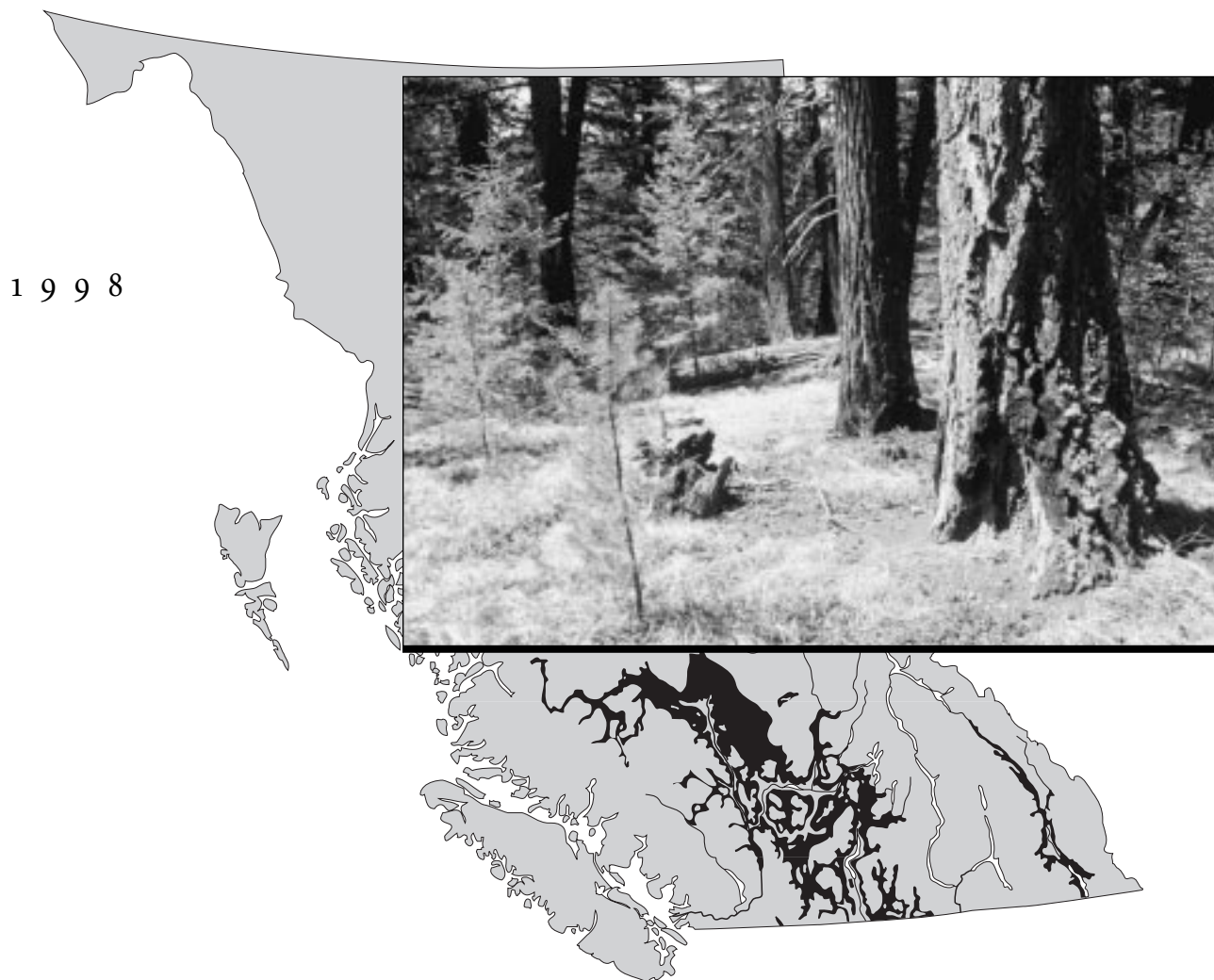


**Managing the Dry Douglas-fir Forests of the
Southern Interior: Workshop Proceedings**
April 29–30, 1997
Kamloops, British Columbia, Canada



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Alan Vyse, Chris Hollstedt, and David Huggard (editors)



Ministry of Forests Research Program

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Managing the Dry Douglas-fir Forests of the Southern Interior: An Introduction to the Workshop

ALAN VYSE

The management of dry Douglas-fir forests¹ of the Southern Interior is a subject of some concern to operational foresters and other land managers. Although the widespread use of uniform stand-level partial cutting rather than clearcutting in this forest type appears to have eliminated public fears about cutting practices, nagging doubts persist about the extensive use of this practice. The issues of regeneration, growth and yield, wildlife, pest management, and cattle grazing continue to be of concern despite the use of “continuous cover” silviculture.

Formal research on some of these issues has been conducted for over 20 years in the Cariboo, Kamloops, and Nelson forest regions. Unfortunately, the results of this work are widely scattered in journals and other publications of varying accessibility. Other issues have received little attention. Added to this situation is the seemingly endless capacity of field foresters and loggers for invention. New approaches are always being discussed and applied in dry-belt Douglas-fir, as they are in other forest types in the province. Therefore, the foresters and others with responsibility for managing these forests are plagued by a double misfortune: they have difficulty learning from researchers and from the experiences of their peers.

This workshop will not solve all of these problems. It was organized primarily to provide researchers with a forum to share research results, identify gaps, and set priorities for the future. However, the publication of the proceedings should also provide managers of dry Douglas-fir forests with a readily available source of information about the forest type and a starting point from which to make contact with the extensive knowledge base.

¹ This term includes forests dominated by Douglas-fir in the Interior Douglas-fir xh, xw, xm, dm, and dk subzones, plus moister sites in the ponderosa pine zone and drier sites in the Montane spruce and Sub-boreal spruce zones.

Fire and Successional Models for Dry Forests in Western Canada

STEVEN W. TAYLOR AND GREGORY J. BAXTER

INTRODUCTION

Historically, dry forests in Southern Interior British Columbia and Alberta were exposed to frequent, low-intensity surface fires. This fire regime resulted in open stands of fire-tolerant species, with little surface fuel. Fire suppression, grazing, and selective logging in these forests are believed to have caused forest encroachment on grasslands and forest ingrowth (an increase in the numbers of trees in the lower canopy layers of previously open stands). Ingrowth may result in the loss of forage production and critical habitat for sensitive wildlife species, a decrease in forest health, and an increased risk of catastrophic wildfires. However, the rate of ingrowth and the effects of ingrowth on other resource values and fire potential have not been well quantified at either a stand or landscape level.

In the Kootenay Boundary Land Use Plan Implementation Strategy, targets have been established (B.C. Ministry of Forests 1997) for the proportion of grassland, and open and closed forests in landscape units in Natural Disturbance Type 4, or NDT4 (*Biodiversity Handbook*, B.C. Ministry of Forests and Ministry of Environment, Lands and Parks 1995). Prescribed burning or thinning programs will be required to achieve or maintain grassland and open forest target proportions. However, no techniques are presently available in British Columbia to project the results of such activities on forest stand structure and composition, even though the Forest Practices Code requires managers to project the future stand structures that result from stand management activities. Techniques are also needed to project successional changes and management interventions at the landscape level.

OBJECTIVES

The goal of this project was to develop techniques to predict future ecosystem successional dynamics and the effect of thinning, prescribed burning, and fire suppression on forest composition, density, structure, and wildfire threat at the stand and landscape scales in dry interior forests. Specific objectives are:

- to adapt and test a stand-level model of fire effects on ecosystem dynamics for use in British Columbia; and
- to assess the historic rate of ingrowth in several landscape units in the Interior Douglas-fir (IDF) and ponderosa pine (PP) biogeoclimatic zones

in the Southern Interior of the province, and to develop techniques to project future changes.

