RELATIONSHIP OF HISTORIC FIRE REGIMES TO DEAD WOOD COMPONENTS IN WHITE FIR FORESTS OF SOUTHWESTERN OREGON

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ABSTRACT

White fir (*Abies concolor*) forests are abundant in southwestern Oregon. These forests occur in many environments. Average annual temperature ranges from 5 °C in the High Cascades and Siskiyous to 9 °C in lower-elevation areas. Average annual rainfall varies between 114 cm in drier areas of the Cascades to 259 cm near the coast. The white fir forests have been stratified into 19 plant associations, characterized by environment and plant composition. Historic fire regimes for each plant association were estimated using tree age cohort distributions and species composition after disturbance. Median fire return interval ranged from 20 to 83 years, average fire severity rating ranged from 1.45 to 2.44, severity rating of the last fire ranged from 1.45 to 2.20, and length of the last fire return interval ranged from 25 to 89 years. Snag and down wood measurements were summarized for each plant association. We report only information on large snags and down wood over 50 cm in diameter. Dead wood was highly positively correlated with median fire return interval (0.717) and length of the last fire interval (0.750). Median fire return interval explained 51.5% of the variation in pieces of down wood per hectare. Average fire severity rating explained 83.9% of the variation in snag density. This information will be useful in predicting dead wood levels as fire is returned to these forests. Many species depend on dead wood as habitat; therefore, knowing the relationships between fire regimes and dead wood will allow us to more closely restore habitat to desired conditions.

keywords: Abies concolor, down wood levels, fire regime components, southwestern Oregon, white fir.

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INTRODUCTION

Snags and down wood are important structure components of forest ecosystems (Harmon et al. 1986). These components play a role in microclimatic variation in the forest and provide habitat for a variety of organisms. Little data have been published on levels of dead material in southwestern Oregon, however, and data on processes that create and consume dead wood are even more obscure.

The abundance of snags and down wood is determined by several factors. The initial density and size of a forest stand will regulate the potential for providing snags and down wood. Agents such as fire, wind, insects, and diseases kill trees, often in episodic disturbances. The extent of this mortality depends on the severity and frequency of the disturbance. The abundance of snags and down wood may also depend on competition-induced mortality, particularly when disturbance agents are absent and stands are growing at high densities. Fire and decay cause breakdown and consumption of snags and down wood.

Although all sizes of snags and down wood are important, both for vertebrate and invertebrate habitat, and as in regulation of microclimates, recent emphasis by wildlife biologists has been on large-diameter material. This material takes longer to grow and more time to replace if it were removed from a site. Standards for large down wood and snags are found in the Northwest Forest Plan (USDA Forest Service and USDI Bureau of Land Management 1994). These standards are uniform

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across the complex climatic, edaphic, and vegetation conditions of southwestern Oregon. In this paper we analyze relevant data to examine variation and pattern of density of dead wood, and the relationship of dead wood with fire. Our objective is to provide a framework and understanding of processes for managers to make landscape-level prescriptions for down wood and snags as fire is reintroduced into these ecosystems.

STUDY AREA

Southwestern Oregon (approximately lat 43.5°N, long 122.2°W to lat 42.0°N, long 124.6°W) is an area of high biological diversity (Whittaker 1960). The Siskiyou Mountains, which occur along the coast, are some of the oldest mountains in North America, up to 200 million years old. The southern Oregon Cascade Mountains are much more recent, about 10 million years old, and are of volcanic origin. Between these ranges exist numerous low-elevation interior valleys. The climate is characterized by warm, dry summers and wet winters. Many parent rock types occur (Orr et al. 1992).

The White Fir Series is the most abundant plant group in southwestern Oregon and has been stratified into 19 plant associations (Table 1) (Atzet et al. 1996). It occurs over a wide range of elevations, and on all aspects and slope positions. In the wetter coastal environments, white fir may be codominant with tanoak (*Lithocarpus densiflorus*) (i.e., the white fir–tanoak/common prince's pine [*Abies concolor–Lithocarpus densiflorus/Chimaphila umbellata*] plant association). These stands are highly productive and support Douglas-fir (*Pseudotsuga menziesii*) as a pioneer species (Figure 1). Large amounts of dead wood may be present. In the dry interior valleys, white fir occurs with Douglas-fir, baldhip rose (*Rosa gymnocarpa*), and creambush ocean-spray (*Holodiscus discolor*). Summer drought is prolonged in this environment and summer daytime temperatures may reach over 23 °C. These lower-productivity stands produce lower amounts of dead wood. White fir forests also occur in cool high-elevation sites. Here, Shasta red fir (*Abies magnifica shastensis*) is a common associate (i.e., the white fir–Shasta red fir/common prince's-pine-threeleaf anemone [*Abies concolor–Abies magnifica shastensis/Chimaphila umbellata–Anemone deltoidea*] plant association). Moderate amounts of dead wood are present.

