Influence of Fire on the Dynamics of Dead Woody Material in Forests of California and Southwestern Oregon[1]

Carl N. Skinner[2]

Abstract

The frequent occurrence of fire in most forested areas of California and southwestern Oregon before this century has been well established. Likewise, the importance of dead woody material to various wildlife species as snags and downed logs has been well documented. It is unlikely that much large woody material survived fire long enough to decompose fully in fire regimes that preceded the fire-suppression era. Observations of fire effects on dead woody material, as well as some recent limited data, indicate that fire often consumes most material that is in advanced stages of decay. However, though many appear to be consumed as well, hard snags and logs may, at least in part, survive low severity fires. Fires also help to create snags and, ultimately, downed logs. The frequent low-moderate-severity fires that characterized much of the forested landscapes of California and southwest Oregon burned with varying severity related to topography and weather conditions. The probable result was a landscape with many of the snags and logs clustered both in time and in space and very sparsely distributed in the intervening time and space.

Introduction

Although dead woody material (DWM; snags and logs) is recognized as having great importance for many wildlife species and ecological process (Harmon and others 1986, Hunter 1990), little information is available concerning its interaction with fire before the implementation of fire suppression. As a result, a great deal of uncertainty exists about the long-term role of fire in the dynamics of DWM. Most information that exists about DWM has been developed in temperate forests outside of areas classified as Mediterranean or in forests that have experienced artificially long periods without fire (Harmon and others 1986, Harmon and others 1987, Hunter 1990). Such studies provide little information concerning the historical interactions of fire and dynamics of DWM in forests that developed under the influence of chronic, frequent, low-moderate-intensity fires. Indeed, when the effects of fire are discussed, it is usually in terms of stand destroying events that create large amounts of DWM that then becomes available to the system (Spies 1997). Fire is not usually treated as a recurring ecological process that may have often removed more dead wood than it added. However, the latter was probably characteristic of the type of fires that were common in the forests of southwest Oregon and California (Agee 1993, Skinner and

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[2] Geographer, Pacific Southwest Research Station, USDA Forest Service, 2400 Washington Ave, Redding, CA 96001 (e-mail: cskinner@fs.fed.us)

Chang 1996, Taylor and Skinner 1998). Persistent, recurring fires in concert with other agents of change (e.g., wind, insects, disease) created the conditions and habitat that wildlife in these areas adapted to and lived with before fire suppression and other management activities of the 20th century. Fire ecologists recognize that conditions in today's forests are probably, at least in part, an artifact of many decades of fire suppression (Agee 1997, Chang 1996, Taylor and Skinner 1998).

Fire: An Ecological Process

Fire history studies provide strong evidence that fires of the past occurred quite frequently—many times within the life spans of the dominant tree species (Skinner and Chang 1996). Unlike today, fires of the past did not occur as unusual isolated events. Rather, they occurred regularly and greatly influenced the development of forest conditions (habitat) (Agee 1993, Chang 1996, Skinner and Chang 1996, Mohr and others 2000). Thus, it is more appropriate that fire be viewed as a persistent ecological process rather than as a single event. The forest conditions (habitat) historically available to wildlife were those created and maintained by this process. Indeed, the late-successional forests of today have a long history of frequently recurring fire during their development (Taylor and Skinner 1998).

However, over the 20th century, fire suppression has been successful in limiting the cumulative area burned by fires. The result is that fire has become the exception rather than the rule (Husari and McKelvey 1996). Although we may have some sense of effects associated with individual fires of abnormal severity, we have only limited understanding of the effects of incessant, recurring fires of mostly low-moderate intensity with which these forests originally developed (Agee 1997). It is likely that the interaction of fire and dead wood dynamics were very different under historical fire regimes than those of today. A fire regime in which fires burn only infrequently and often severely will probably produce very different long-term habitat trends than a fire regime in which fire is a frequent visitor and is characterized by mostly low and moderate severity. The former serves mostly to add dead wood to the system in pulses and may lead to a boom-and-bust cycle of DWM. The latter is more likely to limit the accumulation of dead wood over both space and time (Kauffman 1990) and may result in less extreme variations of DWM.

It is necessary to consider both the ecological role and physical potential of fire in these forests in order to increase the long-term likelihood for success of management strategies (Millar and others 1998, Skinner and Chang 1996). Natural resource managers are attempting to balance what is thought to be best in terms of accumulations of DWM with the reality of an environment that tends to burn frequently. It is well known that, although fire spread is mostly related to smaller-sized (fine) fuels, the severity of fire effects and difficulty of fire suppression are primarily associated with the total amount of fuel available and consumed (Martin and Brackebush 1974). As DWM accumulates under a fire suppression management regime, fire hazard increases, often dramatically (Kauffman 1990). In order to assess realistically the likelihood of long-term success of various management strategies, it is necessary to understand why fire was historically frequent in the forests of southwestern Oregon and California and then to consider the ecological role of fire.

