Wildfire Risk and Ecological Restoration in Mixed-Severity Fire Regimes

Peter M. Brown

Wildfire risk to ecosystems and human communities varies considerably depending on the severity of fire behavior that occurs during burning. Fire severity, in turn, is dependent on fuel amount, arrangement, and horizontal and vertical continuity, which – in forests – is often broken into broad categories of surface and canopy fuels. Fire scars – areas of cambial mortality caused by low-severity surface burning – recorded in cross-dated tree-ring sequences have proven extremely useful for documenting that frequent surface fires occurred in many mid-elevation forests in western North America, especially those dominated by ponderosa pine (*Pinus ponderosa*). These fires burned mainly in surface fuels and rarely killed mature trees because of their thick bark and high crowns. Fire cessation in these forests began in the middle to late nineteenth century because of Euro-American settlement, initially as a result of widespread livestock grazing that removed surface fuel biomass and followed later in the twentieth century by active fire suppression by land management agencies. Fire exclusion has resulted in unchecked tree establishment, increased stand densities, a lowering of stand-level canopy base heights, increased numbers of small trees, deeper layers of needle litter, and an overall increase in crown fire potential in current forests. Conversely, canopy fuels have always dominated in upper-elevation subalpine forests, where fires are generally less frequent but much higher severity during which large areas of forest are killed.

Understanding such spatio-temporal variations in fire behavior is important for predicting where fuel management or ecological restoration will be most effective in reducing fire risk. As a general rule, ecological restoration is best suited for ecosystems that experienced surface fires, where modification of fuels or forest structure can play a significant role in reducing both the likelihood of crown fire

P.M. Brown (✉)
Rocky Mountain Tree-Ring Research, Ft Collins, CO 80526, USA
e-mail: pmb@rmtrr.org

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and the potential economic and ecological damage caused by a catastrophic wildfire. However, a question arises in ecosystems that experienced what is often called mixed- or variable-severity fire behavior, in which crown and surface fires occurred during individual fires or during different fires at the same location (e.g. Baker et al. 2007). It is not as clear in these forests that fuel modification or ecological restoration either is warranted or will be potentially effective in reducing the risk of a catastrophic wildfire.

Tree-ring data from ponderosa pine forests of the Front Range of the Rocky Mountains in Colorado and the Black Hills in southwestern South Dakota document that mixed-severity fires were present in some areas prior to Euro-American settlement (Brown et al. 1999; Brown 2006; Sherriff and Veblen 2007). The presence of denser stands and crown fires historically has led some to conclude that large-scale forest thinning or reintroduction of surface fires as means for ecological restoration is not appropriate across many of these forests (Veblen 2003; Baker et al. 2007). However, a major question that must be asked about this conclusion is how often crown fires occurred and how big an area they covered relative to surface fire in the historical forests. For example, a recent dendroecological study at Mount Rushmore National Memorial in the Black Hills – home of the world-famous Mount Rushmore sculpture – used dates and locations of fire scars and tree recruitment to estimate that crown fires burned only about 3.3% of the total area burned between 1529 and 1893 (Brown et al. 2008). The rest of the area burned as surface fire. Other fire history studies have shown that typical sizes of crown fire patches in the past were likely on the order of hectares to tens of hectares at most (Brown et al. 1999; Brown 2006). This strongly contrasts with recent mixed-severity fires, in which areas of crown mortality were orders of magnitude larger, including an area of almost 25,000 ha of almost complete overstory mortality that occurred during the 2002 Hayman Fire in central Colorado (Graham 2003). The scale of crown mortality that occurred not only in the Hayman Fire but also during other recent fires in the Front Range and Black Hills appears to be completely unprecedented relative to all available historical reconstructions, suggesting that forest stand and landscape structures are well outside of their historical ranges of variability. These larger areas of crown fire appear to be a direct result of fire cessation that has led to more contiguous, denser stands across landscapes. Thus, simply to conclude that past fire behavior was mixed- or variable-severity does little either to characterize fire as an ecological process or to provide direction for fuel management or ecological restoration efforts in these forests.

One approach to the question of how mixed-severity fire regimes may have changed from historical to current forests is to focus on the underlying dynamics of fire as a disturbance process and how individual species respond to spatiotemporal variations in fire behavior. Falk (2006) has suggested restoration efforts should focus on the ecological processes that sustain and characterize ecosystem function rather than concentrating solely on local ecosystem patterns produced by those processes. Viewed from a process-centered perspective, the local fire history may be seen as only one realization of multiple stochastic and deterministic processes that affected a particular configuration we see or reconstruct today (*sensu* Lertzman et al. 1998).

The true focus for restoration ecology and fuel and forest management in general should be to characterize underlying ecosystem dynamics that affected both the specific realization that we are able to reconstruct as well as the range of variation possible within a particular ecosystem type.

A process-centered restoration approach defines and uses historical dynamics in both biotic and ecosystem processes as central foci for restoration design and implementation (Falk 2006). In ponderosa pine forests throughout their range, the central ecological theme is that of episodic, frequent, surface fires. Although some ponderosa pine forests, such as those of the Front Range and Black Hills, apparently experienced areas of crown fires of varying sizes in the past, the relative scale of crown to surface burning is often based on questionable evidence, difficult to quantify even when adequate evidence is available, and, perhaps more critically, difficult to address in restoration programs. Furthermore, crown and mixed-severity fires will undoubtedly continue to occur in future wildfires. Funding and management policies for landscape-scale restoration programs are currently not in place, and large areas of dense stands of trees that are highly susceptible to crown fires will undoubtedly continue to persist in most ponderosa pine landscapes well into the future. Yet what is currently missing from virtually all ponderosa pine forests throughout its range in western North America are surface fires, especially those that are allowed to burn across large areas. We know with great certainty from tree-ring evidence that such fires occurred with regularity in the past. Restoration of surface fires and forest structure will not only restore longer-term function and resilience to ponderosa pine ecosystems throughout their range, but also substantially reduce the risk and adverse effects of future wildfires on human communities and natural resources across the region.

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