A Review of Understory Response to Changes in Overstory Conditions and Community Scale Fuel Break Design in Wet Interior Cedar Hemlock Forests in British Columbia

Prepared for the Revelstoke Community Fuel Break Design Project

Thomas Martin

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1. EXECUTIVE SUMMARY

This report attempted to determine an ideal crown closure for a shaded fuel break in an Interior Cedar Hemlock (ICH) forest; an ideal crown closure would slow active crown fires but not promote rapid understory regrowth. However, our research found no perfect level of crown closure. Local foresters and researchers shared experiences of rapid understory regrowth response by herbs, shrubs, and deciduous and conifer regeneration to partial cutting and thinning treatments, but wildfire specialists stated the need to reduce conifer crown closure to reduce the potential for crown fire. The insight provided by researchers and local foresters proved to be invaluable for this project.

A breakdown of our findings is as follows:

- Crown closure of 40% or less is required in conifer dominated forests to effectively slow an active crown fire.
- At 40% crown closure on a mesic ICH site, shade intolerant conifer seedlings can consistently grow over 30cm/year, and shade tolerant conifer species can grow 40cm/year.
- Researchers and local foresters expected that local results would be greater than published trials due to the high productivity of local ICH ecosystems.

We have concluded that the best course of action will be to shift forest species composition in the community shaded fuel breaks from conifer dominated to a deciduous-conifer mix. This process will take time and possibly multiple treatments. Also, prescriptions will differ across the fuel break to account for varying site and forest conditions, and will likely have to be adapted over time as these new forest types develop. A one size fits all approach will not work.

2. INTRODUCTION

As part of their Community Wildfire Protection Plan, the City of Revelstoke is exploring creating a shaded fuel break network in key locations surrounding the community. Shaded fuel breaks maintain a forest canopy but alter forest composition to reduce potential fire behaviour (Agee et al., 2000). However, the forests around Revelstoke are within the Shuswap Moist Warm (mw2), Thompson Moist Warm (mw3), Mica Very Wet Cool (vk1), and Wells Gray Wet Cool (wk1) subzones of the ICH Biogeoclimatic Ecological Classification (BEC) zone, a wet ecosystem with the highest productivity in the interior of the province (Ketcheson et al., 1991). As a result, fuel treatments designed for drier and less productive ecosystems such as the Ponderosa Pine (PP) and Interior Douglas-fir (IDF) forests around Kamloops and Kelowna, or in the Rocky Mountains, would be unsuitable for the Revelstoke region.

In planning an ICH fuel breaks one issue became apparent: fuel breaks designed to slow an active crown fire typically require a crown closure of 35-40% or lower. However reducing local ICH forests to this crown closure would likely result in an immediate significant understory response of herbs, shrubs, and conifer seedlings. The growth response could negate the benefits of fuel treatment, potentially within 10 years, or would require high frequency maintenance treatments. In an attempt to find an ideal crown closure level we reviewed relevant literature and interviewed foresters, scientists, and wildfire professionals.

Through our research we found no such ideal crown closure threshold; fuel treatments must drastically reduce crown closure in conifer forests to reduce fire behaviour potential, and this level of reduction within the wet ICH forests around Revelstoke would result in an explosive understory growth response.

As our research progressed a new practical and effective alternative solution presented itself: the conversion of forest composition over time from conifer dominated to deciduous dominated with some conifer component. Deciduous trees are less flammable and volatile than coniferous species and rarely carry a crown fire. Encouraging deciduous to fill canopy gaps created by treatments would assist in suppressing the understory vegetation response. This concept received support both from the wildfire professionals and local foresters working in the community who were interviewed.

3. LITERATURE REVIEW

This section summarizes the findings from the literature review. A full listing of the literature that was considered is provided in section 8. References. For consistency tree growth over multiple years was converted to annual growth increments. Also due to varying levels of precision amongst studies, all measurements were rounded to whole numbers.

