Appendix 2: Do near-to-natural size distributions of cutblocks create near-to-natural patterns of old forest?

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Introduction

In British Columbia, as part of a coarse-filter approach to biodiversity conservation, guidebooks and land-use plans recommend patch-size distributions for harvest units that reflect the size distribution of natural disturbances. While harvest unit size distributions directly affect the spatial distribution of early seral forest, conservation concern focuses on old seral forest and its spatial distribution. The influence of harvest unit size on the spatial distribution of old forest is not clear. As added complexity, harvesting disturbance can occur at a faster rate than natural disturbance, consequently reducing the total amount of old forest. The influence of disturbance rate on patch-size distribution is also not clear. This study examines the influence of disturbance rate and pattern on the size distribution of old forest patches. It uses seral stage definitions and disturbance rates applicable to the SBSmc Subzone.

Methods

Simulation model

The simulation model consists of

- raster maps representing forest cover and age
- natural disturbance, harvesting and stand ageing simulations
- routines to determine and report on seral stage and patch-size distributions.

I used the Nadina Forest District as template for the simulation experiments in order to provide a realistic distribution of forest and non-forest cover types. The Nadina landscape is 2.6 million ha in size (represented as 1 ha raster cells), 2.0 million ha of which is forested and available to be disturbed. I set the age of all forest to 400 years old and simulated natural disturbance (65 and 125 year return intervals; see below) for 1000 years to produce the initial age maps used in subsequent simulations.

The natural disturbance model simulates natural disturbance every five years, based on a specified mean disturbance rate and patch-size distribution. It selects the area to disturb in a given five-year period from an exponential distribution having a specified mean disturbance return interval of 65 or 125 years. The rate of disturbance is based on the negative exponential equation that is often fitted to natural disturbance data. Using this equation, the expected proportion of a landscape above a given age equals $e^{-t/b}$ where t is the age of interest and b is the disturbance return interval. The simulation then determines whether the period will have large or small disturbances (equal probability of each) and selects the size of each disturbance patch from exponential distributions with means of 10 ha (small disturbances) and 1200 ha (large disturbances). Disturbance sizes were selected to roughly emulate the Beta distribution of patch sizes for the SBSmc described in Steventon[1].

The harvesting model simulates clearcut harvesting every five years, based on specified annual harvest rate, block size distribution and greenup rules. The annual harvest rate is set to leave the same proportion of old seral forest as is left by the natural disturbance simulations (in some simulations, I included constraints to prevent over-harvesting of old forest). Block size can be set either to a uniform 80 ha or to mimic the biodiversity guidebook recommendations (a "pseudo-natural" distribution; Table 1). Note that sometimes blocks do not achieve target sizes, thus simulated blocks sizes tend to be a little smaller than targets. Greenup rules prevent harvesting within 400 m of a cutblock until it reaches 18 yr old. Without greenup rules, cutblocks are more likely to coalesce into larger units. Older stands are harvested preferentially; minimum harvestable age is 81 yrs. Harvesting changes stand age to 2.5 yr (reflecting the middle of the five year disturbance period). Stand ageing is simulated at five year intervals.

The model calculates and reports the patch-size distribution of each 20-year age class and/or seral stage. Seral stage definitions follow the Biodiversity Guidebook for the SBSmc (early seral <= 40 years; old seral > 140 years). Size classes are based on the biodiversity guidebook (Table 1), but add larger patches (1,000-5,000 5,000-10,000; 10,000-20,000; and >20,000 ha) to provide a more complete picture. The model also calculates and reports patch sizes for interior-old-seral forest, where interior is defined as being more than 100m from young seral forest.

Table 1. Recommended patch-size distribution (target size and area) applicable to the SBSmc (Biodiversity Guidebook 1995). The number of blocks in each size class was calculated for use in the simulation.