These highly variable environments result in variable fire regimes, from frequent, low intensity, to moderate, to high intensity (Atzet and Martin 1991). Fire is the most frequent and the most influential natural disturbance affecting structure and composition in white fir forests.

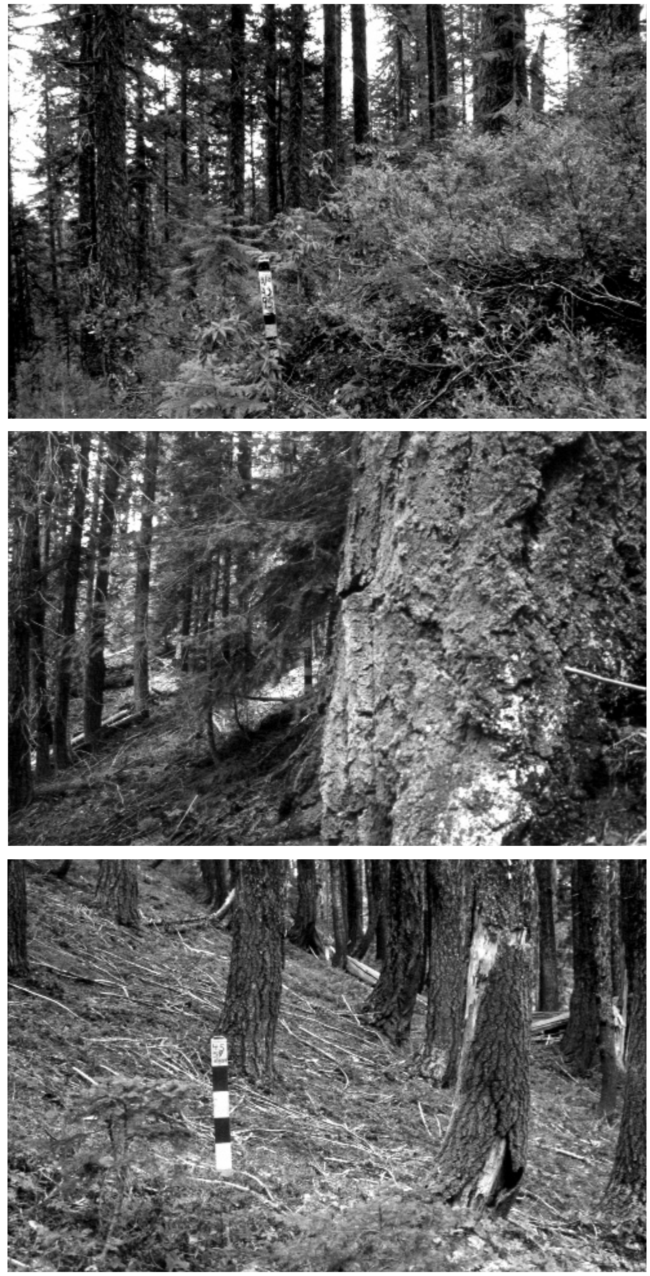

Figure 1. White fir plant associations in southwestern Oregon: white fir–tanoak/common prince's-pine (A); white fir–Douglas-fir/baldhip rose (B); and white fir–Shasta red fir/common prince's-pine-threeleaf anemone (C).

The sites on the Siskiyou National Forest are in the mid-coastal sediments ecoregion, and the sites on the Rogue River and Umpqua National Forests are in the southern Cascades and Umpqua Cascades ecoregions (Omernik 1986). The environmental range is broad, with a mean annual temperature of 5 °C in the Cascade Mountain Range and 9 °C in the Siskiyou Mountains. Average annual rainfall ranges between 114 cm in the drier areas of the Cascades to about 260 cm near the coast.

Table 1. Plant associations, common names, and plant association codes in the white fir plant series (Atzet et al. 1996).

