	207.0	22.9	73
2	Grapple skidder	4746	132.6	35.8	180.0	26.4	74
2	Delimber	4746	84.9	55.9	90.0	52.7	94
2	Loader	4746	29.6	160.4	45.0	105.5	66
3	Feller-buncher	3597	75.7	47.5	90.5	39.7	84
3	Forwarder	3597	188.8	19.1	217.0	16.6	87
3	Processor	3597	192.5	18.7	225.7	15.9	85

[a] PMH = Productive Machine Hours (machine movement and short duration stops less than 15 minutes).

[b] SMH = Scheduled Machine Hours (duration of time from start to end of machine work day minus scheduled work breaks).

understanding by both the contractor and the operator of the harvesting objectives, were significant factors. Pre-harvest planning helped operators minimize tree damage by focussing their harvesting efforts in strategically located trails and using appropriate landing sites. As expected, the general trend was for the productivity and level of residual tree protection to have an inverse relationship. As the level of productivity increased, the level tree protection decreased. Damage levels to the secondary structure ranged from 40% to 60% of the initial pre-harvest stand measurements. This indicates this type of partial harvesting will only have benefit if the pre-harvest stand has sufficient secondary structure to begin with.

Future trials will include clearcut treatments to allow a direct comparison to retention treatments to estimate differences in costs between the conventional harvesting systems commonly used in MPB-attacked areas in British Columbia and the retention harvesting treatments employed in this study and potentially used in the future.

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Abstract

Forrex Watershed Management information tools

Robin Pike[1] and Todd Redding[2]

Poster Abstract

In British Columbia, there are many watershed-related issues of importance to natural resource managers. There are also a number of management initiatives underway to address these challenges. Given the scope of these projects and the range of different organizations involved, there is an immense need to extend relevant water-related information to improve science-based management of peak flows and low flows, small streams, fish habitat, and in the development of sustainable watershed management approaches. A critical component of the Watershed Management Extension Cluster is linking past scientific knowledge and current research results to the various integrated watershed management initiatives.

This poster outlines several information tools key to delivering the Forrex Watershed Management Extension Program. These tools include the *Compendium of Forest Hydrology and Geomorphology in British Columbia*, *Streamline Watershed Management Bulletin*, workshops, syntheses, extension articles, and the Watershed Management Email List and associated Web pages.

KEYWORDS: *applied research, extension, science-based management, synthesis, workshops.*

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Understanding the effects of mountain pine beetle and salvage harvesting on hydrological processes and watershed response

Todd Redding[1], Robin Pike[2], and Pat Teti[3]

Poster Abstract

Mountain pine beetle (MPB) and timber harvesting affect the partitioning and movement of water through forests by modifying (and sometimes eliminating) the forest canopy. Forest canopies exert an important influence on the hydrologic cycle, intercepting a portion of incoming rain and snow, which then is "lost" back to the atmosphere through evaporation or sublimation. Rain and snow that falls through the canopy can infiltrate into the soil or evaporate from the soil surface. A portion of the water stored in the soil is taken up by trees and transpired back to the atmosphere. Excess soil water flows to streams, wetlands, and lakes, or into the groundwater. As trees die or are harvested, there is decreased interception and transpiration, resulting in greater amounts of excess water. This has important implications for the amount and timing of water that appears in streams and lakes. Other influences on the forest hydrologic cycle include harvesting, soil disturbance, and roads.

Given the complex hydrological interactions associated with the MPB infestation and associated salvage harvesting, we endeavoured to develop a conceptual approach to increase non-specialists' knowledge of the effects of canopy changes on various stand-level hydrological processes and watershed hydrological response. The poster illustrates this conceptual model which can also be used to further develop research to quantify post-disturbance changes and interactions among hydrological processes.

KEYWORDS: *disturbance, evaporation, forest canopy, hydrologic cycle, infiltration, interception, soil disturbance, sublimation, timber harvesting.*

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Abstract

The Bowron River watershed: A landscape-level assessment of the post-beetle change in stream riparian function

David Maloney[1], John Rex[2], Lisa Nordin[3], Phillip Krauskopf[4], Peter Tschaplinski[5], and Dan Hogan[6]

Poster Abstract

Substantial harvesting occurred in the Bowron River watershed between the mid-1970s and 1980s as a response to a spruce bark beetle infestation. This large-scale salvage activity was initiated to check the beetle's spread and reduce fire risk. It bears a striking resemblance to current mountain pine beetle (MPB) related salvage operations because of the infestation's watershed scale. As a result, the 30-year record of salvage-harvesting response within the Bowron can be used to identify detrimental harvesting practices and allow the development of best management practices for today's MPB salvage operations. Preliminary results suggest that the recovery of a stream and its riparian zone to a properly functioning condition varies with riparian buffer width and the physical characteristics of an area such as soil type, slope, and stream channel width.

KEYWORDS: *best management practices, channel width, disturbance, riparian zone, salvage operations, slope, soil type, spruce bark beetle.*

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Optimization process on Pope and Talbot's Tree Farm Licence 23

Randy Trerise[1] and Kelly Sherman[2]

Presentation Abstract

Forest managers are charged with an extremely complex assignment of considering many resource values when managing the forest resource. Decisions include where, when, and how to harvest and, conversely, where not to harvest. Over the past decade, Pope and Talbot Ltd. (P&T) has carried out multiple projects to help characterize their resource values including: evaluating ecosystem representation; defining habitat elements important for biodiversity; and assessing timber merchantability. These resource values are in addition to the routinely evaluated multiple resource values that are either legislated or embedded in policy such as caribou habitat, visual quality objectives, community watersheds, domestic watersheds, and ungulate winter range.