METHODS

FVS Fire Model	<p>A review of existing successional models suggested that the Fuel Dynamics and Fire Effects Model (FDFEM) extension to the Forest Vegetation Simulator (FVS) (Teck et al. 1996) could be very useful to help develop stand management prescriptions and prescribed-fire plans for dry forests in Southern Interior British Columbia. The U.S. Department of Agriculture Forest Service began work on the FVS fire model in 1995 and planned to release it in 1997. The model represents woody debris dynamics, the effects of fire on tree mortality, and interactions between surface fuel load, crown scorch, and tree mortality. The base FVS growth model is used to predict regeneration, growth, and natural mortality. The input data required are a tree list file (which can be generated from conventional cruise and pre-harvest silviculture survey data) and surface fuel (woody debris) load data. A keyword file is used to control variables such as the frequency of treatments. The beta version is based on the North Idaho FVS variant; input data and model output are in Imperial units.</p> <p>As part of this project, the beta version of the FDFEM model was obtained and projections of future stand development and fuel dynamics on burned and unburned areas were carried out for two of the EMBER (Ecosystem Maintenance Burning Evaluation and Research) project study sites (Braumandl et al. 1995) (Finlay Creek, Invermere Forest District; and Picture Valley, Cranbrook Forest District).</p>
Assessing and Projecting Landscape Change	<p>Two landscape areas were selected for study: Tata Creek, an interim landscape unit of approximately 30 000 ha in the Cranbrook Forest District, and Okanagan Mountain Provincial Park, an area of approximately 10 000 ha on the east side of Okanagan Lake. Tata Creek is an area of low relief (800–1100 m) in the Kootenay River valley, and is within the PPdh2 and IDFdm2 biogeoclimatic subzones. Okanagan Mountain Provincial Park is a rugged area with an elevational range of 300–1700 m, classified within the PPxh1, IDFxh1, IDFdm2, and MSdm1 biogeoclimatic subzones.</p> <p>Air photo coverage of the study areas was also obtained for contemporary and historic periods (Tata Creek: 1952 and 1992; Okanagan Mountain Park: 1938, 1963, and 1987). Forest stands were identified on the photographs and classified into five crown closure classes:</p> <ul style="list-style-type: none">• Class 0: 0–5% (grassland)• Class 1: 6–15% (treed grassland)• Class 2: 16–40% (open forest)• Class 3: 41–55% (closed forest)• Class 4: >55% (dense forest) <p>The polygons were transferred from the photographs to base maps using conventional photogrammetric techniques. The maps were then digitized to produce digital ARC-INFO map files. All stands of similar class were summed for the study area for each time period (photo date) within ARC-INFO.</p>

Changes in stand conditions were projected as follows: Representative tree list data were obtained for the crown-closure classes in each study area following the *Correlated Guidelines for Management of Uneven-aged Drybelt Douglas-fir Stands in British Columbia* (B.C. Ministry of Forests 1992). Approximately five stands were sampled in each cover class and three plots were sampled within each stand. The FVS model runs were carried out using the British Columbia variant of the model (i.e., a metric version of North Idaho variant) on a 10-year growth cycle with natural regeneration. For Tata Creek, growth rates typical of the Flathead National Forest in northern Idaho were used. For Okanagan Mountain Park, growth rates were based on local periodic increment data.

Crown closure was determined for each time period by applying crown width equations (Moeur 1985) to individual tree data in the detailed FVS list file output; equations were first converted from Imperial to SI units. This was necessary because the FVS cover extension is not presently available within the British Columbia variant of FVS. Regression models of crown closure over time were developed from the modelled output and applied within ARC-INFO to project change in crown closure class for a 40-year period.

RESULTS AND DISCUSSION

FVS Fire Model

Figures 1 and 2 show examples of surface fuel load projections from the FVS model on burned and unburned control areas at Finlay Creek. The potential flame height if areas were exposed to wildfire and prescribed burning is shown in Figure 3. The model suggests that surface fuel loads in the burned area will recover to pre-treatment levels in about 30 years.

Many of the model functions, such as decomposition and snag fall rates, need to be critically examined with local data. Scorch height and crown fire potential functions should be evaluated in light of more recent work (Alexander 1998).

A British Columbia or Canadian variant of the fire model extension is required, mainly because the extension must interact with the British Columbia variant of the base growth model, which is in SI units. A graphical interface is also needed to make the model more accessible to users.

Landscape Change

The amount of area in each crown-closure class is shown in Tables 1 and 2. At Okanagan Mountain Park, a 0, -56, -26, +5, and +26% change occurred in the amount of area in cover classes 0–4, respectively. At Tata Creek, a -57, -54, +8, +51, and +58% change occurred in the amount of area in cover classes 0–4, respectively, as well as a 200% increase in the amount of deforested developed area. The different amounts of change are attributed to differing initial conditions, growth rates, and management histories. In particular, logging, prescribed burning, and development have occurred at Tata Creek, while Okanagan Mountain has been largely undisturbed.

The FVS projections suggest that the area of grassland and open forest will continue to decrease, and the amount of closed and dense forest increase, at Tata Creek (Figure 4). The decrease in grassland is less significant at Okanagan Mountain because it is very dry and rocky and the regeneration success is very low. However, the amount of closed and dense forest at Okanagan Mountain is projected to decrease, and open forest increase, as the

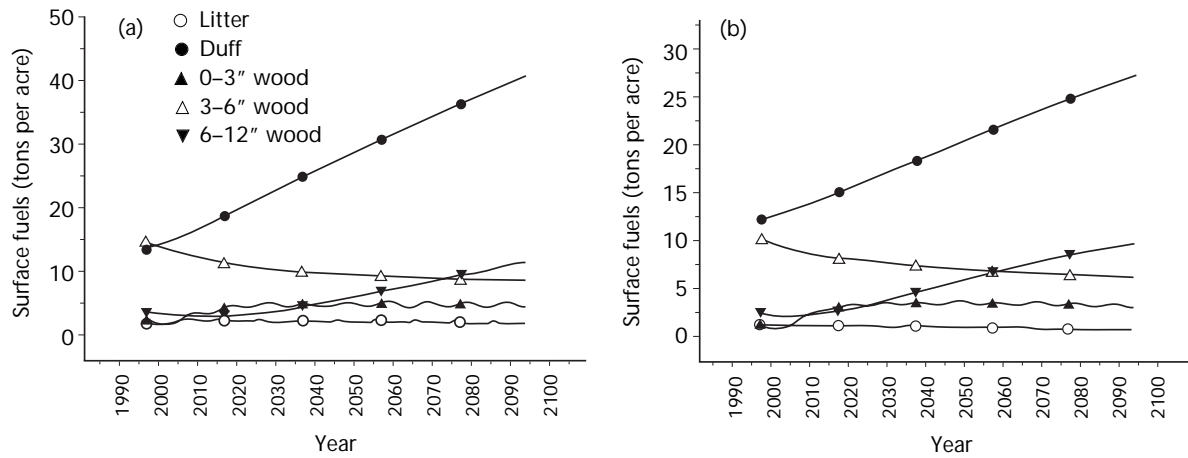


FIGURE 1 Projected trends in surface fuel components on the control (a) and treated areas (b) at Finlay Creek.

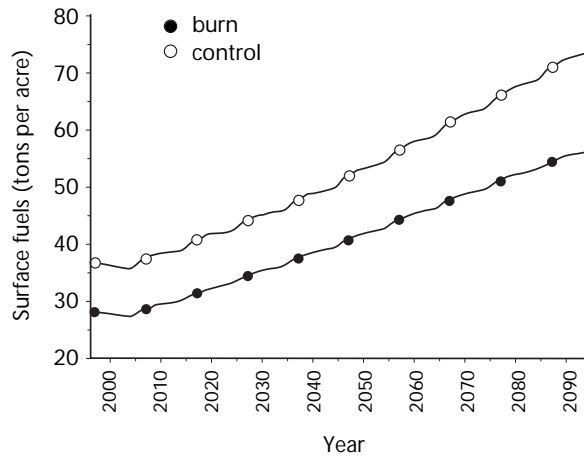


FIGURE 2 Projected increase in total surface load on the treated and control areas at Finlay Creek.

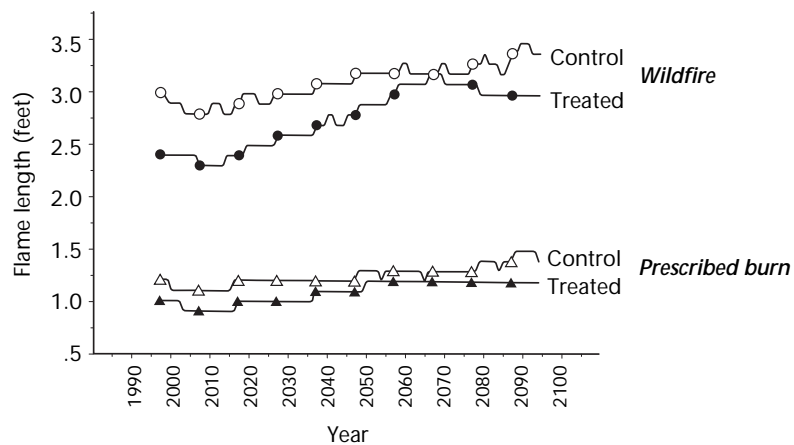


FIGURE 3 Potential flame length on treated and control areas in a typical wildfire or prescribed fire on the Finlay Creek site.

