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Chapter 20

Old-Forest Conservation Strategies in Wet-Trench Forests of the Upper Fraser River Watershed, British Columbia*

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1. INTRODUCTION

Historically, old-forest ecosystems in the upper Fraser River watershed were regarded as non-merchantable or decadent parts of the timber harvesting landbase. Conversion of old forests to more productive younger stands was seen as an appropriate management objective (Sloan 1956). With greater appreciation of the biological values represented by old forest ecosystems, however, management for old-forest values must now deal with the legacy of past forest harvesting practices. In the upper Fraser River watershed these legacy issues fall into three major categories: 1) the loss of old forests within regional landscapes; 2) the spatial configuration of remaining mature and old-growth forests within regional landscapes; and 3) the simplification of the internal structure of previously harvested forest stands. Among major contributing factors that we must consider is that past harvesting pressures have not been evenly distributed within regional landscapes. Rather there have been disproportionate logging impacts on sites that have high biodiversity values. Implementation of policies that recognize the biological value of these sites poses immediate challenges for land managers.

A first step in this direction has been taken with the designation of landscape level targets for retention of old forests, using the historic natural range of variability (NRV) as a guide for setting threshold limits. However, a major gap in public policy persists, in that designated stands which meet the age class threshold for old-forest retention are treated as essentially similar entities. Current policies do not readily distinguish between old forests with high biodiversity values and old forests with low biodiversity values or the differing availability of these forest types in present-day landscapes.

Overriding this discussion is the consideration of how ecosystem processes in the upper Fraser River watershed, which historically shaped landscapes dominated by a range of old-forest communities, will function in future managed landscapes. What trade-offs should we be making between the intensity of forest harvesting practices and the biological attributes desired within future forests? Can alternative forest harvesting practices (e.g., variable retention or partial-cut harvesting) retain aspects of old-forest values within managed forests? Or does the widespread adoption of alternative forest harvesting practices result in fragmentation of a wider landscape, if assumptions of timber supply remain unchanged? Although these questions are faced by forest managers across Canada, the high proportion of old forests within B.C.'s wet trench landscapes creates unique challenges for management of these forests in B.C.

In this chapter, we will address how the proportion and configuration of old forests in regional landscapes has shaped past logging practices and the challenges that this creates for present-day forest managers. We will discuss the growing importance of alternative forest harvesting techniques and their potential to maintain key elements of canopy structure normally associated with old-growth forests. Our assessment will focus primarily upon the response of canopy lichen communities, which represent significant biodiversity indicators in these ecosystems. Finally, we will discuss regulations adopted in the region and the difficulties of reconciling forest management policies – as currently practised – with the preservation of old-growth forests.

2. UPPER FRASER WATERSHED REGIONAL CONTEXT

In north-central British Columbia the upper Fraser River is contained within the Rocky Mountain Trench: a broad valley paralleling the steep western face of the Rockies and separating them from the interior (and much older) ranges of the Columbia Mountains. This area of the upper Fraser River watershed is characterized by high precipitation, up to 480 mm during the summer period alone (out of 1,030 mm annually), as prevailing westerlies carry Pacific storm systems over the interior mountain ranges (Reynolds 1997). The proximity of the upper Fraser to the continental divide and the consequent incursion of arctic air masses during the winter period, however, results in a long lasting snow pack, with up to 2 m of settled snow accumulating in mid-elevation cedar-hemlock stands by late winter.

These conditions of high summer precipitation, prolonged snowmelt into late spring, and summer fog in valley bottom locations, have historically promoted the development of landscapes that were dominated by old forests. DeLong (1998) estimated that fire return intervals in these montane forests ranged from 244 years to over 1,600 years – depending on slope position, precipitation levels, and aspect. Many of the wet toe-slope positions on north-facing slopes show no previous history of stand-destroying fires (from buried charcoal horizons), although individual trees (or clusters of trees) have shown evidence of past lighting strikes.

Forest communities in the Rocky Mountain Trench of the Upper Fraser headwaters include three biogeoclimatic ecosystem community (BEC) zones: the Sub-boreal Spruce (SBS), the Interior-Cedar Hemlock (ICH), and the Engelmann Spruce Subalpine Fir (ESSF) zones (Meidinger and Pojar 1991). SBS and ESSF forests are found in valley bottom and upper elevations respectively. Both of these zones are primarily dominated by hybrid white spruce (*Picea engelmanni* Parry × *P. glauca* [Moench] Voss) and subalpine fir (*Abies lasiocarpa* [Hook] Nutt.) (though stand structural characteristics and understory forb composition are noticeably different between these two forest types). Between these two spruce-fir-dominated BEC zones lies a band of ICH forests at mid-elevations. These forests are dominated by western red cedar (*Thuja plicata* Donn.) and western hemlock (*Tsuga heterophylla* [Raf.] Sag.), with the presence of Douglas fir (*Pseudotsuga menziesii* [Mirb.] Franco.), subalpine fir, and hybrid white spruce (depending on site conditions).

