J2A.6 REPORT ON THE USE OF THINNING AND PRESCRIBED FIRE TO CONTROL FUELS AND WILDFIRE THREAT IN YOUNG DOUGLAS-FIR/PONDEROSA PINE PLANTATIONS

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1. INTRODUCTION

Prescribed fire, either alone or in combination with thinning operations, is often used to reduce fuels and improve wildfire resilience in mature stands in the interior west (Harrington 1991; Arno *et al*. 1994; Fule *et al*. 2001; Pollet and Omi 2002). Fire is typically applied to these stands once they reach a critical physical state of height and or diameter growth that will enable the majority of the stand to survive either crown and/or cambium heating (Ryan *et al*. 1988; Ryan and Reinhardt 1988; Ryan and Steele 1989; Ryan 1990). Similarly, ecosystem restoration plans, often focusing on developing multi-aged stands where single age-cohort stands currently occur, rarely detail how these new cohorts will be maintained through subsequent understory maintenance burns (Fiedler 1996; Fule *et al*. 2001). These plans, once again, focus primarily on mature stands (>40 years old), not on younger, even-aged plantations or naturally regenerated stands.

Throughout the interior west there are thousands of hectares of even-aged plantations of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), and western larch (*Larix occidentalis* Nutt.) occurring as a result of clearcut, seedtree or shelterwood silviculture systems, and naturally regenerated stands resulting from wildfire. The wildfire threat and resilience of these stands appears to be a function of several site and land management variables. Weatherspoon and Skinner (1995) found a significant correlation between site preparation method and fire damage class (a ranking of fire severity by crown damage) in the 20,000 hectares of area burned in 1987 in the Hayfork Ranger District wildfires in Northern California. Plantations that received no prior treatment after harvest burned completely and severely while broadcast burned units suffered significantly less damage, and even appeared to slow or retard the spread of fire. Hall et al. (1999) found a high correlation between the damage to regeneration stands and aspect, plant association, and post-harvest fuel treatment in western Montana.

For areas that were treated with some form of fuel reduction treatment prior to natural stand or plantation establishment, the issue becomes the length of time it will take before the initial surface fuel treatment wears off. Eventually surface fuels and aerial fuels increase as these stands fill in, begin to self-thin, and subsequently accumulate more and more fuels (Graham *et al*. 1999; Fule *et al*. 2001). The rate at which the threat increases is a function of many site factors aswell as being a function of stand density. Working against the resolution of wildfire threat in these new forests are legislated minimum stocking guidelines (British Columbia Ministry of Forests and Ministry of Environment, Lands and Parks 1995), which are typically focused more on future commercial timber yields than on future wildfire resilience or ecosystem structure.

For areas that did not experience a fuel reduction treatment post-harvest, the new forest is at high risk to excessive fire damage from the outset. Decomposition rates in dry forest types are very slow, meaning, harvest-generated fuels will be a fire hazard for a long period of time.

The conundrum for fuels and fire managers is how to treat the surface and aerial fuels problem without causing excessive mortality to the young stand. The option of simply thinning these stands and waiting for fuels to decompose and hazard to diminish is a long-term, risky proposition. Pre-commercial thinning of stands can create an extreme fire hazard for an extended period of time. Fuels become elevated and as such are much slower to decompose. Thinned stands also allow more irradiance and winds to reach surface fuels, leaving them dryer longer during the fire season. Thinning followed by fuel alteration treatments, such as chipping, piling or complete removal off the site, are prohibitively expensive options considering the scale of the problem. The least expensive option could be thinning followed by broadcast burning.

In 1989 the “Grav” wildfire burned approximately 5 ha of a mixed stand of Douglas-fir and ponderosa pine less than 1 km from the community of Devine, B.C. The area was salvage logged following the fire and replanted the following spring to 1,100 trees/ha. Most planted trees were Douglas-fir, but a small contingent of western larch was also planted even though larch does not naturally occur in the area. The latest regeneration survey carried out by the Squamish Forest District found >7,000 trees/ha, mostly Douglas-fir, but also a moderate density of natural ponderosa pine. Legislatively, the stand is fully stocked and free to grow. A thinning treatment would not be required unless the stocking exceeded 10,000 trees/ha. At

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13 years of age this stand will constitute a significant wildfire threat for many years if left as is. In many cases to date, forest managers in B.C. have left these types of stands untreated. Once declared “free-growing” the obligations to the licensee have been fulfilled and any future stand tending is at the discretion of the Ministry and is prioritized by opportunities for future commercial yields.