Target patch size (ha)	Target Forest area (%)	Mean patch size (ha)	Number of blocks (%)
< 40	10-20	20	78
40 - 250	10-20	145	11
250 -1,000	60-80	625	11

Simulation Experiments

I ran two simulation experiments. The first simulation experiment examined the influence of time since disturbance and seral stage area on patch-size distribution. I set a natural disturbance rate and patch-size distribution to values that are characteristic of the SBSmc (Table 2, scenario 1). I simulated disturbance for 1,500 years and recorded the patch-size distribution in each age class (20 year class size) every 20 years during the last 1,000 years of simulation. I calculated the mean patch-size distribution (mean and standard deviation of the proportion of area in each size class) in each age class over the 1,000 year recording period, translated it to a cumulative patch-size distribution and plotted the cumulative distribution for selected age classes. I repeated the simulations using a higher disturbance rate (Table 2, scenario 6) and compared old seral patch-size distributions under different disturbance rates.

[1] Steventon, J.D. 2002. Draft discussion paper. Historic disturbance regimes of the Morice and Lakes Timber Supply Areas. Ministry of Forests, Smithers, B.C.

The second set of simulations examined the influence of harvest unit size and greenup rules on old seral patch-size distributions. I simulated harvesting with varying harvest unit size and greenup rules (Table 2, scenarios 2 to 5 and 7 to 10) and compared resulting old seral patch-size distributions to distributions generated by natural disturbance (Table 2, scenarios 1 and 6).

Table 2. Parameters used in different simulation scenarios.

Scenario	Target Old seral	Disturbance Type (code)	Natural disturbance return	Natural disturbance frequency[a]	Logging harvest rate[b]	Harvest unit size[c]	Green up applied[d]
1	32%	ND	125	0.80% / yr	---	---	---
2	32%	80a	---	---	0.49% / yr	80	---
3	32%	80b	---	---	0.49% / yr	80	yes
4	32%	250a	---	---	0.49% / yr	1 – 1000	---
5	32%	250b	---	---	0.49% / yr	1 – 1000	yes
6	11%	ND	65	1.54% / yr	---	---	---
7	11%	80a	---	---	0.64% / yr	80	---
8	11%	80b	---	---	0.64% / yr	80	yes
9	11%	250a	---	---	0.64% / yr	1 – 1000	---
10	11%	250b	---	---	0.64% / yr	1 – 1000	yes

a) example calculation: ln(0.32) / -140
b) example calculation: (1 – 0.32) / 140 yr
c) see Table 1 for 1 – 1000 ha size distribution
d) no harvesting within 400 m of harvest units until 14 years have elapsed

Results

Effect of time on patch size

Under natural disturbance, older age classes have more smaller and fewer larger patches than younger age classes. Note that older age classes also have less area because of repeated natural disturbance.

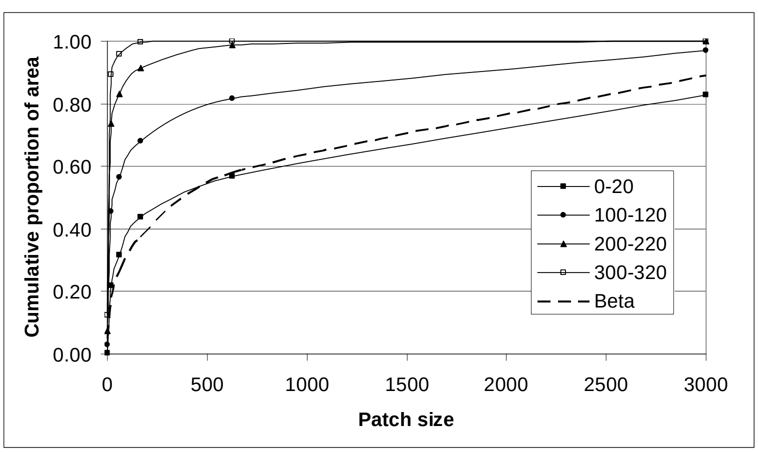

Figure 1. Cumulative proportion of area in each age class (20 year classes) versus patch size, using a 125 year natural disturbance return interval. The disturbance simulation attempted to emulate the Beta distribution of patch sizes in the SBSmc reported by Steventon 2002[1].