A two-tier Optimization Analysis was carried out that: (1) evaluates and relocates old growth management areas (OGMAs); and (2) optimizes a harvest schedule considering all the identified resource values. The OGMA relocation step provides a ranking for each resource value and evaluates the quality of each proposed OGMA. Less desirable OGMAs are replaced with alternative OGMAs that better achieve the objectives (i.e., ideal OGMAs have high ecological value and low timber value). Harvest schedule optimization uses Patchworks to consider all the indicated objectives and find a near-optimum harvest schedule that best meets all the objectives defined. Patchworks is a spatially explicit harvest scheduling optimization model developed by Spatial Planning Systems, Ontario. It can be used to explore trade-offs between a broad range of conflicting management and harvest goals. Optimization occurs when the model seeks a solution that minimizes the costs of the total objective function, which is the sum of all costs incurred from deviating from objectives. The spatial optimization allows P&T to consider many additional values in their harvest planning than the legislated requirements modelled in their timber supply review. The harvest schedule from this optimization is currently being used in two ways: (1) to drive forest operations on TFL 23; and (2) to assess actual harvest locations against the objective function and to update the files for the next iteration.

KEYWORDS: *biodiversity, ecosystem representation, harvest schedule, OGMA, optimization analysis, resource values, timber merchantability, trade-offs.*

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Abstract

Ecosystem Management Emulating Natural Disturbance Project (EMEND)

Jason Edwards[1]

Presentation Abstract

Many forest companies operating in the boreal forest have recently adopted harvesting practices based on the natural disturbance paradigm. This paradigm has led away from extensive clearcutting and toward retention of unharvested residual trees as stand and landscape elements and as a basis for biodiversity conservation and forest regeneration. Although effects of size and distribution of residual patches have been well studied, the important question of "how much residual is enough to protect critical aspects of ecosystem function?" has received little attention.

The Ecosystem Management Emulating Natural Disturbance (EMEND) Project, located in the mixedwood Boreal Plains of northwestern Alberta, is a long-term variable retention experiment designed to test effects of residual structure on ecosystem integrity and forest regeneration at the stand level. Research at EMEND has focussed on understanding natural forest succession and identifying useful analogues of natural disturbances that can be incorporated into forest practices. We will provide a history of the project and highlight some challenges and outcomes of the research to date.

KEYWORDS: *biodiversity conservation, forest regeneration, residual trees, succession, variable retention.*

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Abstract

Kamloops Indian Band partial retention harvesting: Operational challenges on both Crown and federally designated lands

Jim McGrath[1]

Presentation Abstract

The Kamloops Indian Band (KIB) is situated in the Southern Interior Forest Region. It has a diversity of forest tenures across a spectrum of timber types. In terms of variable retention harvesting, the KIB and Adams Lake Indian Band are jointly managing a partition cut licence that is specific to suppressed Douglas-fir stands in the dry belt region of Kamloops. The KIB owns and manages a woodlot that is a variable retention area due to mule deer winter range and in which the predominant timber type is Douglas-fir. The KIB is also currently carrying out a thinning project on reserve land for wildlife management purposes and fuel reduction. The diversity of the tenures run from a replaceable area-based woodlot to non-replaceable forest licences to harvesting on Federal Reserve land. There are a number of differing policy and regulatory requirements across the spectrum of licences and permits that make variable retention harvesting challenging. This presentation focusses on the operational and legislative requirements that KIB is managing on a day-to-day basis and some of the philosophical points of First Nations forest management.

KEYWORDS: *area-based woodlot, Douglas-fir, Federal Reserve lands, fuel reduction, harvesting, INAC Timber Permit, partition cut licence, wildlife management.*

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Abstract

Managing silviculture operations safely in high-density damaged stands

Mike Nielson[1] and Dean McGeough[2]

Presentation Abstract

By definition, retention means that trees, standing living or dead, will be left behind. The complication for forestry activities in areas where retention exists is that some of those residual trees can pose a safety hazard to forest workers and the public. A dangerous tree is defined by Workers' Compensation Board of BC (WCB) regulations as "any live or dead tree that is hazardous to people or facilities because of: location or lean; physical damage; overhead hazards; deterioration of limbs, stem or root system; or a combination of any of these." To conserve the value of the residual trees and protect forest workers and the public, a variety of standards exist and should be applied. This presentation discusses some of those standards and how they should be implemented. A case study illustrates a situation in which these standards were not applied when silvicultural activities were scheduled in a high-density mountain pine beetle and fire-killed stand. Since the planning and implementation of retention is relatively new, one of the first steps that should be taken before any plan is implemented is contacting and initiating communications with local WCB representatives so that they can advise on implementation rather than play the role of enforcer. In addition, the brochure developed by the Wildlife Tree Committee of British Columbia entitled "Dangerous Tree Management in Preparation for Silviculture Activities" should be referenced during the planning stages of silviculture operations. This brochure defines operational standards when attempting to reserve residual trees in silviculture projects and clarifies roles and responsibilities for all entities from owners and prime contractors to tree planters.

KEYWORDS: *danger tree, mountain pine beetle, public hazard, residuals, retention, WCB standards, worker safety.*

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Abstract

Is it really that difficult to implement structure retention? Structure retention within harvest sites in Weyerhaeuser Forest Management Areas in the boreal forests of Alberta

Wendy Crosina[1] and Luigi Morgantini[2]

Presentation Abstract

Beginning in 1998, Weyerhaeuser Company aggressively adopted new practices aimed at conserving biodiversity across all of their Forest Management Areas in the boreal forests of Alberta. At the stand level, these new practices focus on permanently retaining significant amounts of trees, snags, and woody debris in harvested areas. The practice is intended to provide future forest stands that more closely mimic conditions following a natural disturbance event. Structure retention goals are now incorporated into Weyerhaeuser's CSA sustainable Forest Management certification process in Alberta. Weyerhaeuser's experience with various challenges, including administrative issues and measurement and how they were overcome, is presented.

The simple and pragmatic approach of advising forest operations to leave as much structure as possible where consistent with Forest Management Plans, and to take advantage of opportunities wherever they occur, has resulted in significant structural retention in all cutblocks. Examples of this include anchoring structure retention to wet areas or other ecologically significant sites. In one Forest Management Area, out of the 876 cutblocks surveyed since 1999, 72% had single tree retention, 86% contained clumps (small group of fewer than 10 trees), and 61% had tree patches (larger groups of more than 10 trees). *(continued on next page)*

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In 184 cutblocks, the proportion of the harvested area still covered by woody vegetation was more than 10%. These stand-level practices are complementary to a landscape approach requiring a range of patch sizes, the maintenance of post-rotation mature forest stands, and a shift away from the traditional two to three pass system to ensure interspersion of patches of different age, size, and composition.