3. LOSS OF OLD-GROWTH FORESTS WITHIN REGIONAL LANDSCAPES

Human impacts in the wet portions of the Rocky Mountain Trench have occurred mainly along valley bottoms (SBS) and mid-elevation slopes (ICH), commonly in parallel with the development of modern transportation corridors. Extensive forest harvesting (and accidentally set fires) accompanied the development of the railroad along the south-facing slopes of the Rocky Mountain trench in the early twentieth century. Similarly, development of a highway corridor in the mid-60s along the north-facing slopes of the Rocky Mountain Trench resulted in extensive fragmentation of ICH stands. Although nearly 80% of the higher elevation mountain forests in the wet-trench area (figure 20.1) can still be classified as mature or old-growth forest cover (>140 years in age), only 40% of valley bottom spruce forests in the wet-trench are still greater than 140 years in age (Anonymous 2005). A major priority of landscape level forest management policies in the upper Fraser River watershed has been one of minimizing risks to biodiversity. This area contains provincially significant populations of mountain caribou (*Rangifer tarandus caribou*), grizzly bears (*Ursus arctos*), and several species of Pacific salmons.

Figure 20.1
Location of wet-trench mountain and wet-trench valley natural disturbance units in the Prince George Timber Supply Area, central-interior B.C.

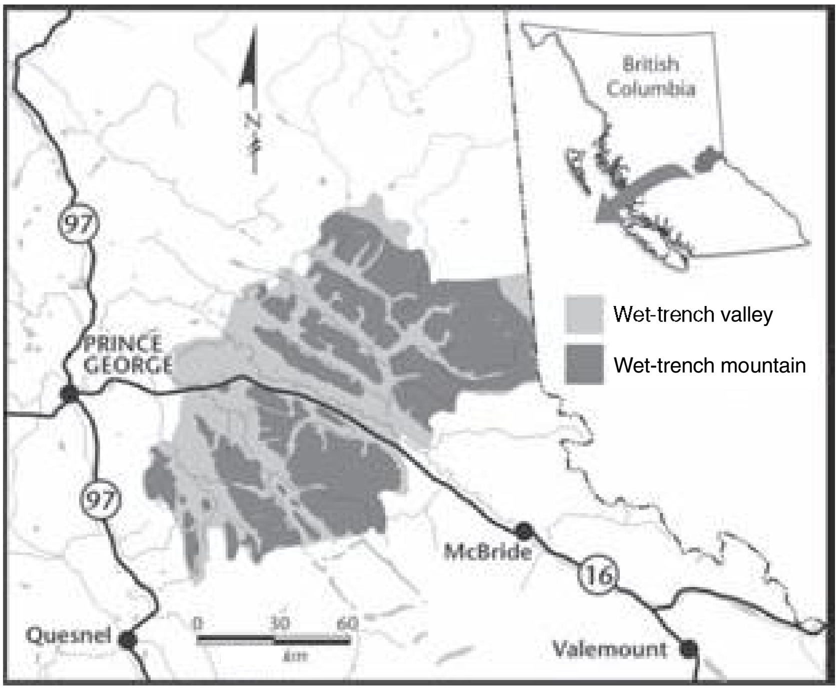


Table 20.1
Old-forest cover in wet-trench landscapes

	Natural disturbance unit	
	Wet-trench valley	Wet-trench mountain
Total (ha)	457,333	312,471
Current old forest (ha)	228,554	244,929
% current old forest	50.0	78.3
Current interior forest (ha)	144,154	212,106
% current interior forest	31.5	67.8

3.1. Measures Based on the Natural Range of Variability

In a comprehensive review of landscape level management objectives, the Prince George Timber Supply Analysis (Anonymous 2004) adopted the concept of managing landscapes within "a natural range of variability" (NRV). NRV-based management tries to predict the natural range of variability that has occurred in a given ecological attribute over time and then set management practices that will maintain that ecological attribute within "naturally occurring" boundaries (see Vaillancourt et al., chapter 2). Under a NRV concept we can estimate, for instance, what proportion of regional landscapes would historically have been covered in old forests and how much variation would have occurred in this proportion over long time periods (see box 20.1).

Box 20.1
Retention of old-growth forests in a context of climate change

When evaluating the adoption of landscape level management targets for old forests based on a natural range of variability (NRV) concept the assumption is that past climatic events (and calculated NRV values) provide an appropriate template upon which to plan future landscape patterns. However, there may be an element of hubris in planning future land use allocations from historic NRV patterns.

Predictions for future climate change in the upper Fraser River watershed, based on models of Hamann and Wang (2005), estimate a change in mean annual temperature in the ICH ranging from 2.9°C to 5.7–6.9°C. The greatest component of this change is predicted to occur in the winter period, as more precipitation events occur as rain, instead of snow. This may have a major impact on the future sustainability of areas designated for old-forest retention; given the role that ground water recharge from melt of winter snowpack plays in sustaining their growth during the summer period, especially during where precipitation are below normal.

