Ecological Restoration Institute
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Protecting Old Trees from Prescribed Burning

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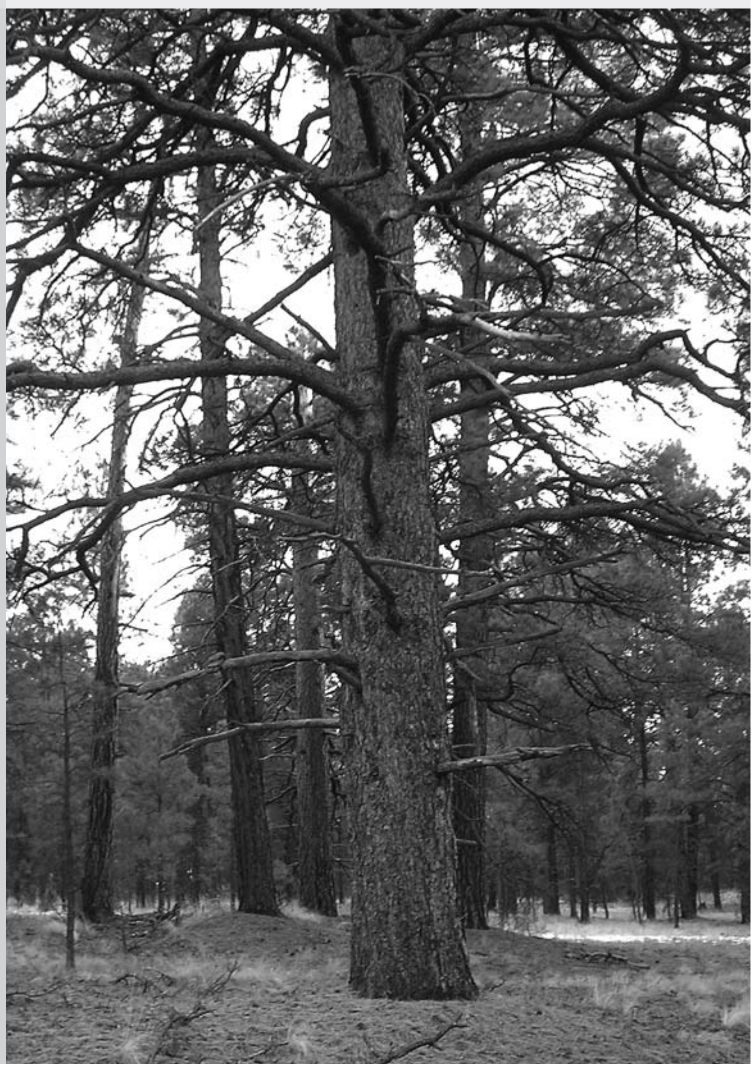

NORTHERN ARIZONA UNIVERSITY

Ecological Restoration Institute

Working Papers in Intermountain West Frequent-fire Forest Restoration

Ecological restoration is a practice that seeks to heal degraded ecosystems by reestablishing native species, structural characteristics, and ecological processes. The Society for Ecological Restoration International defines ecological restoration as "an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability.…Restoration attempts to return an ecosystem to its historic trajectory" (Society for Ecological Restoration International Science & Policy Working Group 2004).

Most frequent-fire forests throughout the Intermountain West have been degraded during the last 150 years. Many of these forests are now dominated by unnaturally dense thickets of small trees, and lack their once diverse understory of grasses, sedges, and forbs. Forests in this condition are highly susceptible to damaging, stand-replacing fires and increased insect and disease epidemics. Restoration of these forests centers on reintroducing frequent, low-severity surface fires—often after thinning dense stands—and reestablishing productive understory plant communities.

The Ecological Restoration Institute at Northern Arizona University is a pioneer in researching, implementing, and monitoring ecological restoration of frequent-fire forests of the Intermountain West. By allowing natural processes, such as low-severity fire, to resume self-sustaining patterns, we hope to reestablish healthy forests that provide ecosystem services, wildlife habitat, and recreational opportunities.

The ERI Working Papers series presents findings and management recommendations from research and observations by the ERI and its partner organizations. While the ERI staff recognizes that every restoration project needs to be site specific, we feel that the information provided in the Working Papers may help restoration practitioners elsewhere.