Effect of age class breadth on patch size

Seral stages that include a wider range of ages cover more area (e.g., in simulations with the same natural disturbance rate, 0-20 yr covers 14% ± 6%; 0-40 yr covers 29 ± 8%) and have more larger patches and fewer smaller patches than those that include a narrow age range (Figure 2).

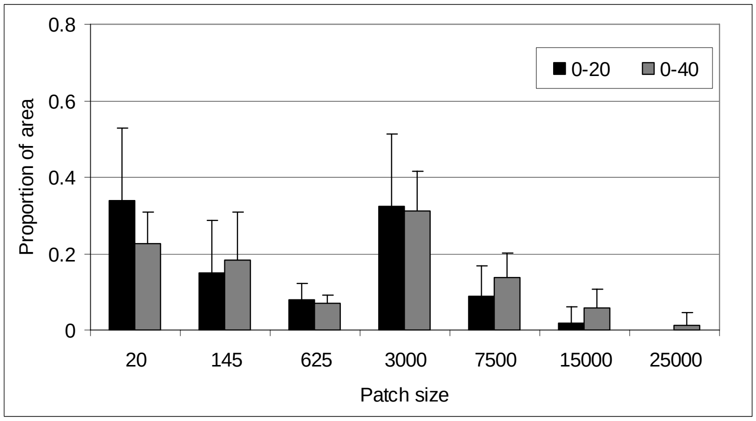

Figure 2. Proportion of area in different patch size classes for different age class ranges: 0-20 yr and 0-40 yr.

Effect of disturbance rate on age class area

Increased natural disturbance rates reduce the amount of mature and old forest (Figure 3).

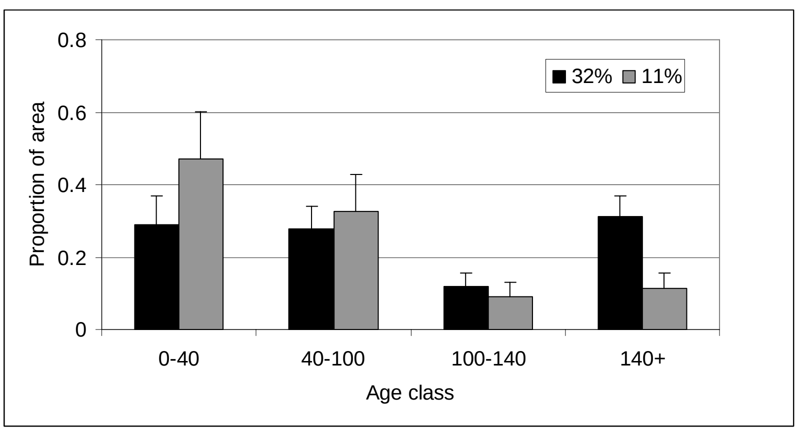

Figure 3. Proportion of area in different age classes for 125 yr (black; leaves 32% old) and 65 yr (grey: leaves 11% old) disturbance return intervals.

Effect of age class area on patch size

If a particular seral stage covers more area because of disturbance history (Figure 3), it has larger patches (Figure 4). As above (Figure 2), more area correlates with larger patch sizes.

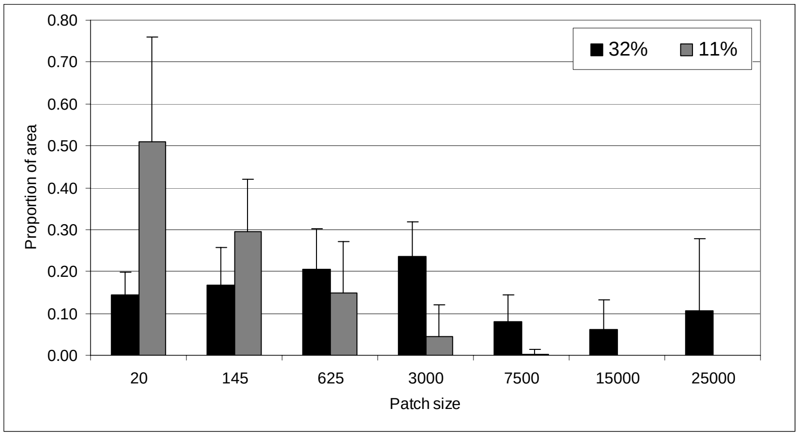

Figure 4. Proportion of area in different patch size classes for different percentages of old seral forest.

