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Working Papers in Southwestern
Ponderosa Pine Forest Restoration

Prescribed and Wildland Use Fires in the Southwest: Do Frequency and Timing Matter?

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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).

In the southwestern United States, most ponderosa pine forests have been degraded during the last 150 years. Many ponderosa pine areas are now dominated by 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-intensity 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 southwestern ponderosa pine forests. By allowing natural processes, such as 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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Introduction

Support for the use of prescribed fire and wildland fire use has increased in the Southwest in recent decades. However, the frequency and seasonality of these contemporary fires is typically different than historical fires, which burned during late spring and early summer in the driest and windiest time of the year. Contemporary changes in the landscape, including unprecedented fuel loads and human development in and around forests, now limit the ability to use fire during those times of the year. Most managed fire now occurs outside the windy fire season because it is safer and allows managers to provide greater protection to susceptible cultural or natural resources, such as historic structures or dry snags.

By interpreting fire scars, researchers know that fires in southwestern forests historically varied across time and space, and burned at various levels of severity. This variability affected fuel levels, fire behavior, and post-fire regeneration. Moreover, historical fires burned for long periods (weeks to months) and varied in behavior according to topography, fuel types and loads, and weather fluctuations--burning hotter in some areas and leaving others unscorched. In addition to considering the mean interval of historical fire, fire planning and management personnel should keep in mind the variability of historical fires because almost all forests studied have had at least one instance of fires in two subsequent years as well as maximum fire-free periods reaching one to several decades. This suggests that a different strategy may be needed for modern prescribed burns—one that is more variable than present-day burns, which are often conducted at regular intervals, generally in the fall using the same ignition strategy, and have the goal of burning the entire site.

Land managers concerned with restoring fire often ask: What is the best time to burn? What are the implications of burning in different seasons to the plants and animals of southwestern ecosystems? How often should a given site be burned? These questions are linked to the various ecological aspects of fire and fire management (fire frequency, fire severity, amount of fuel load) and plant seasonal development (phenology) and the seasonal use of habitat by a variety of wildlife species.

Plants

Researchers and land managers know that the season, regularity, and duration of a fire can significantly affect fire severity and, therefore, the ability of the plants to grow, reproduce, and even survive. However, plant susceptibility to fire varies among species and according to individual and site conditions.

Trees

Fire can damage the roots, trunk or crown of a tree, and a severe fire can seriously affect all these tree parts. Tree roots are typically safe from fire if they are below the soil surface and the soil is moist. However, when fire is reintroduced to a site that has been without fire for long periods of time, it will often burn slowly through the accumulated duff and litter creating lethal temperatures because of the long residence time of the smoldering fire (Herman 1954, Harrington 1993). Intense or long duration fires around the base of a tree can kill the cambium tissue, effectively girdling the tree.

Fires in tree crowns will typically kill or severely damage most tree species. Small trees and seedlings are especially susceptible to fire (even low-severity fires) because their crowns are so close to the ground. Moreover, their bark is thin and a poor insulator against excessive heat. Harrington (1993) found that ponderosa pine trees with a 12-inch dbh or more typically survived regardless of the burn season, while smaller-size trees (6-inch dbh or less) tended to die, although more so after spring and summer burns. However, fire effects on mature trees vary by species—that is, some are fire tolerant, others fire intolerant. Firs, for example, are fire intolerant and incapable of surviving most fires due to their shallow roots, thin bark, and closed crowns. Tree species with thicker bark and higher canopies, such as ponderosa pine and Jeffrey pine, are fire tolerant. Some trees (e.g., oaks, locust) and shrubs (e.g., ceanothus; Kauffman and Martin 1990) will resprout after being topkilled by fire.