KEYWORDS: *biodiversity conservation, certification, measurement, natural disturbance, patch size, snags, stand-level practices, woody debris.*

Popular Summary

Retention planning for wildlife habitat and biodiversity during salvage harvesting, and some obstacles to implementation

Walt Klenner[1] and Doug Lewis[2]

Presentation Abstract

There are clear social expectations that wildlife habitat, biodiversity, and ecosystem processes need to be protected in British Columbia. The *Forest and Range Practices Act* (*FRPA*), and higher-level plans such as Land and Resource Management Plans, identify the need to protect and manage non-timber forest resources. However, accelerated salvage to recover timber affected by the current mountain pine beetle epidemic may undermine the ability to achieve non-timber objectives unless appropriate retention practices are implemented. We review some of the issues that underlie the need for stand- and landscape-level retention in areas of large-scale salvage harvesting. Stand-level retention should focus on retaining large live trees and snags as well as immature and mature trees (especially non-pine species), and protecting advanced regeneration. Landscape retention complements stand retention. Key habitat issues that need to be considered include: retaining mature and old forest; maintaining connectivity; establishing enhanced riparian reserves and management zones; prompt access management; and maintaining the heterogeneity of treatments. Forest management professionals, tenure holders, and other stakeholders should form landscape planning coalitions to ensure that the management of non-timber resources is addressed with the same technical rigour and attention to detail as timber values.

KEYWORDS: *connectivity, landscape-level retention, non-timber resources, salvage harvesting, stand-level retention.*

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Introduction

Certain aspects of the current mountain pine beetle (MPB, *Dendroctonous ponderosae*) attack in British Columbia, including the likely progression of the attack, effects on short- and longer-term timber supply, wood quality issues, and possible effects on hydrology, have been examined in some detail (e.g., Eng *et al.* 2005; also see ***http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/stewardship/hydrology/***). It appears that there is relatively little that can be done to diminish the extent or severity of the current attack, and given the scale of potential economic losses, salvage harvesting in stands attacked by MPB will continue to be a priority for several years. By itself, the loss of extensive areas of live mature timber represents a significant challenge to maintaining habitat for identified species of wildlife and for biodiversity in general. Salvage harvesting is likely to further diminish stand structure that would have remained following an MPB attack, and unless retention strategies are adequately developed and applied, could have undesirable effects on wildlife habitat (Lindenmayer *et al.* 2004).

Historically, natural disturbances were often viewed as "catastrophic events" or "disasters" that disrupted the balance of nature and caused widespread and undesirable disruptions to ecosystems. This view has largely been replaced by a more dynamic, non-equilibrium view (see Pickett and White 1985; Botkin 1990) where ecosystems recover from and likely depend on many types and spatial scales of natural disturbances. Severe disturbances such as the 1980 Mt. St. Helens eruption or the 1988 Yellowstone fires were initially viewed as catastrophes, but subsequent research has shown that despite their severity, succession is proceeding towards the re-establishment of the former vegetation community (Turner *et al.* 1997). Furthermore, these areas clearly demonstrate the importance of remnant vegetation and residual structure in shaping the direction and speed of succession (Foster *et al.* 1998; Turner *et al.* 1998). Structure within disturbed areas is critical for two key reasons:

1. it provides a "lifeboat" function for species that rely on structural attributes (e.g., large live trees or snags, downed wood, abundant lichens, etc., [Franklin *et al.* 2000]) usually associated with mature or old forests; and
2. structural legacies and the species using them represent the "ecological memory" (Bengtsson *et al.* 2003) that is critical if disturbed ecosystems are to regain the species and processes that existed prior to disturbance.

Natural disturbances are characterized by complexity, not only in the return interval of the disturbance, but also in the amount and dispersion of live and dead structural legacies that remain following the disturbance. For example, within the perimeter of a wildfire, unburned areas representing up to 25% of the overall area are common (Eberhardt and Woodard 1987; Delong and Tanner 1996). As the size of the wildfire disturbance increases, the size range of green residual patches also increases. Similar patterns of variable mortality within stands and across landscapes also characterize MPB attack (Table 1), as the level of mortality depends on a number of factors including the species composition, basal area, age, stand density, location of the stand, and MPB populations in the surrounding area. Across multiple stands, variability in the severity of attack, along with no attack in non-pine stands, is common. The current MPB outbreak is extensive and of high severity across the interior of British Columbia, and presents a challenge to the retention of mature green trees in lodgepole pine-dominated landscapes. Although salvage harvesting is inevitable in most areas affected by MPB within the timber harvesting land base, good habitat management practices can be implemented during the salvage of individual stands and at broader spatial scales to ensure adequate retention is left, and that the retained areas are located in critical habitats and spatially arranged to be of greatest value to wildlife and biodiversity.

Stand-level Retention

Within individual salvage blocks, retention practices should maintain important mature forest structures that are diminished during salvage operations, including large live trees, large declining or recently dead stems, and snags and large downed wood representing a diversity of sizes and decay (Franklin *et al.* 2000). Such features are used or required by approximately 35–40% of the terrestrial forest-dwelling vertebrates (Bunnell *et al.* 2004) and can be maintained in the salvage area through the retention of individual trees or a combination of individual structures and patch retention. Many retention options are possible, with some examples identified in Figure 1. Several practices would help to maintain habitat within the salvage block and complement the habitat value of retention patches.

