

Assessing the Effect of Fire Regime on Coarse Woody Debris¹

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Abstract

This study used field data and modeling to examine how coarse woody debris (CWD) differs between two areas that experienced different fire regimes (120- to 300-year mean fire return intervals) in the 1500-1850 period. Although fire frequency and severity established the overall pattern of CWD succession, the interaction of fire regime with other controlling factors caused the differences in CWD mass at the landscape scale. CWD mass was almost twice as high in landscapes having an infrequent, stand-replacing fire regime (173 Mg/ha) as in landscapes having a moderately frequent, mixed-severity fire regime (95 Mg/ha). Factors that appear to have the greatest influence are decomposition rates, fire severity, fire frequency, and fuel consumption, suggesting that environment and stand structure—together with fire regime—are more important than fire regime alone. CWD levels have greater temporal variability in the infrequent, stand-replacing fire regime than in the mixed-severity regime, primarily because of the different timing of mortality.

Introduction

Although a few studies have examined the relationship between coarse woody debris (CWD) and natural disturbance, particularly fire, they have primarily examined the most simple, stand-replacing fires in which all trees are killed and no subsequent fire occurs for several hundred years. Studies and syntheses by Agee and Huff (1987), Harmon and others (1986), and Spies and others (1988) depict the succession of CWD conditions after fire. During a stand-replacing fire, large amounts of biomass are converted from live to dead matter. While some biomass is consumed in a fire, much more is converted from live to dead and is carried into the subsequent stand. CWD is therefore highest just after such a fire. This material persists as the regenerating stand develops and usually is the dominant source until the live trees begin to provide woody debris of a large size. As the pulse from the fire begins to decompose, CWD in the stand decreases, reaching its lowest level in the mature

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stand. CWD rises again in late succession as mortality from the regenerated stand increases. It levels off when mortality and decomposition reach a “steady-state.”

Although this simple pattern occurs in many areas, more complex fire regimes with multiple fires during the life of a stand, which kill only some trees, are also common. The purpose of this paper is to examine the effect of fire regime on CWD amounts. Specifically, we asked: 1) Do the CWD levels differ among two fire regimes? 2) How are CWD levels affected by fire severity and frequency? and 3) How do the other factors that control CWD vary by fire regime?

To answer these questions, we contrasted two regimes in the west Central Oregon Cascades that were distinguished in fire history studies on the basis of fire frequency and severity (Connelly and Kertis 1992, Morrison and Swanson 1990, Teensma 1987). One regime had infrequent, high-severity fires. The mean fire return interval was more than 300 years, and the oldest trees—more than 450 years old—originated from stand-replacing fires that occurred during drought periods in the 1500s. This regime occurred in cool, moist environments, such as north-facing slopes and headwaters. Fires in this regime created large patch sizes of single-aged stands. The second regime exhibited more frequent, mixed-severity fires. Here, the fire severity ranged from low to high, creating a mosaic of small patches with multiple disturbance cohorts of shade tolerant tree species within single stands. The mean fire return interval was 95 to 150 years with a mean of about 120 years. Some trees survive these fires, but the oldest trees were usually just 200 years old. This regime occurred on south-facing slopes and south-facing drainages.

Our first step was to develop a conceptual model of how CWD was affected by different fire regimes. The second step was to collect data on trees, snags, and downed logs, in areas with both fire regimes. Third, we developed a simple model that simulated the pattern of CWD mass after fire and did a comparative analysis of field data and model results. We then used the model to understand how fire frequency and severity, stand growth and development, decomposition and mortality rates, and fuel consumption may have affected the CWD levels observed in the field, and to investigate how each of these factors may have affected the CWD mass in the two regimes.