Plant association	Common name	Code
Abies concolor–Abies magnifica shastensis/Quercus sadleriana	White fir–Shasta red fir/Sadler oak	ABCO–ABMAS/QUSA2
Abies concolor–Abies magnifica shastensis/Achlys triphylla	White fir–Shasta red fir/vanillaleaf	ABCO–ABMAS/ACTR
Abies concolor/Xerophyllum tenax	White fir/common beargrass	ABCO/XETE
Abies concolor–Abies magnifica shastensis/Chimaphila umbellata–Anemone deltoidea	White fir–Shasta red fir/common prince's-pine–threeleaf anemone	ABCO–ABMAS/CHUM–ANDE3
Abies concolor/Quercus vaccinifolia	White fir/huckleberry oak	ABCO/QUVA
Abies concolor–Picea breweriana/Chimaphila umbellata–Pyrola picta	White fir–Brewer spruce/common prince's-pine–whitevein pyrola	ABCO–PIBR/CHUM–PYPI2
Abies concolor/Arctostaphylos nevadensis	White fir/pinemat manzanita	ABCO/ARNE
Abies concolor–Lithocarpus densiflorus/Chimaphila umbellata	White fir–tanoak/common prince's-pine	ABCO–LIDE3/CHUM
Abies concolor/Rhododendron macrophyllum–Berberis nervosa	White fir/Pacific rhododendron–dwarf Oregongrape	ABCO/RHMA3–BENE2
Abies concolor/Rhododendron macrophyllum–Quercus sadleriana	White fir/Pacific rhododendron–Sadler oak	ABCO/RHMA3–QUSA2
Abies concolor/Gaultheria shallon–Berberis nervosa	White fir/salal–Oregongrape	ABCO/GASH–BENE2
Abies concolor/Acer circinatum/Oxalis oregana	White fir/vine maple/Oregon oxalis	ABCO/ACCI/OXOR
Abies concolor–Tsuga heterophylla/Berberis nervosa/Linnaea borealis longiflora	White fir–western hemlock/Oregongrape/western twinflower	ABCO–TSHE/BENE2/LIBOL
Abies concolor/Berberis nervosa/Achlys triphylla	White fir/dwarf Oregongrape/vanillaleaf	ABCO/BENE2/ACTR
Abies concolor/Berberis nervosa/Linnaea borealis longiflora	White fir/dwarf Oregongrape/western twinflower	ABCO/BENE2/LIBOL
Abies concolor–Pseudotsuga menziesii/Rosa gymnocarpa	White fir–Douglas-fir/baldhip rose	ABCO–PSME/ROGY
Abies concolor–Calocedrus decurrens/Trientalis latifolia	White fir–incense cedar/western starflower	ABCO–CADE27/TRLA6
Abies concolor/Berberis nervosa	White fir/dwarf Oregongrape	ABCO–BENE2
Abies concolor/Symphoricarpus mollis	White fir/creeping snowberry	ABCO/SYMO

Table 2. Densities (means and standard errors [SE]) of large (50 cm+) snags and down wood in white fir forests, southwestern Oregon.

Plant association	Snags/ha		Down wood/ha		Sample size
	Mean	SE	Mean	SE	
ABCO–ABMAS/ACTR	26.2	3.7	32.0	8.3	16
ABCO–ABMAS/CHUM–ANDE3	14.2	2.6	31.2	11.0	22
ABCO–ABMAS/QUSA2	11.0	3.5	29.8	26.3	16
ABCO–CADE27/TRLA6	8.6	1.6	15.1	4.8	29
ABCO–LIDE3/CHUM	14.6	2.6	41.6	22.8	16
ABCO–PIBR/CHUM–PYPI2	9.9	2.5	5.2	5.2	11
ABCO–PSME/ROGY	8.9	1.6	17.5	10.9	35
ABCO–TSHE/BENE2/LIBOL	8.9	1.5	47.6	17.0	33
ABCO/BENE2	10.6	1.4	15.1	4.7	71
ABCO/BENE2/ACTR	13.1	1.7	24.7	6.2	39
ABCO/BENE2/LIBOL	8.8	1.9	41.9	13.8	26
ABCO/GASH–BENE2	5.4	2.0	17.7	9.4	9
ABCO/QUVA	9.4	2.9	20.1	16.2	10
ABCO/RHMA3–BENE2	9.7	1.5	35.4	12.4	28
ABCO/SYMO	5.5	2.3	25.5	10.9	13

