The Complex Nature of Mixed Severity Fire Regimes

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ABSTRACT

Mixed severity fire regimes are the most complex fire regimes in the western United States. Their landscape ecology is not intermediate between that of low and high severity fire regimes, but is unique in terms of patch metrics and the life history attributes of the species that are found there. Fire histories, in particular, are difficult to determine because most fire history techniques have been developed to study either of the extremes in fire regimes: low or high severity. Representing the variability in fire history of mixed severity fire regimes is essential. The application of surrogates, like timber harvest, to mimic the fire regime must take into account this intricate variability across the landscape.

INTRODUCTION

The concept of the fire regime has a long history. Some have been based on the characteristics of the fire, such as frequency and intensity (Heinselman 1973). Others have been based on potential vegetation (Davis et al. 1980). Still others have been based on fire severity (Agee 1993, Quigley et al. 1996, Hardy et al. 2001), and these appear to currently be in vogue. A fire regime classification based on fire effects incorporates both the physical attributes of the fire, such as fireline intensity, and the fire tolerance of the vegetation. The systems range from three-class (low or non-lethal, moderate or mixed, high or lethal) to five-class (0-35 yr low-mixed, 0-35 yr high, 35-100 yr mixed, 35-100 yr high, 100 yr + high severity). Yet each of these systems is an artificial construct, providing simple ‘pigeonholes’ for understanding the range of fire severities. In reality, severities occur along a gradient that may not necessarily be stable in space or time. Those pigeonholes, while quite useful, do create artificial breaks along the fire severity gradient, which are magnified in importance in the middle: the mixed severity fire regimes.

A mixed severity fire regime exists where the typical fire, or combination of fires over time, results in a complex mix of patches of different severity, including unburned patches, low severity patches where the fire may have been a low intensity underburn, moderate severity patches where perhaps one-third to two-thirds of the vegetation is killed, and high severity patches, where almost all the vegetation is killed. This description was derived for forest vegetation, but can also be applied to woodland and range ecosystems. The most common way that the fire regime is applied is to historical conditions. For example, in considering the concept of condition class, current states of the ecosystem are compared to the historical fire regime in order to assess deviation from historical condition. At any single point on the landscape, there is no characteristic signature of a mixed severity fire regime: it is visible only at an appropriately coarse scale. The fire may be the ‘friendly flame’ at one place in space and time, and make toast of the landscape at another. This complicates study of such fire regimes, and presents unique challenges to fire managers.

The nebulous classification of mixed severity fire regimes carries over into all aspects of fire ecology. The landscape ecology of mixed severity fire regimes is not simply an intermediate state between low and high severity fire regimes. It has unique characteristics found only in these fire regimes. Fire history methods are difficult to apply in mixed severity fire regimes. For low severity fire regimes, fire scar analysis works well (Agee 1993, Wright and Agee 2004). For high severity fire regimes, either natural fire rotation (Heinselman 1973) or fire cycle (Johnson and Van Wagner 1985) techniques that are partially or wholly based on age class analysis, can be applied. But in mixed severity fire regimes, even-aged vegetation classes and fire scars are both present, and to make sense of the history, both sources of information may be needed. Challenges also exist with the application of fire surrogates such as timber harvest, given the complex nature of the fire regime that harvest may attempt to mimic.

LANDSCAPE ECOLOGY OF MIXED SEVERITY FIRE REGIMES

In its simplest form, landscape ecology deals with the metrics of landscape patches: their composition, size, and interspersion. When the landscape ecology of fire is considered, real differences show up between low, mixed, and high severity fire regimes. Patch sizes in low severity fire regimes are generally small, intermediate in mixed severity fire regimes, and large in high severity fire regimes (Agee 1998). This is one of the few characters of mixed severity fire regimes that is intermediate between low and high severity fire regimes. Edge, for example, tends to be low and relatively “soft” in low-severity fire regimes: the difference between a patch of 200- and 350-year-old ponderosa pine is scarcely noticeable. In high severity fire regimes, while edge often increases with size (e.g., Eberhart and Woodard 1987), it is at best moderate, while edge is maximized in mixed severity fire regimes (Figure 1).