Climate

A fundamental reason that fire is an integral factor in the dynamics of forests of California and southwest Oregon is climate. This region has a Mediterranean climate characterized by hot, dry summers and cool, wet winters. Although this climate provides ample annual precipitation to grow productive forests, there is a pronounced annual drought. The Mediterranean climate guarantees that, even in years that are much wetter than average, the conditions for fire to spread easily are achieved annually in the dry season (Stine 1996). Considering the features of the Mediterranean climate and the fact that fire history research shows that fires were generally frequent, it is logical to surmise that fires regularly influenced the patterns and accumulations of DWM.

Dynamics of Dead Woody Material in Forests of Mediterranean Climates

Because of spatial and temporal patterns of fire frequency, severity, and seasonality, fires are likely to have influenced the spatial and temporal patterns of DWM accumulations in historical landscapes. Variation in fire regime parameters probably contributed significantly to and helped support habitat and species diversity (Martin and Sapsis 1992). The variation within the fire regime at broad, landscape scales helped contribute to the dynamics of habitat pattern over time (Agee 1998). However, few landscape-scale, fire-history studies have been undertaken, primarily because of time and costs involved (Skinner 1997a). Most fire history studies have been conducted on small areas or a few plots that were widely scattered over large areas. Fire ecologists are just beginning to understand fire regimes at landscape scales. The interpretation of the dynamics of fire and vegetational patterns at the landscape scale are primarily focused on live vegetation because little DWM survives from before the fire suppression era except in rare cases. Even so, recent landscape-scale, fire-history studies may eventually help in understanding historical patterns of DWM through describing the developmental patterns of stand structure that appear related to variation in fire regime parameters.

Fire Frequency

In California and southwestern Oregon, fires are known to have been frequent historically in most locations studied (Skinner and Chang 1996, Taylor and Skinner 1998). Median fire return intervals (FRI) for most sites from the southern Cascades, Klamath Mountains, and Sierra Nevada in the foothills, mixed-conifer, eastside pine, and some upper montane areas are generally less than 20 years (McKelvey and others 1996, Taylor and Skinner 1998).

From the perspective of DWM, the variation in fire frequency is probably at least as important as average or median FRI. Fire history studies indicate that before fire suppression it was rare for forested landscapes larger than a few hundred hectares to go for long periods (e.g., > 30 years) without fire (Skinner and Chang 1996, Swetnam 1993, Taylor and Skinner 1998). However, individual sites occasionally experienced longer (several decades) periods without fires severe enough to cause fire scars. FRI variation appears to be related to topography of the landscape (Beaty and Taylor 2001, Taylor and Skinner 1998), elevational gradients (Skinner and Chang 1996), and riparian corridors (Skinner 1997b). Notably, considerable variation in FRI within any given site is often present. These and other factors influencing variation in FRI undoubtedly helped to create diverse and changing patterns of DWM across landscapes. As a result, DWM would probably be clustered both in time and in space and sparsely distributed in the intervening time and space.

Several important patterns of variation appear to be emerging from intensive, landscape-scale, fire-history studies. Two studies in the Klamath Mountains have shown that fires were historically frequent (median FRI <20 yrs) throughout the studied landscapes regardless of tree species composition patterns (Taylor and Skinner 1998).[3] However, variation in fire frequency was found to be associated with slope orientation (aspect) (Beaty and Taylor 2001, Taylor and Skinner 1998) and broad elevational gradients (Agee 1991, Caprio and Swetnam 1995, Taylor 2000). Notably, the variation of FRI within a sample site is often as great or greater than are the differences among sample sites within a particular study. Generally, it appears that FRI is more closely related to a landscape's topographical structure than to the species composition of vegetation.

Although the frequency of past fires is important, it is but one of many factors that define fire regimes. In order to understand how fires may have influenced the dynamics of DWM, there is a need to better understand other characteristics of fire regimes, such as patterns of seasonality and severity.

Severity

Intensive landscape-scale studies in both the southern Cascades and the Klamath Mountains have shown that patterns of fire severity appear to be strongly related to a landscape's topography (Beaty and Taylor 2001, Taylor and Skinner 1998). The pattern that emerged in these studies indicates that slope position and aspect influenced fire severity *(fig. 1)*. Generally, within the local topography, the upper third of slopes displayed the highest proportion of area burned at greater severity, the middle third was intermediate, while the lowest third of the slopes displayed the least amount of severely burned area. When aspect was considered, a higher percent of area burned at higher levels of severity on south and west facing slopes. These are the slopes that are more strongly exposed to afternoon sun and the up-slope winds associated with more severe burning conditions. In contrast, the east and north facing slopes, associated with cooler, more humid conditions, had considerably less area with evidence of severe burns.