Old Interior-Cedar Hemlock (ICH) stands in the upper Fraser River watershed (the wet-trench landscapes) may have disproportionate national conservation biology significance, as the climate envelope for the development of wet ICH forests shrinks in areas further south within British Columbia. Inland rainforest stands of the upper Fraser River watershed may, in the future, represent the sole examples of old-forest stands within the remaining ICH climate envelope. Though new areas to the north and east of the upper Fraser river watershed may develop characteristics of climate associated with the present-day inland rainforest, forests that develop on these new sites will not attain old-growth status for many centuries. Additionally, limitations of dispersal may pose serious obstacles to the colonization of new habitats by old-growth-dependent species. This also places a greater premium on the value of retaining forests in wet toe-slope positions within these mountain valleys, where groundwater flow from higher elevation may confer greater resistance to forest fires and disease in the face of the predicted climate changes.

Estimates of NRV for old forests in the upper Fraser were calculated by DeLong (2007) using a stochastic landscape model implemented in SELES (Spatially Explicit Landscape Event Simulator). This simulation was based on repeated runs using known fire return intervals calculated over a 1,000-year period. The natural range of variability in the cover of old forests in the Rocky Mountain Trench was estimated between 76 and 84% in wet-trench valley environments (ICH and SBS), and between 80 and 88% in wet-trench mountain environments (ESSF) (DeLong 2007). These NRV estimates represent an averaging of fire return intervals on different slope positions and hence would tend to underestimate NRV in wet site positions (i.e. toe-slope positions). However, even with this averaging they are still much narrower in range than those observed by Wimberly et al. (2000) in the Oregon Coast Range, where the calculated NRV for old forests ranged from 25 to 75%, or Agee (2003), whose NRV for old forests in the eastern Cascades fell between 38 and 63%. The relatively high NRV values obtained for the wet-trench landscape units of DeLong (2007) emphasize the significance of old-forest cover as a predominant seral stage in wet-trench landscapes of the upper Fraser River watershed.

In landscapes with a history of forest harvesting, old-forest cover values will typically fall below NRV targets. However, in wet-trench environments of the upper Fraser River watershed old-forest cover values of mountain forests (ESSF) fall close to NRV values, reflecting the inclusion of many non-commercial forests in the wet-trench mountain modelling area. In contrast, old-forest cover values for wet-trench valley forests, at 50% (Anonymous 2005), fall well below the historic NRV (76 to 84%) recommended by DeLong (2007), a disparity that may be even steeper when considering specific forest types, such as wet cedar-leading stands, which historically, rarely experienced stand level disturbances.

It is difficult to determine how great a disparity can be accommodated between NRV estimates of past old-forest cover and future (remnant) old-forest cover before the resilience of regional biota is placed at risk during future disturbance events (anthropogenic or natural). Little guidance is available in this regard. Most published studies, such as those of Agee (2003) or Wimberly et al. (2000), report on landscapes where present-day old-forest values fall well below NRV values. Several authors have speculated that risks to biodiversity are high if old-forest retention values within the landscape fall below 30% of the area determined by the minimum NRV estimates (Angelstam 1997). They make the important point that the longer old-forest patches remain as small refugia within the landscape, the greater the risk of extinction from stochastic events. Alternatively, risk to biodiversity will be lower when old-forest retention is nearer to 70% of the minimum range of NRV estimates (Angelstam 1997).

Given the pressing need for policy decisions in the upper Fraser watershed, DeLong (2002) recommended that the area of retained old forest be set between 41 and 61% of the area calculated to represent the natural range of variability for moist interior montane forests of the upper Fraser watershed. The implementation of this target resulted in a mandated requirement that 53% of ICH stands and 38% of SBS stands in the wet-trench valley be retained as old forest (that is forests greater than 140 years in age). It is important to note that this designation was aspatial in nature. In other words, these proportions have no fixed boundaries over time; rather it may be located in quite different parts of the landscape as harvesting proceeds regardless of tree species composition or site condition (i.e., wet versus dry soil moisture conditions). The strength of old-forest retention policies based on NRV estimates is that they force an examination of forestry practices at a regional level, where conservation biology planning has often been weak in the past. Their weakness, however, is that they cannot be used to dictate site level planning. The biological attributes of individual stands must also be considered in designated old-forest conservation biology priorities in regional landscapes.

3.2. Conservation of High-Value Old-Forest Stands

An outstanding policy need in wet-trench forests is the development of mechanisms to recognize and protect old-forest sites with high ecological values. Recent research suggests that high levels of canopy lichen diversity can be found in productive valley bottom forests, especially in the so-called "antique" forest stands (>500 yrs since the last fire + uneven-aged stands), old and very old cedar-hemlock stands located on wet toe slope and bench topographic positions (figure 20.2) (Goward 1994). Many of these antique forest stands appear to have had no major stand-level disturbance for periods in excess of a thousand years or more. As a consequence, they support rich canopy lichen communities, including many species of lichens not found elsewhere in regional landscapes (Arsenault and Goward 2000; Goward and Spribille 2005). Unfortunately, the location of antique forest stands on mid-slope benches, in the same areas where rail and road corridors were developed, means that these stands were historically disproportionately targeted for harvest.