The controls over the mixed severity fire regimes are equally complex. There is no doubt that fuels, weather, and topography all play important roles in all fire regimes, but the relative importance of these may vary. It is usually argued that in high severity fire regimes, weather is a dominant factor (Bessie and Johnson 1995, Agee 1997). When the rare fire does occur, it kills most vegetation in its path. In low severity fire regimes, fuel is a key factor in assessing fire severity (Agee 1997). Patch dynamics were controlled by where dead fuels had accumulated, such as bark beetle-killed patches of old senescent pines. While climate, as a top-down factor, was also important (Heyerdahl et al. 2001), local scale variation was fuel-driven. The major factor in the deterioration of low severity fire regimes from condition class I to III is the change in fuels.

Mixed severity fire regimes appear to have significant controls by fuels, weather, and topography. Fuels are variable because of the past history of fire. Low severity patches in the last fire lost dead fuels, moderate severity patches generally had a net gain, and high severity patches had a large gain. In some sense, this preconditions variability for the next fire. Weather is operable often for many weeks to months, so the fires burn at day and night, during cloudy or sunny weather, in calm and windy conditions. This creates more variability within and between fires. Topography may also play an important role. In some mixed severity fire regimes, low-severity patches are most commonly found on lower portions of slopes and north/east aspects, while high severity patches are found on upper slopes and more on south/west aspects (Taylor

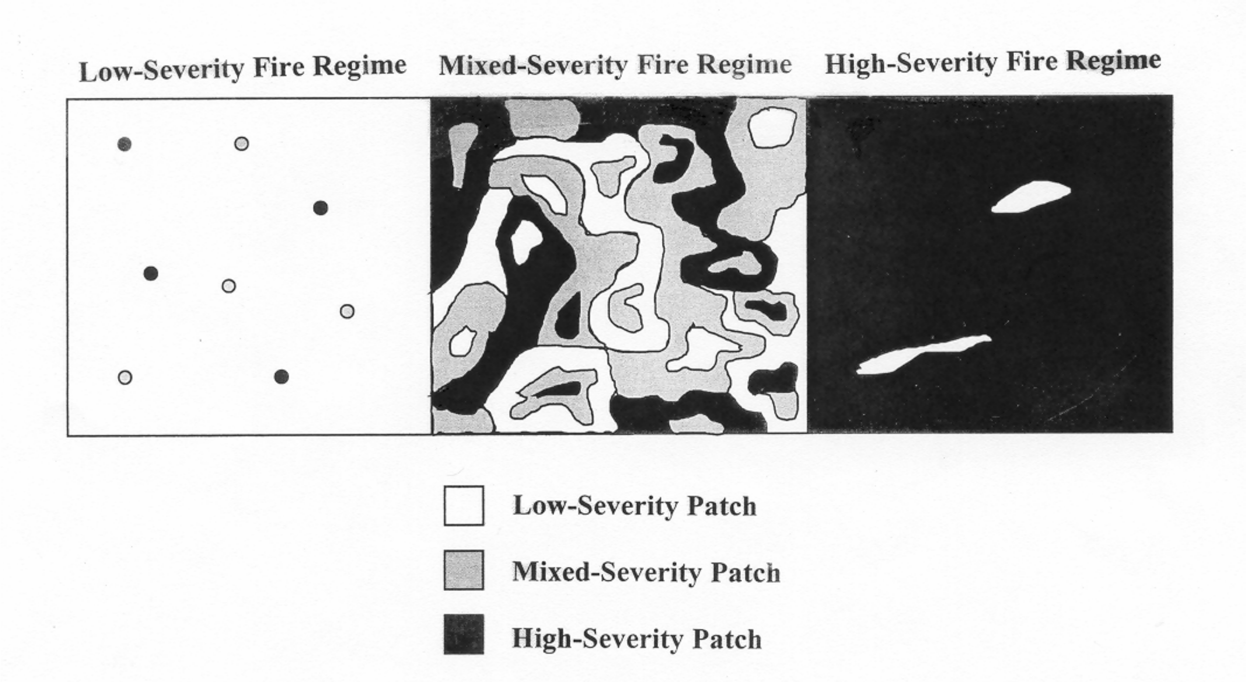

Figure 1. Mixed severity fire regimes are in the middle of the fire severity gradient, but the characteristics of the fire regime are not always intermediate to those of low and high severity fire regimes.

and Skinner 1998). The variability in patches then acts as a filter for future fires, sometimes stopping a fire and at other times, when fuel or weather are more extreme, letting the fire pass through the patch.