Trees are most susceptible to fire damage in the spring and early summer, when cellular activity is high and trees are restocking stored carbohydrates that were used to grow foliage and fine roots. In general, trees are less susceptible to heat damage during their dormant season because cellular activity is low. However, the data from a few studies on seasonal burning show mixed results. For instance, Harrington (1993) observed 2.5 times greater mortality in ponderosa pines trees that were burned in late spring and midsummer than those burned during fall dormancy. Thies and colleagues (2005) found more dead ponderosa pine after a fall burn than a spring burn, although they noted that the fall burns were more severe than the spring burns. Schwilk and colleagues (2006), in a replicated study of multiple species, including ponderosa pine and Jeffrey pine, in a Sierra Nevada mixed-conifer forest found a direct link between fire intensity and mortality, but no relationship to early or late-season burning. This limited information suggests that heat damage in any season is the most important factor affecting tree survival, although trees are more susceptible to the same fire intensity during the growing season.

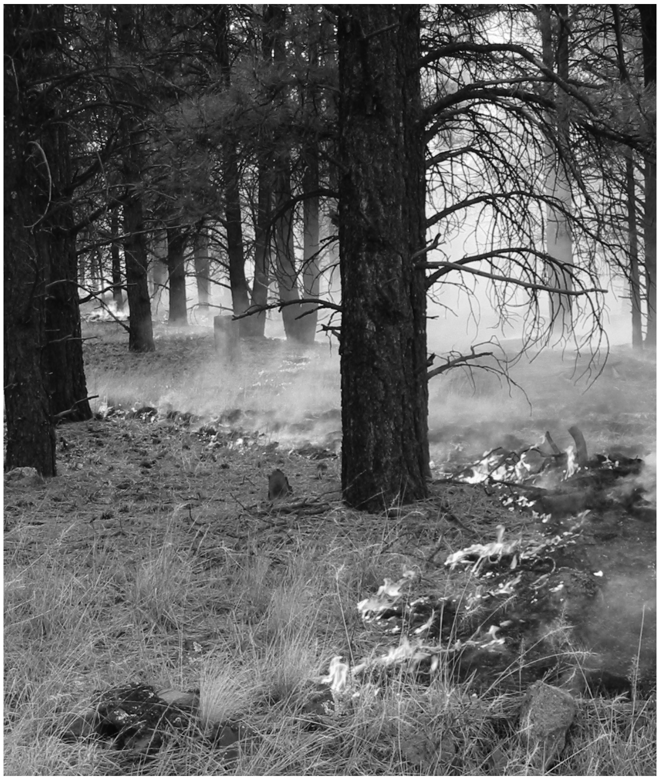
The amount of duff and the moisture level of the fuel play key roles in determining the duration and intensity of a fire. If the duff is deep and moisture low, the result may be a high-severity fire that will injure or kill even large trees. Raking fuels away from “leave” trees and removing dead and downed logs will increase the survival of old trees (see ERI Working Paper #3, Protecting Old Trees from Prescribed Fire).

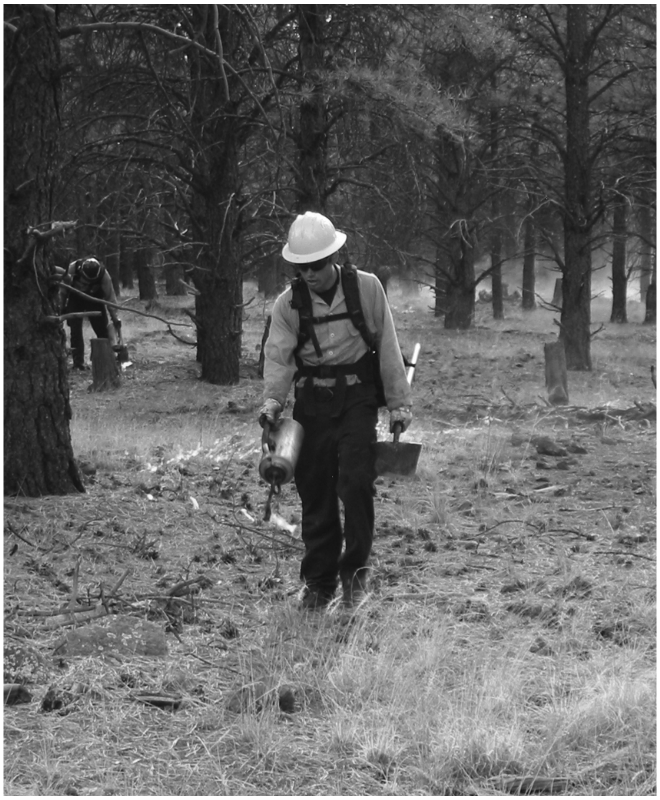
Low-severity fires can destroy snags (dead trees) that are used by wildlife for habitat. While it is impossible to save all snags during a prescribed burn, consider maintaining a population of snags of all age classes, especially relatively new snags, for wildlife purposes (see ERI Working Paper #16, Snags and Forest Restoration). Raking around the bases of snags is probably the best way to ensure their presence. High-severity burns typically destroy and create snags but, given the present deficit of old trees in most ponderosa pine forests, most newly created snags will likely be small and short, and unsuitable for wildlife use.