TABLE 1 *Historical and projected changes in crown closure in Okanagan Mountain Provincial Park*

Year	Crown closure class				
	0	1	2	3	4
1938	211	1125	3655	2993	2559
1987	205	505	2692	3135	4002
2036 FVS projection	0	202	10250	0	0

TABLE 2 *Historical and projected changes in crown closure in the Tata Creek landscape unit*

Year	Crown closure class					
	0	1	2	3	4	Non-forest
1952	7055	8274	9128	2602	2040	3143
1992	3083	3840	9879	5274	4804	5376
2032 FVS projection	0	0	3095	4791	18991	-

stands mature. All of these projections are preliminary and require critical evaluation.

The next step in developing the model is to devise evaluation techniques to document changes in forest cover and other stand characteristics and how these will affect values such as wildlife habitat suitability, and risks such as wildfire threat. Techniques are also needed to model multiple stands in a landscape and the effects of different management scenarios.

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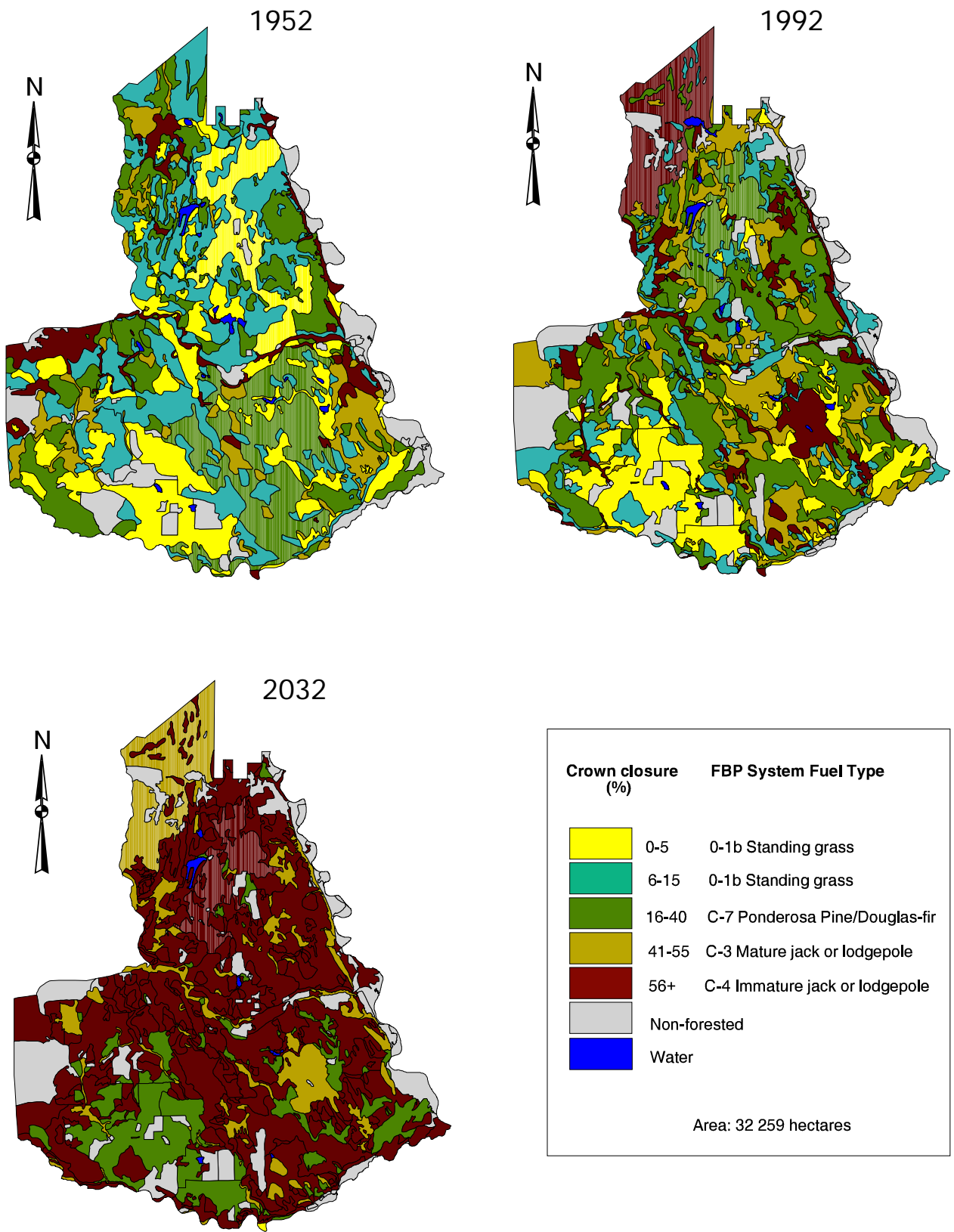


FIGURE 4 Historic and projected changes in crown closure at Tata Creek.

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Landscape Attributes of Interior Douglas-fir Forests on the Fraser Plateau

RICK DAWSON

INTRODUCTION

Resource managers are showing increased interest in natural disturbance regimes and the resulting landscape-level vegetation patterns. Wildlife managers are beginning to relate wildlife requirements to landscape patterns and processes. Timber managers are looking to the natural disturbance baseline for clues on how to manage large landscapes for long-term sustainability and resistance to catastrophic disturbances. Those interested in forest biodiversity are seeking to understand how landscape pattern and dynamics relate to ecosystem functioning and the maintenance of ecosystem diversity.

To develop the understanding of landscape sought by these resource managers, the patterns found on natural forested landscapes must first be described. Describing these patterns is a first step in understanding:

1. how they have developed,
2. how they relate to ecosystem function,
3. how they are changed by development,
4. what the implications of these changes might be, and
5. what management approaches will help achieve our management objectives.

The Forest Practices Code *Biodiversity Guidebook* (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995) outlines the different ecosystem types and their associated natural disturbance regimes, which create distinct landscape-level vegetation patterns. This guidebook classifies the Interior Douglas-fir (IDF) Biogeoclimatic Zone as natural disturbance type 4, which has “ecosystems with frequent stand-maintaining fires.” This paper is one component of a three-part study of the IDF zone. The study’s stand component, which measures the forest structure and attributes of 79 natural and managed stands, is not yet published. The wildlife component, which relates breeding bird abundance to forest attributes, is reported in these proceedings (Waterhouse and Dawson, p. 90). The landscape component described here will document seral and species composition, patch size, and interior versus edge forest for both the current landscape and for a modelled reconstruction of the natural landscape. The focus is on the methodology used and the basic results of the landscape analysis. A more detailed analysis of the results and an in-depth discussion of the implications will be addressed in a future paper.

The study area includes an 1800 km² portion of the Fraser Variant of the Interior Douglas-fir Dry Cool Biogeoclimatic Subzone (IDFdk3), which is located on the Fraser Plateau in the Cariboo Forest Region. The topography of the IDFdk3 is predominantly level to gently rolling and ranges from 750 to 1200 m in elevation.

The landscape was analyzed using a Geographic Information System (GIS) and B.C. Ministry of Forests forest inventory data at 1:20 000. Forest cover polygons were grouped into 19 land cover types (Table 1). Sixteen forested land cover types were defined by leading overstorey species, forest age class, and crown closure for Douglas-fir types. Crown closure was included for Douglas-fir stands because partial cutting, which is the predominant harvesting method for this species in the study area, affects both age and crown closure. Different partial-cutting prescriptions result in stands with various age and crown closure attributes. To aid in analysis and discussion, the forested land cover types are grouped into five age classes in Table 1. These age groupings predate the seral classification developed for the *Biodiversity Guidebook* and use different criteria for different purposes. For example, the “older” forest type discussed here would not necessarily contain the characteristic attributes of old IDF forests. Douglas-fir stands greater than 140 years of age with crown closure of less than 36% are not included in the older category because they are virtually nonexistent in unharvested stands in the study area. The three nonforested land cover types are open range, meadow/shrub/wetland, and water.

