WORKING PAPER 64

Natural Regeneration of Small Patch Cuts in a Southern Interior ICH Forest

2002

BRITISH COLUMBIA

Ministry of Forests Forest Science Program

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Jean L. Heineman, Suzanne W. Simard,
and W. Jean Mather

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National Library of Canada Cataloguing in Publication Data
Heineman, Jean.
Natural regeneration of small patch cuts in a southern interior ICH forest

(Working paper ; 64)

Includes bibliographical references: p.
ISBN 0-7726-4712-7

1. Forest regeneration - British Columbia - Salmon Arm Region
I. Simard, S. (Suzanne). II. Mather, J. (Jean). III. British Columbia. Ministry of Forests. Research Branch. IV. Series: Working paper (British Columbia. Ministry of Forests) ; 64.

SD409.H44 2002 634.9'56'0971168 C2002-960032-4

Citation
Heineman, J.L., S.W. Simard, and W.J. Mather. 2002. Natural regeneration of small patch cuts in a southern interior ICH forest. Res. Br., B.C. Min. For., Victoria, B.C. Work. Pap. 64.

www.for.gov.bc.ca/hfd/pubs/Docs/Wp/Wp64.htm

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ABSTRACT

Almost all harvested sites in the Interior Cedar Hemlock zone are currently planted, but natural regeneration can be a viable reforestation alternative in small patch cuts or where a partial canopy is retained. Natural regeneration is also vitally important in helping to maintain the natural diversity of most reforested sites. In 1997, five small, variable-sized patch cuts in an ICHmw2 forest were studied to determine the effects of opening size, edge characteristics, and substrate quality on the distribution and composition of natural regeneration. All of the openings were readily regenerated with conifers within 50 m of forest edges, but regeneration was patchy in the centre of the opening that exceeded 100 m in width. Regeneration was denser at the south than north edge of openings, and most was of seed-origin that had germinated on forest floor materials. Species composition was similar at the north and south edges, but varied across the opening in response to changes in resource conditions and distance from seed source. Composition of the natural regeneration closely resembled that of the overstorey in adjacent stands.

ACKNOWLEDGEMENTS

This study was originally conducted to facilitate a discussion on natural regeneration during the summer SISCO (Southern Interior Silviculture Committee) field tour in the Salmon Arm Forest District in 1997. The location for the study was suggested by Jim Wright, Don Hudson, and Jeff Fukumoto of the Salmon Arm Forest District. Field work was conducted by Jean Heineman, Jean Mather, David Sword, and Deb Remnant with assistance from Suzanne Simard and Barbara Zimonick. The SISCO field stop was led by Jean Heineman, Suzanne Simard, and Deb Delong. We are grateful to Alan Vyse, Deb Delong, Phil LePage, and Herb Noren for reviewing the manuscript.

Funding for the field work, analysis, and writing was provided by the Ministry of Forests and Forest Renewal BC. Funding for publication of this report was provided by Research Branch, Ministry of Forests. Funding assistance by Forest Renewal BC does not imply endorsement of any statements or information contained in this report.

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INTRODUCTION

Young seral forests of the moist, warm Interior Cedar Hemlock (ICHmw) subzones of southern interior British Columbia are composed of complex mixtures of as many as 12 coniferous and broadleaf tree species that vary in shade tolerance. Natural regeneration of the species mixtures is widely known to occur on cutover sites in the ICH zone, often promptly and abundantly (Weetman and Vyse 1990; Ferguson 1994). Following clearcut harvesting, however, openings in this subzone are typically planted to a relatively few shade-intolerant conifer species such as Douglas-fir (*Pseudotsuga menziesii* var. *glauca* Mirb. Franco) and lodgepole pine (*Pinus contorta* var. *latifolia* Dougl.). Planting is thought to be a more reliable reforestation method than natural regeneration: it can help achieve regeneration obligations within the legislated time period, and it can reduce the need for costly fill-planting should natural regeneration fail. Natural regeneration adds to the stocking and diversity of the plantations, but is usually considered to be of secondary importance in meeting silviculture objectives. One exception where natural regeneration is used exclusively in the ICH is in partially cut areas that were already stocked after harvest (J. Wright and D. Purdy, B.C. Ministry of Forests, pers. comm., 2001).

Alternative silviculture systems that include partial canopy retention and small-sized openings are being increasingly used in the southern Interior (Smith and Smith 1994; Vyse and Delong 1994). One of the expectations with using these systems is that natural regeneration will be a more viable reforestation method than it is for clearcuts (Leadem et al. 1997). Natural regeneration is attractive in these systems for its potential to lower reforestation costs, maintain natural levels of diversity, and ensure healthy root systems (Weetman and Vyse 1990). We undertook this study to improve our understanding of some of the factors affecting natural regeneration in small patch cuts in the ICH zone, and to provide some predictive tools that might help us reduce our reliance on planting under certain conditions.