Understory Plants

Unlike other parts of the country (Platt et al. 1988, Henderson and Statz 1995, Thompson 2006, Knapp et al. 2007), there is little research in the Southwest about the effects of fire timing or fire frequency on understory plants. Researchers do agree, however, that pre-settlement, low-severity fires helped maintain the understory vegetation of ponderosa pine forests. James Agee (1993), for example, provides this summary: “The typical fire in ponderosa pine forests had little effect on the herbaceous component besides removing the cured material above the ground. Removing the accumulated needles and topkilling shrubs [and tree seedlings] generally aided the grasses and forbs (Weaver 1951b, Biswell 1973) and stimulated flowering. Bunchgrasses normally recover in one to three years, and most forbs recover quickly (Wright et al. 1979). Bulb and tuberous species are rarely harmed by fire.” Research from other ecosystems—mixed-conifer forest, pinyon-juniper woodlands, and chaparral—indicates that historical fires were also a key disturbance factor in those systems, and that understory species were adapted to the fire regimes of these different ecosystems.

Like woody plants, there are many variables that affect how herbaceous plants respond to fire—fire parameters, site conditions, weather conditions, and plant morphology and physiology. In terms of these last two items, most land managers realize that burning during periods of active herbaceous plant growth harms plants, affects the amount and timing of flowering and seed production, and can cause plant death, especially if the fire is too severe. This occurs because plants that are burned while they are actively growing no longer have the photosynthetic structures (stems and leaves) needed to produce the carbohydrates required for future growth and reproduction (Moser 1977). Thus, burning in the early summer before the cool-season C_3 grasses have gone dormant can harm those species, while fall burning can damage or, at least, slow the growth of the warm-season C_4 grasses. A 14-year study of vegetation response to thinning and burning by Moore and colleagues (2006) produced findings consistent with this point. After thinning and several fall burns in a ponderosa pine forest, these researchers noted an increase in cool-season grasses but no increase in warm-season grasses. Other studies (Gaines et al. 1958, Haisley 1984) found decreases in mountain muhly, a prominent warm-season grass in northern Arizona, following fall burning.





The morphology of a grass, especially the location of its meristems and buds, also affects its vulnerability to seasonal and/or frequent fires. In general, grasses that expand by means of aboveground stolons (e.g., buffalograss, black grama, curly mesquite) are most susceptible to fire at any time, while rhizomatous grasses (e.g., Kentucky bluegrass, western wheatgrass, galleta grass) are least susceptible, and often react positively, to fire because their growing points are below ground. However, rhizomatous grasses in forested stands may be more susceptible to seasonal fires because their meristems and buds