Study Area

The study was conducted on the Willamette National Forest near the town of Blue River, in the Central Oregon Cascades. Two areas were sampled that are 35 km apart and lie north and south of the McKenzie River in the Willamette Basin. The study area has long, wet winters and relatively dry, warm summers, typical of the west side of the Oregon Cascades and Coast Range. The average annual temperature is 9.5°C at 430 m elevation, and precipitation is 2,400 mm per year with more than 70 percent falling from November through March. The sampled stands are primarily within the Western Hemlock Forest Vegetation Zone (670-1,067 m), although some upper elevation plots fell in the ecotone between the Western Hemlock Zone and the adjacent Pacific Silver Fir Zone (1,067-1,676 m) (Franklin and Dyrness 1988). Field sampling included all parts of the moisture and temperature gradients in the Western Hemlock Zone, although it did not include all conditions found in the central Cascade Mountains described by Zobel and others (1976) (*fig. 1*).

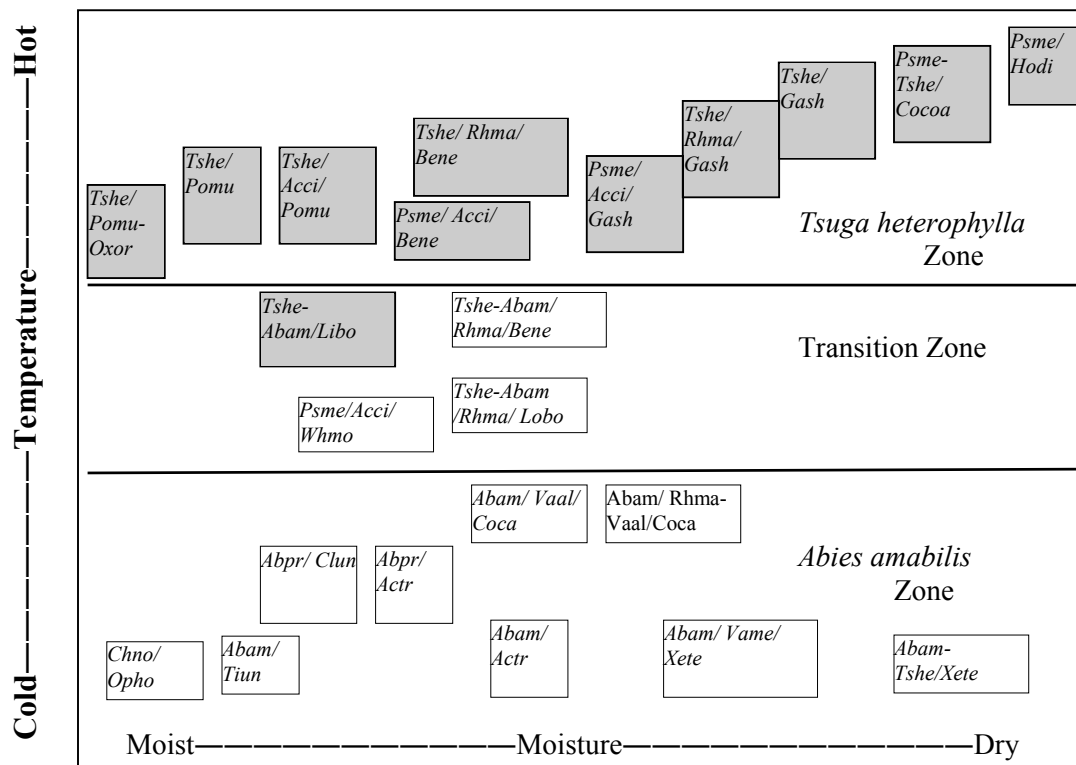


Figure 1—Vegetation along temperature and moisture gradients for the central western Cascade Mountain Range (Dyrness and others 1974, Zobel and others 1976). Shaded boxes are plant associations sampled in the study area.

Field Sampling

The study area was stratified by fire regimes defined by other studies and stands were sampled in two areas for each of the two fire regimes described above. Field sampling included an inventory of a total of 57 stands ranging in size from about 50 to 150 ha. Stands were delineated on aerial photos to sample the full range of stand ages, elevations, and aspects, and to sample the extent of the area identified by the fire history studies. Within each stand five randomly selected variable-radius plots were sampled.

At each plot, information was recorded about physical conditions such as percent slope, aspect (degrees azimuth), topographic position, plant association (Hemstrom and others 1987), and elevation (m). In each stand, variable radius plots were used to sample live trees. Diameter at breast height (DBH) of each tree tallied >23 cm was recorded to convert basal area to stem count per ha (Dilworth and Bell 1985).