OBJECTIVES

The specific objectives of this study were to:

- assess the spatial and species distribution of natural regeneration in patch cuts of various sizes and under the forest canopy;
- compare regeneration origin and substrate among species; and
- compare the height of natural and planted seedlings.

METHODS

Study Site

This study was conducted in several small patch cuts at Ptarmigan Creek, which lies on the windward side of the Hunter Mountains between Sicamous and Enderby in the Salmon Arm Forest District (Figure 1). This mesic site, located at 600 m elevation, has a gentle slope and west aspect. It occurs in the Shuswap Moist Warm Interior Cedar Hemlock variant (Lloyd et al. 1990), where it typically experiences warm, moist summers and moderately cold, snowy winters. Mean temperature during the growing season is 16°C, mean minimum temperature in January is –7°C, and mean annual precipitation is 670 mm, of which 290 mm falls as rain during the growing season.

The study area originally supported a 125-year-old stand dominated by Douglas-fir, western redcedar (*Thuja plicata* D. Don.), western larch (*Larix occidentalis* Nutt.), and paper birch (*Betula papyrifera* Marsh.). A series of small patches was harvested in the summer and fall of 1993. In 1995, the harvested patches were planted with a 50:50 mixture of Douglas-fir and lodgepole pine seedlings. The seedlings had been grown for 1 year as plugs in styroblocks that contained cavities either 4 cm wide × 15 cm deep (Douglas-fir stocktype, 1+0 PSB 415B) or 3 cm wide × 13 cm deep (lodgepole pine stocktype, 1+0 PCT 313B). At the time of planting, a considerable amount of post-logging regeneration was observed on the site.

Regeneration Assessments

The study was conducted in five of the Ptarmigan Creek patch openings, which varied in size from 0.4 to 4.3 ha. Only one replicate of each patch size was available for sampling because the cuts were not applied within the framework of an experimental design; instead, operational patch cuts were sampled retrospectively, originally for demonstration purposes at a SISCO workshop (Heineman et al. 1997). The four smallest openings (0.4 ha, 0.6 ha, 0.8 ha, 2.0 ha) were irregular in shape and generally less than 100 m across from the south to the north edge. The largest opening (4.3 ha) was rectangular, measuring about 200 m across from the south to the north edge. The orientation of the cuts and the position of the sun from the south resulted in the north edge of each block receiving the most light over the course of the day.

Regeneration was assessed using a systematic sampling survey during a 1-week period in mid-July 1997. Transects were laid out across the openings in north-south orientation and 40 m apart. Circular plots (10 m^2) were surveyed at 10-m intervals along the transects, starting at the south forest edge and continuing across the opening to the north forest edge. Similar transects were established from the opening edges into the forest and leave areas.

A total of 153 plots were surveyed in the openings and a combined total of 103 plots were surveyed in the forest and leave areas. In every plot, each seedling was tallied according to species, origin (new seedlings, advance regeneration of seed-origin, advance regeneration of layered origin, or planted), and substrate composition (mineral soil, forest floor, or rotting wood). To expedite the tallies in the characteristically dense plots, only seedlings past the cotyledon stage were counted. The height of the tallest natural and tallest planted seedling of each species was also recorded. In the