are often be located in litter or duff layers or near woody fuels. Bunchgrasses (e.g., blue grama, muttongrass, Arizona fescue, little bluestem, Sandberg bluegrass, side-oats grama), are considered more susceptible to seasonal fires than rhizomatous grasses, especially those that are warm-season grasses because their growing points elevate as the plant matures (typically when leaves are 4-6" long). However, bunchgrasses with densely clustered culms, such as Idaho fescue and needle-and-thread, tend to burn longer and hotter because of their structure, as do bunchgrasses with fine leaves and stems, such as Arizona fescue. Larger-diameter bunches also tend to burn hotter and more slowly than smaller bunches. Fire is also especially detrimental to bunchgrasses that are burned when they are in seed because bunchgrasses, unlike stoloniferous and rhizomatous grasses, reproduce solely by seed.

There is little evidence to indicate that the seasonality of fire negatively affects long-lived, native perennial forbs (Kerns et al. 2006), unless the fires are extremely severe or occur too frequently over the course of several growing seasons (Armour et al. 1984). Perennial forbs generally have the ability to resprout from belowground buds, rhizomes, or tap roots. Woody forbs, however, are slower to recover. Fire during the growing season can also affect seed production, often positively by increasing post-fire flowering in members of the Iris, Orchid and Lily families, and by producing a favorable seedbed. However, as with the bunchgrasses, if the fire is set at the time when the plant is producing seed, then the entire year's seed production is typically lost, which can affect annual and biennials.

While there are virtually no studies of spring fire effects in the Southwest (but see Fiedler et al. 2006 for study in Montana), studies of fall fires in ponderosa pine restoration areas indicate that they encourage the emergence and growth of native and exotic annuals and biennials (Abella and Covington 2004, Laughlin et al. 2004, Kerns et al. 2006, Moore et al. 2006). Most of these annuals and biennials are short-lived, although some exotic species, including dalmatian toadflax and cheatgrass, can be serious ecological problems. More specific information on fire effects for individual plant species, especially grasses, can be located on the Forest Service Fire Effects Information Systems (FEIS) web site: www.fs.fed.us/database/feis/plants.

Regardless of the ecosystem, it remains difficult in the Southwest to determine whether changes in understory vegetation are due to differences in burn prescriptions or are related to site conditions, including plant composition, density and biomass; live and dead fuel conditions; or soil conditions at the time of the burn. It is, therefore, difficult to determine which factor--the season of the burn, the intensity or duration of a burn, or the frequency of burning—produced the most significant effects on understory vegetation. Because climatic differences, especially the amount of yearly precipitation, play a major role in understory performance, long-term monitoring of burning effects of understory change is necessary to determine variability in understory biomass and diversity (McLaughlin 1978).

Soil Nutrients & Biota

Fires in the Southwest may produce other effects on the environment, such as the removal of vital ectomycorrhizal fungi and the loss of live root biomass and fine root length (Smith et al. 2004, Hart et al. 2005), and the creation of favorable conditions (bare soil and increased soil nutrients) for invasive species (Harris and Covington 1983, Covington and Sackett 1992). However, these effects may be due to the soil moisture conditions and the intensity and/or duration of the burn rather than the season of burn (although for the effects of fall burning on ectomycorrhizal fungi, see Smith et al. 2004). Research by Shearer (1975) and Frandsen and Ryan (1986) indicates that burning when the soil and lower duff layer are moist will produce fewer negative effects on grasses, forbs, and ectomycorrhizal fungi than burning when those layers are dry. In terms of soil nutrients, Wright and Hart (1997) found that burning too frequently (every two years) may reduce carbon and nitrogen in the soil and may also affect phosphorus availability in ponderosa pine ecosystems.