To estimate the mass of downed CWD, we sampled logs >23 cm in diameter at the point of intersection (Brown 1974, Van Wagner 1968) with two perpendicular transects intersecting at plot center 100 m in total length (50 m up and downhill, 50 m along contour). Diameters of logs were measured, and species and decay class were recorded according to a classification system widely used in the Pacific Northwest (Fogel and others 1973, Sollins 1982, Triska and Cromack 1980).

Snags were measured in an 800 m² belt transect. Snags >23 cm diameter and greater than 0.5 m tall were measured at breast height and recorded by species, diameter, height, and a decay class scheme developed by Cline and others (1980) similar to the log decay classification scheme. Heights were estimated visually after the heights of a few snags on each transect were measured with a clinometer and tape.

To compare mortality rates for the areas having different fire regimes, we calculated the ratio of CWD volume by decay class to live tree volume, and estimated the volume of CWD that accumulated each year. We calculated the total CWD volume in each decay class and estimated the length of time the trees had been dead, using rough estimates of residence time in each decay class. To estimate the average mortality rate for each fire regime for the past 2 centuries, we averaged the rates for all decay classes in the four sampling areas. The mortality rate was calculated as:

$$\text{Mortality Rate year}^{-1} = (\text{CWD Volume/Live Tree Volume})/\text{Residence Time year}^{-1}.$$

in which *CWD Volume* is the total *CWD volume* by decay class for each sampling area, *Live Tree Volume* is the mean tree volume for stands in each sampling area, and *Residence Time* is the number of years CWD remains in each decay class.

This assumes live tree volume is static through time, which is probably only true for older stands when tree volume levels off. Residence time for Douglas-fir log decay classes are comparable to other studies, and since it dominated species composition, it was used to estimate the mortality rate for field data. Residence time was estimated by assuming CWD remains in Decay Class 1 for 15 years, in Class 2 for 15-44 years, in Class 3 for 45-89 years, in Class 4 for 90-145 years, and in Class 5 for 150-225 years.

Statistical Analysis

We performed a randomized block, two-way analysis of variance (ANOVA) and paired t-test with the two geographic sites (north of the McKenzie River and south of the McKenzie River) as blocks to determine if the CWD mass in the two fire regimes varied significantly at a p-value < 0.10. (SAS Institute, Inc. 1992). We also performed a Chi-squared test to determine whether the distribution of CWD among the decomposition classes differed significantly between the two fire regimes.

A paired t-test was used to determine whether site productivity of the sampling areas with different fire regimes varied significantly. Using the plant associations identified in the field, we compared site indices (height of a Douglas-fir in 100 years from McArdle and others 1961) and performed a paired t-test at a p-value of 0.10 to determine if the differences in mean site indices were statistically significant between the two regimes.

Model Description

We constructed a simulation model, FIRECWD, based on the conceptual model developed by Harmon and others (1986), which considers the store of CWD in an ecosystem and how it changes through time. The model accounts for the CWD that is input to the system by mortality (e.g., fire events, bark beetles, or root rot), the

amount that is lost (e.g., decomposition and consumption by fire), and the levels of CWD mass that result.

The purpose of the model was to simulate CWD dynamics for the two fire regimes, compare the mean and standard deviation of CWD between modeled and field estimates, and gain insights into the behavior of the system by changing input and control variables. The model was built to run in Microsoft Excel or Quatro Pro for Windows 5.0,⁵ and used to explore the effects of fire frequency, fire severity, site productivity, decomposition, mortality, stand growth, and fuel consumption on CWD succession.

A full description of the model can be found in Wright (1998). A general description follows. This model expresses the essential elements of vegetation and fuel succession using the body of knowledge from previous research. A stochastic element allows the model to simulate the variability that might be expected for CWD. FIRECWD randomly selects years in which fire occurs within the limits that reflect the fire regime, such as once every 200 years or once every 500 years. It is programmed to simulate the natural variation expected in maximum biomass, decomposition and mortality rates, growth parameters, and pre-fire CWD.