1. Partial retention harvesting is an application of variable retention harvesting (Mitchell and Beese

TABLE 1. Some within-stand structures that would likely be created during a MPB attack in a mature lodgepole pine stand, and activities that would help to maintain important aspects of these conditions during salvage harvesting

Structural attribute	Treatment
High density of medium (20–30 cm DBH) and large (> 30 cm DBH) snags	Well-dispersed single tree, small group (100–2000 m^2), and larger patches (> 0.25 ha) as wildlife tree retention areas
Between 5% and > 50% medium and large trees left alive, selective mortality of pine	Designate wildlife tree retention patches in areas where some medium and large trees are likely to survive
	Identify areas within the block where species composition would allow for partial cutting in one or more subunits of the block
Dispersed snags and live trees	Identify well-dispersed single tree, small group, large patch, and partial retention strategies (< 75% volume removed, with residuals representative of pre-harvest species and diameter profile)
	Keep distances between retention patches (partial cutting, WTR, and partial retention) to < 150 m wherever possible
Early and advanced pine and non-pine regeneration in the understorey	Protect advanced regeneration wherever possible
Downed wood widely distributed	Attempt to retain as much large downed wood (> 15 cm, and preferably > 30 cm diameter) as possible, especially long pieces, well dispersed across the site
Riparian areas with a higher proportion of large live trees	Develop enhanced riparian reserves or riparian management areas around streams and wetlands using partial cutting, wildlife tree retention, or partial retention practices
Little or no access	Identify opportunities for access management in the retention plan for the block and the landscape in general, and promptly deactivate road systems wherever possible

2002) and will help to maintain a component of the mature green tree and snag structure of the original stand, while allowing for the removal of much as 75% of the timber. Where residual volume is left in areas of partial retention harvesting, further harvest should not be anticipated. Residual volume can include advanced regeneration, mature stems recently killed or in the process of being killed by MPB, and green mature stems (where available) that will remain alive or serve as long-term snag and downed wood recruitment material.

2. Well-designed partial-cut harvesting systems that are appropriate for the stand type and where the residual timber has a reasonable likelihood of surviving to the next planned entry (i.e., following green-up on the remainder of salvage block) will enhance the habitat value of retention patches. The placement of these areas should be carefully planned to increase the benefits to other values such as watershed hydrology and visual impact, and to avoid isolating future timber from areas of permanent access. Clearcutting mixed-species stands would represent a sharp departure from the structural conditions that would develop in the absence of salvage harvesting (Table 1).
3. Retain downed wood, especially large, intact pieces, well dispersed across the site, wherever feasible. Scattered small piles of downed wood (e.g., 10–20 m^3) would complement dispersed downed wood by providing subnivian access points for species such as marten.

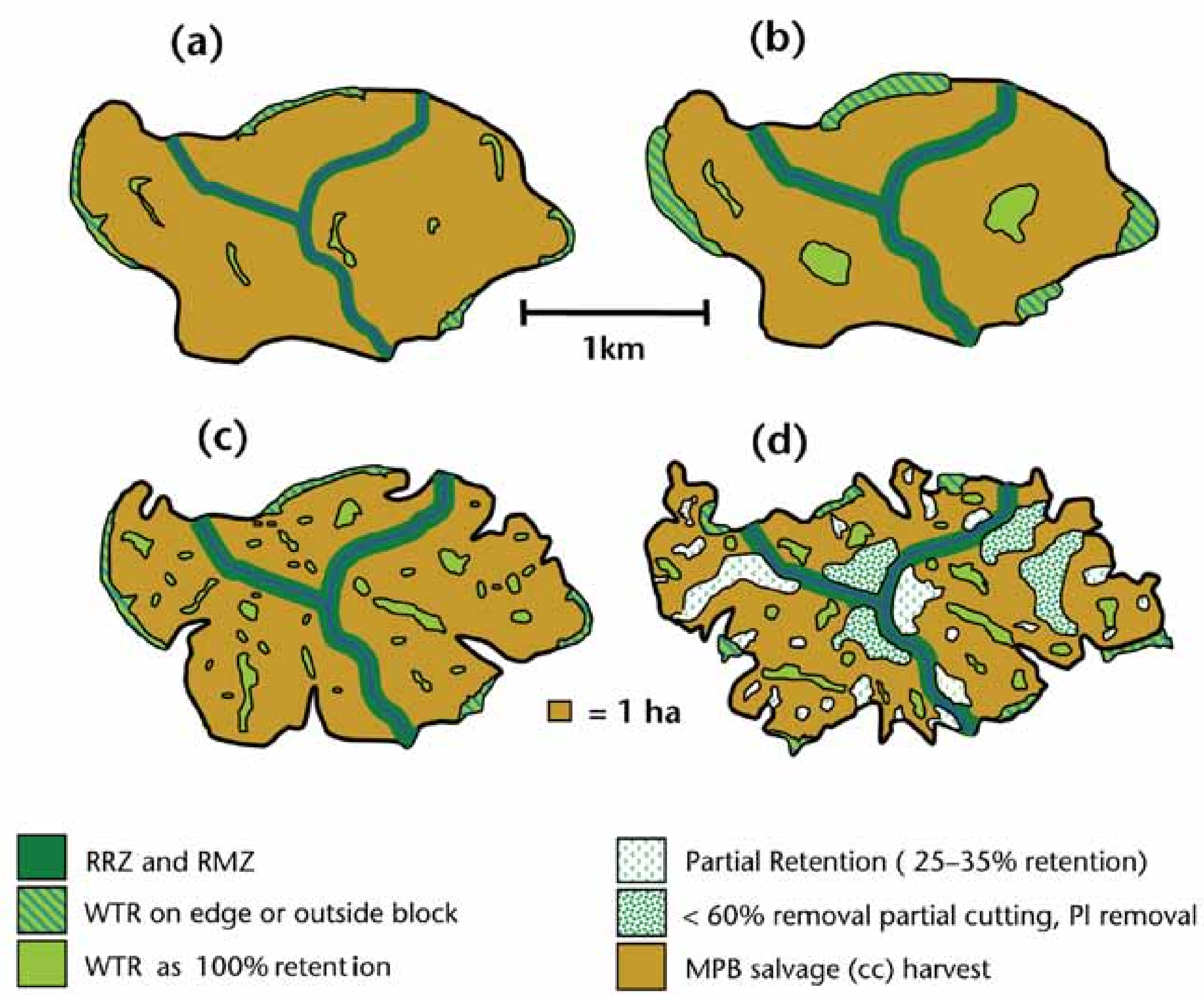

FIGURE 1. Conceptual examples of retention options for a large (250-ha) MPB clearcut (CC) salvage block. Retention includes Riparian Reserves and Management Zones (RRZ and RMZ), Wildlife Tree Reserves (WTR), Partial Retention, and Partial Cutting: (a) minimum retention practices (e.g., 19 of 250 ha, or 7.5%); (b) retention practices that leave more (e.g., 38 of 250 ha, or 15%), but widely dispersed structural diversity and legacies in a large MPB salvage area; (c) retention practices that use a similar level of retention as in (b) but with improved dispersion to effectively address habitat connectivity (most retention patches are within 150 m of other retention patches); (d) a combination of retention, partial retention, and partial cutting to achieve a greater amount (50 of 250 ha, or 20%) of well-dispersed structural diversity.