In recognition of the limitations of an approach for designating old-forest habitats based on "aspatial" regulations alone (a given percentage of that landscape that was not fixed in any one location), a series of spatially designated old-growth management areas (OGMAs) were legislated in 2002. These OGMAs, which cover 19% of the overall forested land base in the wet trench (including both commercial and noncommercial forests) (Carson et al. 2002), were placed so as to protect spatially fixed features with high biodiversity value. Although the placement of OGMAs was initially limited to non-commercial forests, several were ultimately placed in commercial forests, in recognition that full representation of habitats would not otherwise be obtained. In total, some 8% of valley stands in the wet trench were removed from the commercial forest harvesting land base through designation of OGMAs.

Given the longevity of cedars (often up to 1,000 yrs) as a dominant tree species in most stands designated as OGMAs, one might expect that the old forest attributes they support will be stable over long time periods. However, given the high edge-to-interior ratio of many of the designated OGMAs and the absence of any formal requirement for the establishment of buffers in adjacent stands, the long-term resilience of OGMAs remains open to question. The designation of adjacent harvest blocks as partial-cut harvesting units would be one means of reducing these adjacency impacts. Current policy states that where adjacent forest harvesting or natural disturbance events are considered to have significantly impacted the value of an OGMA they can be considered for relocation

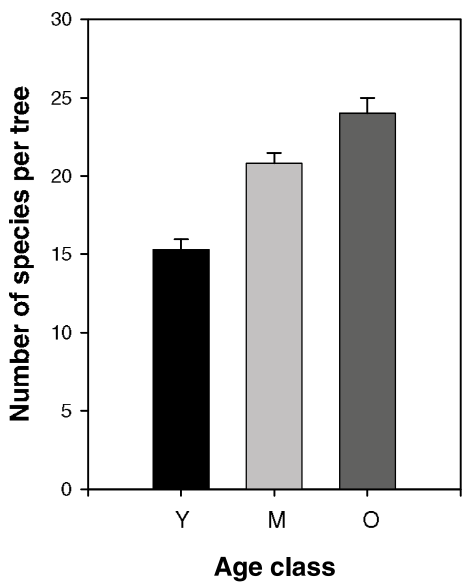
Figure 20.2
Remnant western red cedar trees of exceptional stature and age can be found in old-growth antique forest stands located in wet toe-slope positions

These sites appear to have escaped disturbance for very long time periods. This tree, located on the "Ancient Forest Trail," falls within a stand that was designated for harvesting until the winter of 2008, when its status was changed to that of an Old Growth Management area.

(Carson et al. 2002). Options for future designation may be quite limited, however, particularly for high-value old-forest habitats, such as toe-slope antique forest stands.

One caveat on the implementation of old-forest retention targets in the upper Fraser River watershed has been the use of an age class threshold of 140 years for designating old forests. Campbell and Fredeen (2004) found that overall lichen diversity was much greater in old (250 years +) cedar-hemlock forest stands, compared to mature (140–250 years) or young forests (60–120 years) (figure 20.3). An even more striking difference between mature and old forest can be seen if one examines foliose cyanolichens. Radies and Coxson (2004) conducted paired comparisons on hemlocks of the same size and age growing in even-aged (120–140-year-old) and adjacent old-growth cedar-hemlock stands. Of nine cyanolichens species found growing on hemlocks in the old-growth stands, only one species was found in the younger even-aged stands. Clearly, as the accuracy of the forest inventory improves, designated thresholds for determining what qualifies as an old forest stand should be increased to recognize the greater biodiversity values in old (i.e., 250–500-year-old stands) and antique (i.e. 500-year-old + multigenerational stands) cedar-hemlock stands.

Figure 20.3
Mean epiphytic macrolichen species richness (species per tree) for hemlock trees in three age classes in interior cedar-hemlock stands



Legend: Young (Y): 60–120 years old. Mature (M): 140–250 years old. Old (O): >250 years. Global lichen diversity is higher in old stands than in mature and young stands. Adapted from Campbell and Fredeen (2000).

4. SPATIAL CONFIGURATION OF OLD FORESTS WITHIN REGIONAL LANDSCAPES

Spatial configuration of old residual forests is another major issue in managed landscapes. Small patches of old-growth forests maintained in highly fragmented landscapes can be more susceptible to edge effect and could also be affected by stochastic events.

DeLong (1998) found that the mean patch size for regenerating stands (after previous stand-destroying fire events) in wet cool montane forests was 74 ha, with a maximum patch size of 1,931 ha. Although DeLong's (1998) recommendations on the mean patch size of disturbances resulting from fire formed a part of the NRV calculations that ultimately led to the adoption of targets for overall retention of old forests within regional wet-trench landscapes (see section 3.1), his specific recommendations on patch size limits on harvest block size were not implemented. Given operational constraints faced by forest companies it was deemed infeasible to mandate patch size distribution of harvest blocks.