Live Biomass

The live biomass function simulates tree growth and biomass that accumulates in the stand between fires. In the years when fires occur, a portion of the trees are killed and live biomass representing that portion is converted to CWD mass, while a small portion is consumed by the fire. The amount of the conversion depends on fire severity. The portion of the live biomass remaining continues to grow, and live biomass continues to accumulate from the level it was reduced by the fire. In the case of the stand-replacing fire regime, the live biomass would be reduced 85 percent $\pm$ 15 percent, and for a mixed-severity fire regime, it would be reduced 50 percent $\pm$ 15 percent. For example, in the stand-replacing fire regime, the live biomass begins accumulating from an average 15 percent of the live biomass existing in the year of the fire.

The total live biomass of trees was estimated from stand age, a Richards function parameterized with the maximum live biomass the site can support, the time to reach the maximum biomass, and a parameter that controls the point of inflection (Richards 1959). The maximum biomass was estimated from site index based on plant associations and a growth and yield model, DFSIM (Curtis and others 1982). DFSIM output indicated that a site with average productivity in the study area at a stand age of 300 years would have a live biomass of about 700 Mg/ha.

Fire Disturbance

This part of the model is used to simulate the direct effects of fire on CWD mass. In the year when a fire occurs, the pulse input of CWD mass created by a fire depends on the total live biomass currently in the system and the fire severity. Fires occur stochastically based on a probability estimated from the fire return interval for a site. To simulate randomly occurring fires, a spreadsheet cell indicating fire

⁵ Mention of trade names or products is for information only and does not imply endorsement by the U.S. Department of Agriculture.

occurrence is linked to a column in which a random number is produced for each annual time step. If this random number is greater than the annual probability of fire, a fire occurs. This allows the model to simulate the fire frequency and severity of a regime, such that severity is greater when time intervals between fires are longer.

Fuel Consumption

This part of the model calculates the mass of CWD lost due to fuel consumption. The model also tracks the portion of CWD stores that are not reduced by fuel consumption. Fuel consumption, estimated from previous research, is assumed to average 20 +/- 5 percent of the total CWD mass already present in the year of the fire, and 5 percent of the live biomass converted to CWD mass by the fire (Brown and others 1985, Reinhardt and others 1991).

Non-fire Mortality

This part of the model is used to simulate the CWD mass that accumulates from chronic mortality in the new stand from factors such as stem exclusion, insects, pathogens, and wind. We assume that as the new stand grows, 0.005 per year of the live tree biomass dies. This amount varies randomly +/- 0.00125 per year for each model run. For the first 50 years after a fire, trees are quite small (diameters <10 cm) and not considered CWD. The dead trees that accumulate after the fiftieth year are considered CWD mass.

Decomposition

This part of the model is used to simulate the decomposition of CWD mass. For any given year, the total CWD mass has three sources: fire created CWD, old CWD, and CWD created by non-fire mortality. The decomposition function is applied to all three sources calculating the mass of CWD lost from decomposition. The average decomposition rate constant for the ecosystem is assumed to be 0.020 +/- 0.005 per year.

Randomization

The model is stochastic with each simulation run producing a slightly different output. Consequently, the model can generate “data” to test effects of different fire regimes and control variables using statistics. Each run generally parallels the mean value, but individual runs can be quite a bit higher or lower than the mean depending on the parameter values selected. To vary the parameters between model runs, we created one cell in the spreadsheet for the mean value and one for the standard deviation for each parameter, and two associated cells with random numbers. One specifies how much to deviate the parameter, and another indicates whether the deviation is added to or subtracted from the mean value. We divided this uniform distribution into unequal segments so that its frequency distribution took on the form of a normal distribution.

Results

Coarse Woody Debris Mass

The field measurements of CWD indicate that on average stands with the mixed-severity fire regime had about half as much CWD as sites with the stand-replacing fire regime (*table 1*). However, an ANOVA and a paired t-test revealed no statistically significant difference ($p < 0.29$) in total CWD mass between the two regimes.

Table 1—Mean, standard deviation, and range of CWD mass for field data for each regime individually and sites combined by regime.