4. As the size of the salvage block increases, the need for and amount of retention also increases. In large openings (e.g., > 500 ha), the influence of mature forest surrounding the opening diminishes and higher levels of retention (approaching 25% or more; Eng 2004) represented by individual trees, retention patches, riparian reserves, partial retention, and partial cutting are essential to maintain habitat values.

Landscape-level Retention

Landscape or multi-stand issues have an important bearing on the need for and nature of retention within individual salvage blocks. Multiple stand-level salvage operations often coalesce into salvaged landscapes representing 10 000 ha or more. In these circumstances, the amount, type, and location of retention is important to maintain habitat for wildlife and biodiversity.

Retention, if not located appropriately, may be of limited value and planning should consider the diverse needs of many organisms (D'Eon *et al.* 2002). Several wildlife habitat and biodiversity issues should be considered when planning retention at the landscape level.

1. **The amount of mature and late seral habitat –** Although there is little long-term research to evaluate the success of different retention practices in addressing wildlife concerns in relation to extensive salvage harvesting, there is good indication that increasing retention levels at both the stand and landscape level is appropriate (see discussion in Eng 2004; Snetsinger 2005). A conservation "uplift" provides a mechanism to retain increased levels of structure to offset the negative effects of the extensive loss of mature and late seral forest.
2. **Patch size and the dispersion of leave areas, which affect habitat connectivity and isolation –** For example, species such as marten (Huggard 1999) seldom forage more than 50 m away from a forest edge and are reluctant to cross large openings (e.g., > 100 m).
3. **Access management –** New roads built to reach salvage areas can affect habitat quality and may exacerbate stream sedimentation with associated undesirable effects on aquatic biota (Forman and Alexander 1998). These effects can be reduced by keeping the amount of new roads to a minimum and deactivating existing or new roads promptly.
4. **A diversity of treatments –** One of the key principles of managing habitats to maintain biodiversity is to maintain heterogeneity (Lindenmayer and Franklin 2002). A key characteristic of natural disturbance is variability in the intensity, frequency, duration, and severity of the disturbance. However, unless carefully addressed, this variability can be lost through poorly planned salvage harvesting (Lindenmeyer *et al.* 2004).

We suggest that, in addition to retaining increased levels of structure in large openings, increased retention be allocated to areas where much of the landscape is available for timber harvest, or where MPB salvage operations will strongly reduce the amount of mature and late seral habitat (e.g., to < 33%; see Figure 2). In addition to these general conditions, landscapes where higher-level plans identify priority species that require mature or old forest conditions, or where visual resources or watershed issues are a concern, may require a retention uplift (Klenner 2006).

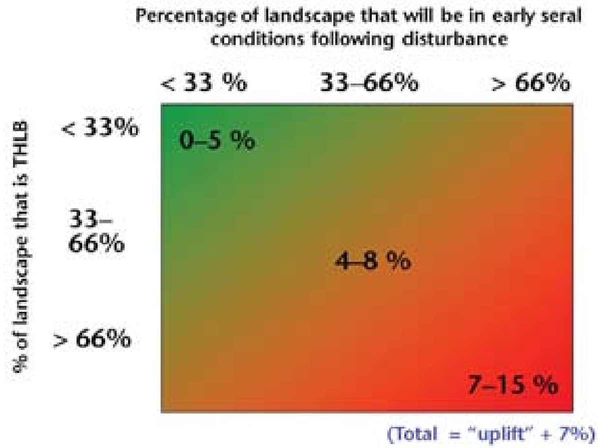

FIGURE 2. Conceptual representation of the allocation of a retention or conservation "uplift" in addition to existing requirements (e.g., *Forest and Range Practices Act* regulations). Areas where a relatively small proportion of the landscape is available for timber harvesting and where most remains as mature forest following salvage (top left of figure) may require little or no additional retention. Areas where most of the landscape is available for timber harvesting and where most is in an early seral condition following salvage (bottom right of figure) may require up to 15% or more additional long-term retention.

Obstacles to Implementing Variable Retention

A strong body of evidence clearly indicates the benefits of structural retention in harvested stands and the need for well-designed retention at the landscape level to ensure suitable habitat is maintained in appropriate places; however, there is little evidence to indicate a consistent and structured approach to addressing retention is being applied in MPB salvage operations. Wildlife habitat and biodiversity issues have been recognized as important factors to address in salvage operations (e.g., Kamloops TSA MPB Strategy 2006), but there appear to be impediments to moulding these concerns into a regional or provincial strategy. We suggest that there are three key obstacles that interfere with developing a more rigorous approach to retention planning.

1. ***There is little co-ordination in the planning and implementation of strategic land-use objectives at the landscape or watershed scale.*** British Columbia has moved from a more prescriptive regulatory environment under the Forest Practices Code, to a "results-based" model under the *Forest and Range*

Practices Act (*FRPA*). A high level of uncertainty exists regarding the role of various players that formerly co-ordinated land use planning (i.e., agency staff, public stakeholders, forest tenure holders, other commercial interests, etc.). Procedures to co-ordinate the multiple licensees that manage shifting and non-spatial, volume-based tenures, and adherence to maintaining identified resource values within areas addressed by former land-use planning initiatives (e.g., Land and Resource Management Plans) are poorly developed at best. This condition is exacerbated by uncertainty surrounding the relationship between regulatory waivers associated with salvage logging, professional reliance (a key underpinning of the *FRPA*, see Reader 2006), a tenure holder's freedom to balance resource values, non-spatial Forest Stewardship Plans, the non-binding nature of Forest Practices Board reports or "guidance" documents, and the complexity of evaluating long-term cumulative ecological impacts.