As an alternative to the direct management of patch size within the upper Fraser watershed, regulations have instead been adopted on the percentage of retained old forest in the landscape that must meet additional interior habitat◆ requirements. Current regulations state that 40% of the old forest designated for retention be maintained as interior habitat. The spatial designation of cut-blocks under these regulations can vary widely. DeLong (2007) compares two patterns resulting from the implementation of these regulations (figure 20.4). In the first

◆ Forest area that is not affected by edge effect. Following Burton (2001, 2002) recommendations, a forest located at 200 m or more from an edge is considered as interior forest.

Figure 20.4
Illustration of two areas that both meet the definition of interior old forest developed by the Landscape Objective Working Group for the Prince George Timber Supply Area

Figure A illustrates the disruption of continuity due to the pattern of dispersed block harvesting commonly practiced in B.C. Figure B illustrates a aggregated pattern of old-forest retention. In the two cases, the pattern respects current regulations in the Prince-George Timber Supply Area. From DeLong (2007).

example, the adoption of dispersed harvest blocks results in a landscape that is highly fragmented, notwithstanding the harvest blocks meeting regulations for the retention of interior forest (figure 20.4A). In the second example, the aggregation of retained forest patches resulted in much greater continuity of forest cover, albeit at the cost of greater harvesting impacts in adjacent areas (figure 20.4B).

Another major factor to consider is the quality of retained old-forest habitats. Many old-forest lichens in the ICH are sensitive to edge effects. When taken together, the two major components of regulations controlling old-forest retention (total old forest and proportion of interior old forest) will result in only 21% of wet-trench landscapes being retained as interior old-forest habitats. Although still a significant proportion of the landscape, the quality of these designated interior old-forest habitats must also be considered. Much of the designated old-forest habitat falls in sites that have little or no commercial forest harvesting values. In the wet ICH this often means hemlock-dominated stands growing on steep slopes with dry, nutrient-poor soils. Recent surveys suggest that these sites have low levels of canopy lichen biodiversity (D. Radies and D. Coxson, unpublished data).

5. RESIDUAL HABITAT QUALITY AND IMPACT ON CANOPY LICHEN COMMUNITIES

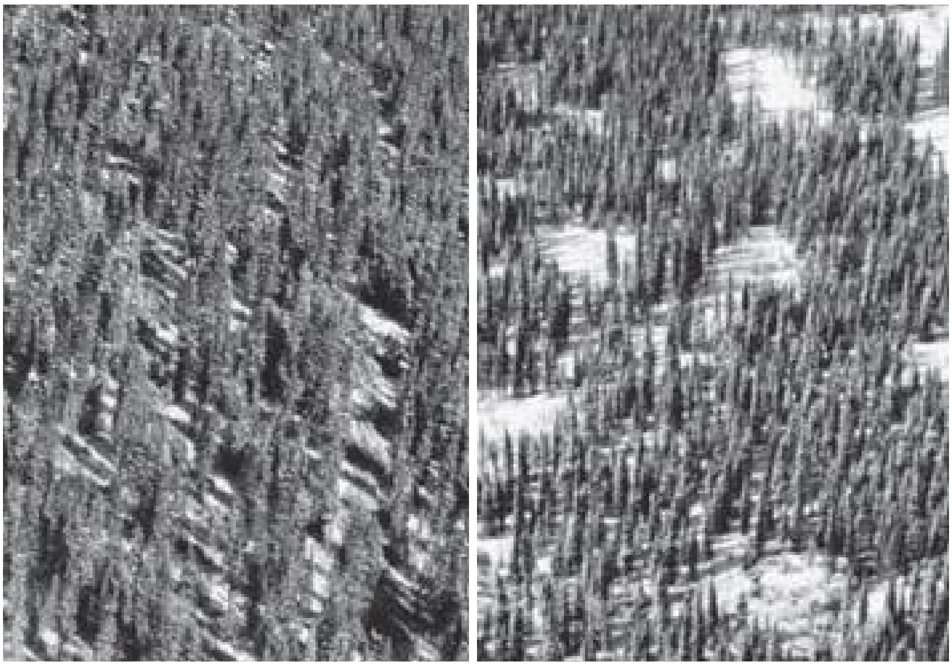
The imposition of regulations that require relatively high levels of old-forest retention within wet-trench landscapes of the upper Fraser River watershed are unprecedented within a B.C. context and set standards that are much higher than are remnant levels of old-forest retention in much of the U.S. Pacific Northwest. However, these standards do not, in themselves, ensure that biological values will be maintained in the future within the upper Fraser River watershed. Consideration must also be given to the nature and type of internal stand structures that are maintained within regional landscapes.

One group of organisms for which these considerations are particularly important is that of canopy lichens (see Drapeau et al., chapter 14). Wet-trench forests contain exceptionally diverse canopy lichen communities, including many threatened and rare interior forest habitat specialists (Goward and Spribille 2005). The conservation biology status of canopy lichens in wet-trench forests will increasingly reflect the interaction of two major factors. The first of these is the quality of old-forest habitats that are retained in wet-trench landscapes. However, equally important, given the social and economic constraints on designation of protected areas, will be our ability to maintain/regenerate future lichen habitats within managed (second-growth) forests.