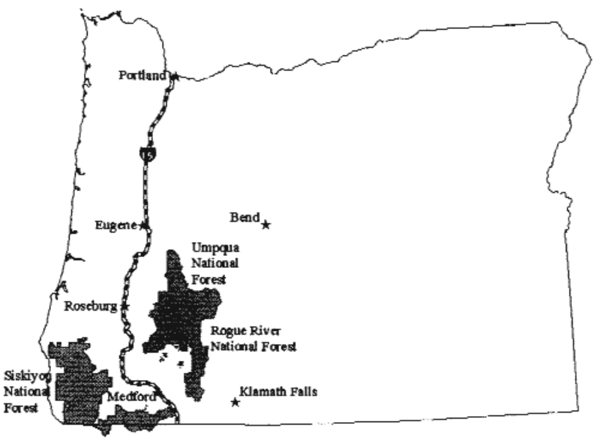

Figure 2. Location of the Rogue River, Siskiyou, and Umpqua national forests in southwestern Oregon.

Parent rock ranges from igneous and metamorphosed materials (diorite, granite, gabbro, andesite, basalt, schist, slate, and sandstone) to peridotite and mixed sediments and intrusives (Atzet et al. 1996).

METHODS

Field Data Collection

Data were collected from permanent plots located on the Rogue River, Siskiyou, and Umpqua national forests (Figure 2). Plots were located so that the variation in vegetation over the landscape was represented. Within each plot, a single plant association was present. The full range of elevation, aspect, slope, and parent rock types was sampled. Plots were selected to minimize previous human disturbance and tended toward fully stocked mid- to late-seral stands. Sample size ranged from 9 to 71, depending on plant association (Table 2).

Subplots were established within each plot using the USDA Forest Service's Pacific Northwest Region 10-point timber inventory diamond cluster protocol (USDA Forest Service 1970). Five subplots were installed. Within each variable radius subplot, the diameters of all species of trees and snags were recorded. Five dominant (site) trees of each of the most common species and 3 to 5 trees of each codominant species were chosen, and heights and ages were recorded. The ages at diameter at breast height were estimated as number of annual rings when the core reached the pith. When the cores did not reach the pith, age was estimated by extrapolation using diameter and rings per inch closest to the inner end of the core. Height, diameter, species, and decay class (Cline et al. 1980) were recorded for each snag.

The environmental variables elevation, aspect, percent slope, and slope position were recorded for each plot. Slope position was defined as ridge top, upper third of slope, middle third of slope, lower third of slope, bench, toe of slope, canyon bottom, edge or in wetland basin, and draw or intermittent stream bottom.

Down wood data were collected by installing three 22-m transects with random direction segments. At the point of intersection with a discernible piece of wood at least 12.70 cm in diameter, the diameter at the intersect, large end, and small end were recorded, along with the length, species, and decay class. Decay was recorded as classes 1–5, where a rating of 5 represents the most advanced decay (Fogel et al. 1972).

Analyses

Analyses were conducted at a landscape scale, which corresponds to the relationship of snags and down wood and fire by plant association. The following four plant associations were not included in the analyses because of small sample sizes ($n < 8$): ABCO/XETE (*Abies concolor/Xerophyllum tenax*), ABCO/ARNE (*Abies concolor/Arctostaphylos nevadensis*), ABCO/RHMA3-QUSA2 (*Abies concolor/Rhododendron macrophyllum–Quercus sadleriana*), and ABCO/ACCI/OXOR (*Abies concolor/Acer circinatum/Oxalis oregana*).

The disturbance regimes were characterized by cohorts of live trees (Arno et al. 1997). Within each plot, the trees were arranged in descending order by age. Patterns of age and/or species change were noted. When a pioneer species (e.g., Douglas-fir or ponderosa pine [*Pinus ponderosa*]) was present, the age was noted. If more than one tree of a pioneer species in a discernable age class was present, it was assumed to be the result of a disturbance event. A surety rating for each event was assigned based on tree age estimate, number of trees present in the age cohort (with multiple trees indicating higher surety), and the species of trees present. The rating ranged from 1 (unsure) to 10 (highly likely), and only events with a rating of 8 or higher were used for the analyses. The disturbance regimes, or return intervals, were not normally distributed so the central tendency and variation are expressed by Weibull medians and confidence intervals, rather than the means and standard errors used for length of the last interval.