An additional control on mixed severity fire regimes is the presence, usually at local scale, of vegetation that is well adapted to a variety of fire severities. In red fir forests, for example, red fir (*Abies magnifica*) is thick-barked when mature, and acts as a *resister* species (sensu Rowe 1981). But these forests also contain thin-barked lodgepole pine (*Pinus contorta*), more of an *evader* species easily killed by fire but capable of high regeneration rates after fire. The severity of the fire is not only dependent on fuels, weather, and topography, but also on the tolerances of the species growing at the site. In red fir forests, Chappell and Agee (1996) found that old forest (300-500 yrs) that had recently burned had a distribution of low, mixed, and high severity of 68-27-5%, while young forest (50-80 yrs) had a distribution of 41-35-24%.

A similar case can be made for Douglas-fir forests where knobcone pine (*Pinus attentuata*) is present. Serotinous-coned knobcone pine, along with sprouting hardwoods, tend to dominate high severity patches, while thick-barked Douglas fir (*Pseudotsuga menziesii*) dominates places on the landscape where they have survived multiple fires, and hence themselves define much of the low severity portion of the landscape. On the 200,000 ha Biscuit fire in southern Oregon in 2002, knobcone pine was selectively removed by fire from mixed Douglas-fir/knobcone pine stands (Raymond 2004).

Forest structure may also influence fire frequency as well as severity, although this is more speculative. Open patches tend to be warmer, drier, and have less fire-tolerant and more flammable vegetation (particularly grass or bracken fern), so fire can recur more easily in these areas. Before timber salvage was practiced, snags and downed logs also helped carry reburns through the forest. In some regions (e.g., Kootenai National Forest, Montana), once forest canopy was re-established, reburns at short intervals were greatly reduced (personal observation of the author, Summer 2004). The Tillamook Fire (albeit a high severity fire regime), which burned in 1933, 1939, 1945, and 1951, and not since, is a good example of this phenomenon (Heinrichs 1983).

Mixed severity fire regimes also have complex patterns of coarse woody debris (CWD) dynamics. These patterns create consistently high levels of CWD, and likely have major implications for wildlife, as a majority of wildlife species in the Pacific Northwest utilizes CWD. In low severity patches, there is likely a net loss of CWD; in moderate severity patches, some CWD is consumed, but some is created through the mortality created by the fire; and in high severity patches, all the lives trees are converted to CWD. These effects occur at a local scale, opening patches for prey species while maintaining cover and CWD for birds and mammals of concern, such as the pileated woodpecker (*Dryocopus pileatus*), American marten (*Martes americana*) and fisher (*Martes pennanti*) (Agee 2002). CWD levels were likely, on average, higher in the mixed-severity fire regimes than either of the other two fire regimes.

CHALLENGES IN FIRE HISTORY

Mixed severity fire regimes are difficult to study because of the mix of techniques that are required to determine an adequate fire frequency record. Generally, both fire scar and age-class data must be utilized. Even then, average fire return intervals are much less useful than metrics of variability. For example, at Desolation Peak in Washington, Agee et al. (1990) found an average fire return interval of 100 years, but when parsed out by century, the range was 60-208 years; by aspect, 65-182 yrs; and by forest community type, 52-137 years. Another technique is to use a statistical distribution such as the Poisson distribution (Agee 1993).