Recent history in this regard is not promising. The adoption of clear-cut harvesting as the dominant silvicultural system in the Rocky Mountain Trench has led to a significant loss of old forest dependant canopy lichen communities. Major lichen functional groups, such as Alectoriod lichens (Stevenson et al. 2001) and canopy cyanolichens (Radies and Coxson 2004), typically require in excess of 200 years in which to colonize wet-trench forests after disturbance events. As this time period considerably exceeds that anticipated for stand age at harvest (rotation age) within managed forests of the wet trench, we must consider the retention of canopy structural components within harvest blocks as a major element of any plan to maintain future canopy lichen communities.

Several partial-cut harvesting trials point to the value of retaining canopy structural components in harvest blocks. Coxson et al. (2002) found no significant decline of Alectoriod lichen communities (lichen loading on a per-tree basis) in group selection harvesting plots within the ESSF (figures 20.5 and 20.6). However, the same study also found that Alectoriod lichens showed a significant post-harvest decline in single-tree selection partial-cut harvest blocks. The nature and pattern of harvesting intensity is clearly important. Similarly in ICH stands, Coxson and Stevenson (2005) found that for three of four lichen functional groups (cyanolichen, foliose, and *Bryoria* group lichens) there were no significant treatment effects of group selection and group retention partial-cut harvesting on post-harvest lichen retention within marked trees (assessed two years after harvesting). Old-forest cyanolichens within wet-trench valley forests, may indeed, react positively to the creation of small canopy gaps, which emulate natural openings within old forest canopies, providing that the surrounding old-forest

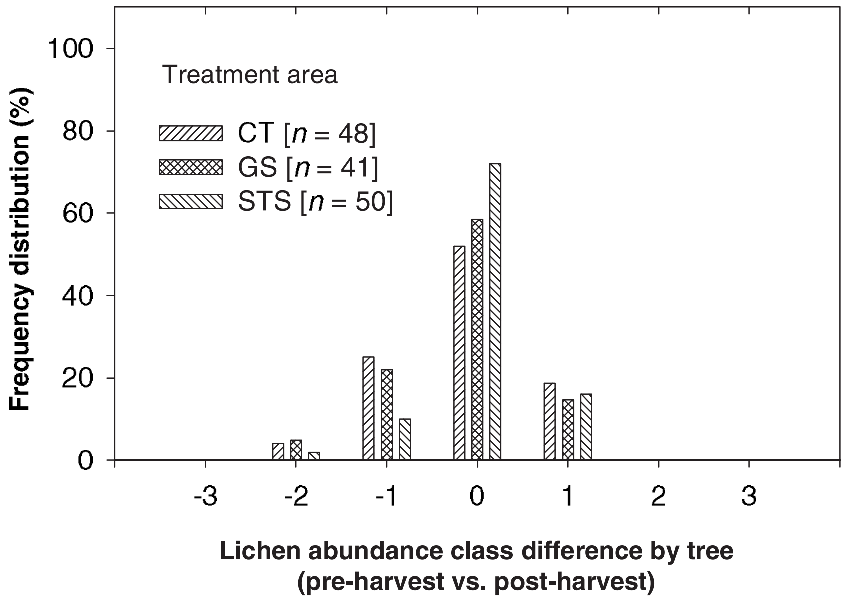
Figure 20.5
Oblique aerial view of single-tree selection (A) and group selection (B) partial-cut harvesting areas in Engelmann–spruce–subalpine fir forest at Pinkerton Mountain Silvicultural Systems Trial



A) B)

From Coxson *et al.* (2002).

Figure 20.6
Percent frequency distribution of changes in lichen abundance class by tree for three partial-cut treatments at Pinkerton Mountain

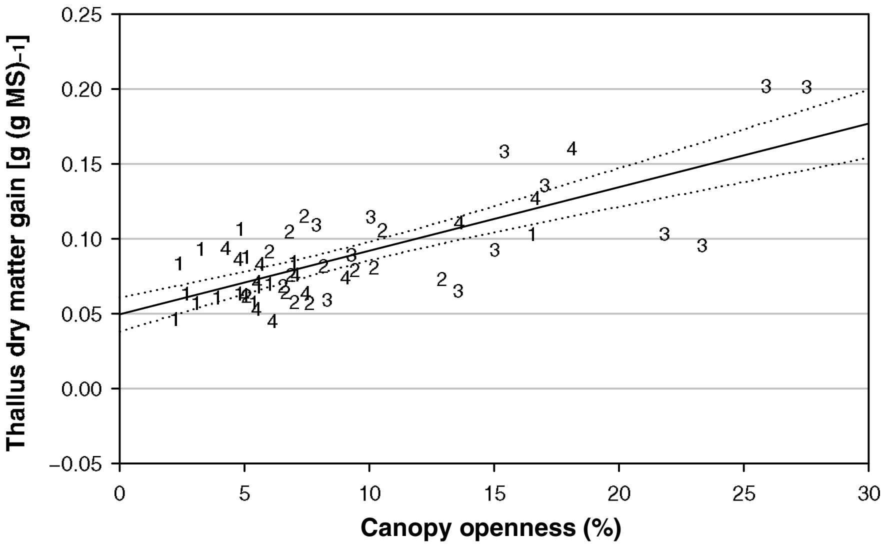


Legend: 0: no difference in visual estimates; 5 the greatest differences in lichen abundance; NT: no harvest treatment; GS: group selection; STS: single-tree selection. The sample size (number of tress) for each group is indicated in brackets. From Coxson et al. (2002).