Silviculture staff in the Squamish Forest District Small Business Forest Enterprise Program (SBFEP) carried out an experiment in the spring of 2002 to see whether or not a 13 year-old plantation could be thinned and treated with prescribed fire. The theory behind this exercise was to determine the earliest date at which fuel and stand density reduction treatments could be carried out in a young stand, and hypothesize on how often these treatments will likely need to take place in order to maintain lower, yet sustainable stand structure while at the same time address the annual accumulation of fuels. The results from a recent spatial wildfire threat analysis (Blackwell *et al*. 2002a) have determined a high to extreme level of wildfire threat in these ecosystems. Developing low fuel loading, wildfire resilient stands throughout the landscape is seen as a primary component of the SBFEP’s sustainable forest management philosophy (Blackwell *et al*. 2002b).

2. METHODOLOGY

2.1 Thinning prescription

In the fall of 2001 a Stand Management Prescription (SMP) was written guiding and rationalizing the thinning of 1.3 ha of the plantation from >7,000 t/ha to just over 300 t/ha. The target residual density was derived from a) the need to significantly reduce crown bulk density, and b) approach a compromise between the historic range of variability (HRV) for stand structure and species composition for this ecosystem and contemporary societal values. The crown bulk density pre-thinning was 0.4822 lbs/ft³. The HRV for this ecosystem, determined by Gray and Riccius (1999), included 15-35 trees/ha consisting mostly of ponderosa pine, with a smaller proportion of Douglas-fir than there is today. Society’s values for these ecosystems include esthetics, future economic return from timber, wildlife habitat attributes, and wildfire resilience. The balance between these competing values is simplified if we consider the base level of management to be long-term wildfire resilience.

The value of 300 trees/ha was not the initial target; at the outset the experimental unit was divided in two; one section was to be thinned to ~700 trees/ha, and the other ~300 trees/ha. Tree marking focused on the tallest trees with a bias towards ponderosa pine first, western larch second, and Douglas-fir last due to relative fire tolerance at an early age (Crane 1990; Howard 2001; Steinberg 2002). The prescribed spacing in the two units could not be met by marking to leave trees of sufficient height (~2 m) to survive the burn so the default design was to mark all the tall trees in a non-uniform pattern. The result post-thinning was 406 trees in total (312 trees/ha) (Table 1) mostly 2.1 m to 4.0 m in height (Figure 1).

Table 1. Post-thinning stand structure in the plantation.

	Douglas-fir	Ponderosa pine	Western larch	Total
Total no. trees	255	88	63	406
Percentage of total	63	22	15	100

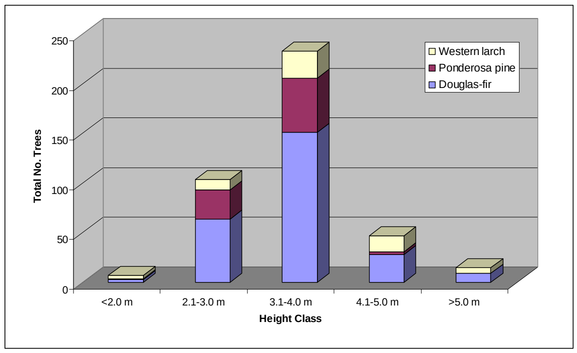

Figure 1. Post-thinning stand density by height class and species.

2.2 Burn prescription

The stand that was affected by the “Grav” fire was densely stocked (>2,000 trees/ha), predominantly 90 year-old Douglas-fir and ponderosa pine. Most trees dated back to the last recorded fire in the area in 1906. Prior to 1906 fires occurred on average every 6.2 years (Gray 2000), and generally resulted in very low stocking. Scattered through the dense stand of small-diameter trees were old (>300 years), large-diameter ponderosa pine and Douglas-fir. Following the salvage operation a large amount of fuel was added back to the surface fuel layer, mostly in the form of branches and small logs. Sixteen permanent fuel inventory plots were randomly placed in the unit utilizing methodology described in Brown *et al*. (1982). The thinning treatment resulted in a large component of 1- and 10-hr fuels (Figure 2) being added to the surface fuel complex. A high level of spatial variability existed for 10-, 100-, and 1000-hr fuels. Fine fuels, the needles from the thinned trees, were spatially consistent throughout the entire unit.