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Cover Photo: An old tree with a duff mound and small, coarse woody debris at its base. Prescribed burning through the area shown could cause the duff mound to ignite and smolder, potentially damaging fine tree roots or the tree cambium. While earlier recommendations suggested raking duff away from all old trees, more recent research suggests that removing duff from the base of old trees may be necessary only in cases where the tree has signs of previous damage (i.e., fire scars, pitch seams, lightning scars). This and other recommendations about prescribed burning near old trees are updated in this ERI Working Paper. *Photo by Dave Egan, ERI*

Introduction

Although now relatively rare due to high-grade logging throughout the Intermountain West, old trees and old-growth stands still exist in the region's frequent-fire forested landscapes (SREP 2000, Kaufmann and others 2007). These old trees and old-growth stands help sustain the ponderosa pine ecosystem in terms of structure, processes, composition, and food-chain interactions—at a variety of scales. Older trees are also important because they have survived centuries of environmental and biotic fluctuations, and their seeds and pollen may make critical contributions to genetic diversity (Kolanoski 2002, NCSSF 2008).

One of the real problems restorationists encounter when they work in areas with old-growth trees is the possibility that prescribed burns—a recommended and useful restoration technique, especially when proceeded by mechanical thinning—may kill or seriously injure these biologically and socially important trees. This tricky situation developed in part because decades of fire suppression have allowed needle litter and duff to accumulate at the base of old trees instead of being consumed by frequent, surface fires. In ERI Working Paper No. 3 (Minard 2002), author Anne Minard cited a variety of ways to prevent fire-caused old tree mortality in southwestern ponderosa pine stands, including raking fuels away from the base of old trees. This working paper will review and update the recommendations made in that earlier ERI working paper in light of new research findings as well as the desire to expand restoration efforts to the landscape scale throughout the region.

Why Fires Can Kill Old Trees

Although tree species with thick bark, such as Douglas-fir *(Pseudotsuga menziesii)*, ponderosa pine *(Pinus ponderosa)* and western larch *(Larix occidentalis)*, are adapted to survive low-intensity, surface fires, they may be susceptible to such fires when the depth of litter and duff around them increases dramatically due to decades of fire suppression and the natural tendency of ponderosa pine, in particular, to slough off bark flakes as well as needles. As these flakes and needles decompose, they form a duff layer around the base of a tree that increases with time unless it is removed by fire or another disturbance. The ability of fire to remove the duff depends largely on the fire intensity, the amount of duff, and the duff's moisture level. Thicker duff and duff that is moist take longer to burn than thinner duff and dry duff. While a thin layer of duff will be quickly consumed by fire, a thicker, dry duff will burn slowly and at high temperatures injuring the nearby tree by damaging its cambium and roots.

For example, Ryan and Frandsen (1991), in their analysis of 19 old ponderosa pines following a late summer, low-intensity prescribed burn in northwestern Montana, found that burning duff mounds beneath those trees produced a lethal level of heating in 45 percent of the cambium samples, causing the subsequent death of four trees after six years.

While these results are from only one site, they are likely to be fairly representative because smoldering mounds of duff can produce high, damaging temperatures for long periods of time. For example, Agee (1973) measured temperatures greater than 572°F for as long as two hours when burning ponderosa pine duff. Similarly, Hartford and Frandsen (1992) reported soil temperatures of 750°F under smoldering duff mounds, with duff temperatures greater than 212°F for more than 16 hours.

These and other studies (see Fowler and Sieg 2004, Hood 2010) provide strong evidence that there are three general ways that prescribed fire can kill trees, including old trees: 1) injury or destruction of the cambium; 2) injury or death of the roots, including fine roots; and 3) secondary effects, due to bark beetles, disease, and climate stress.

Cambium

The cambium is a layer of living cells, between the inner bark and the sapwood, that each year produces additional wood (xylem) and bark (phloem) cells. It is responsible for the diameter growth of a tree. The cambium is killed when temperatures reach approximately 140°F, a temperature that can easily be reached during a prescribed burn as noted above. Cambium kill occurs when fire destroys enough of the cambium layer to effectively girdle the tree and, thereby, stop the flow of nutrients and water. In trees with thick bark, this occurs when a smoldering fire settles into the duff layer and burns slowly, but with enough heat, to severely impair the cambium at the base of the tree. This type of fire tends to leave a ring of blackened, charred bark near the ground. Partial cambium kill often results in a fire scar. Fire-scarred trees are more vulnerable to future cambium kill because fire scars often provide openings for fire to enter underneath the bark following xylem (wood) decay.