The Poisson Distribution as a Measure of Fire Variability

The natural fire rotation technique (Heinselman 1973) was chosen for the reanalysis of fire data collected in the South Deep watershed, Colville National Forest, Washington (Schellhaas et al. 2000). Using fire scar analysis within roughly 240 ha (600 ac) polygons, they concluded that for the watershed as a whole, mean fire frequency was 5.9 years before settlement (pre-1860) and 2.5 years after that (1861-1924). But this means only that a fire occurred somewhere in the watershed at that frequency and has little relevancy at the stand level. Point-based fire return intervals ranged between 15.7 and 46.7 years, but this is still at an area frequency (the area being defined by the 240 ha polygon size). I reanalyzed these data with the objective of providing a better picture of the variability that these metrics implied.

The time period used here is for the entire period used by Schellhaas et al. (2000): 1683-1924. The NFR for the period, which says nothing about the variability across the landscape, was:

$$\text{NFR (years)} = 241/(87985/11759) = 32 \text{ years}$$

Variability across the landscape was analyzed by a Poisson technique (Agee 1993, p. 103-106). A roughly 57 acre grid was placed over the landscape, and each time a fire burned at least one-half of a grid cell, that grid cell was counted as burned. Over time, some grid cells accumulated many burns, while others had but a few. The average number of times a grid cell burned becomes the Poisson parameter α. If done accurately, the time period divided by α should be equivalent to the natural fire rotation. Due to the coarse grid cell used, and the rule that one-half of a cell had to burn for the grid cell to be counted as burned, it was expected that the NFR calculated this latter way would be slightly longer than by the former technique.

Once the Poisson parameter is determined, the expected proportion of the landscape that burned 1, 2, 3, 4 …..n times can be calculated from the formula

$$P(x = k) = e^{-\alpha} \alpha^{k} / k!$$

Where

x = number of fires in a grid cell
k = a discrete value of x
e = base of natural logarithms
α = the Poisson parameter (average number of fires per cell)

Before the Poisson can be interpreted as a way to describ variability in NFR, it must be checked against the actual distribution of grid cells stratified by the number of times each burned. This was accomplished using the Kolmogorov-Smirnov test. The Poisson distribution was not significantly different from the actual distribution at the 5% significance level, and therefore it was used to describe fire return interval variability. By obtaining the quotient of the expected number of times a cell burned and the time period, an equivalent NFR can be calculated for that portion of the landscape. The modal NFR is 34 years (Figure 2), and more than 15% of the landscape has a NFR above 60 years. On the other end, about the same proportion has a NFR below 25 years.

The value of the Poisson analysis is that it illustrates the variability found in a mixed severity fire regime such as occurs at South Deep and elsewhere. There are spatially discrete areas in South Deep that have burned frequently and likely with low severity. There are also areas with much longer fire return intervals and likely much higher severity. The relevance of this to land management is that there are likely places in South Deep that, because of fire exclusion efforts, are now subject to higher severity fires than they would have been had fire been allowed to play a more natural role in the ecosystem. Based on the entire time series, it appears that about 20% of the watershed had a NFR less than 25 years. There are also areas where it would be difficult to conclude that any unnatural fuel accumulation had occurred.

The Confounding Effect of Frequency and Severity

Mixed severity fire regimes where high severity fire patches occur, can destroy possible sample trees with multiple fire scars. Studies that are oriented around fire scar analysis may find less fire scar material there, and possibly conclude that fire is less frequent, when it