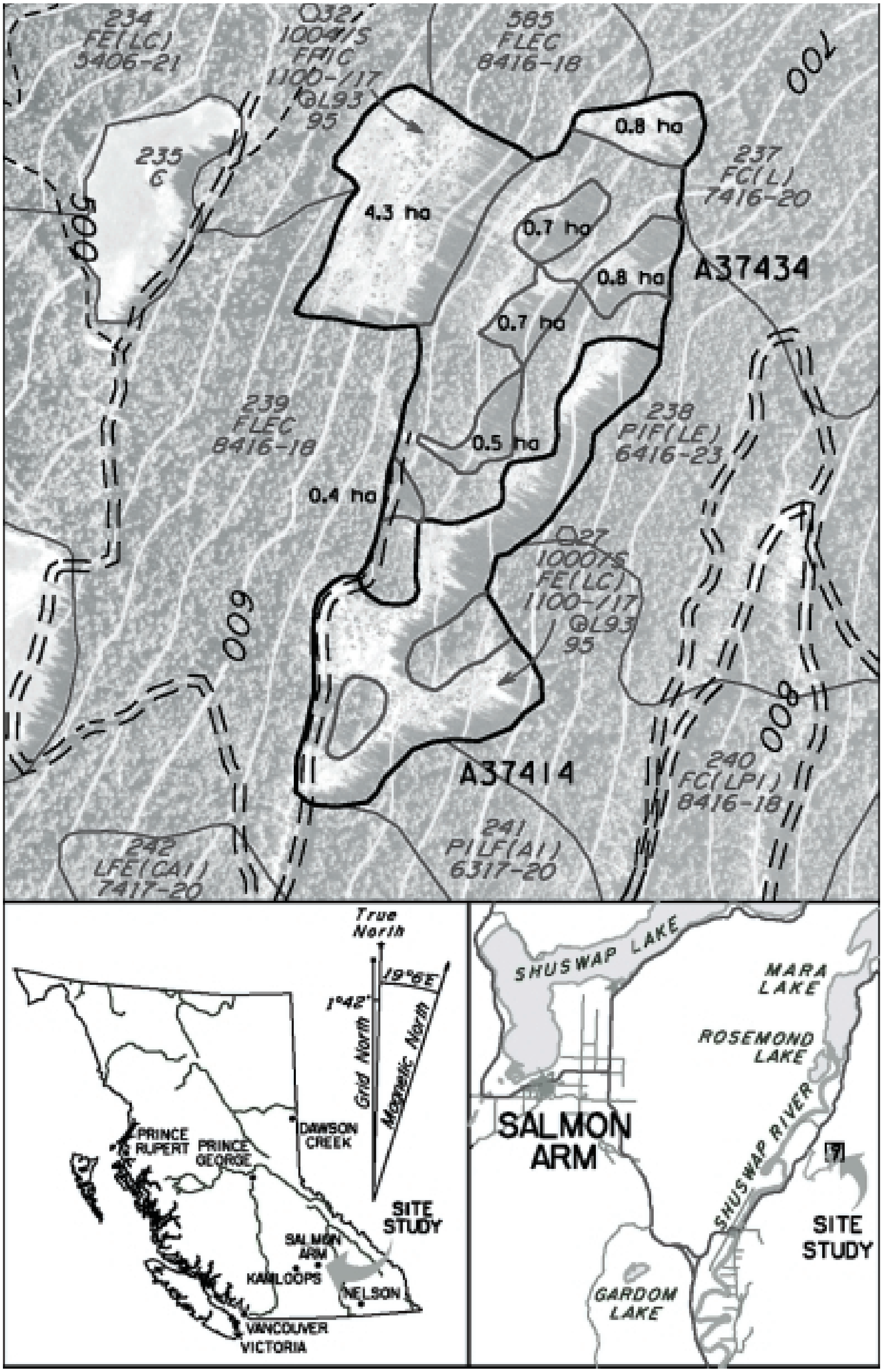

FIGURE 1 *Location and layout of the Ptarmigan Creek study site.*

forest, advance regeneration was tallied and the diameter of each overstorey tree was recorded to determine species composition by basal area.

Analysis

Because only one site was sampled, the scope of statistical analysis was somewhat limited. Nevertheless, trends in regeneration characteristics were identified by calculating mean densities at specific distances from forest edges. Linear regression analysis was used to examine relationships between density of conifer or broadleaf regeneration and distance from the forest edge. Regressions were run separately for the largest opening and the smaller openings combined. One linear model was tested:

$$[1] \quad \log_{10} Y = a + bX$$

where Y is seedling density, X is distance from the forest edge, *a* is conifer or broadleaf density at the forest edge (intercept), and *b* is the slope of the relationship. All conifer tree species and all broadleaf tree species were combined for the conifer and broadleaf density regressions, respectively.

RESULTS

Composition of the Surrounding Forest

Basal area of the forest surrounding the patch cuts at Ptarmigan Creek was 90% coniferous (54% Douglas-fir, 25% western redcedar, 10% western larch, 1% lodgepole pine) and 10% broadleaf (8% paper birch, 2% trembling aspen (*Populus tremuloides* Michx.)) (Figure 2). These species were not evenly distributed, however, and Douglas-fir in particular, was more dominant in some areas than others. The average canopy cover was 65%. Under the canopy, there were an average of 3945 stems ha^{-1} advance regeneration, of which 64% were western redcedar, 24% Douglas-fir, 8.5% paper birch, and 3.5% trembling aspen.