Using these land cover types, two types of GIS databases were produced. The first contains the most up-to-date digital information available in 1993

TABLE 1 Land cover type categories used in IDFdk3 landscape attribute analysis

Land cover type	Age (years)	Age classification	Leading tree species	Crown closure (%)
1	1–20	Regenerating	Any	all
2	21–80	Young	Douglas-fir	all
3	21–80	Young	Lodgepole pine	all
4	21–80	Young	Spruce	all
5	21–80	Young	Aspen/Cottonwood	all
6	81–140	Mature	Douglas-fir	0–25
7	81–140	Mature	Douglas-fir	26–35
8	81–140	Mature	Douglas-fir	36+
9	81–120	Mature	Lodgepole pine	all
10	81–140	Mature	Spruce	all
11	81+	Mature	Aspen/Cottonwood	all
12	141+	Mature	Douglas-fir	0–25
13	141+	Mature	Douglas-fir	26–35
14	141+	Older	Douglas-fir	36+
15	121+	Older	Lodgepole pine	all
16	141+	Older	Spruce	all
17	N/A	N/A	Open range, urban	N/A
18	N/A	N/A	Non-productive brush, wetlands, meadows	N/A
19	N/A	N/A	Water	N/A

and is called the “current landscape.” The second database contains a reconstruction of the landscape without forest harvesting and is called the “natural reference landscape.” The natural reference landscape was reconstructed by substituting a new inventory label for each logged block on the current landscape. The new label estimates the current forest cover attributes of the polygon if it had not been harvested. The reconstruction rules used to derive the new label (Appendix 1) were spot-checked using old forest inventory maps (1972–1974). These rules were based on local knowledge of historical logging methods, species use, and forest development following logging. However, no attempt was made to remove the effects of forest fire control when reconstructing the natural reference landscape. The potential effects of the high-frequency, low-intensity fire regimes that characterized this natural disturbance type will be discussed later. From these databases, the area and perimeter of each land-cover polygon were recorded in spreadsheets that were then used for further data analysis. The databases were also mapped to provide a visual record of landscape attributes.

For more focused analysis of the older-forest components, additional databases were produced by grouping land cover types 14, 15, and 16 into combined “older forest” polygons. These polygons were given buffer zones to differentiate the interior or core forest from the outer edge types. In these edge environments, habitat attributes may be significantly affected by surrounding younger or more open habitat. Forest interior polygons were located inside the buffer zones surrounding the interior portion of each older forest polygon. The width of the buffer zone was varied depending on the type of adjacent polygon. For instance, buffers were wider when adjacent to regenerating and younger forest or open habitats, and narrower when adjacent to more mature forests and partially cut stands. Three edge buffer types were defined based on the type of adjacent polygon.

1. Soft edges occurred where a combined old forest polygon borders types 7–13.
2. Hard edges occurred where a combined old forest polygon borders types 2–6 or 12.
3. Very hard edges occurred where a combined old forest polygon borders types 1 or 17–19.

To allow for different interpretations of buffer width, three buffer width scenarios were chosen for the analysis (Table 2). Buffer zones were not produced around small inclusions (3 ha or less) within the perimeter of a combined old forest polygon. The area and perimeter of each interior old forest polygon and the length of each edge type were recorded for both the current and natural reference landscape. These were also mapped as a visual record of the analysis.

RESULTS

The natural reference landscape is dominated by older forest types that form a matrix covering 64% of the total landscape area (Figure 1). This matrix consists mostly of uneven-aged Douglas-fir forests, and lodgepole pine stands, which often include a significant Douglas-fir component in various canopy layers ranging from understory regeneration to large veterans. The

TABLE 2 *Buffer width scenarios used in the analysis of interior and edge old forest.*

	Buffer width (m)		
	Narrow	Medium	Wide
Soft edge	20	40	60
Hard edge	40	100	140
Very hard edge	100	140	200

matrix is highly connected and concentrated in large patches. Approximately 70% of the older forests in the landscape are found in patches greater than 1000 ha in size (Figure 2). Within this mature and old forest matrix, numerous wetlands, small lakes, and surrounding meadow and shrub vegetation areas occur. These brushy wetland and meadow areas are relatively small (i.e., 6 ha average), but can sometimes form larger connected complexes. Other land cover types embedded in the matrix include both deciduous and spruce forests, each of which comprise approximately 2% of the landscape. Younger lodgepole pine stands aged 21–80 years make up 5% of the landscape, while 81- to 120-year-old lodgepole pine stands add a further 12%. Although most early and mid-seral forest types are distributed in relatively small patches, approximately one-third of the 81- to 120-year-old lodgepole pine type is found in patches greater than 1000 ha.

Forests dominated by Douglas-fir and lodgepole pine each form a large proportion of the natural reference landscape (50 and 45% of the forested area, respectively), but differ in both their age structure and spatial distribution. Over the whole landscape, 94% of stands dominated by Douglas-fir are greater than 140 years of age. Stands dominated by lodgepole pine have a greater age spread with 13, 31, and 56% in the 21–80, 81–120, and 120+ age categories, respectively.

The distribution of these two species also varies with elevation within the study area. The lower elevations (i.e., below 1000 m) are almost entirely

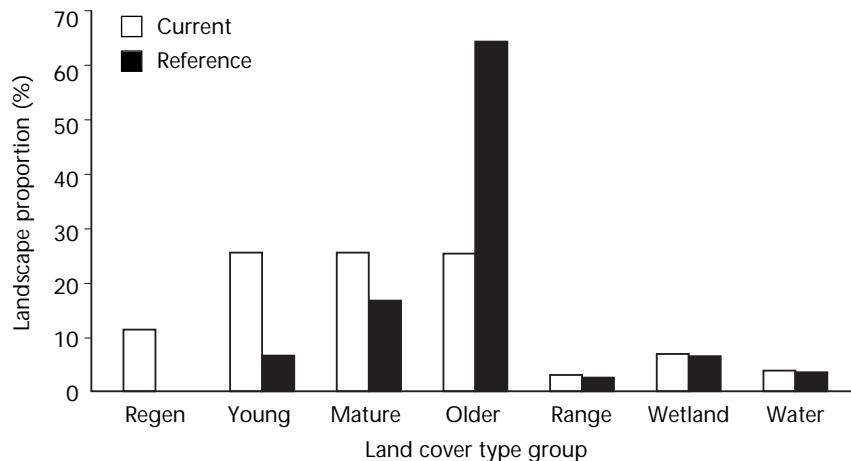


FIGURE 1 *Landscape composition of current and natural reference landscapes in the IDFdK3. The forested component of the landscape is grouped into the four age groupings documented in Table 1. The wetland type includes wetlands, brush, and meadow types.*

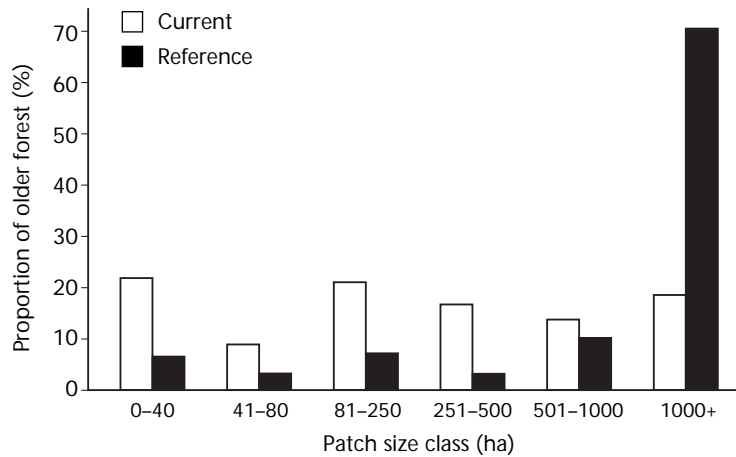


FIGURE 2 *Patch-size distribution of older forest types in current and natural reference landscapes in the IDFdk3.*

forested by Douglas-fir stands. Elevations above 1150 m, which include approximately one-fifth of the study area, are dominated by lodgepole pine (77%), with only 18% of the area forested by Douglas-fir stands.

Older forest types comprise 73% of the forested area in the natural reference landscape (Figure 3). Using the medium buffer-width scenario, approximately two-thirds of this area, or 52% of the total forest area, is far enough from edge influences to be classified as interior forest. The average size of these interior forest polygons is 111 ha, with a very large standard deviation. In contrast, the current landscape has more, but much smaller, interior forest patches with older forest types comprising 29% of the total forest area. Using the medium buffer-width scenario, approximately 45% of the current older forest area, or 13% of the total forest area, can be classified as interior forest.