3.1 Understory Vegetation Response

As known to the authors, ICH understory vegetation growth response to canopy reduction has not been thoroughly researched. Although similar sites often develop similar plant communities "the successional pathways that lead to these plant communites are not well understood" (Stevenson et al., 2011, p. 37). Burton et al. (1998) studied berry producing shrub response to partial cutting in the ICH mc2 subzone. Results varied across species and sites but the five shrub species, *Cornus stolonifera (*red-osier dogwood), *Oplopanax horridus* (devil's club), *Rubus parviflorus* (thimbleberry), *Shepherdia canadenis* (soapberry), and *Vaccinium membranaceum* (black huckleberry), were found to have peak growth in 40% to 90% sunlight, or inversely 60% to 10% crown closure. The authors note that full sunlight may not be detrimental to shrub growth, but the loss of moisture through increased exposure and the distubance associated with clear cut logging causing full canopy loss decreases shrub growth. Another study found little change in overall herb cover 5 years after logging via partial cutting in the wk3 subzone, as compared to unlogged control sites (Jull, Stevenson, & Sagar, 1999). However, species composition changes in the opening. Jull et al. (1999) reference an increase in pioneer species such as *Epilobium augustifolium* (fireweed*)*, *Rubus idaeus* (raspberry), and thimbleberry, but a decline in *Meziesia ferruginea* (false azalea) and *Vaccinium ovalifolium* (oval-leaved blueberry). Despite the increase in understory biomass, these deciduous shrub speices would likely reduce fire behaviour potential due to their non-flammable characteristics.

3.1.1 Western hemlock (*Tsuga heterophylla)* ICH Response

Researchers found *Tsuga heterophylla* (Hw: Western hemlock) regeneration to consistently grow well under low light conditions in ICH forests. Backman (2006) measured commercial conifer species seedling growth in varying light conditions at a study site 55km north of Revelstoke in ICHmk1. Under full canopy cover, Backman measured the mean annual growth of Hw seedlings at 15cm. In low cover plots, further than one tree length from the edge of 1ha patch cut, this increased to 21cm. The difference between Hw growth on wet and dry sites was insignificant. Hw was the fastest growing species in the low cover sites, with *Thuja plicata* (Cw: western redcedar) second at 5cm annual growth. In a mw2 site Delong (2000) also found

Hw seedlings to grow vigorously under low light conditions: 8cm/year at 80% crown closure and increasing to 13-30cm/year at 40% crown closure.

In the ICHmc2, with partially logged gaps of 10-300m^{2,} Coates (2000) recorded planted Hw's mean annual growth at 8cm. This increases to 20cm in 1001-5000m^2 gaps. Also, the presence of parent trees contributes to natural regeneration from seed in canopy openings. Coates (1999) found Hw annual growth increases significantly as crown closure is reduced from 100-60% in ICH mc2, which results in 30cm/year growth. Further reduction from 60-0% crown closure only increased growth an extra 7cm/year, or 37cm/year total growth.

3.1.2 Western redcedar (*Thuja plicata*) ICH response

Researchers also found that western red cedar regeneration consistently grew well under low light conditions. In one ICHwk3 trial, planted Cw seedlings grew 22cm/year at light levels of 50-62% (Jull et al. 1999). Coates (1999) also measured Cw seedling growth in ICHmc2 to increase from 0-30cm/year as crown closure was reduced from 100-60%. A further reduction of crown closure to 0% increased growth only 6cm/year, for a total growth of 36cm/year. Coates (2000) found planted Cw seedlings in the ICHm2 grew approximately 3cm annually in undisturbed forests. This increased to 9cm in gaps 10-300m^2 and 18cm in gaps 301-1000m^2.

In an ICHmk1 trial 55km north of Revelstoke, Cw grew less than Hw in low light conditions, but more than shade intolerant species. Backman (2006) measured the annual growth of planted Cw in full canopy cover at only 5cm, compared to 15cm for Hw. Cw increased to an annual growth of 17cm in both moderate and low cover. Moderate sites were within one tree length of the edge of a 1ha patch cut, and low cover sites were further than one length from the edge. Incidentally, when Backman compared Cw seedlings growing on wet (ICHmk1/01 & 04 site series) and dry (ICHmk1/05 site series), average annual leader growth ranged from 15cm on wet sites, to 10cm on dry sites.