The fuel size category that was considered to constitute the greatest threat to the residual trees was the 14 year-old large, >7.5 cm, wildfire salvage-generated slash. Burning when this material was cured would result in excessive cambium damage to the small diameter residual trees. Crown scorch was more a result of the highly porous and fluffy fuelbed layer made up of tree crowns. Between November and March, however, the unit received several heavy, wet snows that compacted this layer (Figure 3).

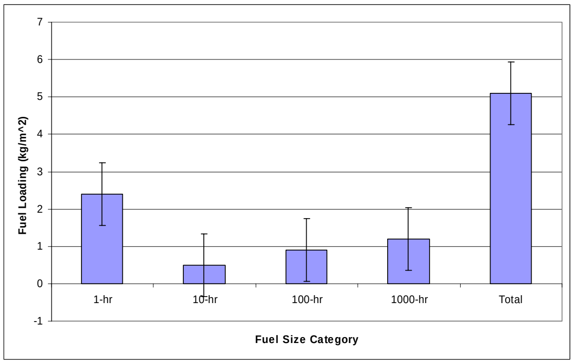

Figure 2. Mean fuel loading by size class and standard error of observations.

The burn prescription was constrained by three objectives: 1) high fuel moisture content in the cured 1000-hr fuels; 2) light winds; and, 3) increasing foliar moisture content in residual trees. The high fuel moisture content in large fuels would limit their combustion and residual tree cambium damage, light winds were needed to dilute convective gases and push the heat through the boles instead of directly up into the crowns, and, increasing foliar moisture was intended to retard foliar flammability.

Figure 3. Gravel pit plantation burn unit 3-months post-thinning. The pre-wildfire stand structure can be seen in the background stand. The tall shrub visible in the photograph is redstem ceanothus. This shrub is not found in the adjacent closed stand, but it is highly likely that ceanothus seeds are stored in the forest floor.

The prescription was built using the CrownMass™ model within the Fuel Management Analyst (Fire Program Solutions L.L.C. 2001) suite of models. A gaming exercise was used to determine the best range of indices that would result in the lowest scorch level and probability of mortality for the residual stand. The range of environmental indices prescribed focused on fuel moisture content (Table 2), midflame windspeed (0-4 km/h), and flame length (<0.5 m) that would keep scorch height below 1 m.

Table 2. Fuel moisture content during the burn.

	1-hr	10-hr	100-hr	1000-hr
Prescribed moisture content range (%)	<8	>9	>11	>17
Actual moisture content range (%)	3-7	5-25+	5-25+	>17

Ignition operations began at 1700 hrs on April 16, 2002. Foliar budburst was underway and the site had received some light precipitation several days prior to light-up. The fuel moisture range during the two day burn was 1-hr = 7%, 10-hr = 6-28+ (6-8% for cured material and >28% for green material), 100-hr = 5-25+ (5-15% for cured material and >25% for green), and 1000-hr = 17-40+. The cured material was differentiated by the presence or absence of bark. The lowest moisture contents for cured material had no bark while cured material with bark contained 5-10% more moisture. Windspeed averaged 2.5 km/h during the burn. Minimum relative humidity the first day was 37% and 15% the second day. Maximum temperature was 12.6˚c and 17.5˚c.

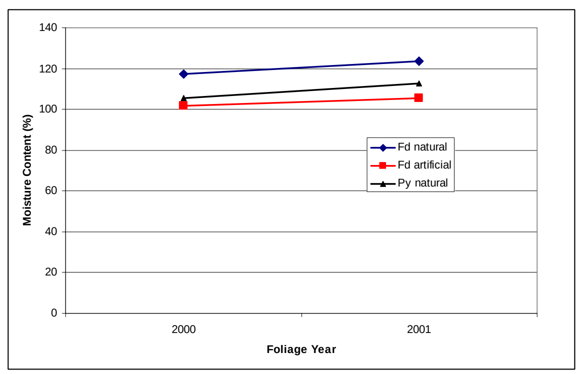

Figure 4. Foliar moisture content by foliage year and species. The treatment contained a combination of both naturally- and artificially-regenerated Douglas-fir. Concerns over off-site planted trees and a lack of physiological adaptations to local site conditions lead to the decision to sample them separately.