2. ***Lack of incentives to implement structured and consistent retention planning and applications.*** A mechanism has not evolved to track and reward tenure holders for the application of well-designed retention plans for wildlife habitat, biodiversity, or other resource values. Unless a "conservation" or "stewardship" credit system evolves, the tension between short-term economic issues (e.g., operational and appraisal costs) and longer-term environmental values is unlikely to be resolved. Forest Stewardship Certification is one, albeit long-term, incentive to implementing well-designed retention planning, but this needs to be complemented with more immediate measures that relate to salvage harvesting in the context of the current MPB outbreak.
3. ***Enforcement of the FRPA regulations and professional practices and ethics.*** Although a last resort to prevent socially unacceptable conduct by a tenure holder or licenced professional, enforcement of regulations identified in *FRPA* appears to be extremely complex. It may be difficult or impossible to measure non-compliance where clauses such as "to the extent practicable" allow variance from achieving some biodiversity objectives. This creates a high degree of uncertainty around both legal and professional expectations to meet some *FRPA* objectives (i.e., biodiversity) for which measurable benchmarks are not clearly defined (see Reader 2006).

Moving Forward

Despite the many obstacles that may frustrate attempts to develop and implement retention planning to maintain wildlife habitat and biodiversity during salvage harvesting, excellent examples of retention applications exist. Where salvage harvest has been completed, a careful analysis of post-salvage conditions and reconciliation with wildlife habitat and biodiversity needs is an urgent priority to identify changes to existing plans or practices that would benefit ecological values. Although the infrastructure for co-ordinated landscape planning is poorly developed, informal landscape planning coalitions can play an important role in identifying values and approaches to achieving them and, in the process, build long-term relationships between stakeholders.

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Popular Summary

Improving mid-term timber supply in Timber Supply Areas affected by mountain pine beetle

Brian Raymer[1] and Alan Waters[2]

Presentation Abstract

Mid-term timber supply shortage is a significant concern due to the current mountain pine beetle epidemic. The Forest Practices Branch of the B.C. Ministry of Forests and Range is currently working on policy designed to protect suitable secondary structure in stands with mountain pine beetle-killed timber, where it is believed there is sufficient stocking of "suitable secondary structure" trees with sufficient size to produce a merchantable stand sooner than if the area was clearcut and reforested. TIPSY (Table Interpolation for Stand Yields) growth projections were conducted to determine the number of well-spaced subalpine fir or hybrid white spruce understorey trees per hectare required to produce a merchantable stand sooner than clearcutting a mountain pine beetle-attacked stand and planting pine seedlings. The proposed policy will require protection of areas with sufficient stocking of suitable stand structure to be protected by not harvesting or by harvesting them in a way that protects the secondary structure. A decision to harvest and not protect the secondary stand structure can be made if supported by a rationale prepared by a professional forester. In some situations, the best forest management decision will be to selectively harvest some of the dead lodgepole pine, leaving some of the dead pine and other trees standing for shade in addition to using harvesting techniques designed to protect the understorey trees. This policy is being developed with the intention of ensuring the best forest management decisions are made to the extent possible within the constraints of operational factors and other policies.

KEYWORDS: *mid-term timber supply, mountain pine beetle epidemic, secondary structure.*

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Introduction

The mountain pine beetle epidemic has attacked and killed an enormous volume of pine over the past decade in the interior of British Columbia. It is likely that significant quantities of dead pine will not be recovered through harvesting before the wood quality makes those trees unsuitable for processing into lumber. This likelihood and the desire to improve the mid-term timber supply are the reasons behind current development of policy to protect suitable secondary structure.

Modelling

TIPSY (Table Interpolation for Stand Yields) was used to estimate how many years it might take to produce 150 m^3/ha of net merchantable volume from 400, 600, 800, 1000, 1200, 2000, 3000, and 4000 naturally regenerated Bl(Sx) trees per hectare with a given site index (SI). The number of years required to produce 150 m^3/ha of net merchantable volume from 1200 planted Pl seedlings per hectare on the equivalent SI for Pl was also determined. The use of 1200 planted Pl seedlings per hectare as the basis for comparison was based on information in RESULTS from Nadina, Vanderhoof, Fort St. James, and Prince George forest districts. The data indicates that 87% of what were originally lodgepole pine-leading stands were planted, 76% of the seedlings planted were Pl, and the average planting density was 1441 seedlings per hectare. To account for 13% of the areas that were naturally regenerated, 1200 planted seedlings per hectare was used as the basis for comparing pine plantations with the growth of understorey Bl(Sx). TIPSY growth projections for Pl plantations were also used as the basis of comparison as they produced 150 m^3/ha of net merchantable volume faster than other species. All net merchantable volume estimates were based on a 12.5 cm minimum merchantable DBH for all species and the normal operational adjustment factors (OAFs) for all growth projections (OAF 1 = 15% and OAF 2 = 5%).

Analysis

The initial analysis used a SI of 16 for Bl(Sx) and a SI of 18 for Pl as these reflect the 2006 SIBEC SI estimates for these species on SBSmc2/01 sites where Coates reported the best secondary structure. A naturally regenerated stand of 1000 Bl(Sx) trees per hectare on SI 16 took approximately 80 years to produce 150m^3/ha. It took approximately 50 years for 1200 planted Pl seedlings per hectare on SI 18 to produce 150m^3/ha. Going back 50 years in the TIPSY output table from when the 1000 Bl(Sx) trees per hectare yielded 150 m^3/ha, the top height of the Bl(Sx) stand is estimated at 3.6 m. Using this methodology, it was assumed that a stand with 1000 Bl(Sx) understorey trees per hectare with a top height of 3.6 m would produce 150m^3/ha of net merchantable volume in the same amount of time as if the area was clearcut and planted with 1200 Pl seedlings per hectare, after a 3-year regeneration delay.