matrix is functionally intact and continues to support major relevant ecological values. Coxson and Stevenson (2007) found a strong relationship between growth rates in the canopy cyanolichen *Lobaria pulmonaria* and exposure to small gaps within old-forest canopies (figure 20.7). This attribute of lichen response is promising, to the extent that we can create or retain the structures of uneven-aged forest in second-growth stands (though contributing factors such as soil moisture, proximity to riparian corridors, and topographic position will clearly remain important site specific factors).

The adoption of forest harvesting practices that minimize edge effects may have an important influence on landscape level retention of canopy lichens. Coxson and Stevenson (2007b) found that growth of small thalli of *Lobaria pulmonaria* was much higher at stand edges when the adjacent harvest block was a variable-retention harvest block (creating a low-contrast or "soft" edge) compared to stands where the adjacent harvest block was a clearcut harvest block (creating a high-contrast or "hard" edge) (figure 20.8). Larger thalli of *L. pulmonaria*, in contrast, were far less sensitive to the nature of the adjacent edge. This points to the importance of considering the reestablishment phase when examining the impact of forest harvesting practices on canopy lichen communities.

Figure 20.7
Cumulative percent lichen growth rates in Lunate and Viking stands as a function of % canopy openness



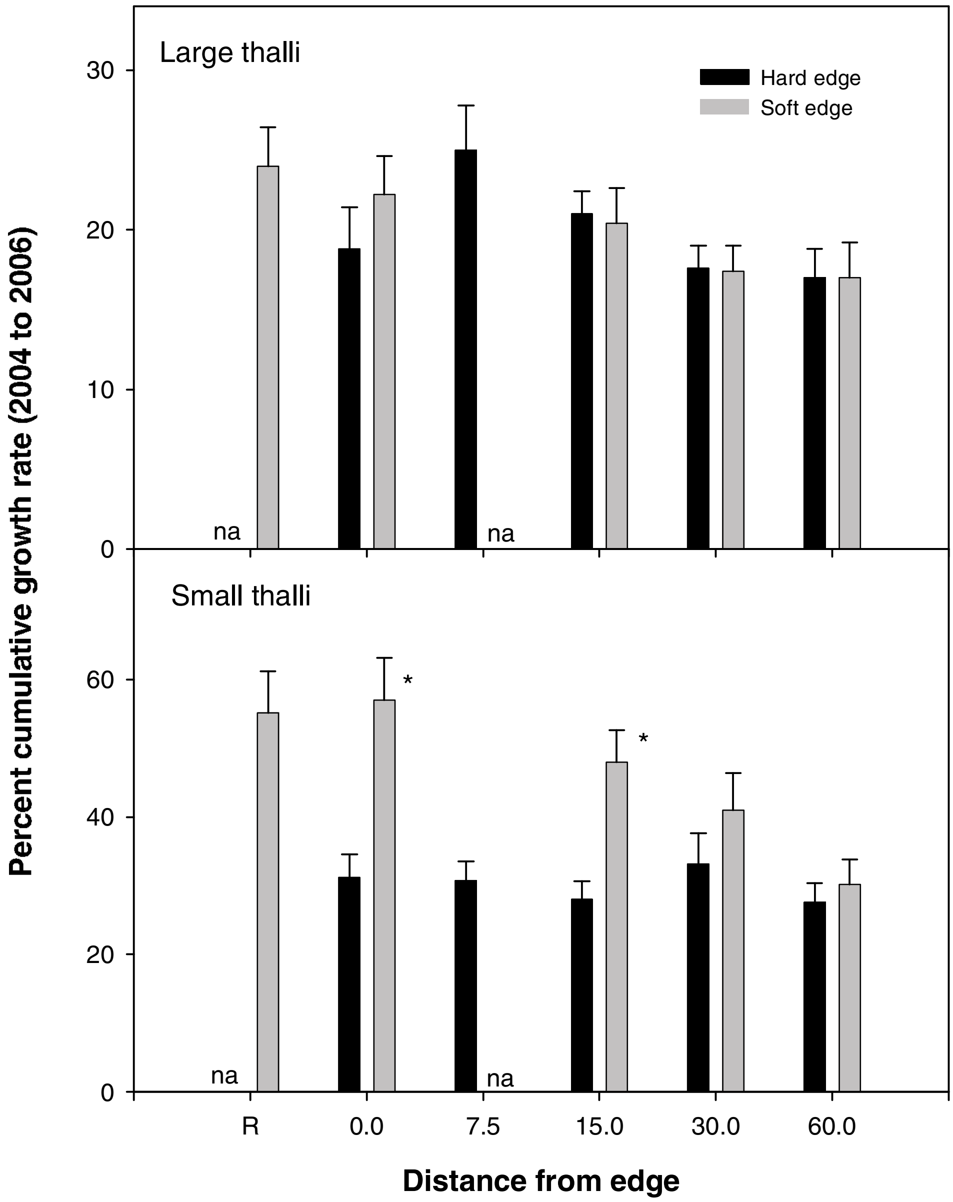
From June 2002 to June 2004, in even-aged stands (respectively plot symbols 1 and 2) and old-growth stands (respectively plot symbols 3 and 4). Linear regressions (solid lines) through scattergram, plus or minus 1 standard error (dotted line) are shown on plot. Adapted from Coxson and Stevenson (2007a).