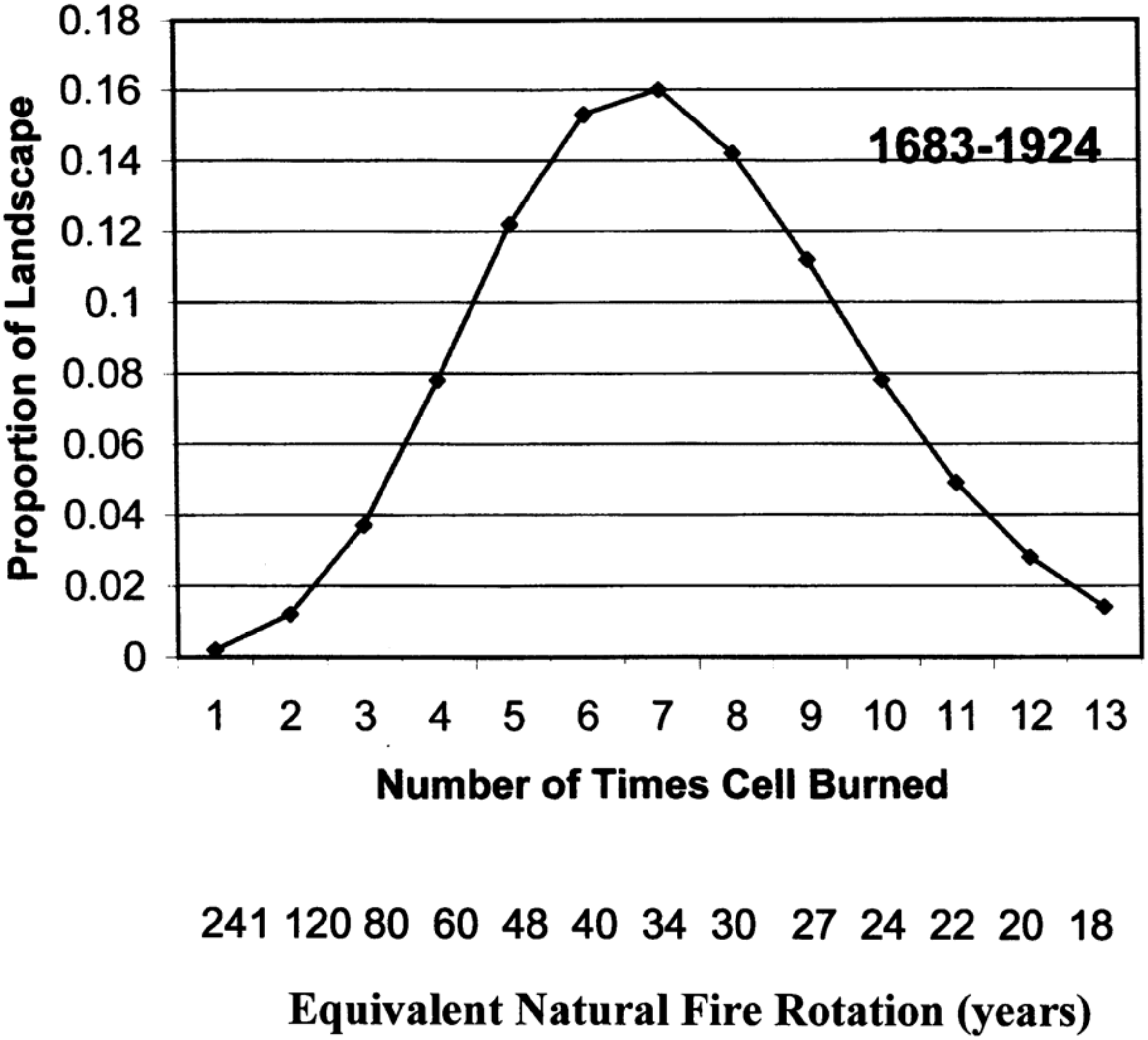

Figure 2. A Poisson distribution, illustrating the variability in the fire regime of the South Deep watershed, Colville National Forest, Washington. Based on a grid cell analysis, it shows the proportion of the landscape that burned 1, 2, …n times, and the equivalent natural fire rotation (years) between 1683-1924 A.D. The natural fire rotation over this roughly 5000 ha landscape ranges from 18 to 241 years.

may be of similar frequency but have a higher severity. Two examples from the Umpqua National Forest, Oregon, illustrate this conundrum.