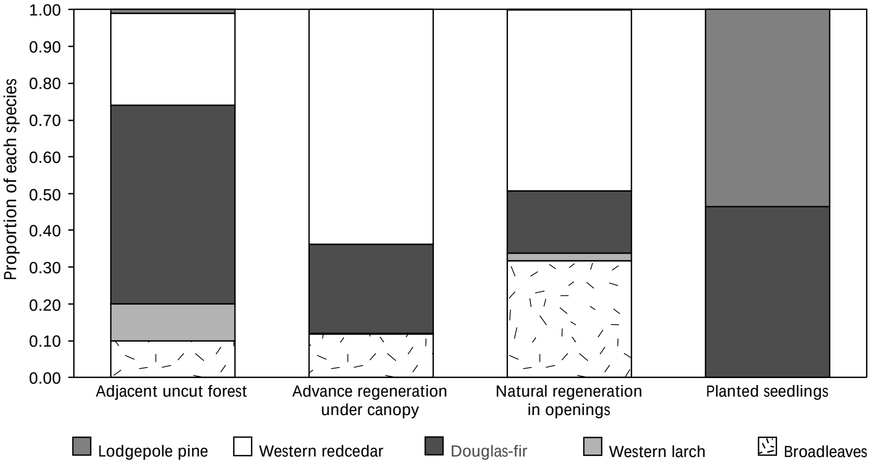

FIGURE 2 *Species composition of the adjacent uncut forest, compared with species composition of advance regeneration under the forest canopy, natural regeneration in harvested openings, and planted seedlings in the harvested openings.*

Distribution and Species Composition of Regeneration Across Openings

Distribution Regeneration density was generally higher in the smaller openings (<2.0 ha) than the large one (4.3 ha), and in both groups of openings the amount and species composition of regeneration varied with distance from the north and south edges (Figures 3 and 4). Regeneration tended to be denser at the south edge (i.e., adjacent to the north-facing forest edge) than at the north edge (i.e., adjacent to the south-facing forest edge), particularly in the small openings. The average combined stocking of conifers and broadleaves within 50 m of the south edge of all openings was 25 000 stems ha^{-1}, of which 17 000 stems ha^{-1} were conifers. Within 50 m of the north edges of the openings, there were 12 000 naturally regenerated stems ha^{-1}, of which 6200 stems ha^{-1} were conifers. The densest regeneration was found within 20- 30 m of the south edge of the small and large openings.

The four smaller openings were, on average, well to heavily regenerated throughout (Figure 3), but the large opening showed patchy regeneration in the centre (Figure 4). Although seedfall is known to decrease with distance from the forest edge, seed from all edges would be distributed throughout small openings because of edge proximity. This appears to be the case in our study, but we have limited confidence in our results at distances >30 m because the sampling density was lower than for distances of 0- 30 m. Data from the largest opening also showed that natural regeneration was abundant to at least 50 m from the forest edge, corroborating the small opening results.

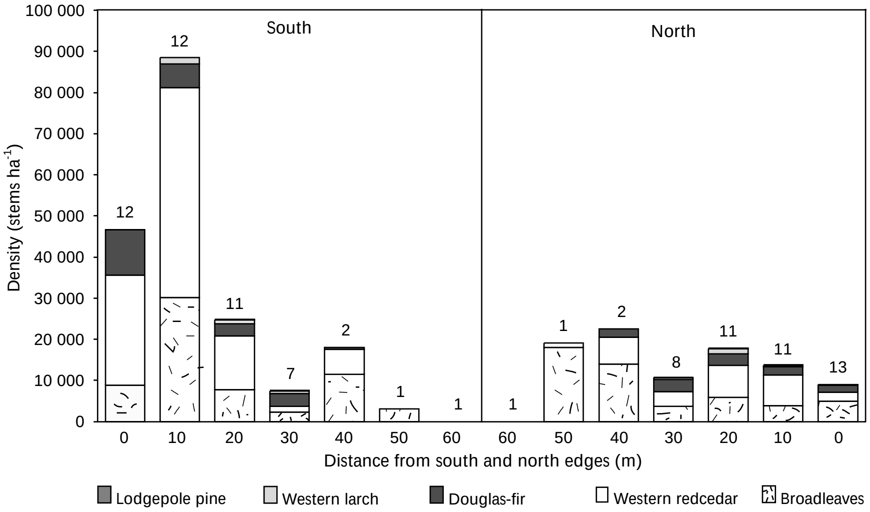

FIGURE 3 *Mean density of natural regeneration at 10-m intervals distributed south to north across the four smallest openings (0.4 ha, 0.6 ha, 0.8 ha, 2.0 ha). Values above each column represent the number of observations at each distance. The left side of the graph shows distance into the gap from the south edge of the opening and the right side shows distance into the gap from the north edge. The centre line represents the approximate centre of the 2.0-ha opening, which was a maximum of 120 m across. The other openings were narrower, resulting in fewer observations at greater distance from the forest edge. Note that Figures 3 and 4 have different y-axis scales.*

Regression analyses indicated generally poor relationships between distance from the forest edge and density of conifer or broadleaf regeneration (Table 1). This was particularly true for the four smaller openings, where distance accounted for less than 8% of the variation in regeneration density. In the large opening, the relationship between distance from forest edge and density was similarly poor for conifers. For broadleaves, however, 37- 38% of the variation in regeneration density was accounted for by distance from the forest edge in the large opening.