Foliar moisture content samples were collected prior to the day of ignition as well as on the day of ignition. Samples were weighed wet, oven-dried, and weighed dry to determine net moisture content. Douglas-fir foliar moisture content (Figure 4) was higher than ponderosa pine, with both averaging >100% moisture content at the time of the burn. Western larch foliar samples were not taken. This off-site species had experienced budburst upwards of 10 days ahead of the planted Douglas-fir and naturally-regenerated ponderosa pine.

3. RESULTS

Post-burn fuel loading (Figure 5) indicates a significant reduction in fine fuels and a minor reduction in the large fuels that were of concern. Foliar fuels, those in the 1-hr timelag category, were reduced 70%, from 2.4 kg/m² to 0.7 kg/m², while branchwood, the 10-hr fuels, were reduced 40%, from 0.5 kg/m² to 0.3 kg/m². The larger branches and boles, 100-hr and 1000-hr timelag categories, were reduced by 18 and 14% respectively, from 0.9 to 0.7 kg/m² for the 100-hr fuels, and 1.2 to 1.0 kg/m² for the 1000-hr fuels.

The burn resulted in a fairly low level of immediate mortality. Douglas-fir experienced the highest level of mortality at 13%, with both western larch (3%) and ponderosa pine having significantly less mortality (2%). A significant number of Douglas-fir "torched" without any prior pre-heating of the crowns despite a >100% foliar moisture content. Ponderosa pine and western larch required extensive crown pre-heating before they would "torch". A breakdown in mortality by height and species (Figures 6-8) reveals somewhat of an expected pattern of decreasing mortality with increasing height. In the case of Douglas-fir and ponderosa pine, the smallest height class (<2 m) had no recorded mortality while the next two height classes, 2.1-3.0 m and 3.1-4.0 m contain all the mortality. No mortality was recorded in the two tallest height classes. Western larch did not experience any mortality in the first two height classes, but did in the next two; 3.1-4.0 m and 4.1-5.0 m.

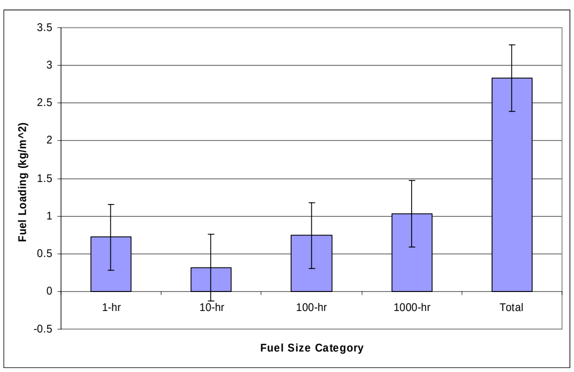

Figure 5. Mean post-burn fuel loading by size class and standard error of observations.

The reasons for the lack of mortality in the smallest height class for all three species could be due to several causes. There were very few of these individuals in the first place (four in total) and they could have all been located in areas that didn't burn very well. Another likely cause is due to ignition crews carefully avoiding these locations in order to prevent damage to these trees.

The proportion of trees in each scorch class by species (Figure 9) follows a similar trend except for the highest scorch class. For each species the proportion of trees scorched decreases from 0-80%, and then shows a significant increase for the 80-100% scorch class.

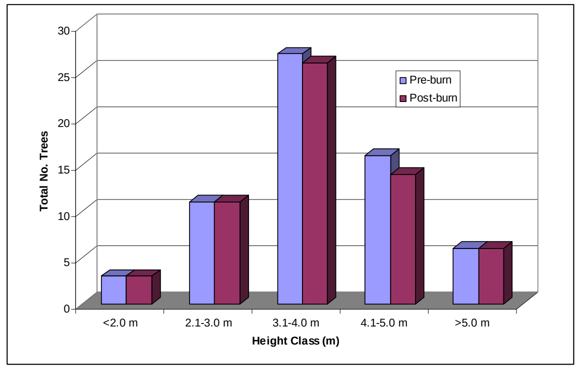

Figure 6. Douglas-fir survival by height class.

