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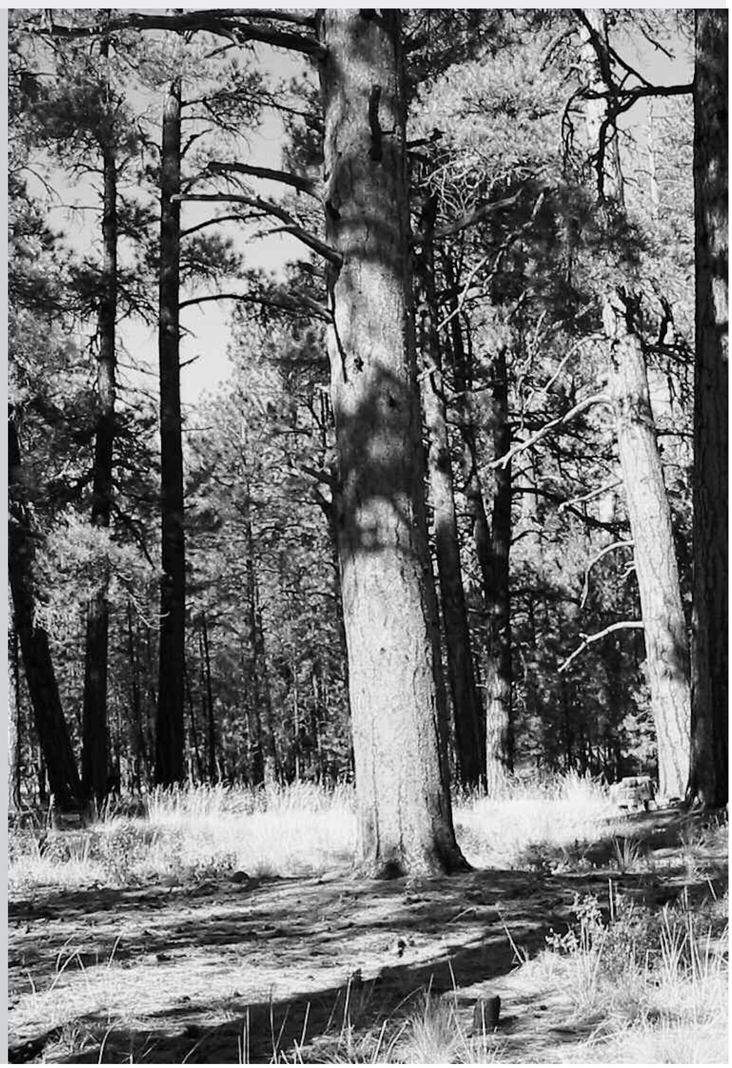
Working Papers in Southwestern Ponderosa Pine Forest Restoration

Restoration of Ponderosa Pine Forests to Presettlement Conditions

February 2005



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Working Papers in Southwestern Ponderosa Pine Forest Restoration

Ecological restoration seeks to heal degraded ecosystems by reestablishing native species, structural characteristics, and ecological processes. The Society for Ecological Restoration International defines 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 2004).

In the southwestern United States, most ponderosa pine forests have been degraded during the last 150 years; many areas are now dominated by dense thickets of small trees and have lost their once diverse understory. 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 first 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.

Every restoration project needs to be site specific, but the detailed experience of field practitioners may help guide practitioners elsewhere. The Working Papers series presents findings and management recommendations from research and observations by the ERI and its partner organizations.

This publication would not have been possible without significant funding from the USDA Forest Service.

1: Restoring the Uinkaret Mountains: Operational Lessons and Adaptive Management Practices

2: Understory Plant Community Restoration in the Uinkaret Mountains, Arizona

3: Protecting Old Trees from Prescribed Fire

4: Fuels Treatments and Forest Restoration: An Analysis of Benefits

5: Limiting Damage to Forest Soils During Restoration

6: Butterflies as Indicators of Restoration Progress

7: Establishing Reference Conditions for Southwestern Ponderosa Pine Forests

8: Controlling Invasive Species as Part of Restoration Treatments

Treatment Type

Emulation of the forest structure prevalent before the landscape-level disturbances that followed Euro-American settlement.