In contrast, Delong (2000) found that in ICH mw2 Cw outperformed Hw in low light conditions. At 80% canopy closure Cw seedlings grew 10-13cm annually. This increased to 15cm at 60% canopy closure and 26cm at 40% crown closure.

3.1.3 Douglas-fir (*Psuedodotsuga menziesii*) & hybrid spruce (*Picea hybrids*) ICH response

Both *Psuedodotsuga menziesii* (Fd: Douglas-fir) and *Picea hybrids* (Sx: hybrid spruce) performed as expected for shade intolerant species in research studies, with greater annual growth at lower crown closure levels. In Backman's (2006) patch cutting ICH mk1 trials, both Fd and Sx were excluded from high cover results; not enough seedlings survived to form significant sample sizes. However in moderate cover, defined in the study as one tree length from the edge of a 1ha patch cut, growth increased. Fd seedlings grew 36cm annually and Sx 30cm. Soil moisture affected growth less than light availability. Fd grew 41cm on wet (ICHmk1/01 & 04) sites and 40cm on dry (ICHmk1/05) sites. Sx grew 34cm on wet sites and 29cm on dry sites. Delong et al. (2000) found similar results in a similar patch cutting trail situated south of Nakusp in ICH mw2. At 10% and 20% crown closure Fd grew 20cm and 16cm annually, and *Picea Engelmannii* (Se: Engelmann spruce) grew 16cm. However, at 60% crown closure Fd grew 12cm and Se 7cm. At 80% crown closure growth was limited to 3cm for both species.

Jull et al. (1999) found similar growth results in a northern ICH site. In 0.24ha patch cuts planted Fd seedlings grew 71cm, and Sx 72cm over four years. In comparison Cw grew 88cm. However only 86% of Cw seedlings survived, compared to 95% of Sx and 93% of Fd. Coates (2000) found similar results for Sx in a study site in ICH mc. In gaps of 1001-5000m^2 Sx grew 22cm/yr, but only 2cm/yr in undisturbed forests. Fd was not studied in those trials.

3.2 Fuel Break Effectiveness

Many authors studied fuel treatments and found effective treatments reduce fire behaviour and assist suppression activities (Agee & Skinner, 2005; Agee et al., 2000; Brown, Agee, & Franklin, 2004; Cochrane et al., 2012; Finney, 2001; Graham, Harvey, Jain, & Tonn, 1999; T. B. Jain et al., 2008; Mooney, 2007, 2010; Stephens et al., 2009; Valhalla Wilderness Society, 2004; Wagtendonk, 1996). However, authors also caution the need to tailor fuel treatments specific to place (Agee et al., 2000; Brown et al., 2004; Valhalla Wilderness Society, 2004). One review of American fuel treatments found that some treatments increased predicted fire size, due to increased drying of surface fuels resulting from canopy thinning (Cochrane et al., 2012). Also, understory fuel regrowth can quickly counteract the positive effects of costly fuel treatments (Finney, 2001; T. Jain & Graham, 2007). Therefore, shaded fuel breaks in a moist forest type, such as the ICH found around Revelstoke, need to incorporate local ecology and relevant studies into the design.

An effective fuel break relies on two factors: effective fuel treatment coupled with effective fire suppression response. Despite the differences in fuel types, effective fuel treatments generally follow the same principles: reducing surface fuels, decreasing crown bulk density, raising crown base height, and retaining large, fire resistant trees in an effort to reduce fire behaviour (Agee & Skinner, 2005). Alexander and Lanoville (2004) demonstrated that thinning by itself wasn't effective as the increased exposure accelerated drying of surface fuels. However, fuel treatments do not stand alone; fuel breaks aid fire suppression activities and contribute to wildfire suppression success rates (Moghaddas & Craggs, 2007; Mooney, 2010).