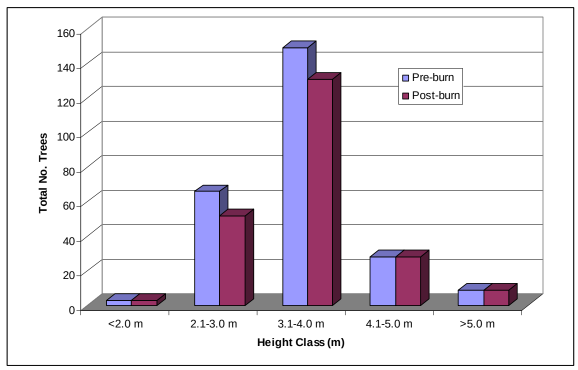

Figure 7. Ponderosa pine survival by height class.

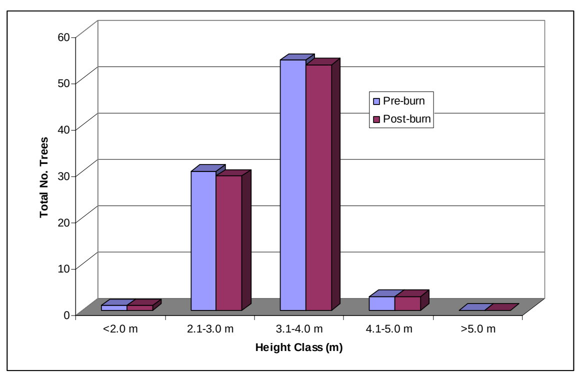

Figure 8. Western larch survival by height class.

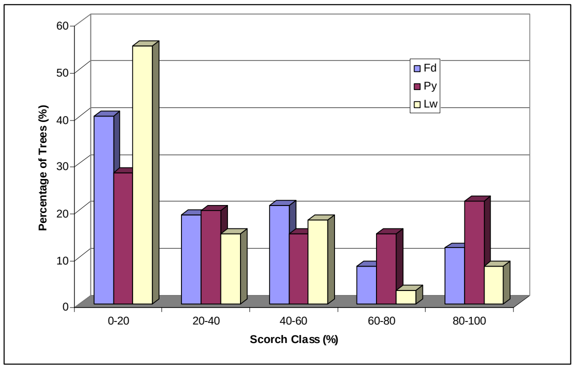

Figure 9. Proportion of trees in each scorch class by species.

Efforts to correlate the proportion of the crown scorched with tree height by species were largely unsuccessful. In each case a minor trend of decreasing proportion scorched with increasing height is evident (Figures 10-12); however, the correlations are very poor.

Mortality one-year post burn by species revealed an unexpected outcome of the burn. Both western larch and Douglas-fir experienced very little increased mortality over the year (3% for LAOC and 4% for PSME) (Figure 13). Ponderosa pine, on the other hand, experienced a 14% increase in mortality. When tested to see if the level of crown scorch had a significant influence on mortality at year-one, PSME mortality was strongly associated with high levels of crown scorch (mean = 92% scorch, p=0.1538), while PIPO was not (mean = 79%, p=0.8052). Too few LAOC are in the stand to compute any useful statistics. Upon investigation, the year-one increase in PIPO mortality appears to be due to an infestation of red turpentine beetles (*Dendroctonus valens* LeConte).