Seasonality

Time of year is important for understanding potential effects of fire on DWM. Fires are primarily spread by smaller dead fuels that dry out rapidly following the cool, wet season (Rothermel 1983). Notably, the larger the DWM, the longer it will take to dry out sufficiently to burn (Agee 1993, Martin and Brackebusch 1974). Thus, fires that occur in late summer and early fall are likely to consume more DWM than fires that occur in spring and early summer (Kauffman and Martin 1989).

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[3] Unpublished data for the Hayfork Adaptive Management Area on file at the Silviculture Laboratory, Pacific Southwest Research Station, Redding, Calif.

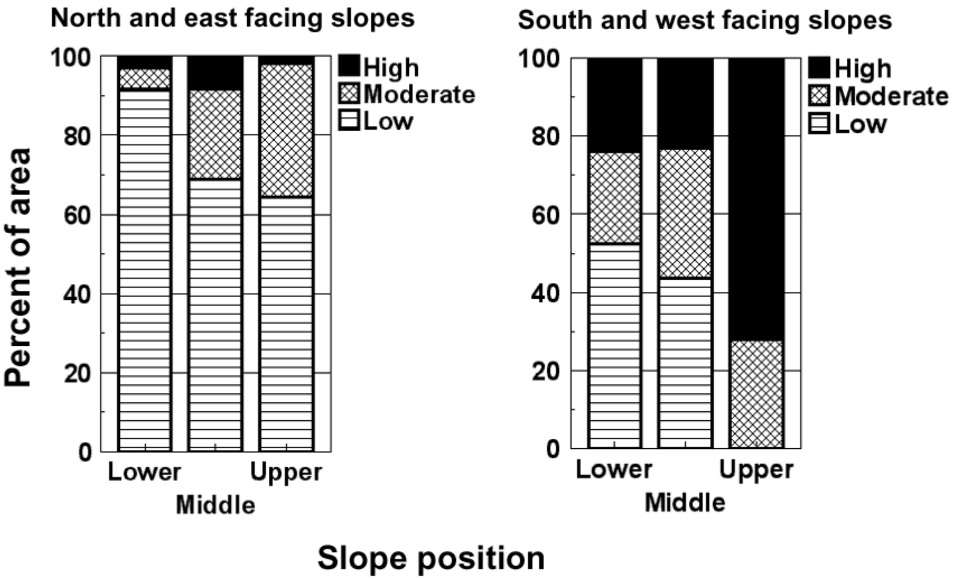

Figure 1—Topographical pattern of historical fire severity found by Taylor and Skinner (1998).

Season of burn may be inferred from the position of the fire scar within a particular tree ring (Caprio and Swetnam 1995). Generally, in California and southwestern Oregon, earlywood scars are interpreted as late spring/early summer fires, latewood scars as midsummer fires, and dormant season fires as late-summer or fall (Caprio and Swetnam 1995, Taylor 1998a, Taylor and Skinner 1998).

Fire history studies from the Klamath Mountains, southern Cascades, and northern Sierra Nevada commonly record the predominance of fire scars in the dormant period *(fig. 2)*. This suggests that most fires occurred in the late summer and fall—the driest part of the fire season and the time of year supporting the most consumptive burns (Thornburgh 1995). In the southern Sierra Nevada most fires were recorded in latewood, suggesting mid- to late-summer fires *(fig. 2)*. Fires burning at this time, while not necessarily at the driest part of the fire season, would also have burned under relatively dry conditions and would have been consumptive.

The likelihood that DWM will be consumed in a fire is related not only to season of the burn, but also to the degree of decomposition. Generally, the more decomposed the wood, the more likely it is to be consumed by fire during the drier portions of the fire season (Kauffman and Martin 1989, Martin and Brackebush 1974). Thus, in southwestern Oregon and California, it is unlikely that much DWM was able to decompose fully before fire suppression was implemented. The annual dry season and the frequency of fire suggest that a major role of fire was to accelerate the removal of DWM from the forests of this region.

It appears that landscape patterns of seasonality may be similar to patterns of severity. South and west facing slopes, especially the upper thirds and ridgetops, often have a portion of fires recorded in earlywood. In contrast, the fire scars found on trees occupying the lower thirds of slopes, especially on east and north facing aspects, are almost exclusively found in the dormant season (Beaty and Taylor 2001).[3] It is unlikely that early-season fires are necessarily more severe. Rather, these data suggest that those places that undergo early drying and can burn early in the fire season are also those that will probably burn more severely later in the season in other years. This is probably a result of more complete drying over the course of the fire season.