This methodology was used repeatedly to determine the height that 400, 600, 800, 1000, 1200, 2000, 3000, and 4000 Bl(Sx) understorey trees per hectare would need to possess, at various SI values, to produce 150m^3/ha in the same amount of time as 1200 planted Pl seedlings at appropriately higher SI values. The top heights for various densities of Bl(Sx) understorey trees that should produce 150m^3/ha in the same amount of time as a Pl plantation were determined.

It is believed that stands with a high percentage of beetle-killed Pl should have sufficient light, moisture, and nutrients for the secondary structure to release and grow even if the dead Pl overstorey isn't harvested. It is believed the Bl(Sx) secondary structure trees will initially respond better to release in the shade of a dead Pl overstorey than if they are exposed to full sunlight by harvesting the overstorey (Coates, pers. comm.). If not all beetle-killed Pl stands can be harvested before the timber gets too badly checked for lumber production, it would be desirable, from a timber supply perspective, to retain stands that have secondary structure that is most likely to produce a harvestable forest without reforestation treatments.

The TIPSY growth projections for free-growing natural Bl(Sx) stands may overestimate the growth of Bl(Sx) understorey trees that are growing in the shade of dead overstorey pine or the competition and shade from remaining live merchantable trees. Contrary to this concern, Coates has suggested that 5 years after the overstorey pine has been killed, the Bl(Sx) understorey is showing consistently better annual height growth than the SI curves from TIPSY would estimate.

Risk of Blowdown

Due to the high potential for blowdown when stands with greater than 30% Pl are partial cut, it is believed that live merchantable secondary structure trees (> 17.5 cm DBH) should not be left unless the trees are especially windfirm. Harvesting guidelines designed to protect understorey trees in Alberta suggest that trees greater than 10 m tall should not be left due to the high risk of blowdown compared to smaller understorey trees. It is suggested that removing the majority of the overstorey in a manner that protects the understorey may be one way to release the secondary structure in stands with greater than 30% Pl. Vigorous stands with less than 30% Pl are likely to be the best candidates for partial harvesting that removes the dead pine and leaves a healthy residual stand that is windfirm. It is also suggested that leaving approximately 30% of the overstorey (in the form of low-value trees) may provide shade that is necessary to release the Bl secondary structure while allowing trees with reasonable lumber recovery to be salvaged.

Cost Recognition

The current *Interior Appraisal Manual* doesn't provide any recognition for carrying out harvesting in a manner that protects unmerchantable understorey trees. In order for licensees to carry out careful harvesting that protects the stocking of unmerchantable secondary structure trees, there will need to be an amendment to the *Interior Appraisal Manual* to recognize the additional harvesting cost. Without such a cost allowance, licensees may be unwilling to harvest stands in a manner that protects the secondary structure.

Conclusion

Protecting secondary structure where it has the potential to produce a merchantable stand sooner than a plantation appears to be a reasonable strategy to improve future timber supplies 40 to 50 years from now. It is also a priority to use the current AAC to harvest as much beetle-killed Pl as possible and convert these stands into regenerated areas that will produce merchantable volume as soon as possible. Harvesting the dead overstorey Pl in a manner that protects good secondary structure may provide the dual benefits of utilizing the dead Pl and producing a merchantable stand sooner than if the secondary structure was destroyed. There is, however, a concern that the secondary structure will not respond well to the sudden and complete removal of the overstorey tree.

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Popular Summary

The politics of retention

Bruce Fraser[1]

Presentation Abstract

Retention harvesting is a forestry technique intended to balance the extraction of value with the maintenance of associated values. We intend to harvest an economically sound timber volume, while leaving a pattern on the ground that promotes a structurally diverse and ecosystematically functional forest for the future. Why would we do this? It could be for wildlife habitat, for hydrological security, for limitation of visual impact, or enhancement of productive timber values in a future forest. When we do it, we have a complex of issues to deal with: blowdown of leave patches, faller safety, quality of trees, infestation potential, efficacy of patch distribution, changing climate, and so on. In microcosm, retention in forest harvesting is analogous to the issues we face on a landscape scale when we take all of our rapidly accumulating natural resource extractions into consideration. How can we manage our natural resource industries as a whole to balance the extraction of value with the maintenance of associated values—the ultimate political job of managing the commons sustainably for a very wide range of values?

KEYWORDS: *cumulative impacts, economics, ecosystem function, sustainable resource management, timber harvest volume.*

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"We realized that the conventional wisdom is mistaken in seeing priorities in economic, environmental and social policy as competing. The best solutions are based not on tradeoffs or 'balance' between these objectives but on design integration achieving all of them together at every level, from technical devices to production systems to companies to economic sectors to entire cities and societies."

—Paul Hawken, Amory Lovins, and Hunter Lovins, in their preface to *Natural Capitalism* (1999)

Introduction

Retention harvesting is a forestry technique intended to balance the extraction of present value with the maintenance of associated values into the future. We intend to harvest an economically sound timber volume, while leaving a pattern on the ground that promotes a structurally diverse and ecosystematically functional forest for the future. Why would we do this? It could be for wildlife habitat, for hydrological security, for limitation of visual impact, or enhancement of productive timber values in a future forest. When we do it, we have a complex of issues to deal with: blowdown of leave patches, faller safety, quality of leave trees, infestation potential, efficacy of patch distribution, changing climate, and so on. In microcosm, retention in forest harvesting is analogous to the issues we face on a landscape scale when we take all of our rapidly accumulating natural resource extractions into consideration. We need to know whether our variable retention efforts are leading to desirable results in the forestry context. We need to know whether our ecological footprint is maintaining ecosystem carrying capacity in the larger resource management context. How can we manage our natural resource industries as a whole to balance the extraction of value with the maintenance of associated values? That is the ultimate political job of managing the commons sustainably for a very wide range of values and a diversity of human interests.