Fire regime	Sample area	Number of stands	CWD mass (Mg/ha)		
			Mean	Standard deviation	Range
Stand-replacing	Lookout	12	190	99	100-420
	Augusta	15	155	105	55-411
	Combined	27	173	102	55-420
Mixed-severity	Cook-Quentin	14	73	40	30-155
	Chucksney	16	115	72	18-258
	Combined	30	95	56	18-258

The model predicted a more similar CWD mass between the two regimes than did the field data (*table 2*). The model results also indicated less variability in CWD mass within the fire regimes than the field data. These model results indicated that fire frequency and severity alone are probably not responsible for the different amounts of CWD mass found in the field data and that site productivity, decomposition and mortality rates, and/or stand growth may also control CWD mass differences in the areas with different fire regimes.

Table 2—Mean, standard deviation, and range of CWD mass (Mg/ha) from model data varying all the control factors within the expected range for two fire regimes. Control factors include fire-killed biomass, decomposition rate, mortality rate, maximum biomass, and B1 and B2 in the growth function. Range is the mean minimum and maximum for 30 model runs.

-----CWD mass (Mg/ha)-----				
Fire regime	Mean fire return interval	Mean	Standard deviation	Range
Stand-replacing	300	212	28	133 - 807
Mixed-severity	125	188	39	102 - 571

Site Productivity

Field results of the site indices in the study area overlap considerably. The mode of site indices in the study area was 136, and the stands experiencing a stand-replacing fire regime had only a slightly higher mean site index than stands with the mixed-severity fire regime (135 vs. 132). A paired t-test indicated that site productivity was not different statistically ($p < 0.80$).

The site indices for the study area span only a small range of the possible values for site index, and consequently the effect of site productivity on differences in CWD mass between the fire regimes is not significant. Sensitivity analysis indicates that the model is highly responsive to this factor. Within the area we sampled, however, site productivity probably plays a minor role in controlling the different levels of CWD mass found in the two fire regimes because site index is fairly constant.

Tree Biomass

Tree biomass measured in the field showed that stands with the stand-replacing fire regime had 100 Mg/ha more mass than the average of the stands in the mixed-severity fire regime (752 and 649 Mg/ha respectively). The stands with a stand-replacing regime are older (100-450 years) than stands with a mixed-severity regime (90-150 years), and older stands would be expected to have greater tree biomass than younger stands. The model has low sensitivity to the parameters that influence the amount of time necessary for the stand to become established and the time period required for mean annual growth to level off. Varying these parameters has little effect on differences in CWD mass. Accordingly, these growth, rate-related parameters have little effect on CWD over time, and they probably also have little influence on the different levels of CWD between the two fire regimes.

Mortality

The mortality rates from the field data for the two fire regimes indicate that the non-fire mortality rate (i.e., suppression mortality, disease, wind, etc.) is only slightly different between the areas having different fire regimes. The model has an intermediate level of sensitivity to mortality, but varying the mortality rate within the expected range had little effect on the total CWD mass. The combined results from the field data and the modeling indicate mortality is a relatively unimportant factor in explaining the difference in total CWD accumulation between the areas having two fire regimes.

Decomposition

Sensitivity analysis indicates that the model is highly responsive to changes in the decomposition rate constant. Previous research efforts indicate that a high degree of variation exists in decomposition rate estimates (Harmon and others 1986, Sollins 1982, Spies and others 1988). Varying the decomposition rate within the range found in the west central Oregon Cascade Mountains results in considerable differences in CWD mass over time. Decomposition rate appears to have the greatest effect on CWD of all control factors examined. For example, increasing the decomposition rate to 0.050 year^{-1} would reduce CWD mass to less than one-third the mass that would be present if the decomposition rate were 0.010 year^{-1} (*table 3*).

Table 3—Modeled mean CWD mass (Mg/ha) averaged more than 500 years for the two fire regimes for decay rates 0.01 to 0.05 from 30 model runs for each regime.