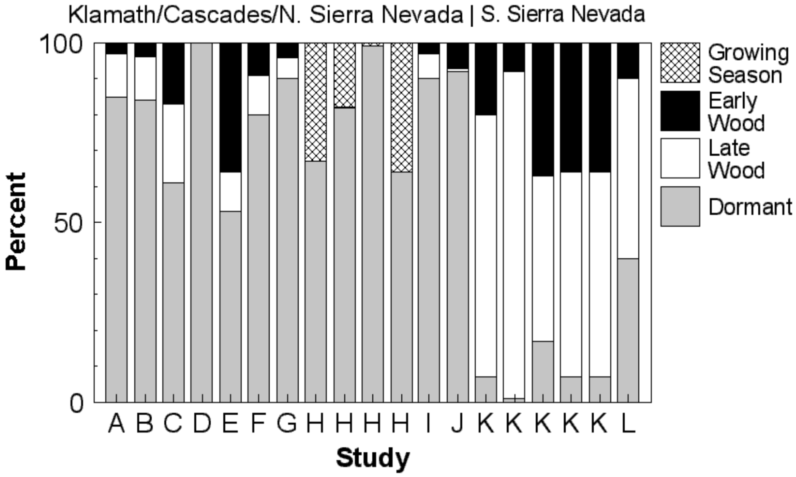

Figure 2—Intra-annual locations of fires scars in fire history studies from the Klamath Mountains, southern Cascades, and Sierra Nevada ranges arranged from north to south. Dormant season scars indicate late summer and fall fires; latewood scars indicate mid to late summer fires; and earlywood scars indicate spring and early summer fires. Where 'Growing Season' is used the study did not differentiate between late and early wood scars. Sources of data: A—Taylor and Skinner (1998); B—Unpublished data for the Hayfork Adaptive Management Area on file at the Silviculture Laboratory, Pacific Southwest Research Station, Redding, Calif.; C—Bekker and Taylor (2001); D—Solem (1995); E—Taylor (1998b); F—Norman and Taylor (1996); G—Norman and Taylor (1997); H—Taylor (2000); I—Beaty and Taylor (2001); J—Taylor (1998a); K—Swetnam and others (1992); L—Caprio and Swetnam (1995).

In climate regions characterized by less frequent fires and significant moisture in the warm season wood is often able to more fully decompose over time. In these more moist climates DWM has been found to be an important factor influencing patterns of nutrient cycling, micro-site moisture regimes, and development of invertebrate and fungal habitats among others (Harmon and others 1986). However, since it is unlikely that much DWM was able to decompose fully under historical fire regimes in the summer-dry climate of this region, very different ecological processes, of which there is only limited understanding today, were operating to influence these same ecological factors.

There are many other factors that may influence the variation of fires as they move across landscapes: fuel loading (often influenced by site quality), weather conditions, past history of fires, riparian corridors, rock outcrops, lakes, and patterns of insect activity and windthrow, among others. The factors that have been discussed in this paper are those that have been found to be important *ipso facto*.

Summary

Before this century, fires in the forests of southwestern Oregon and California were frequent and mostly of low and moderate severity. This was primarily because of the Mediterranean climate that virtually guaranteed a fire season every year regardless of total annual precipitation (as it does today) coupled with ample ignition sources and an absence of fire suppression. As a result, it was rare that any sizable areas would have escaped fire for more than a few decades. The frequency of the fires suggests that it was rare for DWM to have decayed fully before being consumed. Variability in fire regime characteristics has been found to be related to topography of landscapes. This variability probably contributed to variation in the spatial distribution of DWM over time. How past fire regimes would have affected the spatial patterns of accumulations of DWM through time is not yet known and is an important question for future research. Fire history research can help one to understand the variation in fire regimes and their contribution to vegetation patterns. This will help to suggest patterns of stand structures and dynamics that would have influenced spatial and temporal patterns of DWM. At the same time, there is a great need for empirical studies that evaluate the effect of fire on DWM under a variety of burning conditions (Kauffman and Martin 1989) in different landscapes and forests. Long-term experimental studies or adaptive management projects that monitor repeated prescribed burns over time would be especially useful.

Without further research, we will continue to be limited to conjecture in regards to the historical or reference spatial/temporal dynamics of DWM in regions characterized by annual summer drought and frequent fires. To fill the lack of knowledge, we will probably continue to impose standards from forests of other climate types that will carry with them a great deal of uncertainty in terms of the potential to successfully achieve long-term goals in our fire prone environments.

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