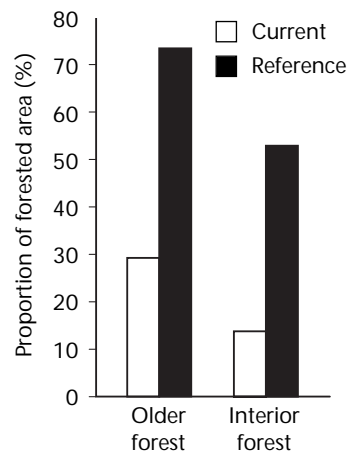


FIGURE 3 *Older forest and interior forest as a proportion of total forest area for current and reference landscapes in the IDFdk3.*

In the current landscape, the older forest matrix is contained in smaller patches and covers less area than it does in the natural reference landscape (Figures 1 and 2). Older forests make up 28% of the current landscape as compared to 64% of the reference landscape. The proportion of older forests in the current landscape in patches greater than 1000 ha is 18% compared to 70% for the natural reference landscape. The portion of the landscape in patches containing water, wetlands, brush, meadows, deciduous, and spruce forests is similar for both landscapes. The major differences in composition are the result of forest harvesting. A 12% increase in the proportion of 1- to 20-year-old forest results from the clearcutting of

older lodgepole pine forests. The 16% increase in 21- to 80-year-old Douglas-fir forests results from the partial cutting of mature and old Douglas-fir stands. The increase in several other age and crown closure categories of Douglas-fir also reflects various levels of partial cutting.

DISCUSSION

The comparison between the current landscape and the natural reference landscape indicates some clear trends in the IDFdk3 landscape since timber harvesting replaced fire as the principal agent of forest disturbance. However, the results described above must be interpreted in the context of the limitations inherent in this type of study.

First, the forest inventory database that formed the foundation of this study was not designed for assessing seral-stage attributes. This is especially true for uneven-aged forest types such as unharvested old Douglas-fir stands, as well as partially harvested stands that are managed as uneven-aged forests. The forest inventory database tends to simplify the complexity of the forest pattern in a number of ways. Forest types covering less than 2 ha are not identified and a large amount of variability in stand structure is often incorporated within the same polygon. Also, the use of a single age as a descriptor of the multi-aged stands common in the IDF does not capture the complex structure of these stands nor the complex disturbance history that has led to their development. As a result, it is only a very approximate predictor of stand-level attributes in either natural or partially harvested stands. Consequently, using the forest inventory data and combining forest inventory polygons into land cover types presents a simplified picture of the actual pattern of vegetation on the landscape.

The natural reference landscape must also be interpreted with caution because it was constructed without accounting for the effects of recent fire suppression. In the last 40 years especially, fires have been vigorously controlled in the IDFdk3. Fire suppression has affected the two main forest types of the IDFdk3 differently. In the lodgepole pine type, suppressing fires has probably resulted in fewer natural young stands, while a greater area of mature and old forests has developed because past wildfires were primarily stand-replacing. In the Douglas-fir type, however, fire suppression has probably not increased the area in young stands, but has altered the structure of mature and old stands. The major change is increased density of Douglas-fir in intermediate and suppressed canopy layers. Data from the Alex Fraser Research Forest in the IDF just outside the study area indicate that fire has been absent for the past 80 years in stands that previously experienced wild-fire on average every 12 years (M. Feller's data in Parminter [1995]).

Results showing a natural reference landscape dominated by a matrix of older forest types in large, well-connected patches are consistent with a disturbance regime of relatively infrequent stand-destroying disturbances. This pattern is especially apparent at lower elevations in the study area where older Douglas-fir stands occupy over 80% of the forested area. Where stand-destroying fires are infrequent, many stands survive to old age, which results in a landscape dominated by a matrix of mature and old forests. The results are also consistent with a regime of frequent low-intensity ground fire that favours the development of biological communities made up of fire-resistant species such as Douglas-fir (Agee 1993; Gayton 1996). The lodgepole pine

component of the landscape, which is increasingly concentrated in the higher elevations in the study area, shows a greater spread in age-class distribution. This type of age-class distribution is more characteristic of the regime of frequent stand-destroying fires common in the adjacent Sub-boreal Pine–Spruce Biogeoclimatic Zone.

The attributes of the natural reference landscape provide a unique pattern of habitat for the biological community adapted to the IDF forests of the Fraser Plateau. This landscape, composed of predominantly older forest types, provided habitat, facilitated movement, and ensured genetic exchange for the organisms that required older forest attributes. The relatively small patches of spruce and aspen found throughout the landscape provided habitat attributes that contrast with the dominant Douglas-fir and lodgepole pine matrix. The many small wetlands and their surrounding forests and shrublands provided habitat for organisms that require the combined resources of these habitat types. Trends showing changes in some of these attributes with development can highlight potential issues of concern for timber, wildlife, and biodiversity resource managers.

ACKNOWLEDGEMENTS

I would like to thank Ordell Steen for his advice throughout the project and thank Michaela Waterhouse and Harold Armleder for their review of this paper. Also I would like to acknowledge the contribution of Ron Fretwell who did the GIS analysis and worked with me to develop the methodology.

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TABLE A1.1 Rules for reconstructing forest cover attributes of logged polygons from the current landscape database to model the natural reference landscape. Each polygon in the current landscape with a history of forest harvesting was given a new set of attributes for species, age class, and crown closure according to the rules in this table.

Group	Current inventory type		Current polygon label		Natural reference attributes			
	Species ^a		Age	Crown closure (%)	Year of harvest	Leading species	Age class	Crown closure (%)
1, 4, 5, 8	Fd, FdS, FdPl, FdDec		all	all	all	Fd	Older	>36
21	S		all	all	all	S	Older	> 36
28	Pl	1-80	all	all	< 1971	Fd	Older	> 36
28	Pl	81+	0-39	0-39	< 1971	Fd	Older	> 36
28	Pl	81+	40+	40+	< 1971	Pl	Older	NA
28	Pl	all	all	all	> 1970	Pl	Older	NA
29	PlFd	1-80	all	all	< 1971	Fd	Older	> 36
29	PlFd	81+	0-39	0-39	< 1971	Fd	Older	> 36
29	PlFd	81+	40+	40+	< 1971	Pl	Older	NA
29	PlFd	all	all	all	> 1970	Pl	Older	NA
31, 41, 42	PlDec, AtComif, AtDec	all	all	all	all	Pl	Older	NA

^a Species abbreviations used in this table: Fd = Douglas-fir; Pl = lodgepole pine; S = spruce; At = trembling aspen; Dec = deciduous; Conif = coniferous.

APPENDIX 2 Detailed landscape attribute data

TABLE A2.1 *Summary of land cover type composition and polygon size in natural reference landscape in IDFdk3*

Composition Land cover type ^a	Proportion of area (%)	Number of patches	Polygon size (ha)	
			Mean	SD
1 Age 1–20 All tree species	0.0	13	3	7
2 Age 21–80 Fd	1.0	101	19	28
3 Age 21–80 Pl	5.1	544	18	36
4 Age 21–80 S	0.0	13	7	6
5 Age 21–80 Aspen	0.9	109	15	40
6 Age 81–140 Fd (cc 1–25)	0.0	4	14	7
7 Age 81–140 Fd (cc 26–35)	0.1	14	18	21
8 Age 81–140 Fd (cc 36+)	1.1	97	21	28
9 Age 81–120 Pl	12.3	572	41	180
10 Age 81–140 S	1.4	205	13	24
11 Age 81+ At	1.3	181	13	16
12 Age 140+ Fd (cc 1–25)	0.1	30	9	12
13 Age 140+ Fd (cc 26–35)	0.4	59	13	26
14 Age 140+ Fd (cc 36+)	41.5	478	165	2100
15 Age 121+ Pl	22.1	464	91	581
16 Age 140+ S	0.5	31	33	62
17 Open range, urban	2.5	147	32	128
18 NPbrush, wetlands, meadows	6.3	2032	6	15
19 Water	3.3	699	9	22

a Species abbreviations used in this table: Fd = Douglas-fir; Pl = lodgepole pine; S = spruce; At = trembling aspen; Dec = deciduous; Conif = coniferous; cc = crown closure; NP = nonproductive.