Species composition Species composition was similar at the north and south opening edges, but varied with distance from the edge. Broadleaves, mainly paper birch seedlings and trembling aspen suckers, were well represented all the way across the four smaller blocks. Douglas-fir and western redcedar regenerated mainly within a distance of 40 m from the north and south edges of these openings, and western larch within a distance of 30 m. There was very little natural regeneration of lodgepole pine, but where it occurred it tended to be within 30 m of the north and south edges.

In the largest opening, broadleaves occurred mainly within 30- 60 m of the forest edges, but were generally absent right at the forest edge (Figure 4), possibly because of light and soil water limitations. Western redcedar regeneration occurred irregularly across the opening. Its distribution may have been somewhat related to the location of pre-harvest cedar trees and forest gaps. However, only 10% of seedlings were advance layered regeneration. Douglas-fir was the most abundant naturally regenerated conifer species, and it occurred at varying densities across the entire 200-m width of the block. This was probably related to its predominance in the surrounding forest, particularly uphill from the opening. There was very little natural regeneration of lodgepole pine or western larch in the large opening.

In general, natural regeneration was less abundant right at the forest edge than at a distance of 10 m. Brang (1998) noted a similar trend for Norway

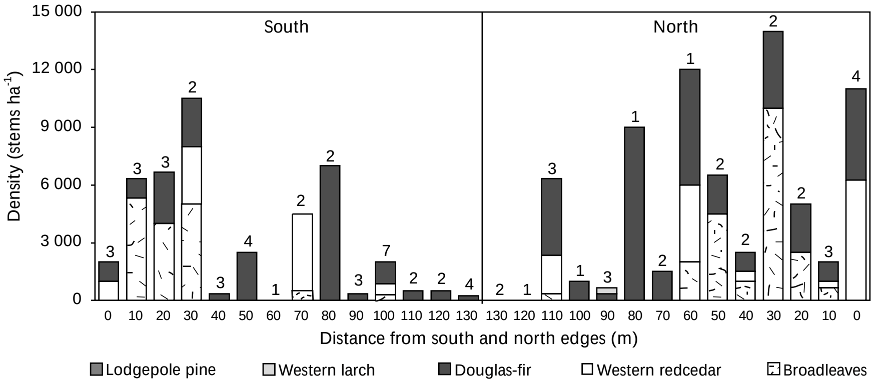

FIGURE 4 *Mean density of natural regeneration at 10-m intervals distributed south to north across the largest opening (4.3 ha). The left side of the graph shows distance into the gap from the south edge of the opening and the right side shows distance into the gap from the north edge. The centre line represents the approximate centre of the opening, and values above each column represent the number of observations at each distance. Note that Figures 3 and 4 have different y-axis scales.*

spruce (*Picea abies* (L.) Karst) that was related to rainfall interception by the canopy edge. In our study, there was an exception to this trend at the north edge of the large opening, where high numbers of Douglas-fir and western redcedar occurred in two plots. This may have been due to particularly heavy seed rain in the local area of those plots.

Origin of Regeneration

In every opening, all species regenerated mainly from seed dispersed since logging (new seedlings) (Figure 5). This was also the case for a natural regeneration study conducted in the ICH in the Nelson Forest Region (Delong and Butt 1994). At Ptarmigan Creek, greater than 99% of regeneration was from new seed for all species, except Douglas-fir (10% advance regeneration of seed-origin) and western redcedar (7% advance regeneration of layered origin). A small amount of trembling aspen regenerated from suckering, and some paper birch had sprouted from stems cut during harvesting. Under the forest canopy, the majority of western redcedar regenerated from layering rather than seed. The number of layered western redcedar stems was higher under the forest canopy than in cut areas, suggesting that many of the layered stems had not survived the harvest. The number of Douglas-fir stems of advance seed-origin was also higher under the forest canopy than in the openings, again suggesting that many had not survived the harvest.