The Province of British Columbia recently published a guide to assist planning fuel treatment areas (Morrow, Johnston, & Davies, 2013). However, little research has been conducted on fuel break design and effectiveness in wet forest ecosystems such as the ICH (Brown et al., 2004; T. B. Jain et al., 2008).

3.2.1 Fuel Break Effectiveness in Wet Forest Types

Little relevant fuel treatment work in moist forest is known to the authors. A locally written report discusses the challenges of fire management in moist forest types around Vahalla Provincial Park (Valhalla Wilderness Society, 2004). The authors state that a one size fits all approach will not work, and fire managers should not blindly use tactics developed for dry, open forest types on the moist ICH. The report advocates the use of understory burning as an ecologically sound management tool, but is often logistically unfeasible due to the catastrophic consequences of an escape. The report recommends using mechanical treatments as an alternative to prescribed fire in close proximity to values at risk, such as within the community of Revelstoke, but offers little specific relevant advice.

Jain et al. (2008) studied the theoretical alteration of fire behaviour from various thinning, patch cutting, and partial cutting silvicultural prescriptions in a moist forest type dominated by western hemlock, western redcedar, Douglas-fir, *Pinus ponderosa (*ponderosa pine), *Pinus monticola* (western white pine), and *Abies grandis* (grand fir) in northern Idaho's Selkirk Mountains The authors applied various treatments to achieve a fuel treatment and ecological resiliency objective. Using FARSITE to evaluate their landscape level treatments, the authors found that fuel treatment reduced spotting, lowered the percentage of crown fire, and reduced overall area burned. However, as the authors created a mosaic of different fuel treatments over the landscape, determining the exact influence of treatment characteristics on fire behaviour, such as crown base height, proved impossible. Unfortunately current literature provides no specific detailed guidance for establishing effective community fuel breaks in the forests around Revelstoke. This heightens the importance of interviews with wildfire specialists.

4. INTERVIEW FINDINGS

As a crucial part of research for this report, we conducted expert interviews with ecosystem scientists, wildfire researchers, wildfire suppression specialists and local foresters. These interviews served two purposes. Firstly, they gathered expert opinions to aid in answering research knowledge gaps. Secondly, they provided local knowledge and opinions regarding establishing shaded fuel breaks in the forests surrounding Revelstoke. The interviewees were asked a specific set of questions depending on if their expertise was in forestry and ecology or wildfire and fuel treatments (Appendix A). We are indebted to those who took time to provide us with their valuable insights.

4.1 Wildfire Specialists and Researchers

Wildfire professionals and researchers included professionals working for British Columbia's Wildfire Management Branch, and national and provincial level wildfire researchers. Experience varied from a lifetime of operations work, strictly research, or a combination of both research and operations experience. The consensus was that an effective fuel break in a coniferous forest requires a crown closure of less than 40%.

4.1.2 Crown Spacing and Closure

All wildfire specialists and researchers agreed that reducing crown canopy cover to a target of 35-40% would greatly increase the probability of slowing or disrupting an active crown fire, likely reducing behaviour to a surface fire and slowing the rate of spread. However, reducing crown closure and the associated forest density allows for increased wind speed and surface fuel drying. One researcher stated that crown closure above 50% would be a waste of time. However they supported back-filling canopy gaps with deciduous trees as an alternative to an open crown spacing; a researcher recommended western larch (*Larix occidentalis*) as a "fire-proof" species, if appropriate for the specific site conditions.

4.1.3 Presence of Deciduous

All wildfire specialists and researchers supported the resilience of deciduous against a continuous crown fire. One said that if we created a deciduous only fuel treatment with road access, it could be defended from almost any crown fire. Another researcher provided anecdotal observational evidence of a continuous crown fire burning into a forest stand of leafed-out aspen and stopping dead. As mentioned earlier, wildfire specialist and researchers supported encouraging or planting of deciduous species, but not always as a first choice. *Larix occindentalis* (Western larch) was also identified as a "fire-proof" conifer species.