TABLE A2.2 *Summary of percent area by polygon size for land cover types in the natural reference landscape in IDFdK3*

Land cover type ^a	Percent of area by size class (ha)					
	0-40	41-80	81-250	251-500	501-1000	1000+
1 Age 1-20 All species	0	0	0	0	0	0
2 Age 21-80 Fd	0.4	0.3	0.3	0	0	0
3 Age 21-80 Pl	2.3	1	1.4	0.5	0	0
4 Age 21-80 S	0	0	0	0	0	0
5 Age 21-80 Aspen	0.4	0.1	0.2	0.2	0	0
6 Age 81-140 Fd (cc 1-25)	0	0	0	0	0	0
7 Age 81-140 Fd (cc 26-35)	0.1	0	0	0	0	0
8 Age 81-140 Fd (cc 36+)	0.5	0.2	0.3	0	0	0
9 Age 81-120 Pl	2.5	1.2	2.1	1.2	1.4	3.9
10 Age 81-140 S	0.9	0.3	0.1	0.1	0	0
11 Age 81+ At	0.9	0.4	0.1	0	0	0
12 Age 140+ Fd (cc 1-25)	0.1	0	0	0	0	0
13 Age 140+ Fd (cc 26-35)	0.3	0.1	0.1	0	0	0
14 Age 140+ Fd (cc 36+)	2.0	0.9	2.2	0.8	2.2	33.5
15 Age 121+ Pl	2.1	1.3	2.2	1.1	4.1	11.2
16 Age 140+ S	0.1	0	0.2	0.1	0	0
17 Open range, urban	0.5	0.3	0.7	0.2	0	0.8
18 NPbrush, wetlands, meadows	4.3	1	1	0	0	0
19 Water	1.8	0.6	0.7	0.1	0	0
TOTAL	19.2	7.7	11.6	4.3	7.7	49.4

a Species abbreviations used in this table: Fd = Douglas-fir; Pl = lodgepole pine; S = spruce; At = trembling aspen; Dec = deciduous; Conif = coniferous; cc = crown closure; NP = nonproductive.

TABLE A2.3 *Summary of land cover type composition and polygon size in the current landscape in IDFdK3*

Composition Land cover type ^a	Proportion of area (%)	Number of patches	Polygon size (ha)	
			Mean	SD
1 Age 1–20 All tree species	11.6	300	74	241
2 Age 21–80 Fd	16.6	379	83	239
3 Age 21–80 Pl	7.8	665	22	48
4 Age 21–80 S	0.3	15	33	75
5 Age 21–80 At	0.9	117	15	39
6 Age 81–140 Fd (cc 1–25)	1.8	72	48	91
7 Age 81–140 Fd (cc 26–35)	1.2	56	41	77
8 Age 81–140 Fd (cc 36+)	2.3	129	34	72
9 Age 81–120 Pl	13.3	623	41	172
10 Age 81–140 S	1.6	207	14	31
11 Age 81+ At	1.1	160	13	16
12 Age 140+ Fd (cc 1–25)	1.4	84	33	70
13 Age 140+ Fd (cc 26–35)	2.6	123	40	109
14 Age 140+ Fd (cc 36+)	12.1	759	30	133
15 Age 121+ Pl	12.8	512	48	188
16 Age 140+ S	0.3	27	21	35
17 Open range, urban	2.8	152	35	128
18 NPbrush, wetlands, meadows	6.3	2034	6	15
19 Water	3.3	699	9	22

a Species abbreviations used in this table: Fd = Douglas-fir; Pl = lodgepole pine; S = spruce; At = trembling aspen; Dec = deciduous; Conif = coniferous; cc = crown closure; NP = nonproductive.

TABLE A2.4 *Summary of percent area by polygon size for land cover types in the current landscape in IDFdK3*

Land cover type ^a	Percent of area by size class (ha)					
	0–40	41–80	81–250	251–500	501–1000	1000+
1 Age 1–20 All species	1.6	1.6	2.3	1.2	1.2	3.8
2 Age 21–80 Fd	1.9	1.8	2.9	2.4	0.9	6.7
3 Age 21–80 Pl	2.8	1.5	2.1	1.0	0.3	0
4 Age 21–80 S	0	0	0.1	0.1	0	0
5 Age 21–80 At	0.4	1.5	0.2	0.2	0	0
6 Age 81–140 Fd (cc 1–25)	0.5	0.4	0.4	0.2	0.3	0
7 Age 81–140 Fd (cc 26–35)	0.4	0.2	0.2	0.1	0.3	0
8 Age 81–140 Fd (cc 36+)	0.7	0.2	0.9	0	0.4	0
9 Age 81–120 Pl	2.7	1.5	2.7	1.2	1.9	3.3
10 Age 81–140 S	0.9	0.3	0.1	0.3	0	0
11 Age 81+ At	0.7	0.3	0.1	0	0	0
12 Age 140+ Fd (cc 1–25)	0.3	0.4	0.3	0.4	0	0
13 Age 140+ Fd (cc 26–35)	0.5	0.2	0.9	0.4	0	0.5
14 Age 140+ Fd (cc 36+)	3.1	1.3	2.8	1.5	1.2	2.2
15 Age 121+ Pl	2.0	1.1	2.4	2.6	2.2	2.4
16 Age 140+ S	0.1	0	0.1	0	0	0
17 Open range, urban	0.5	0.3	1.0	0.2	0	0.8
18 NPbrush, wetlands, meadows	4.3	1.0	1.0	0	0	0
19 Water	1.8	0.6	0.7	0.1	0	0
TOTAL	25.2	14.3	21.2	11.9	8.7	19.7

a Species abbreviations used in this table: Fd = Douglas-fir; Pl = lodgepole pine; S = spruce; At = trembling aspen; Dec = deciduous; Conif = coniferous; cc = crown closure; NP = nonproductive.

TABLE A2.5 *Proportion and patch size of combined old forest interior polygons for three buffer-width scenarios in the IDFdK3*

Buffer-width scenario	Old forest (% of forested area)			Patch size (ha)		
	Total old forest	Interior forest	Forest buffer	Mean	N	SD
Natural reference landscape						
Narrow	73	60	13	121	830	782
Medium	73	52	21	111	779	616
Wide	73	46	27	118	648	596
Current landscape						
Narrow	29	18	11	22	1352	128
Medium	29	13	17	20	1011	121
Wide	29	9	20	21	724	126

Partial Cutting in the Coast-Interior Transition: Seedfall, Regeneration, and Stand Structure Changes

BRIAN D'ANJOU

INTRODUCTION

Warm, dry sites in the Coast-Interior transition (e.g., southerly aspects in the IDFWw and CWHds1) are often difficult to regenerate following clearcutting. Severe water deficits combined with planting stock limitations can result in low plantation survival. Silvicultural systems focusing on partial cutting and natural regeneration have good potential for improving regeneration success in these ecosystems. Such silvicultural systems may also satisfy some of the recent concerns expressed about clearcutting and retention of biodiversity in managed stands. Experience with partial-cutting systems is currently lacking in south coastal British Columbia.

The principal objective of the study is to compare clearcut, seed-tree, and shelterwood silvicultural systems for harvesting and regenerating dry Douglas-fir ecosystems in the Coast-Interior transition.

METHODS

The study was established east of Boston Bar at the confluence of the East Anderson River and Utzlius Creek. The site, dominated by Douglas-fir of 110–140 years of age, falls within the Interior Douglas-fir Wet Warm (IDFWw) biogeoclimatic subzone on a southwesterly aspect at 600–800 m elevation. The area was divided into two study blocks: the upper block (25 ha) has gently sloping (10–30%) benched topography, while the lower block (18 ha) is steeply sloping (50–70%) with well-defined draws. Table 1 summarizes stand features.

TABLE 1 *Pre-harvest stand features of upper and lower blocks
(min. 17.5 cm dbh)*

Property	Upper block	Lower block
Gross volume (m ³ /ha)	391	449
Stems per hectare	385	332
Average dbh (cm)	40	45
Average basal area (m ² /ha)	48	52
Average volume per tree (m ³)	1.1	1.4

TABLE 2 *Partial-cutting treatments*

Property	Treatment		
	Seed tree	Shelterwood heavy removal	Shelterwood light removal
No. leave trees per hectare	15	45	83
Tree spacing (m)	26	15	11
Crown cover (%) ^a	10	25	50
Volume removed (%) ^a	95	80	65

a Targets

Treatments The treatments were designed to yield a range of residual overstorey cover from open to full canopy retention and included clearcut, seed-tree, shelterwood heavy- and light-removal treatments, plus full canopy retention (an unlogged control). Table 2 summarizes the partial-cut treatment prescriptions. Leave trees were marked with blue paint before harvesting. In the spring of 1990, 10–12 leave trees per hectare were stressed in an attempt to stimulate cone production in the following year. Stressing was done by cutting the cambium with two narrow saw cuts on opposite sides of the stem.