Substrates

More than 90% of seedlings that originated from seed since harvest were growing on forest floor materials. Fewer than 10%, regardless of species, were growing on bare mineral soil and fewer than 5% were on well-decomposed rotten wood. These results likely reflect the abundance of these substrates in openings rather than indicating that forest floor materials are more conducive to regeneration than are other substrates. However, the distribution of forest floor materials was not assessed in this study. Forest floor materials were categorized as thick (>1 cm) or thin (<1 cm), and the distribution of seedlings on the two thicknesses was approximately equal.

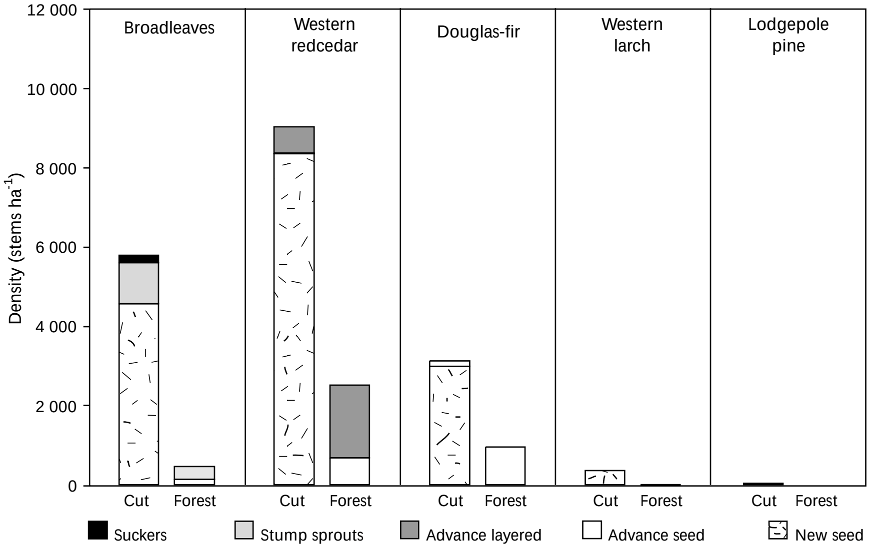

FIGURE 5 *Origin of natural regeneration in openings and under the forest canopy.*

Height of Planted Versus Natural Regeneration

Height of the tallest naturally regenerated and planted seedlings of each species was recorded for each 10-m^2 plot (Figure 6). Planted and natural lodgepole pine both had a mean height of 71 cm, and naturally regenerated western larch was almost as tall (65 cm). Planted Douglas-fir had a mean height of 48 cm, which was nearly twice the mean height of the tallest natural Douglas-fir (26 cm). The lower average height of Douglas-fir naturals suggests a longer ingress period and slower juvenile height growth rate rather than indicating lesser vigour compared with lodgepole pine and western larch naturals. Mean height of the tallest western redcedar seedlings was only 20 cm.

DISCUSSION

Forest management objectives have become increasingly diverse in British Columbia. Markets and technology are changing so rapidly that it is difficult to predict which timber species will be economically valuable in the future. Maintaining diversity in the forest is one way of providing insurance against both ecological and economic unknowns. Even on sites where planting is the best regeneration option, an awareness of the distribution and density of natural regeneration allows the forester to consider a greater variety of species during brushing and juvenile spacing, and thus promote diversity in second-growth ICH forests. This small survey provides some information about natural regeneration potential in the ICHmw subzone.

Our results suggest that small openings in the ICHmw2 can regenerate naturally within 50 m of opening edges, but that openings more than 100 m wide are likely to require planting to ensure adequate stocking throughout.

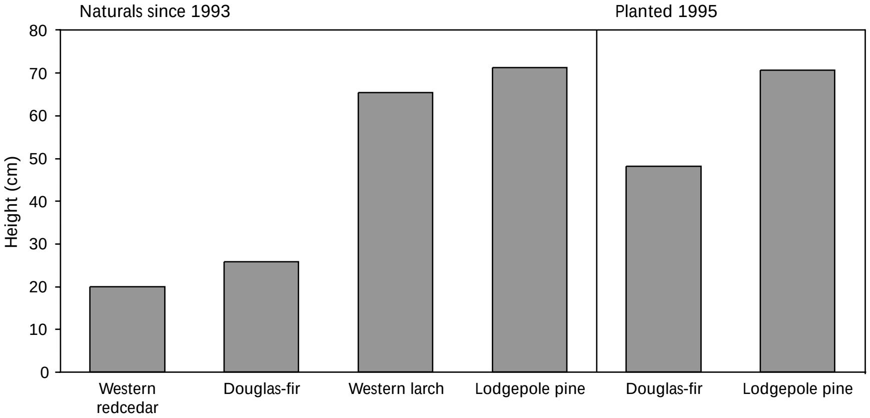

FIGURE 6 *Mean height of the tallest natural and planted seedlings occurring in each plot. Naturals averaged 4 years old and planted seedlings 3 years old (1 year in the nursery and 2 years out-planted) when measurements were taken in 1997.*