A severity rating was also assigned to each event: 1 = low severity—climax trees established after the disturbance; 2 = moderate severity—pioneer species established after the disturbance; and 3 = high severity—pioneer species established after the disturbance with climax species establishing later. These are patterned after Brown's (1995) fire regime severity classes. Date of disturbance was calculated using tree ages and plot data.

Disturbance dates derived from tree age and stand structure data, rather than fire scar data, are a more liberal approach. Fire scars likely miss some events; however, this method likely detects some disturbances not recorded as fire scars. Others have used the method, however (Agee 1991, Arno et al. 1997), and shown it to be a reasonable approximation of the fire history record. Although it may be possible that disturbances other than fire were detected, our plot data showed that fire was overwhelmingly the dominant natural disturbance (83%); hence, the probability of a disturbance being the result of fire was quite high. Only disturbances before 1930 were used in the analyses because we believe fire regimes may have been substantially altered by human influence (fire suppression) after that time.

Density of down wood was calculated using the methods described by DeVries (1973).

Simple linear and nonlinear regressions, and multiple regression were used to show relationships between plant associations and disturbance characteristics. The software SPSS was used for all analyses (SPSS 1998).

Table 3. Historic fire return intervals (FRI) and fire severity ratings (Weibull medians and means) in white fir forests, southwestern Oregon. Weibull medians include 80% confidence intervals (CI); means include standard errors (SE).

	Weibull median FRI (years)		Last FRI (years)		Average fire severity rating[a]		Last fire severity rating[a]	
Plant association	Median	CI	Mean	SE	Mean	SE	Mean	SE
ABCO–ABMAS/ACTR	46	21–136	47	8	1.45	0.13	1.53	0.15
ABCO–ABMAS/CHUM–ANDE3	50	20–137	50	11	1.74	0.06	1.56	0.12
ABCO–ABMAS/QUSA2	36	23–88	56	26	1.71	0.15	1.75	0.20
ABCO–CADE27/TRLA6	44	18–139	57	5	2.22	0.07	2.03	0.12
ABCO–LIDE3/CHUM	39	12–161	64	24	2.40	0.12	2.18	0.20
ABCO–PIBR/CHUM–PYPI2	20	11–56	28	5	2.21	0.44	2.18	0.19
ABCO–PSME/ROGY	30	8–99	39	11	2.12	0.12	2.08	0.10
ABCO–TSHE/BENE2/LIBOL	83	30–205	89	17	2.24	0.07	1.89	0.13
ABCO/BENE2	47	14–141	51	5	1.72	0.05	1.45	0.08
ABCO/BENE2/ACTR	52	18–161	49	8	1.92	0.08	1.70	0.12
ABCO/BENE2/LIBOL	61	22–138	65	11	1.83	0.06	1.56	0.12
ABCO/GASH–BENE2	46	19–95	34	9	2.17	0.07	1.89	0.12
ABCO/QUVA	36	12–116	40	16	2.32	0.13	2.20	0.14
ABCO/RHMA3–BENE2	54	16–161	45	12	2.44	0.06	2.17	0.12
ABCO/SYMO	33	12–123	25	8	1.88	0.15	1.50	0.20

[a] Fire severity rating, where 1 = low, 2 = moderate, and 3 = high.

RESULTS AND DISCUSSION

Fire Regime Characteristics

Median fire return intervals ranged from 20 years to 83 years (Table 3). Although variation was high, and there were no significant differences between plant associations, a general trend showed shorter fire return intervals in the warmer, drier associations and longer return intervals in the cooler, moister associations. The median of all the fire return intervals was 47 years. The mean last fire return interval displays a similar range, 25 to 89 years. The average fire severity rating and last fire severity rating generally showed higher severity in the warmer plant associations and lower severity in plant associations in colder environments (Table 3).

Although the range of fire return intervals over the white fir plant associations was similar to that of the western hemlock (*Tsuga heterophylla*) plant associations, the median was about 20 years shorter (White et al. 2002). This was expected since the White Fir Series occurs in drier environments. The fire return intervals of 20 to 83 years fall within the 8-to-87-years fire return intervals of the white fir–Douglas-fir plant communities in a study area on Thompson Ridge, Klamath Mountains, California (Taylor and Skinner 1998). It is also similar to the range reported by Stuart and Salazar (2000) of 12 to 82 years for white fir plant series. The range suggests that the White Fir Series falls within the low- to moderate-intensity fire regimes described by Agee (1993).