To date there has been little adoption of partial-cut harvesting within commercial blocks in wet-trench forests. However, some forest licensees have adopted the practice of leaving significant amounts of advance regeneration (young and mature trees) on harvest blocks. In the short term this will help ameliorate edge effects within adjacent (remnant) old forest patches. It is less clear, however, to which degree these practices will contribute to the development of future old-forest characteristics. Much of this advanced retention comes from non-commercial species, mainly hemlock; species which tend to be more susceptible to natural disturbance events such as insect outbreaks and windthrow. Further, planned rotation age (time to the next harvest) in these harvest blocks would generally preclude the development of future old-forest structural characteristics.

6. IS NATURAL DISTURBANCE EMULATION POSSIBLE?

Trade-offs between the intensity of harvesting and retention of unfragmented old-forest patches are now at the heart of a major debate over the management of wet-trench landscapes. The challenge for forest managers is therefore to design silvicultural practices that both retain contiguous old-forest habitats and create harvest cut blocks that mimic natural disturbance processes.

Figure 20.8
Percent cumulative growth rates of large and small *L. pulmonaria* thalli at defined transect positions along soft- and hard-edge transects for the period from fall 2004 to fall 2006



Mean and standard error of large (top) and small (bottom) *L. pulmonaria* thalli (n = 3 stands). R: residual trees located in cutblocks. ND: positions where comparisons between hard- and soft-edge transects were not available. Asterisks, where present, indicate where significant differences were found (Bonferonni t-tests, p <= 0.05) between growth rates of *L. pulmonaria* thalli at defined positions along hard- and soft-edge transects. From Coxson and Stevenson (2007b).

The different types of old-forest stands (e.g., wet north-facing toe-slope antique forest stands or dryer upslope and/or south-facing stands) in the upper Fraser River watershed have very likely been shaped by varying types and intensities of natural disturbance processes in the past. However, an important limitation at the present time on the implementation of harvesting practices based on natural disturbance emulation is the lack of baseline data on prevailing natural disturbance regimes within the upper Fraser River watershed. For example, Hoggett and Negrave (2001) examined impacts of a major western hemlock looper outbreak in the early 90s, but we have little information on the overall intensity of past outbreaks within regional landscapes.

Nonetheless, partial cut harvesting trials that have been conducted in wet-trench forests (Jull et al. 1999) provide a possible template upon which forest harvesting practices that emulate natural disturbance patterns could be based, if key elements of both forest canopy structure and tree species composition are maintained within harvest blocks. Coxson and Stevenson (2005), for instance, found that many of the structural characteristics retained within partial-cutting harvest blocks provided suitable habitat attributes for old-forest lichens (see also section 3.2). However, maintaining both of these objectives (natural disturbance emulation in harvest blocks and retention of significant unfragmented old forest patches) within landscapes of the upper Fraser River watershed would necessitate accepting reductions in the annual allowable cut (yearly wood supply), depending on the level of variable retention or partial-cut harvesting adopted.

If natural disturbance emulation is chosen as a desired form of ecosystem management it should be remembered that no one harvesting strategy can emulate natural disturbance patterns over the diverse wet-trench landscapes of the upper Fraser River watershed. Forestry prescriptions should instead be based on a consideration of site specific factors. Clear-cut harvesting may be appropriate in areas where stand-destroying fires do occur, such as hemlock-dominated forests on rocky soils; whereas in other areas, such as cedar-leading wet toe-slope positions, natural disturbance events occur mainly as the single-tree gap dynamics, and forestry practices should be scaled accordingly.

7. CONCLUSION

The calculation of natural range of variability estimates for old-growth forest cover in wet-trench forests of the upper Fraser River valley has provided a valuable benchmark against which landscape level retention targets for old-growth forest management can be evaluated. However, these targets cannot substitute for the identification and protection of spatially designated high-value old-growth forest stands, particularly old-growth cedar stands located in wet toe-slope positions. The long-term retention of canopy lichen communities within regional landscapes will require both protection of these specific high-value areas and the greater adoption of partial-cut harvesting techniques in the surrounding forest harvesting land base. The adoption of forest harvesting practices which more closely emulate natural disturbance processes must be accompanied by a reduction in annual allowable cut, otherwise the net result will be one of landscapes that are highly fragmented and have few areas of viable interior forest habitat for lichen growth.

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