4.1.4 Wildfire Behaviour Prediction and Modeling

We were cautioned on relying too heavily on fire behaviour predictions for the fuel types surrounding Revelstoke. The Canadian Forest Fire Behaviour Prediction System (FBP) fuel types were developed primarily for boreal forests and the classification of fuel types around Revelstoke are merely best guesses, and often lack validation. One researcher described the FBP fuel types as "weak in shrublands, coastal forests, and the ICH…but I don't know of anything else demonstrated to be better". Also, due the varying forest stand composition of the ICH, the fire behaviour can vary greatly in a small geographic area. Any FBP fire modeling software would incorporate these unverified predictions into its outputs. That being said, the FBP system still provides a decent prediction of fire behaviour, but may not provide an accurate tipping point for crown fire initiation or sustentation.

Alternative fire behaviour prediction models are available. Two researchers recommended the non-FBP Crown Fire Initiation and Spread model (CFIS) (M.E. Alexander, Cruz, & Lopes, 2006) to identify the “sweet spot” for breaking up a crown fire, but this tool does not address understory fuel issues which is considered critical in the ICH. One researcher indicated the Prognosis^{BC} model could be useful for determining stand response to treatments and necessary maintaince interval, but the model is still being developed.

4.1.5 Additional Insights

One researcher cautioned that the thick organic layer found in ICH forests may be underrepresented in fuel models, and a thick organic layer will increase fire severity, but not necessarily increase rate of spread. An understory broadcast burn would reduce the duff layer, but may be operationally and ecologically unfeasible.

Wildfire specialists were hesitant to suggest an optimum width for fuel breaks due to the unknowns of ICH fuel breaks and the variance in needs due to specific sites. One specialist suggested a minimum width of 60m and an ideal width of 100m, when coupled with a road. A wildfire specialist requested that a fuel treatment be built in tandem with a road large enough to accommodate a full sized pickup. It was their opinion that a fuel treatment without road access would need to be greater width than one with road access. Firstly, an adjacent road provides a pre-built guard alongside the fuel treatment area. Secondly, a road allows efficient road access for fire suppression ground crews, which greatly aids suppression activities.

4.2 Ecosystem Researchers and Professional Foresters

There was an overwhelming consensus that the objective of 35-40% crown closure in the forests around Revelstoke would result in a massive understory growth response of herbs, shrubs, and juvenile deciduous and conifers, with the post-treatment understory composition depending on the pre-treatment composition, season of logging and seed trees. In most cases conifers would dominate this dense understory over time requiring expensive, repeated maintenance or the effects of the fuel treatment would be negated. One experienced local forester commented, “at that level of crown closure I’d expect my hemlock understory to grow a metre a year”.

4.2.1 Crown Spacing and Closure

The complete consensus was that 35-40% crown closure would allow for extensive understory growth response. However, there was no consensus on the appropriate crown closure to inhibit understory regrowth, partially due to differing opinions and partially due to site variability. A forester commented that in their partial cutting silviculture treatments thinning crown closure to 40-50% encourages understory regrowth; a crown closure of 60% and greater suppresses the understory.

One researcher stated that a northern ICH research forest thinned to ~40% crown closure has taken over 20 years to return to ~80% crown closure. Two separate researchers commented on both western hemlock’s more compact crown, which allows less light penetration, and it’s acidic needles which inhibit understory regrowth. A local forester voiced his concern for windthrow susceptibility following partial cutting, especially in hemlock forests, having seen windthrow occur in local forests where fuel break treatments are being considered. This risk should be assessed and addressed in fuel treatment prescriptions.