Dead Wood Characteristics

Snag densities were highest in the high elevation, cool white fir–Shasta red fir/vanillaleaf (*Abies concolor–Abies magnifica shastensis/Achlys triphylla*) plant association, with a mean of 26.2 snags/ha. Other associations have snag densities ranging from 14.6 snags/ha to 5.5 snags/ha (Table 2). The variation around each mean was large.

Down wood densities ranged from 47.6 pieces/ha to 5.2 pieces/ha (Table 2). The variation around the means is even larger than the variation associated with snags. This may be a reflection of the potential length of residence in the forest. Down wood generally has a longer residence time than snags and so the potential for consumption may be affected by many factors.

Densities of large snags from white fir series forests on the Six Rivers National Forest in California are 12.1/ha in old-growth stands and 13.8/ha in late-mature stands (Jimerson 1999). Densities of large logs are 33.8/ha in old-growth stands and 22.7/ha in mid-mature stands (Jimerson 1999). Our findings were similar to these densities. Snag densities in the cool, moist western hemlock series forests of southwestern Oregon are lower, ranging between 18/ha and 3.6/ha, and down wood densities are higher and more variable, ranging between 113 pieces/ha and 0 pieces/ha (White et al. 2002).

The ranges in dead wood density is not as large as that found further to the north in western Oregon, however. There, stand-replacement fires create large amounts of dead wood, though on an infrequent basis. In southwestern Oregon, the amplitude of variation is smaller, because of more frequent fires (Skinner 2002).

Relationships Between Fire and Dead Wood

Environmental variables were not significantly correlated with dead-wood variables; however, environmental variables were significantly correlated with fire variables and fire variables were significantly correlated with dead wood (Table 4). Elevation was negatively correlated with severity (–0.69 and –0.53) and percent slope was negatively correlated with median fire return interval (–0.516). Moister plant associations found at lower elevations on gentle slopes generally had burned infrequently with high severity. The number of pieces of down wood per hectare was highly positively correlated with median fire return interval and length of the last fire interval (0.717 and 0.750), indicating more time for large dead wood accumulation with the longer time between burns.

The relationships between dead wood variables and fire variables were best fit using quadratic expressions (Figures 3–5). Median fire return interval explained 51.5% of the variation in pieces per hectare of down wood ($y = -2.7214 + 0.6979x - 0.0012x^2$) (Figure 3); length of the last fire return interval explained 57.1% ($y = 7.5385 + 0.2082x + 0.0031x^2$) (Figure 4). When both last fire severity and length of the last fire interval were used in multiple regression, 61.5% of the variation was explained. Average fire severity rating explained 83.9% of the variation in snag density ($y = 236.792 - 224.08x + 54.6215x^2$) (Figure 5). Multiple regression did not increase the predictability. The high R^2-value for snag density is likely driven by the single point at 28 snags/ha. This model shows high snag density at low fire severity rating. This may be explained by the predominance of Douglas-fir snags. Douglas-fir has thick bark, and the snags may have been able to withstand low-severity burns without falling to the ground. At moderate fire severity, snag density is decreased, suggesting consumption, and snag density increases as fire severity increases, suggesting tree mortality.

Table 4. Correlations between environmental variables and fire, and fire and large dead-wood components in white fir forests, southwestern Oregon. No significant correlations between environmental variables and dead-wood variables were detected.

Variable	Weibull median FRI (years)	Last interval (years)	Average fire severity rating[a]	Last fire severity rating[a]
Mean elevation	–0.261	–0.091	–0.690*	–0.525*
Median aspect	0.565*	0.301	–0.600*	–0.433
Mean slope (percent)	–0.516*	0.234	0.409	0.221
Median slope position	0.417	0.078	–0.111	0.159
Pieces/ha	0.717**	0.750**	–0.247	–0.113
Snags/ha	0.044	0.113	–0.263	–0.546*

[a] Fire severity rating, where 1 = low, 2 = moderate, 3 = high.
* Correlation is significant at the 0.05 level.
** Correlation is significant at the 0.01 level.