These results support Smith and Smith (1994), who found that group selection cuts up to 0.5 ha in size in the ICH were rapidly and abundantly regenerated with several tree species. Our findings also suggest that height growth of natural seedlings, particularly lodgepole pine and western larch, is comparable to that of planted seedlings. Natural Douglas-fir, although shorter than its planted counterpart, was of good vigour and is expected to grow well once it has passed the establishment phase.

Our results should be used cautiously because many factors contribute to the success or failure of natural regeneration. This survey was conducted during a 1-week period in mid-summer 1997, and described regeneration trends at a single location only. In 1997, germinants ranged in age from <1 year old to 4 years old (established soon after harvest), but it is unknown how numbers of new germinants fluctuated from year to year. We also have no information on seed rain immediately following harvest, which is an important determinant of abundance and composition of natural regeneration (Leadem et al. 1997). Factors such as seed and wing size, production periodicity for different species, height of cone-bearing trees, and wind direction would all influence seed dispersal patterns (McCaughey et al. 1985).

Regeneration Density and Edge Effects

In 1997, 4 years after harvest, we found that regeneration density was higher at the south edge of the openings than at the north edge. This higher density may have resulted from shadier, moister substrate conditions at the south edge, which possibly allowed soil water thresholds for survival to be met on a greater variety of microsites.

Greater seedfall may also have accounted for higher densities at the south edge. The prevailing wind in the valley where the Ptarmigan Creek site was located is predominantly from the south, which may have caused greater seed rain inside the gaps at the southern forest edges (Huggard et al. 1999). At the nearby high-elevation Sicamous Creek Silvicultural Systems Project, Kraft (2000) found that the south forest edge consistently supplied the most subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) and Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) seed into adjacent openings, and that the seed rain was positively correlated with the frequency of prevailing winds from the south.

In another germination study in northern variants of the ICH zone, germination rates for several species of sown seed were higher at the south than north edge of canopy gaps, which the authors attributed to higher soil water availability (Wright et al. 1998). Natural regeneration of Douglas-fir and western redcedar was similarly more abundant at the south edge of 150-m wide strip-cuts on a circum-mesic ICHmw2 site near Burton, B.C. (Delong et al. 2000). By contrast, shade-intolerant western larch was more abundant along the more fully illuminated northern edge, most likely reflecting that species' high demands for light (D. Delong, B.C. Ministry of Forests, pers. comm., 2001).

Subsequent to our study, a silviculture survey that followed the drought of 1998 suggested substantial mortality of both natural and planted seedlings in the large opening. Survival was better in areas that were well shaded by south and west forest edges (H. Noren, pers. comm., 2001), paralleling the patterns we observed in our 1997 survey.

Relationships between Regeneration Density and Distance from Edge

In spite of the strong patterns observed with edge aspect in our study, regression analysis showed that distance from the north or south forest edge (east and west edges were not evaluated) was a poor predictor of the abundance of conifer regeneration in both large and small openings. This result suggests that other factors such as substrate, moisture, shade, predation, seed availability are important to conifer seedling establishment. By contrast, distance accounted for 37- 38% of the variation in density of broadleaf regeneration in the larger opening, probably because paper birch seed is light and dependent on wind dispersal (paper birch was the dominant broadleaf species at Ptarmigan Creek). The relationship between density of broadleaf regeneration and distance was poor in smaller openings, likely because seed from all edges would have been dispersed across the entire area.

Regeneration and Choice of Silvicultural System

Results from our study indicate that silviculture sytems using small patch cuts <100 m wide from the south to north edge can be favourable for abundant and diverse natural regeneration in the ICHmw subzone. Another study in northern ICH variants similarly concluded that a silviculture system which combined the creation of large gaps (60% removal through the creation of 0.1- to 0.5-ha openings) with partial harvest (30% canopy removal by cutting single or groups of stems) was the most conducive to natural regeneration (LePage et al. 2000). In that study, the abundance of germinants surviving at least one winter depended on seed abundance and substrate favourability, and the relative importance of these factors varied with canopy structure. In undisturbed stands, for example, there was an abundant seed source, but the substrate (dense moss) was unfavourable for germination. Gaps had lower seedling densities than did partial cuts because there were fewer trees serving as a seed source, but seed dispersal was better because there were fewer physical barriers to dispersal. Seedling density in 20-ha clearcuts was lower than in the partial cuts, with most seedlings occurring in a narrow strip along the southern edges of the openings, a result supported by our study. Gaps, clearcuts, and partial cuts all had diverse mixtures of substrates as a result of disturbance during harvest, but seedling densities in the clearcut may have been reduced as a result of harsher microclimatic conditions.