__Effect of disturbance pattern on patch size__

Harvesting tends to produce more mid sized patches (particularly, 1000-5000 ha) than natural disturbance (Figures 5 and 6). Both cutblock size and spacing between cutblocks (greenup rules) influences patch-size distribution. A pseudo-natural block-size distribution with greenup rules produces a pattern that seems most similar to natural; this result applies with both 32% old (Figure 5) and 11% old (Figure 6). Ignoring greenup rules has a relatively large influence on the pseudo-natural distribution, but very limited influence on the uniform 80 ha cutblock pattern. The 80 ha cutblock pattern is not clearly worse than the pseudo-natural distribution without greenup rules.

Old forest patch sizes resulting from natural disturbance are more variable than those resulting from harvesting.

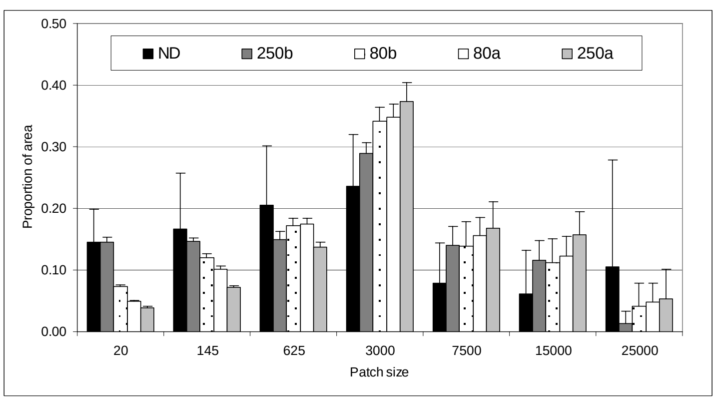

Figure 5. Proportion of area in each patch size class with natural disturbance and different harvesting regimes that leave 32% old forest: 80a means uniform 80 ha cutblocks; 80b is the same as 80a with greenup rules; 250a uses a pseudo-natural patch-size distribution; 250b is the same as 250a with greenup rules.

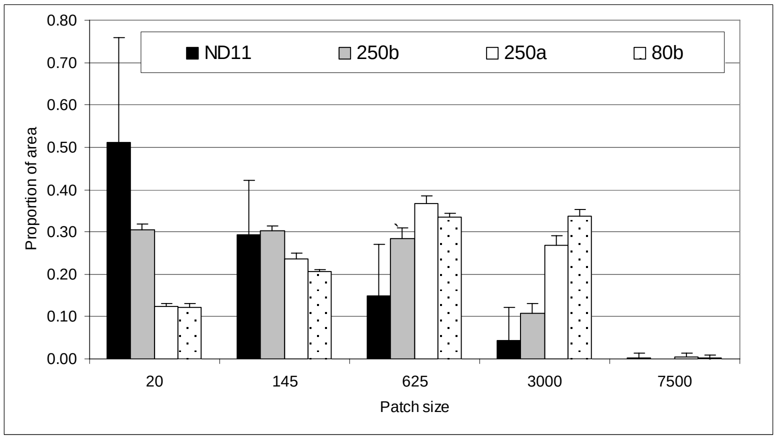

Figure 6. Proportion of area in each patch size class with natural disturbance and different harvesting regimes that leave 11% old forest: 80b means uniform 80 ha cutblocks with greenup rules; 250a uses a pseudo-natural patch-size distribution; 250b is the same as 250b with greenup rules.