In the Little River Adaptive Management Area (AMA), a tributary to the North Fork Umpqua, the watershed analysis (USDA Forest Service 1995) found 31 fire episodes were identified from 1613 to 1938. But the mean fire return interval (FRI) of 13 years must be interpreted as for the South Deep dataset: every 13 years, on average, somewhere in the Little River AMA, there was a fire event. At the stand level, Van Norman (1998) found a median fire return interval of 123 years, which she thought was conservative. Low and moderate severity fires were thought to have been more common than high severity fires. At low elevation, south aspects were interpreted to have longer fire return intervals than north aspects. This may be an artifact of fire severity, as south aspects may be subjected to more stand-replacing events and contain less evidence for repeated fire activity than the lower severity fires on north aspects. Similarly, Olson (1999), working further up the Umpqua River, found less fire scar evidence on west aspects, implying a longer fire return interval, when the same phenomenon may be at work. Teasing out the confounding between fire frequency and severity may be particularly troublesome in mixed severity fire regimes.

THE USE OF FIRE SURROGATES

The use of surrogates for fire such as timber harvest, in addition to fire, may be more likely to be successful in re-establishing a mimic of natural fire patterns on these landscapes (e.g., Cissel et al. 1999) than fire alone. One reason is that the mix of severities presents fire management challenges that are difficult to overcome using prescribed fire, particularly when fire severities increase. Many mixed-severity fire regimes already have a template of management, such as clearcut patches, that have altered the more natural patterns of a spectrum of fire effects. While I do not pretend to argue that timber harvest is a complete substitute for fire, it can be used to restore a more natural pattern. I use the case of the Little River AMA, a mixed severity fire regime, as a case study.

Stand replacement burn activity for Little River over the period ca. 1845-1945 (before the industrial forestry era began there) showed 9250 ha (22,845 ac) burned, resulting in even-aged post-fire stands, of the watershed total of 53,400 ha (131,849 ac) (Ray Davis, Umpqua National Forest, unpublished information). This is equivalent to 17.3% of the watershed area in a century, or 1.73% in a decade, or 0.173% in an average year. Since 1945, about 57% of the Little River watershed has been harvested using even-aged silvicultural techniques. Assuming this has occurred in a 50-year period, it is equivalent to an annual rate of 1.14% of the watershed area. This comparison shows harvest increased even-aged stand creation at a rate 6.6 times that of the historic (fire-generated) rate for the last 50 years. Achieving a balance in the proportion of even-aged to multi-aged forests requires a focus away from future clearcutting and more on intermediate operations to create multi-aged stands from single-aged stands, mimicking the mixed severity fire regime.

Size, shape, and spacing of stands of varying character will be important. Historic fire sizes (which we often do not have) cannot inform us without knowledge about the proportions of fire severity within that fire size. Real historic landscapes had spatial gradients of fire severity linking, for example, a late-seral, old growth stand to a stand-replacement patch. Rarely were the sharp edges we see in recent-decade clearcuts present on the Umpqua landscape. The issue of natural shaping is addressed in current Forest Service NFMA planning regulations but appears to be largely ignored. Within one harvest unit, clearcut, seed tree, shelterwood and selection mimic harvests are not only possible but should be desirable (with the caveat that on the Little River landscape the clearcut patch is already over-represented and should be avoided). In the absence of more information, higher basal areas should be left on flats, nearer to riparian areas, and on north-facing slopes (not surprisingly where past harvest has concentrated).

Where historic stand-replacing fires occurred, even-aged stands would have resulted. It is likely that these types of events were more likely on steeper, south-facing slopes (more likely to be hotter and drier and conducive to torching-type upslope fire runs) and areas with the longest fire return intervals (which only burn in extreme weather). Future regeneration harvests, either by clearcutting or low green tree retention, should be blended in to surrounding areas, not placed as angular blocks on the land. Given the over-representation of young seral stands at present, this is likely to be a rare need in the next few decades. Underburning may still be used, but probably not applied to the whole landscape. Areas where a low severity fire regime are most likely and desired are places that should receive priority for underburning.

SUMMARY AND CONCLUSIONS

Mixed severity fire regimes present major challenges for scientists and managers. Research techniques to characterize such fire regimes are limited, and there is little information to establish whether the complex patch mosaic is stable in space or time. The managerial challenge, where fire or fire surrogates are used, is to mimic the substantial variability in the mixed severity fire regimes.

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