4. DISCUSSION

The experiment was successful in the sense that a 13 year-old heavily stocked plantation could be thinned and burned and not result in a complete loss of the plantation investment. Similar trials are rare in the published literature; Boyer (2000) describes a 16-year biennial burning experiment starting in a thinned 14 year-old longleaf pine (*Pinus palustrus* Mill.) stand in southwestern Alabama, and Biswell (1972), Gartner and Thompson (1972), and Weaver (1967) suggest that burning can be successful under young plantations of ponderosa pine once the trees have reached a certain threshold height. Unfortunately, none of these reports detail fuels very well. Additionally, no studies could be found involving thinning and burning young Douglas-fir or western larch stands. Fire effects information is also sketchy, aside from Boyer (2000) who indicates a stand density reduction of 10% (from an initial 1,243 t/ha to 1,117 t/ha) over the course of eight burns. All suggest that tree height is critical in the decision of when to start understory burning these stands. The longleaf pine stands in the Boyer (2000) study were a mean of 6.7 m in height at age 14 when the first burn took place. Biswell (1972), working in ponderosa pine, suggests that the minimum height should be 3.7 to 4.6 m when burning in litter fuels.

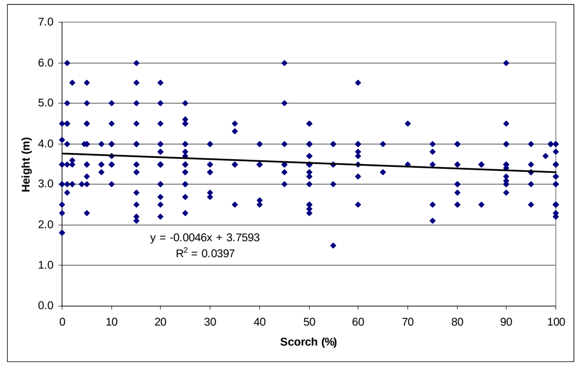

Figure 10. Regression of height over scorch % for Douglas-fir.

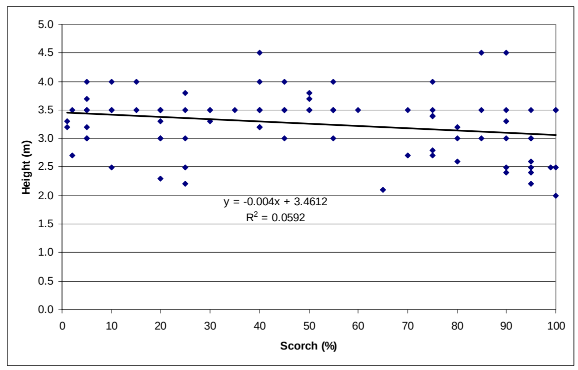

Figure 11. Regression of height over scorch % for ponderosa pine.

From a short term wildfire resilience perspective the treatment was a success. The targeted fine surface fuels that contribute to rapid fire spread were reduced, while the larger fuels that could potentially cause excessive cambium damage were retained. In this sense the fire behavior prescription was accurate for meeting the fuels objective. The thinning prescription was successful in meeting a crown bulk density reduction objective by reducing density 400% from 0.4822 lbs/ft³ to 0.0012 lbs/ft³. This stand could not now support an active crown fire for an extended period of time. The high reduction in surface fuels will prevent fire spread for several years until the grass layer fills in. Unfortunately, many of the large fuels remain, which could, if burned when dry, result in additional stand mortality. This particular fuelbed component continues to be a significant management issue.

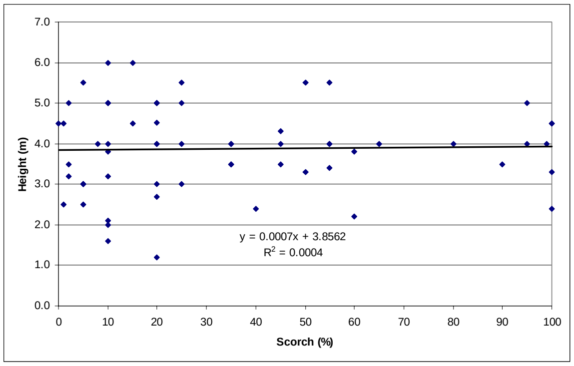

Figure 12. Regression of height over scorch % for western larch.

The results from this experiment pointed out several significant issues affecting our ability to accurately predict ahead of time the effects of this particular treatment on young plantations. While the variability in surface fuel characteristics had little impact on meeting the fuel reduction/maintenance objectives, it may have significantly contributed to the high level of variability in stand-level fire effects. When modeled under uniform fuel and fire behavior conditions, mortality is strongly correlated with species and physical characteristics such as diameter and height. At a critical threshold level of fuel characteristics, i.e., loading, particle distribution, and depth, the probability of complete stand loss stays constant despite a high variability in fire behavior. Below this critical threshold fire effects variability could be attributed to both fuel characteristics and fire behavior.