Treatment Objectives

To emulate the forest structure characteristic of the period immediately preceding Euro-American settlement in order to return forest conditions to their natural range of variability. This greatly reduces risks of stand-replacing fire, allows frequent ground fire to be safely reintroduced in order to regulate forest structure, and promotes the growth of understory plants that fuel such fires and support wildlife.

Steps

Overstory Trees:

- All living trees that existed at the time of local Euro-American settlement are identified and left standing. Depending on the location, area, and resources available, this may be assessed through increment boring, size, or the presence of yellow bark.
- All indicators of trees standing at the time of settlement that are no longer present as living trees—including snags, downed logs, stumps, and stump holes—are identified. Read more about this in *Working Paper 7: Establishing Reference Conditions for Southwestern Ponderosa Pine Forests.*
- Younger trees to replace the trees that have fallen, burned, or decayed since settlement are selected. “Extra” trees are left standing—that is, each missing tree is replaced with more than one—to compensate for possible mortality after treatment, and because most of the replacements are much smaller than the large trees that were removed or have died. In tests these trees have been chosen according to several different replacement rates, depending on local conditions, social considerations, wildlife needs, wildfire hazards, and other factors:
    - 1.5/3 (full restoration). If the replacement trees are over 16 inches in diameter, 1.5 trees are left standing for each presettlement indicator. If they are smaller, 3 trees are left standing for each indicator.
    - 2/4 (modified restoration). If the replacement trees are over 16 inches in diameter, 2 trees are left standing for each presettlement indicator. If they are smaller, 4 trees are left standing for each indicator.
    - 3/6 (minimal restoration). If the replacement trees are over 16 inches in diameter, 3 trees are left standing for each presettlement indicator. If they are smaller, 6 trees are left standing for each indicator.
- Replacement trees are chosen from within 60 feet of indicators, though a smaller distance (15 or 30 feet) can result in a more desirable clumping pattern among the remaining trees. Where possible, replacements should include the largest and healthiest postsettlement trees, and/or clumped trees, especially those with interlocking canopies.

Treatment Options

This Working Paper is one of a series that describes the planning and implementation of restoration treatments in southwestern ponderosa pine forests. It presents the best scientifically based knowledge currently available about treatment types and effects. But this Working Paper is not a prescription. Restoration decisions need to be made with close attention to local conditions—there is no “one size fits all” approach, and specific prescriptions must be determined according to project objectives. Use this publication as an aid in making informed decisions about how to restore more natural conditions, and greater health, to the southwestern ponderosa pine forests.

- Trees that are neither of presettlement age or designated replacements are removed using either manual or mechanical means. Choice of equipment can have a great impact on ecological impacts such as soil compaction, which can be minimized through careful planning. Read more about this in *Working Paper 5: Limiting Damage to Forest Soils During Restoration.* In most cases deciduous trees such as Gambel oak and aspen are left standing while shade-tolerant conifers such as white fir and Douglas-fir are removed, but this may vary depending upon local conditions and project objectives.

Fire:

- Prescribed burns are conducted after thinning.
- Slash can be treated by gathering it into piles for burning prior to broadcast burning.
- It is also possible to scatter slash throughout a treatment area and leave it to settle before burning; some practitioners have tried compacting it with a small tractor before burning to reduce flame heights (Jerman et al. 2004).
- Ground fires should recur on the site in years to come, at intervals that reflect the site's "range of natural variability"—often from 2 to 12 years in many parts of the Southwest (Swetnam and Baisan 1996; Landres et al. 1999).
- Raking thick duff about a foot away from the trunks of remaining large trees—especially large trees—before fire may be necessary in order to prevent excessive bark scorch or root mortality (see *Working Paper 3: Protecting Old Trees from Prescribed Fire*). Particular caution is needed on lava soils, which may make trees especially susceptible to fire damage (Fulé et al. 2002).