Effect of disturbance rate and type on interior old forest

Interior old forest is a subset of old forest that is situated more than 100 m from early seral forest. The interior proportion of old forest is higher when old forest abundance is higher (i.e., lower disturbance rate) and when disturbance is caused by harvesting rather than by natural disturbance (Table 3). Both increased old forest area and harvesting (versus natural) disturbance correlate with increased patch sizes (Figures, 4, 5 and 6). In general, large patches are expected to have less edge. Old forest area and disturbance type interact. The effect of old forest area is larger under a natural disturbance regime.

Table 3. Proportion of old forest classified as "interior" (i.e., situated more than 100 m from early seral forest) under different disturbance rates and types of disturbance.

	Type of disturbance				
Old forest	**Natural**	**80a**	**80b**	**250a**	**250b**
32%	0.73	0.89	0.87	0.92	0.82
11%	0.63		0.85	0.89	0.77

Discussion

The intent of the Biodiversity Guidebook is to maintain biodiversity by maintaining landscape conditions that are similar to natural. The biodiversity guidebook states

…the combination of seral stage distribution and harvest unit size recommendations are designed to ensure that some large, unfragmented mature forests are always present on the landscape.

The near-natural spatial distribution of old forest, envisioned in the Biodiversity Guidebook, may not be achieved for two reasons: first, harvesting disturbance occurs at a faster rate than natural disturbance; and second, cutblock size does not predict old forest patch size. In essence, the patch size distribution of old forest is largely determined by the harvest rate, not by the harvest patch-size distribution.

Reducing the area of old forest reduces the area of large patches. In the SBSmc, the natural disturbance regime disturbs about 0.8% of the forest per year and leaves approximately 32% old forest; at this rate of disturbance, natural disturbance simulations leave about ¼ of old forest in patches exceeding 5000 ha. The biodiversity guidebook recommends leaving 11 – 16 % old forest. Using the same natural disturbance simulation with an altered natural disturbance rate of about 1.54% leaves 11% old forest and produces a very different patch-size distribution than found with 32% old forest, leaving about 1% of old forest in patches exceeding 5000 ha. Similarly, harvesting that leaves 11% old forest leaves about 1% in patches exceeding 5000 ha.

Harvesting to create near-to-natural disturbance patch-size distributions does not create near-to-natural distributions of old forest. If greenup rules are not used, such harvesting tends to create less natural patterns than uniform 80 ha cutblocks. When greenup rules are used, such harvesting creates more natural patterns.

Patch size distributions of old forest do not mirror patch-size distributions of young forest for two reasons. First, natural disturbance chips away at forested patches over time. Without delineation and protection of old forest, harvesting also chips away at mature and old forest, however, to a lesser extent (need to add fig 250b-20yr xxxx). Thus, old forest patch sizes reflect a process of surviving disturbance; they do not strongly reflect the size of the disturbance events themselves (e.g., see 80 ha cutblocks in Figure 6). Second, older age classes include broader age ranges than the recently disturbed age classes (e.g., a 125 year natural disturbance return interval produces 15% < 20 years and 32% > 140 years), thus the total area in the older age class is increased and the probability of forming larger patches is increased (see Figure 2 for effect of area).

Other important aspects of pattern include edge and inter-patch distance. This study indicates that harvesting disturbance increases the proportion of interior habitat relative to a similar amount of natural disturbance. However, because the rate of harvesting is higher than the rate of natural disturbance, the total area of interior forest is much reduced.

This study did not look at inter-patch distance. Other studies show clearly that inter-patch distance increases as patch size increases and as habitat abundance decreases. Thus, although harvesting disturbance tends to produce larger old forest patch sizes than natural disturbance, this occurs at the expense of inter-patch distance. Similarly, with old forest area reduced to 11%, a near-natural patch-size distribution would create larger than natural inter-patch distances. To be meaningful, near-natural patch size targets must be applied in the context of near-natural disturbance rates.