Roots

Root injury occurs when smoldering ground fires kill roots growing near the soil surface or in duff or litter. Like cambium kill, root injury and/or mortality result from temperatures of 140°F and long-duration, smoldering fires in the duff and litter. Sackett and Haase (1998) found that deep, smoldering duff in ponderosa pine forests can heat the soil at least 8 inches deep to more than 140°F. They also found that similar conditions in mixed conifer forests produced lethal temperatures to 4 inches deep in mineral soil. Such fires kill fine roots, which are vital for water and nutrient uptake, and may force trees to use available carbohydrates stored in coarse roots in order to survive. Fine roots are especially susceptible to these smoldering fires because they are often growing in the duff rather than underground. Cavities in the root zone of old trees as well as nearby rotten stumps with dead roots make old trees vulnerable to damage from surface fires and smoldering, ground fires. Determining root kill can be difficult because there is limited visual evidence of injury to the tree.

Secondary Effects

Once trees have been severely injured from fire, it's usually only a matter of time before they will die due to pine beetles, disease, and/or drought-induced stresses. How rapidly this happens depends on the severity of the fire damage, beetle population levels, number of diseased trees in the area, and climatic conditions.

Review of Previous Recommendations in Light of Recent Research

Burn When Trees are Dormant and Forests are Moist
The original ERI working paper recommended dormant season (late fall) burning as the best way to protect large ponderosa pine trees from prescribed burning, and this still holds true for the southwestern United States. Burning during the dormant season, ideally with a somewhat moist duff layer, significantly reduces the chances that fine roots will be destroyed in this region (Sackett and others 1996, Hood 2010). In other areas of the Intermountain West, early spring burns, again when duff moisture levels are relatively high, may be the best option (Perrakis and Agee 2006, Hood and others 2010) for prescribed burning near old ponderosa pines.

Use Fire Spread Types and Ignition Techniques that Result in Low-intensity Fire
As reported in the earlier working paper, the low-intensity heat created by backing fires, short-run strip fires, and spot ignitions create conditions that help prevent old-tree mortality. That said, Weatherspoon and his colleagues (1989) warn against using backing fires or strip-head fires in downslope situations where those very slow-burning fires can reside long enough to preheat the uphill side of a tree causing the bark to ignite when the flames reach the tree.

Avoid Burning on Lava and Very Thin Soils
While little additional research has been done to confirm this recommendation, which was based largely on ERI research at Mt. Trumbull in northwestern Arizona (Fulé and others 2002, 2007; Waltz and others 2003; also see study from Oregon by Swezy and Agee 1991), burning on thin lava-based soils and other very thin soils is still not recommended because fires tend to have long residence times in these substrates, which can kill fine tree roots and important soil microfauna.

Rake Fuels Away from Old Trees to Increase Their Survival Rate
Recent studies indicate that saving old trees by removing fuels from their bases is more complicated than previously thought. Since the earlier ERI working paper, there have been two controlled experiments dedicated to exploring this issue and making management recommendations (Fowler and others 2007, 2010; Hood and others 2007, Hood 2010). While these studies were limited, the results suggest the following:

- Removing litter and duff from around old trees may not be necessary, except in those cases where old trees have fire scars and/or pitch seams, are located near old stumps, or are growing in droughty microsites.

- The decision to rake or not around old trees should be based on management goals and objectives, tree species involved, current level of bark beetle activity, amount of duff, and prescribed burning conditions. While some small-scale studies show the effectiveness of raking (Swezy and Agee 1991, Covington and others 1997, Kolb and others 2001, Fule and others 2002), there will likely be situations were manually removing litter and duff is not worth the time and/or effort (Hood and others 2007).

- Manually removing litter and duff from around old trees is basically an individual tree-level operation. It could be employed at the stand level but only if the necessary resources can be found and deployed.

- If the decision is made to remove litter and duff, the material should raked or blown at least 9 inches away from the base of the tree, and removed 3 feet (or more, as necessary) if shallow, exposed roots are present. Be careful not to create a berm of raked material around the tree.

- Leaving 2 to 3 inches of duff within a 9-inch radius around old trees will not cause any harm, except to those trees with rotten fire scars; pitch seams; large, nearby stumps; or those growing in droughty microsites. For this group of old trees, completely removing litter and duff from a larger radius will be necessary.

- In a study of ponderosa pine and Jeffrey pine *(Pinus jeffreyi)* stands in northern California, Hood and her colleagues (2007) found that the average time for one person to rake one large, old tree was 16 minutes. The depth of litter and duff near the tree base and the number of shrubs in the removal area were key factors in determining the amount of time involved. Other anecdotal reports (Fulé pers. comm.) suggest that raking can be done more quickly.