Decomposition rate constant	Stand-replacing 300 yr. MFRI	Mixed-severity 125 yr. MFRI
0.010	387	319
0.020	212	188
0.030	153	133
0.040	127	112
0.050	111	96

Fuel Consumption

Although there are no field data for fuel consumption (the study area has been free of fire for decades), we used the model to estimate the effect of fuel consumption on CWD mass for the two regimes. The model has a low sensitivity to fuel consumption, but model runs of randomly occurring fires indicate that the effect of fuel consumption from fires in the mixed-severity regime would be considerably higher than for the stand-replacing fire regime because more fires occurred (4 fires vs. 1.6 fires per 500-year period). Results indicate that even with this reduction from fuel consumption, the mass indicated by the model (206 and 167 Mg/ha) is still considerably higher than the CWD field data (173 and 96 Mg/ha).

Fire Killed Biomass

Using live tree biomass observed in the field as an estimate of potential CWD input from fires and using model data (which indicates low sensitivity), it appears that fire-caused mortality has a large effect on CWD mass for the first 100 years after a fire, but then the effect rapidly diminishes. This is because decomposition is an exponential function and reduces fire-created CWD mass rapidly the first years after a fire. The analysis also indicates that a much longer time period is necessary for CWD to recover in a stand-replacing regime (more than 200 years) than in a mixed-severity regime (about 100 years).

Discussion

CWD Mass in the Two Fire Regimes

Field data indicated that CWD mass is consistently higher across the stands in the stand-replacing regime, with an average CWD mass almost twice as high as the stands in the mixed-severity regime. Although the differences were not statistically significant, due to high variability, there are readily apparent differences in CWD mass (*table 1*). Furthermore, no recently burned stands were sampled, and therefore, stands with high mass created by such fires were not considered. Given that stand-replacing fires initially input a higher dead wood mass, one would expect the differences between regimes might be even greater. Trends may have been even more

pronounced had the field study included areas where fire regimes are more dissimilar than those found in the western Cascades of Oregon.

Fire suppression probably did not influence the field results greatly; however, in areas with the mixed-severity regime it may have some implications for future development of CWD. Over the last 50 to 70 years the effects of wildfire on the landscape have been minor, and much biomass is now tied up in small live trees. Therefore, a wildfire now would probably be more severe than typical for this regime because of the high numbers of small, suppressed trees. The fire-created CWD would then be more similar to that occurring in a stand-replacing regime, including a larger pulse and a much longer recovery time.

Model Uncertainty

Model predictions are uncertain for two reasons: 1) the model's sensitivity to parameters, and 2) the observed variation in parameters. If a model is not sensitive to a parameter, that parameter probably does not greatly influence uncertainty. In contrast, if a model is sensitive to a parameter and its value does not vary, then uncertainty is low. If the model is sensitive to a parameter and its value varies widely, however, it can introduce major uncertainty to the analysis. For example, modeled CWD mass is not especially sensitive to fire frequency and severity, and since the regimes are clearly defined in terms of frequency and severity, the model has a relatively low degree of uncertainty associated with these factors. In contrast, the model has a high degree of sensitivity to maximum biomass (site productivity), but given the limited observed range for this study area, it also has little influence on uncertainty. The model has a high degree of sensitivity to decomposition rate, and given the possible range in this parameter, it has considerable influence on uncertainty. Finally, the model has a moderate degree of sensitivity to the mortality rate, but modeling indicates the observed variation in mortality rate has little influence on CWD accumulation.

The degree to which each factor influences CWD accumulation also depends on whether the factor's effect is occasional or continuous. The model has low sensitivity to both fire frequency and severity, probably because these influence CWD mass only for the first 100 years after a fire and not for the subsequent 400 or 500 years. The growth rate of the stand is important for the first 80 to 100 years while the stand is growing rapidly and less so afterwards. Site productivity continues to have an influence on CWD accumulation after the stand has reached its peak in mean annual growth. Decomposition, and to some extent mortality rate, have an influence on CWD accumulation every year and, therefore, are important regardless of the age of the stand.

Why Are the Fire Regimes Different?