All treatments were repeated in both the upper and lower study blocks. In the upper block each treatment occupied about 5.5 ha, while in the lower block treatments averaged 4.0 ha. The location of the treatments within each block and the selection criteria for representative “wildlife” trees were recommended by the B.C. Ministry of Environment, in consideration of the high usage of the stand by deer for winter range.

Harvesting Both blocks were logged in the spring of 1991. The lower block was cable-yarded using a Skylead C-40 skyline yarder. Yarding corridors 7 m wide were spaced 40 m apart to match the machine’s 20 m lateral yarding capability. Yarding corridors were handfelled downhill, and the remainder of the strips were felled in herring-bone fashion with tops pointing downhill. The Mini-Mak shotgun carriage contained a radio-controlled braking system, operated by the chokerman, and thus was well suited to partial cutting. The upper block was logged using a combination of rubber-tired grapple and line skidders, D6 cat skidders, and an FMC tracked skidder. The cat skidders were generally used for steeper sections, while the grapple skidder was used over most of the remaining area. Falling was mainly by a Caterpillar 277 feller-buncher (with a 60 cm Koehring head), except for large-diameter trees, which were handfelled.

RESULTS

Post-logging Stand Structure Assessment of residual stand densities and understorey light immediately following harvesting revealed a strong relationship between stocking and understorey light conditions (Table 3). The goal of creating a range of understorey conditions was achieved with a minimal level of damage to the residual stands because of effective harvesting practices. Windthrow events (in 1991 and 1994), Douglas-fir bark beetle (*Dendroctonus pseudotsugae*) attacks, and finally a fire resulting from an escaped campfire kilometres away (1995) all

TABLE 3 *Pre- and post-harvesting stand structure, by treatment*

Stand conditions	Upper block			Lower block		
	Light removal	Heavy removal	Seed tree	Light removal	Heavy removal	Seed tree
Density (stems per hectare)						
Pre-harvest	326	373	358	385	318	300
Post-harvest	78	58	14	106	40	18
% reduced	76	85	96	72	87	94
Basal Area (m²/ha)						
Pre-harvest	52	50	42	46	59	53
Post-harvest	19	12	3	18	13	5
% reduced	64	76	94	61	78	91
Volume (m³/ha)						
Pre-harvest	452	418	341	371	538	480
Post-harvest	177	108	22	156	129	48
% reduced	61	74	93	58	76	91
Light (% full sun)						
Pre-harvest	9	8	5	3	2	5
Post-harvest	55	75	95	54	68	86

have subsequently reduced residual stand densities in the upper block since harvest (Table 4). Rooting depth was the main factor influencing blow-down—95% of downed trees were rooted shallowly over bedrock, dense subsoil, or wet soils. Trees in the lower block have been more resistant to windthrow and withstood the beetle and fire events with low stem mortality. The fire affected both blocks, consuming both the thin organic layer and smaller-diameter woody material.

Seedfall Seed traps were placed in three treatments (unlogged control, seed tree, and shelterwood heavy removal) in both the upper and lower blocks before harvest (1990). Seeds collected in the late fall were sent for germination tests. The second seed collection was in the early spring of the following year. In conjunction with seed counts, cone crops were rated each fall by observing tree crowns with binoculars and classifying cone abundance.

Seedfall in the unlogged stand control was heaviest in 1993, and second heaviest in the year before harvest (1990). Cone crops and seedfall in all treatments were light in the 2 years following harvesting. In 1992, seedfall in the partially cut stands exceeded that of the unlogged controls in three of the four treatment blocks. Germination rates of the seed based on lab tests varied from a low of 43% to a high of 71%. Visual assessment of trees stressed before

TABLE 4 *Stand density reductions (stems per hectare) by windthrow, beetles, and fire since harvesting*

	Upper block			Lower block		
	Seed tree	Heavy removal	Light removal	Seed tree	Heavy removal	Light removal
Post-harvest density	14	58	78	18	40	106
Windthrow	(5.3)	(12.6)	(4.4)	0	0	0
Beetle-killed	(0.6)	(3.3)	(7)	(0.3)	0	(0.5)
Fire-killed	(2.1)	(10.1)	(4.2)	(4.2)	(2.2)	0
Current density	6	32	62.4	13.5	37.8	105.5

TABLE 5 Douglas-fir seedfall: 1990–1995 (incorporates germination rates when available; rounded off to nearest thousand)

Year	Upper block			Lower block		
	Control	Seed tree	Heavy removal	Control	Seed tree	Heavy removal
1990	760 000	1 000 000	1 131 000	979 000	486 000	430 000
1991	10 000	500	0	14 000	0	1 000
1992	34 000	12 000	45 000	8 000	31 000	35 000
1993	1 432 000	183 000	612 000	1 761 000	362 000	731 000
1994	16 000	8 000	22 000	72 000	24 000	32 000
1995	122 000	67 000	231 000	64 000	27 000	23 000

harvest failed to consistently demonstrate enhanced cone production. Frequency of all classes of cone production from no cones to a heavy crop was similar for both manually stressed trees and those trees free of stem scarring.

Regeneration

Advanced regeneration Over 92% of advanced regeneration sampled before harvest died during harvesting activities by stem scarring, by smothering, or by being pulled out of the ground. Three-year height growth of the surviving saplings remains below 10 cm per year. Caliper growth also failed to show positive response to release in the 3 years since harvesting.

Post-harvest natural regeneration The majority of post-harvest regeneration originated from the heaviest seed years of 1990 and 1993 (Figure 1), although regenerating trees from all seed years have established in most treatments. The majority of regeneration in the clearcut resulted from seed-fall in the year before harvesting (1990). Trends on the upper block indicate that higher regeneration densities are associated with higher residual stand densities, with treatment differences increasing over time. The lack of natural regeneration establishment in the lower block cannot be explained. Natural regeneration has been observed to frequently occur on the low side of stumps.

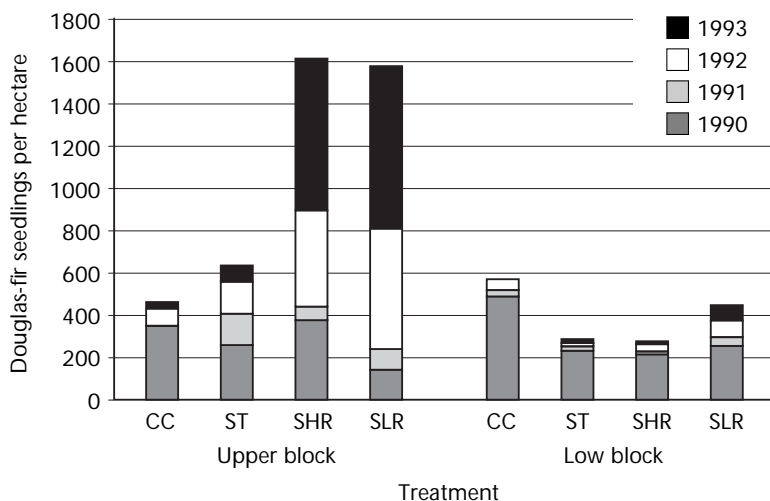


FIGURE 1 Douglas-fir natural regeneration, by seed year.

TABLE 6 *Three-year survival of natural regeneration in the upper block from the 1990 seedfall, by treatment*

Treatment	Survival (%)
Clearcut	75.3
Seed tree	61.4
Shelterwood heavy removal	66.4
Shelterwood light removal	58.3

Survival of the Douglas-fir germinants first sampled in 1991 revealed that 3-year survival was highest in the clearcut and lowest in the shelterwood light-removal treatment (Table 6).

Stocking by naturally regenerated seedlings, including the surviving advanced regeneration, exceeds the minimum goal of 500 well-spaced stems per hectare (minimum 2.5 m spacing), in both upper block shelterwood prescriptions (Figure 2). Naturally regenerated seedling density did not reach well-spaced minimum stocking standards in any lower block treatment.