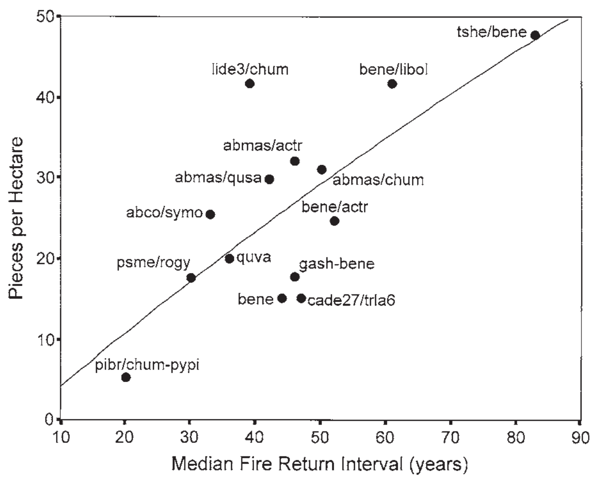

Figure 3. The relationship of fire return interval and down wood in southwestern Oregon. See Table 1 for plant association codes.

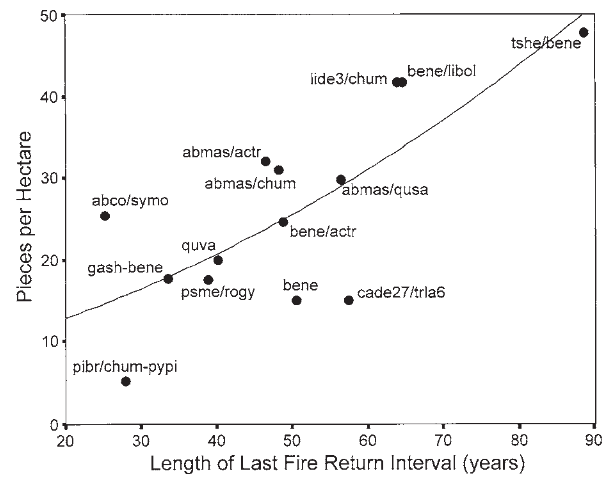

Figure 4. The relationship of fire and dead wood in southwestern Oregon. See Table 1 for plant association codes.

MANAGEMENT IMPLICATIONS

Being aware of the relationships of fire return intervals and fire severity to large dead wood will allow managers to plan levels of dead wood as fire is reintroduced into the ecosystems. Our data indicate the more frequent the fire return interval, the lower the density of dead wood. Intuitively, this makes sense. Recent fire exclusion likely has increased levels of smaller-diameter dead wood, and may have affected levels of large dead wood. Lack of consumption by fire would tend to increase densities of dead wood. In addition, lack of fire has increased densities of understory live trees, creating elevated moisture stress conditions, which have resulted in mortality of large trees. On the other hand, fire exclusion may result in a longer residence time for snags before they fall. The precise mechanisms contributing to the fire exclusion effect are not known.

The large range in densities of dead wood allow

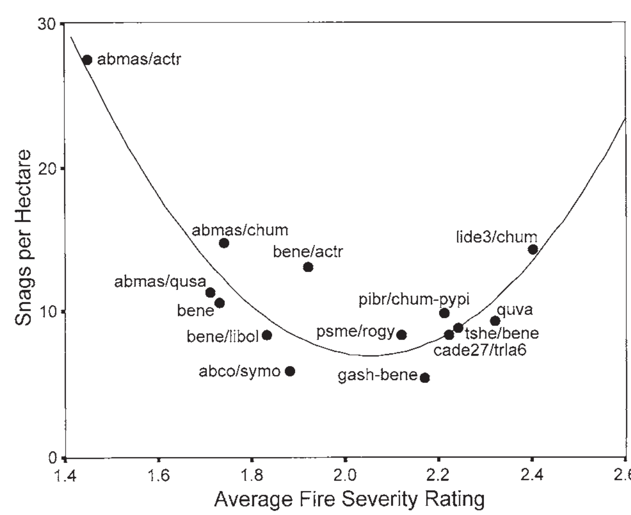

Figure 5. The relationship of snags and fire severity rating in southwestern Oregon. See Table 1 for plant association codes.

managers to tailor prescriptions to specific areas based on management objective, stand history, and environment, among other factors. Over time, attempts to carry high densities of dead wood will create opportunities for more high-intensity fires, resulting in potential soil damage and reduction in late-seral conditions. This may also have negative effects on local species that evolved with frequent, but low-intensity fires.

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