What factors might be controlling the differences in CWD for the two fire regimes? Modeling results suggest that, all other things being equal, the two fire regimes should have about the same CWD mass. Although the temptation is to attribute differences in CWD mass to fire regime per se, differences in fire frequency and severity can only account for about 10 percent of the observed difference in the amount of CWD predicted by the model. This suggests that, although the mixed-severity regime has about half the CWD of the stand-replacing fire regime, the

difference may not be caused by the regime itself. Rather the difference may be due to environment and stand structure. In addition to causing more frequent fires, a warmer, drier environment speeds decomposition, increases fuel consumption, and grows smaller trees (i.e., less biomass).

Model sensitivity analysis indicates that decomposition and fuel consumption may have more effect on CWD mass than fire frequency and severity. Of these two factors, decomposition appears to be the more significant. First, the model is most sensitive to decomposition. Second, estimates of decomposition rates from previous studies vary significantly from 0.018 to 0.029 (Sollins 1982, Spies and others 1988). Third, model simulations using a 0.03 year^{-1} decay rate for the warmer, drier sites having a mixed-severity regime, and a 0.02 year^{-1} for the stand-replacing regime give CWD mass that is 52 percent lower for the mixed-severity regime than the stand-replacing regime. The field data indicate CWD mass is 45 percent lower for the mixed-severity regime. Other research indicates that in this region warm, dry sites have increased decomposition rates, and that excess moisture generally limits log decomposition (Graham 1981, Harmon 1992, Means 1982).

Implications for Management of CWD

CWD mass is much higher in wildfire regenerated stands than in stands intensively managed for timber production (Spies and Cline 1988). To retain functions and processes associated with green trees, some current forestry projects are retaining more live trees in stands in areas that had a mixed-severity regime than in areas with high-severity, stand-replacing regimes. A similar approach could be used for CWD.

To mimic the natural succession of CWD, managers need to consider fire regime, site potential, decomposition rates, fuel consumption, and management objectives. The following questions should be addressed: Does the fire pattern generate the large amounts of CWD of the stand-replacing fire regime or the more frequent, smaller pulses of the mixed-severity fire regime? The latter may be easiest to emulate in stand management, but one should still consider how stand management differs from the CWD cycle of the natural fire regime. Managers should consider whether recent fire history is typical of the natural fire regime or if it bears the influence of post-European settlement burning and suppression. Some information about fire influence may be deduced from the ages of the stands and fire history studies (see examples in Hyderdahl and others 1993). What are the ages of the area's oldest stands in various forest types? What is known about lightning-caused fires and fire suppression? How long since the stand last experienced fire? Managers can also consider the forest structure for its relation to fire severity. Are stands even-aged or do various age cohorts suggest multiple fire-caused stand regeneration events with shade-tolerant as well as shade-intolerant species present? Do stands contain old age cohorts that survived previous fires? If so, what is the proportion of the total stand volume represented by remnant trees?

The rate of decomposition should also be considered, given its substantial effect on total CWD mass through time. On cool and/or wet sites in western Oregon, low temperature and/or high moisture content can limit the activity of decomposing organisms. On the other hand, sites that are excessively dry may also have slow decomposition. The results of this analysis suggest that decomposition rates may vary

considerably, even in stands of close proximity, such as those on opposite sides of a ridge.

Finally, managers should consider that the effect of CWD treatments will persist for decades, even centuries. Management strategies may strive to emulate the natural CWD cycle, but may fall short of this goal because of the volume of potential CWD that is removed to the sawmill. For managers to successfully mimic the dead structure associated with the types of fire regimes in this study area, it is advisable to retain the highest levels of CWD in areas having a stand-replacing regime and lesser amounts in areas having a mixed-severity regime.

We suggest a hybrid approach that combines field data and modeling to address difficult management questions. CWD is highly variable through time, and a model of the processes that affect CWD allows us to consider CWD succession, including a much broader range of conditions than can be observed in the field. It also facilitates estimating CWD levels in stages of succession that do not currently exist because of the limited number of fires in the past.

Although the question of “how much” CWD to retain dominates current management discussions, understanding the processes that control CWD and its link with wildlife and fish may be our greatest challenge. In fact, increased understanding of CWD dynamics and functions is our best path not only to answer “how much” but also to understand what is necessary to sustain forest functions. The limited knowledge about the amount of CWD needed to meet ecological objectives points to the need for more discussion between the management and scientific communities on this topic.

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