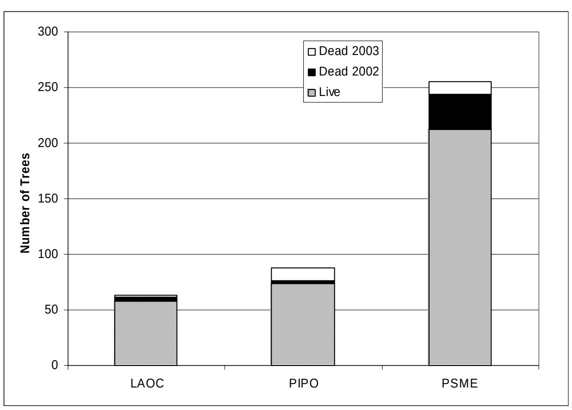

Figure 13. Mortality by species over time.

When the residual stand is modeled in FMA for fire effects using the actual observed environmental indices the outcome is 100% mortality for all species and heights. Adjusting surface fuel moisture content and foliar moisture content only has a negligible effect on mortality. Adjusting the surface fuel characteristics, from a medium logging slash with high depth, to a light logging slash model with high depth, greatly increases the probability of stand survival by dramatically reducing crown volume scorch. The fact that we did not experience 100% mortality could be explained by the high level of variability in surface fuel characteristics.

Other factors that could have contributed to the variability in fire effects include the foliar moisture content of Douglas-fir at the time of ignition, and the variability in flame length caused by environmental factors and ignition patterns. The ease with which Douglas-fir were “torching” suggests that there is possibly a physiological component confounding our predictive abilities. This may be unique to this site or to this climatic cycle. Either way it is something worth researching. The variability in flame length can be caused by any number of things including ignition strip width, wind speed, and fuel characteristics (including moisture content). As a result of the strong correlation between flame length, air temperature, wind speed, and scorch height (Saveland *et al*. 1990), flame length could explain the majority of the variability in crown volume scorch, particularly for the ponderosa pine and western larch.

5. MANAGEMENT IMPLICATIONS

The results of this study suggest that treating with thinning followed by broadcast burning can be used to reduce wildfire threat to these stands for a certain period of time. Stand structure outcomes were somewhat predictable with immediate mortality linked to species adaptability. At the same time, proportion of crown volume scorched was loosely correlated with tree height. These two variables are key components of fire effects prediction models such as BehavePlus, FOFEM, and FMA. The variability in the fire effects experienced could be largely due to non-uniform fuels and ignition patterns.

The treatment successfully reduced crown bulk density below the critical threshold for crown fire initiation and reduced surface fuels, in the short term, to a point where the fire intensity in an unscheduled fire would not adversely affect the residual stand.

From the perspective of other resource values the experiment’s outcomes could be viewed differently. For wildlife species utilizing understory browse, this treatment could successfully provide a continuous source of nutritious and palatable forage. The majority of understory shrubs in the treatment unit are redstem ceanothus (*Ceanothus sanguineus*), which show increased nutrition content following burning (MacKenzie and Gray 2002). For wildlife guilds dependent on the physical characteristics of large, open-grown ponderosa pine and Douglas-fir, the residual trees in the treatment unit could be future replacement trees for the existing cohort of old trees.

From a future commercial timber perspective the outcomes from the experiment would likely be seen as a failure. Tree density on the site is very low, growth rates will be low for several years due to the loss of crown material, and some surviving residual trees will likely contain grade defects due to cambium heating. Leaving a higher density of residual trees on the site could mitigate the first issue; however, these additional leave trees would have to come from the shorter height classes. Lessening the amount of scorch and cambium damage is linked to the fuel characteristics originating from post-harvest site preparation treatments. If these fuels can be minimized by age 13-15 of the new stand, then scorch and cambium damage could be reduced and stand density could possibly be increased. This hypothesis is worth testing if the thin and burn treatment is going to be utilized in future commercial forest settings.

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