Variable Retention as a Strategy

In forestry we see the strategy of variable retention as a means to recognize a variety of other values while extracting and replenishing the fibre resource within the economic, regulatory, and voluntary certification bounds pertaining to the industry. By itself, in the forestry context, it appears to make sense and a great deal of energy is going into researching the efficacy and consequences of its usage. It is not common, however, to relate the strategy of variable retention in forestry to inevitably linked cumulative consequences of the management regimes in oil and gas recovery, mineral development, transmission corridors for small-scale hydro development or coal mining, resort development, residential expansion, or transportation—any or all of which may interact with forest practices on the same landscape.

Taken together, the bundle of natural resource economic activities contributes both to the overall human economy and to the footprint appropriated from nature. But, these elements are rarely taken together by our administrative system and therefore their cumulative effects, both positive and negative, are not measured or managed to ensure that the combined outcome lies within, degrades or enhances the carrying capacity of the supporting ecosystems of our local and global commons. The result is the potential for ineffectively integrated exploitation of natural resources to produce nasty surprises as the side effects of one sector affect the well-being of another. There is potential for productive synergies to be missed. There is potential for the laudable conservation efforts of forest licensees to be vitiated by the activities of other tenure holders on the same landscape. There is the potential for legal and well-meaning initiatives that are relevant and appropriate within the confines of one sector acting at cross purposes with equally legal and well-meaning ones from another.

The public commitment to conserve mountain caribou herds in the province is an example of a sectoral species recovery goal that affects the interests of forestry, mining, commercial recreation, public recreation, and resort development. As each industry or public use proceeds to generate its own bundle of industry supporting and limiting rules, they produce a set of individually worthy economic, social, and environmental objectives. Collectively, these interacting rules can become a labyrinth of competing demands that are not easily integrated in our current system of natural resource management based on legislated administrative silos. The habitat conservation measures looming in the caribou recovery plans of the province, for instance, will affect the availability of timber to forest licensees and may well influence the application of differing harvest and silvicultural approaches on the adjacent lands, particularly in the light of the mid-term timber supply, biofuel development, and community economic diversification issues arising from the mountain pine beetle epidemic.

Overshoot of ecosystem carrying capacity, arising from inadvertent cumulative impacts, can lead to degradation of productivity or irreversible losses, resulting in diminished returns to all those people, public and private, who have invested their lives and finances in each resource-consuming enterprise. Decline of wild fisheries, growing numbers of threatened or invasive species, pest and pathogen explosions, and the increasing biogeographic and hydrologic consequences of climate change are sufficient warning of cumulative ecosystem stress. While we practice variable retention in our forestry silo, to prepare the forest structure for future productivity, we could be undoing those benign effects with resource developments from other sectors. It is in our collective interest to avoid stumbling into cumulative results that injure either the capacity of our ecosystems or the sustainability of our many economic pursuits. It is in our collective interest to design our resource management activity to achieve a broad base of positive results.

The "Design Integration" Objective

Could we take steps to enable the existing agencies of our natural resource administrative system to engage in a process of accelerated integration? Could we establish a period of rapid learning in order to build the capacity to act harmoniously in managing the human footprint both for ecosystem stability and economic advantage? In effect, could we create the capacity for "design integration"?

Taking the First Steps: A Proposed Strategy

Re-task Existing Agencies

Employ our existing inventory of agencies. Develop a mutually supportive task structure and make explicit assignments that promote a steadily increasing understanding of the carrying capacity of our stock of supporting ecosystems that lie behind each natural resource enterprise and the extent to which we are drawing on that capacity. Task the agencies to develop the organization, practices, and limits we may have to adopt to ensure long-term maintenance of capacity.

Reflect Land not Silos

Direct our capacities for research, inventory, sectoral management, monitoring, and evaluation to functionally appropriate units of landscape—reflecting ecology, watershed integrity, and socio-geographic considerations.

Establish Pilots

Begin with forestry, fisheries, agriculture, mining, energy, and tourism, choosing a trio of landscape unit scale (or suitable multiple) pilot areas that incorporate both resource communities and First Nations communities and exhibit all or significant blocks of tenured enterprises and public uses.

Establish Teams

Develop an integrated team for each pilot area, with a designated leadership, decision-making authority, and a core staff. Invest the team with a formal regulation, similar to that which established the Fort St. John Forest Practices Code Pilot (a pilot designed to test aspects of the *Forest and Range Practices Act*—in the Fort St. John example, a successful and enduring model). Have the team leadership report regularly to the Deputy Ministers' Committee on Natural Resources and Economy (DMCNRE), and through them to government.

Engage Key Agencies

Engage the resource ministries behind each sector, supported by the Integrated Land Management Bureau (ILMB for planning assistance), Ministry of Forests and Range (MOFR Research Branch for research organization), the Integrated Land and Resource Registry (ILRR for the overall information base), Front Counter BC (for estimations of development pressure), Forest and Range Evaluation Program (FREP for systematic resource value monitoring), and the Forest Practices Board (FPB for public assurance auditing) appropriately tasked.

Engage Local and Regional Organizations

Engage Beetle Action Coalitions (such as OBAC, CCBAC, SIBAC), LRMP Monitoring Committees (such as the Kamloops LRMP Monitoring Committee or the Bulkley Valley Community Resource Board), Basin Councils or Initiatives (such as the Fraser Basin Council or the Columbia Basin Trust), model forests (such as McGregor or Alex Fraser), regional science institutes (such as the Bulkley Valley Centre for Natural Resource Research and Management in Smithers or Columbia Mountains Institute in Revelstoke), EBM steering groups (such as for the mid and north coast), industrial consortia (such as the Prince George TSA group or the Canadian Association of Petroleum Producers), forest certification public advisory groups (such as those required by the Canadian Standards Association), or other such integrating bodies as are directly engaged with the pilot areas.

Go Public

Conduct a public outreach program consistent with the pilot efforts, using FORREX to manage its delivery.

Document and Use the Results

Document the integrated action thoroughly, with a view to preparing advice for the future evolution of agency tasking and the necessary supporting legislation, regulations, and organization of natural resource management in the province.