Germinants in the upper shelterwood treatments preferred some ground disturbance for establishment, with almost one-half of the surviving germinants occurring on mixed substrate. Germination frequency on the undisturbed (intact humus form) and mineral soil (no overlying organic material) was lower than soil substrate disturbance frequency.

Planted regeneration Douglas-fir seedlings (1+0 PSB 415) were planted in the spring of 1992 in all harvested treatments. Seedling survival declined in all three growing seasons in all treatments. Douglas-fir survival in the lower block was similar in all treatments, exceeding average survival in the upper block (Table 7). In the upper block, treatment differences have increased over time, while survival remains highest in the shelterwood light-removal treatment, exceeding that in the clearcut by 11%.

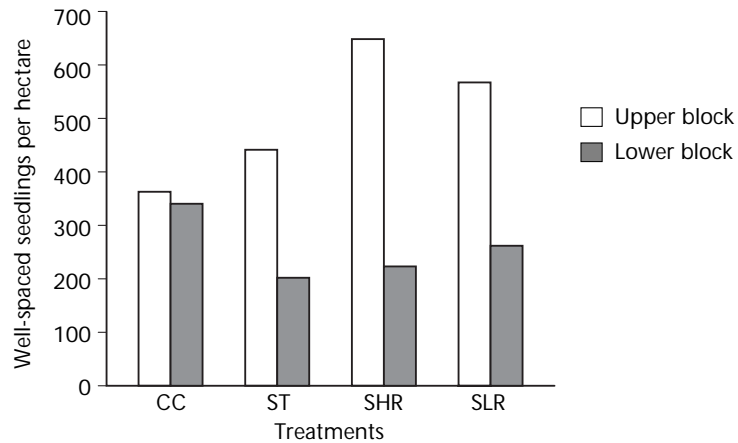


FIGURE 2 *Well-spaced naturally regenerated Douglas-fir seedlings, by block and treatment.*

TABLE 7 Percentage of third-year survival of planted Douglas-fir seedlings, by block and treatment

Treatment	Upper block	Lower block
Clearcut	71.1	84.8
Seed tree	77.8	83.8
Shelterwood heavy removal	74.5	81.3
Shelterwood light removal	82.2	86.2

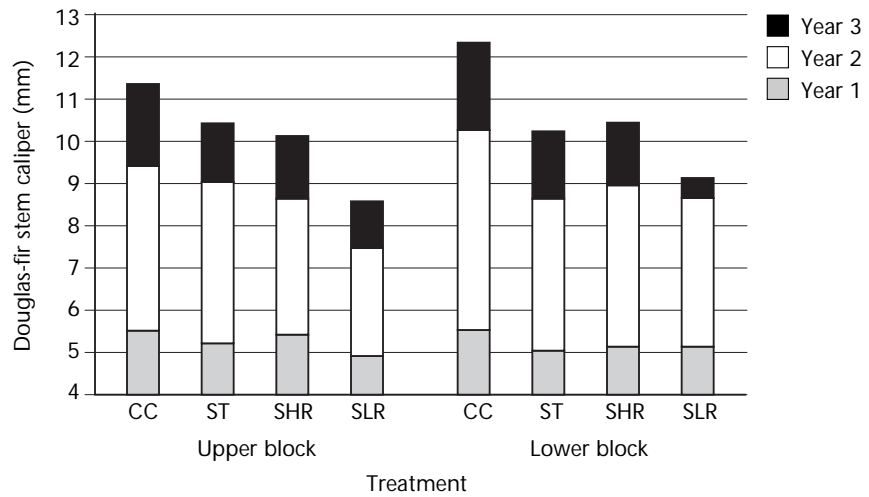
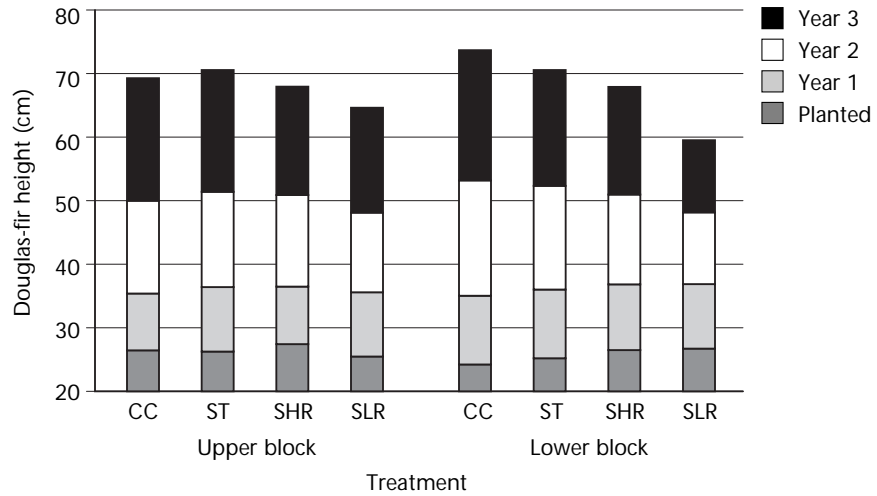


FIGURE 3 Height and caliper growth of planted Douglas-fir seedlings, by year and treatment.

Differences between treatments are greater for total caliper than for total height (Figure 3). Both stem caliper and height appear greater under lower residual overstorey.

SUMMARY

The principal objective of this study was to compare clearcut, seed-tree, and shelterwood systems for harvesting and regenerating dry Douglas-fir ecosystems in the IDFW biogeoclimatic subzone. Monitoring both the stand structure and the establishment of natural and planted regeneration over 3 years has provided some insight into the applicability of these systems in the Coast-Interior transition zone.

Three forces conspired to reduce stand density in the partially cut stands in the upper block since harvesting. Windthrow, which is common following partial cutting, began during the first winter following harvesting in the upper block where thin soils promoted shallow root systems that were ill-equipped to withstand strong winds. A bark beetle attack followed, perhaps in part attracted to the block by the blowdown. Finally the fire, accidental in this case but the common stand-initiating event in these ecosystems, consumed blowdown and killed additional trees. The potential of these agents to affect the desired post-harvest stand structure should be considered when similar silviculture prescriptions are prepared. Partial-cutting prescriptions should allow prompt removal of both windthrow and beetle kill (if volumes justify) in an attempt to minimize subsequent beetle attack. Retaining trees in groups, which furnishes shade and seed to promote regeneration, may provide more windthrow resistance than uniformly spaced single trees. The partially cut stands in the lower block have proved more stable in part because of the deep soils, with little windthrow, beetle attack, or fire-caused mortality. Stand stability means that a greater range of silviculture systems can be considered without large-scale tree loss.

From the regeneration perspective, the substantial differences in natural regeneration abundance was unanticipated between the two blocks. In the upper block, despite two relatively poor seed crops in the three years following harvesting, both shelterwood prescriptions (heavy removal retaining 58 stems per hectare and light removal retaining 78 stems per hectare) enabled natural regeneration to exceed the minimum goal of 500 well-spaced stems per hectare. The upper seed-tree prescription provided a similar number of seeds and surviving germinants to the shelterwood heavy-removal treatment on a residual tree basis, perhaps indicating that the additional sheltering provided by an overstorey was not a significant factor for germinant establishment or survival. The relatively high survival rate of germinants in the clearcut supports that claim. Conversely, in the lower block, natural regeneration establishment has been minimal since harvesting despite comparable seedfall to that in the upper block and suitable soil substrate for germination. Additional research is required to confirm the reason(s) for the differences between the two blocks in natural regeneration development.

Planted stock survival in all treatments and blocks has been encouraging considering the severe water deficits and extreme hot summer conditions on these sites. Planted Douglas-fir survival in the upper clearcut prescription is a concern since survival continues to decline faster than in other treatments

and the lack of natural regeneration recruitment may threaten the goal of meeting stocking objectives. The long-term consequences of reduced seedling caliper and height growth beneath heavier overstories should be considered when prescribing systems that retain a higher number of overstorey trees for extended portions of the stand rotation.

The danger of transferring research results from one site to another within the same ecosystem is demonstrated in this trial where stand response to windthrow and beetle attack, and regeneration dynamics, differ substantially between neighbouring blocks. Establishment and monitoring of operational blocks incorporating shelterwood and seed-tree prescriptions will demonstrate the transferability of the results acquired in this research trial.