4.2.2 Conifer Understory Response

The majority of respondents identified western hemlock as having the potential to show ‘explosive’ growth response, but the amount of growth is site and forest dependent. One local forester predicted that, at 35-40% crown closure, an 80% western hemlock understory would develop that would have to be brushed every 3 years to reduce ladder fuels. Another local forester stated that brushing of hemlock is required after partial harvesting. However, western red cedar was also identified as having the potential for significant growth response dependent on the site. Less shade tolerant species such as Douglas-fir and spruce were less of a concern to local foresters.

One researcher commented that conducting treatments in the ICH during the winter would disturb the soil less, thus leading to low density conifer natural regeneration. In his view, the difference was from 100's of seedlings per hectare from winter logging to 1000's of seedlings per hectare due to summer logging. A forester commented that in local ICH forests soil disturbance also depends on the machine operator and the site moisture, and that time of year wouldn't make or break the treatment but winter is preferred. Also, soil disturbance promotes a greater variety of conifer response. With little or no soil disturbance typically only hemlock and white pine naturally regenerate, but with disturbance more spruce, cedar and some fir will also regrow.

4.2.3 Deciduous Understory Response

When asked, foresters and researchers supported the concept of encouraging deciduous regrowth to fill in gaps left by removing overstory conifers. The ability of deciduous to grow in canopy gaps, if not out competed by conifer regeneration, was endorsed by local foresters. A researcher further stressed the importance of leaving deciduous trees to control the presence of *Armillaria ostoyae* (armillaria root rot). A local forester suggested clearcutting and planting deciduous should be considered. Another forester suggested, in appropriate areas, reducing conifer overstories to ~20% crown closure and then heavily promoting deciduous regrowth. However this process takes several years and multiple entries. A local forester commented that, at current market prices, high quality birch sells for more than hemlock.

4.2.4 Vegetation Understory Response

We asked interviewees to predict understory plant response, other than conifer seedling growth response to a crown closure reduction of 35-40%. One researcher specifically identified the potential for herbs and ferns growing extensively following overstory thinning, where these species existed on-site before treatment. Other interviewees predicted moderate to extensive growth response for various understory plants, but acknowledged that post-treatment species composition and response specifically depended greatly on the pre-treatmennt site and plant communities. One local forester predicted an extensive shrub response on wetter sites, which would in turn suppress conifers. However on drier sites would reverse the trend with conifers taking off and suppressing the understory vegetation. Another forester commented that cedar dominated sites tend to have greater understory brush than hemlock and fir dominated sites. We believe, where appropriate, an extensive vegetation response could be utilized by reducing fire behaviour and suppressing conifer regeneration, which would delay maintenance treatments.

4.2.4 Additional Insights

Two researchers suggested that trials from cooler or drier ICH subzones, such as Date Creek, would provide similar results overall, but likely the ICH wetter and warmer subzones around Revelstoke would provide a greater understory growth response. One local forester strongly stressed the importance of leaving some specific suppressed understory and intermediate conifers in order to manage forest succession and root rot.

A consistent theme throughout the interviews was the need for the prescription to be site specific. Many interviewees specifically avoided broad generalizations to apply to all situations. We were told numerous times that answers were “site dependent” or “site specific”. Also interviewees stressed the importance of changing the fuel treatment prescription throughout the treatment area, rather than a one-size-fits all landscape approach, as well as needing to adapt prescriptions over time, as forests respond to treatments and successional patterns develop.

All foresters and researchers stressed the importance of site specific prescriptions to create deciduous dominated shaded breaks in the forests around Revelstoke. The appropriate treatments will depend on the site conditions (ecosystems, soils, terrain, etc.); pre-treatment forest conditions (species composition of herbs, shrubs, deciduous and conifers; age distribution, forest health, etc.); non-timber values/uses; and the feasibility of alternative treatments. It was recognized that multiple entries might be required in some situations to shift overstory species composition from conifers to deciduous. There was agreement that this was a challenging but doable silviculture challenge.

One local forester requested, if possible, to simultaneously manage fuel treatment area for both timber values as well as fire protection values. This forester also stated that while the current price for high quality birch is greater than the price for hemlock, growing and marketing conifer species typically is easier. Also, a local forester asked that woodlot owners displaced by fuel treatments be compensated with new tenures.