Wildlife

Although reliable data on the subject is scarce, the frequency and timing of fire can have direct effects (mortality, reduced reproduction) and indirect effects (temporary or long-term habitat modification, changes in food supply, changes in competitors and/or predators) on wildlife. The effects vary depending on the size, duration, and severity of the fire as well as the life history of the animal. Large, mobile animals (raptors and ungulates, for example) can typically escape fires. Similarly, mammals, reptiles, and birds that live belowground or in trees usually experience low mortality (Smith 2000). At greatest risk are aboveground nesters, including ground-nesting birds, rabbits, mice, and woodrats (Smith 2000). Breeding animals are also at risk because they may be less willing to leave their burrow or nest, or abandon their young, or they may attempt to move their young in the midst of a fire (Finch et al. 1997).

Most birds and mammals associated with dry coniferous forests breed from April through June or July (Hoffmeister 1985, Corman and Wise-Gervais 2005), which may coincide with a spring fire. A fall fire may cause less direct mortality because these animals, including migrating neotropical songbirds, would be more mobile. Other bird and mammal species, including wild turkeys, tassel-eared squirrels and mule deer, breed in late summer after the historical fire season. Dusky shrews in northern Arizona breed in April and August, which is both before and after the historical fire season (Hoffmeister 1986). These late-breeding animals are adapted to the late-spring fire season and could be negatively affected by a fire during another part of the year.

Changes in food and habitat, which in turn affects survival and reproduction, are the most important fire effects for wildlife. For instance, animals may not establish nests or breed in response to a fire and the subsequent loss of ground and shrub cover (Patton and Gordon 1995, Short 2002). Juveniles born in late summer depend on fall vegetation as a food source when dispersing and preparing to survive the winter. Botta’s pocket gophers, for example, spend the majority of their life underground and only come aboveground as dispersing juveniles in the fall (Hoffmeister 1986). The fall is also an important season for animals preparing for winter hibernation (e.g., golden-mantled ground squirrels, bears, and raccoons) or late-fall migration (e.g., bats and birds). A fall fire could eliminate food sources and force animals to leave familiar territories during this critical time, which can reduce their ability to effectively forage and escape predators due to the lack of familiarity with a new area (Patton and Gordon 1995). For example, Jourdonnais and Bedunah (1990) found that elk did not use sites where the understory had not recovered immediately after a fall burn.

Management Implications

- Although doing nothing will ultimately result in large uncontrollable wildfires, hasty or poorly planned use of fire can also produce extremely negative consequences for managed ecosystems.

- The existing body of knowledge on fire timing is limited. Managers will have to use fire based on their experience and evidence from the ecosystems they work with, monitoring the results of local fires and adapting management activities according to their own findings.

- It may be possible, in some settings, to allow fire to play a relatively natural role. This might be an aim of managers in some wilderness areas or other preserves. Where they should and can be applied, historical fire patterns are probably the most consistent with forest restoration and fuel management goals.

- However, most wildlands will be managed for the foreseeable future under fire regimes that differ in fire frequency and timing (seasonality) from their historical patterns.

- Managers might consider focusing on the ecological effects of burning, rather than primarily on historical frequency and seasonality. If uncharacteristically infrequent or intense modern fires serve to shift forest fuels and species composition closer to historical reference conditions, these fires may be useful to restore forests and increase resistance to severe fires.

- Effects of fire seasonality should also be evaluated from an ecosystem perspective. Where modern fires burning in uncharacteristic seasons do not result in undesirable changes in species composition, wildlife habitat or invasive plants, the beneficial effects of fire would seem likely to outweigh any negative results.

- Managers may seek to minimize the risk of unanticipated problems by trying to emulate historical fire timing to extent possible. Rather than following rigid burning schedules, it would be prudent to vary burn schedules, seasons, and fire mosaics on the ground when burning at uncharacteristic times.

- When developing a burn plan, remember that historical fires did not occur at regular intervals. Fire occurrences were random and depended on the weather, existing fuel loads, and other factors. In addition, fuel buildup was discontinuous, which means that not every square foot or individual plant burned when fire did return to the landscape.

- The contemporary emphasis on homogenous burning may not be the best approach to restoring fire on the landscape. Land managers might consider altering burning methods in order to achieve a staggered maintenance burning program and a mosaic of burn effects.

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