Regeneration and Substrate Type

In our study, we found that the majority of natural regeneration occurred on organic substrates, which were far more abundant than mineral soil. Mineral soil is documented as the favoured germination substrate for most of the tree species in our study (Leadem et al. 1997), and our results probably reflect the greater availability of organic substrates, more so than their suitability. LePage et al. (2000) found that mineral soil was the most favourable substrate for natural recruitment of most species in the ICHmc in north-central British Columbia, but that it also accounted for less than 7% of total substrate cover. Rotten wood tended to be a favourable substrate for conifers but not broadleaves in that study, and organic materials also supported western hemlock well.

CONCLUSION

Planting, retention of advance regeneration and green trees, the presence of broadleaf trees, and natural regeneration of various conifer species all contribute to the species and structural diversity of regenerating ICH forests. The distribution of natural regeneration 4 years after harvest at Ptarmigan Creek indicates that a second-growth forest of natural origin would eventually resemble the original stand. Our data suggest that Douglas-fir would contribute the greatest basal area, but would be distributed irregularly. Broadleaves and western redcedar would be dominant in localized areas, and lodgepole pine and western larch would form minor but important structural components of the forest. Delong and Butt (1994) also found that natural regeneration on partially cut sites reflected overstorey composition, except in the case of western larch, which did not regenerate well, possibly because of its shade intolerance. The presence of mineral soil as a substrate is also known to be important to the germination and survival of western larch (Stoehr 2000).

By contrast, we predict that favouring the 50:50 mixture of planted Douglas-fir and lodgepole pine as crop trees during subsequent brushing and spacing operations at Ptarmigan Creek would change the character of the mature second-growth forest. In that scenario, the new forest would have a more even distribution of shade-intolerant conifers in the main canopy. Lodgepole pine, which occupied only about 1% of the original stand in our study, would be a major component of the second-growth forest. Shade-intolerant paper birch and aspen would be less prominent than in naturally regenerated stands because the dominant, planted conifers are predicted to be more evenly distributed, reducing the suitability of gaps for broadleaf survival.

Further study is needed to help us increase our understanding of factors influencing natural regeneration in southern Interior ICH variants. The more we know, the better we can confidently prescribe silviculture systems for achieving successful natural regeneration. In this way, not only will we be able to maintain diversity in these complex forests, but we may reduce reforestation costs.

TABLE 1 *Regression coefficients, adjusted r^2 values, and p-values for regression equations relating regeneration density to distance from forest edge for the small and the large openings*

		Small openings (0.4 ha, 0.6 ha, 0.8 ha, 2.0 ha)[a]				Large opening (4.3 ha)[b]			
Edge aspect	**Type of regeneration included in regression**	**n**	**Linear regression equation[c]**	**Adjusted r^2**	**p-value**	**n**	**Linear regression equation[c]**	**Adjusted r^2**	**p-value**
South	Conifers	46	$\log Y = 2.689 - 0.037X$	0.081	0.031	40	$\log Y = 1.193 - 0.001X$	0.000	0.787
South	Broadleaves	28	$\log Y = 2.302 - 0.015X$	0.000	0.410	8	$\log Y = 2.040 - 0.019X$	0.381	0.061
South	All regeneration	48	$\log Y = 2.901 - 0.028X$	0.045	0.079	40	$\log Y = 1.849 - 0.007X$	0.049	0.092
North	Conifers	44	$\log Y = 1.639 + 0.002X$	0.000	0.893	41	$\log Y = 1.686 - 0.005X$	0.064	0.060
North	Broadleaves	28	$\log Y = 1.482 + 0.015X$	0.001	0.321	10	$\log Y = 1.733 - 0.011X$	0.372	0.036
North	All regeneration	45	$\log Y = 2.069 + 0.002X$	0.000	0.857	43	$\log Y = 1.970 - 0.007X$	0.133	0.009

[a] Data from the four smallest openings (0.4 ha, 0.6 ha, 0.8 ha, 2.0 ha) were combined for the regression analysis.

[b] Data from the largest opening (4.3 ha) were used for the regression analysis.

[c] General form of linear equation is: $\log Y = a + bX$, where Y is regeneration density, X is distance from forest edge, a is the intercept, and b is the slope.

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