5. FURTHER RESEARCH

During the development of this project, the following knowledge gaps became apparent:

- Easily accessible data on conifer understory response to reduced crown closure treatments in wet ICH ecosystems.
- Wet ICH specific research on the growth and survival rate of understory deciduous tree species and understory plant communities at varying crown closures.
- Fire behaviour modeling and prediction specifically for wet forest types such as the ICH.

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7. APPENDIX

Appendix A.

Shaded Fuel Break Effectiveness

1. Just to provide some background, what experience do you have with forest fire suppression, fuel break or fuel treatment creation, and/or research in ICH ecosystems?

2. Have you worked on any projects involving fuel breaks or fuel treatments in the ICH (or similar wet forest type)? Do you know of any other projects or research in the ICH?

3. With these projects do you know what long term monitoring and maintenance programs were implemented, if any? If any exist, is information available? What recommendations do you have regarding shaded fuel breaks based on the monitoring results/maintenance?

4. Can you tell me specifics about the implemented treatment in the prescription?

5. From your experience, how important is crown spacing as a fuel break characteristic (as opposed to crown base height, surface fuel loading, vertical fuel continuity etc)? Would crown spacing of less than 40% be workable in this ecosystem or would 40% be required for ecological reasons?

6. Have you used any fire modeling software to assess the needed fuel characteristics, and did this software adequately model fuel break effectiveness?

7. In your experience in fire suppression, have you had any fires involved in changing fuel types, for example changes in stand structure, composition, or natural or man-made fuel breaks?

   If yes: Do you know the incident number?

   What was the original fuel type and stand structure, and what did the fire burn into, and was the width of fuel type/break?

   What was the resulting change in fire behaviour?

   Did the change in fuel type contribute to successful suppression activities?

8. In your opinion, in the ICH, what is the minimum and optimum width needed for a fuel treatment?

ICH Vegetation / Understory growth response

1. Just to provide some background, what experience do you have as a forester or researcher working in the Southern Interior Forest Region, more specifically in the ICH zone? Any experience with wildfire or prescribed burning?

2. Have you worked much with partial cutting silviculture systems, specifically single or group tree selection, thinning, and shelterwood?

3. Do you know of any such projects around the Revelstoke area or in ICH ecosystems around BC?

4. We're looking into the species composition and growth release following opening crown closure to create shaded fuel breaks, which is similar to partial cutting, but most of the limited available research focuses on merchantable timber species, e.g. Cw, Fd, Sx, etc. Have you heard of any work focusing on deciduous trees and shrubs response to partial cutting or similar silviculture systems?

5. There is anecdotal and observed evidence that shaded fuel breaks of 35-40% crown closure substantially lowers crown fire potential, which allows fire suppression crews to use the breaks to safely conduct suppression.

   If a stand was reduced to 35-40% crown closure, do you think the following species will expand:
   - Slightly (0-25% increase in biomass)
   - Moderately (26-50% increase in biomass)
   - Extensively (>50% increase in biomass)

   - Herbs/ferns
   - Low shrubs (falsebox, huckleberry, snowberry)
   - Large shrubs (willow, dogwood, twinberry)
   - Deciduous (aspen, birch, cottonwood)
   - Hw regeneration
   - Cw regeneration
   - Fd regeneration
   - Sx regeneration

6. What crown closure would you recommend in the following vegetation types on mesic sites in the ecosystems around Revelstoke to achieve the objectives of shaded fuel breaks (safe suppression, minimal maintenance)?

   - Hw dominant overstory/herbs & fern understory
   - Hw dominant overstory/shrub understory
   - Cw dominant overstory/herb & fern understory
   - Cw dominant overstory/shrub understory
   - Fd dominant overstory/herb & fern understory
   - Fd dominant overstory/shrub understory

7. What conifer species and under what conditions (crown closure) are you most concerned about regrowth compromising the effectiveness of a fuel break?

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