- Using a commercial-size leaf blower is as effective as raking at preventing cambial kill and bole char, although it may take slightly longer because it requires a two-person crew, one to loosen the litter and duff with a rake and the other to operate the leaf blower.

- Rake or leaf blow during the fall or winter when fine root growth is minimal.

- Allow at least 60 days, and preferably one growing season, after raking or leaf blowing before attempting a prescribed burn. This will give new fine roots time to develop in mineral soil.

- While there is limited research to support the idea (although see Weatherspoon and others 1989), it may be prudent to remove litter and duff from old trees on slopes in drainages, ravines, and canyons because prescribed burns, regardless of ignition type, are likely to burn hotter and less predictably in these landscape positions than in flatter, open topography.

- Some thick-barked trees, notably giant sequoia *(Sequoiadendron giganteum)* and western larch, appear extremely resistant to smoldering, duff fires and probably do not require litter and duff removal (Hood 2010).

Manually Clear Out Live, Dead, and Downed Fuel from Beneath the Canopy of Trees to be Protected

As in the earlier ERI working paper, researchers continue to recommend removing all coarse, woody debris (and even large pine cones, Hood 2010) from the vicinity of old trees because these woody items can ignite and burn slowly and deeply into the duff layer causing damage to fine roots. Masticating coarse woody debris is also an option (Hood and others 2007), although it can be expensive because the process involves equipment and equipment operators.

Burn Frequently to Maintain Healthy Forests

At the stand level and larger scales, prescribed burning, typically preceded by mechanical thinning, may be the best way to remove decades of accumulated litter and duff around old trees. Unfortunately, it cannot be all done at once without damaging or killing old trees. The best strategy is to introduce multiple prescribed burns over the course of a decade or so. For example, Sackett and his colleagues (1996) recommend starting with late fall burns that only consume the litter layer and the upper level of the matted fermentation layer of duff. After one or two of these burns, each conducted four years apart, fuel loading will be reduced and burns can be conducted in the spring or fall. Another possible option, although largely untested, is mixing the litter and duff with a hoe or other implement prior to burning, thereby 1) speeding up their decomposition, 2) "training" the fine roots to grow into the mineral soil, and 3) decreasing the time in between prescribed burns (Graham and Jain 2007, Hood 2010). Such mixing requires 3 to 5 minutes of work per tree (Hood 2010). The initial results of this single experiment look promising in that no healthy, old trees died.

Monitoring

Whatever strategy is used to protect old trees from prescribed burning, including taking no action, it should include a multi-year monitoring protocol and a means to change to a new strategy if old trees are dying. Old trees are too rare and valuable not to have such a plan in place.

While there are few studies to indicate what might be a reasonable level of old-tree mortality following restoration treatments (including removing duff away from old trees), the results of those that do exist (see Kolb and others 2001, Fulé and others 2005) suggest that anything greater than 9 percent mortality is too high and should cause managers to reconsider their restoration treatment approach.

Photo 1: Removing needle litter and duff from around and in between this tight clump of ponderosa pine is probably a good idea if managers want to save these trees. Also note that one of the trees has a pitch seam (see arrow), which makes it vulnerable to prescribed burning. *Photo by Dave Egan*

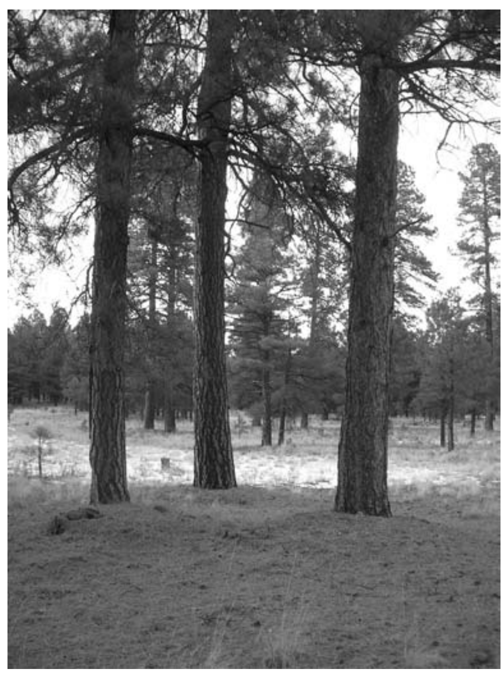

Photo 2: This nicely spaced clump of healthy ponderosa pines on moderately deep soil has a relatively thin layer of needle litter and duff, and may not need to be raked before prescribed burning. *Photo by Dave Egan*

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