Understory Vegetation:

- Treatment of understory vegetation varies. In some cases it may make sense to reseed treated areas with native plants after burning. Seeding can increase species richness, but also poses the risk of introducing invasive species and nonnative genotypes (Springer and Laughlin 2004). Whether it is necessary depends on such variables as the existing understory, distance from seed sources, and contents of the soil seed bank.
- In many places control of invasive plants may be necessary, and in all cases it is prudent to minimize their spread. Read how to do this in *Working Paper 8: Controlling Invasive Species as Part of Restoration Treatments.*

Where It's Been Done

This treatment and variations on it have been implemented at a variety of locations, including:

- Gus Pearson Natural Area, near Flagstaff
- Fort Valley, near Flagstaff
- Mount Trumbull area, in the Grand Canyon–Parashant National Monument
- Other national forest sites in Arizona
- San Juan National Forest, Colorado
- Lincoln and Cibola national forests, New Mexico

Results

Overstory Trees:
Depending on initial conditions and the replacement rate chosen, this treatment has the potential to remove a high percentage of a site's younger trees. At Mount Trumbull, tree density was reduced by an average of 77 percent under a 1.5/3 replacement rate prescription, and basal area by an average of 48 percent (Waltz et al. 2003). This still left a diverse forest, as postreatment basal area varied from about 66 to more than 115 ft^2/acre. In many cases this treatment results in a large number of forest openings of various sizes.

Tree health is enhanced by this treatment, as remaining pines in areas with a 1.5/3 prescription have shown increased resin flow, canopy growth, and water and nutrient uptake (Feeney et al. 1998; Stone et al. 1999; Kolb et al. 2001; Wallin et al. 2004). Windthrow and wind breakage of remaining pines may increase slightly in treated areas, but only a few trees have died from these causes in the areas monitored (Kolb et al. 2001).

Understory Vegetation:
In general, the productivity of the understory increases after dramatic tree thinning (Abella and Covington 2004; Huffman and Moore 2004; Moore and Deiter 1992). This response has been measured at several restoration sites, including the Gus Pearson Natural Area and Fort Valley area (Korb and Springer 2003). In Fort Valley, this treatment resulted in higher species richness, diversity, and cover on treated than untreated sites, though the degree to which understory vegetation responds to increased levels of light, water, and nutrients is significantly affected by year-to-year variability in climate (Korb et al. 2003). Because of the high degree of annual variability, it is important to conduct long-term monitoring that can accurately assess treatment impacts over time (Korb et al. 2003).

The response of specific understory plants to this level of thinning and prescribed burning is also dependent on the seed bank present in the soil. At Mount Trumbull, application of a native seed mix increased the richness and cover of native plants, especially grasses (Springer and Laughlin 2004). Seeding, though, has the potential to introduce invasive species and new, nonlocal genotypes of native species, and needs to be done carefully, with seed that is certified weed-free.

Exotic and invasive species also often increase in number and cover due to the disturbance caused by thinning and prescribed fire (Abella and Covington 2004; Sieg et al. 2003). Controlling them should be a top priority in the design and implementation of this treatment.

Fire:
The degree of thinning associated with this treatment can substantially reduce overall fuel loads, separate tree crowns, and increase the average base height of crowns. This results in a large decrease in crown fire potential. At Fort Valley a computer model predicted that under dry conditions a 28-mile-per-hour wind would result in a crown fire in an untreated stand, but 55-mile-per-hour winds would be needed to fuel a crown fire in stands treated with a 1.5/3 prescription (Fulé et al. 2001). Crown fire potential is reduced less in stands with more replacement trees; a 40-mile-per-hour wind would be required to sustain a crown fire in a stand treated with a 3/6 prescription (Fulé et al. 2001). What degree of fire risk is acceptable in different areas may in part determine which replacement rate is most appropriate.

Logging slash represents a significant fire hazard in treated areas. The burning of slash piles can harm soil health and potentially promote the spread of invasive species (Korb and Springer 2003), but these effects can be ameliorated with seed or soil amendments (Korb et al. 2004). When it is scattered and consumed during a broadcast burn, slash can increase prescribed fire intensity to hazardous levels, resulting in substantial tree mortality due to crown scorch (Jerman et al. 2004). The intensity of future broadcast burns after the initial prescribed burn should be lower, as less woody fuel will be available.

Soils and Hydrology:
Thinning followed by prescribed burning frees water and nutrients for use by remaining trees and understory plants. Thinning in a 1.5/3 treatment area at Gus Pearson Natural Area increased summer soil temperatures (Kaye and Hart 1998b). Subsequent prescribed burning removed organic matter from the forest floor and released nitrogen and phosphorus that could be used for plant growth (Kaye and Hart 1998a). Water outflow has been slightly higher in treated than in control areas (Kaye et al. 1999).

Wildlife:
Wildlife responses to this treatment vary depending on species, tree replacement rate, treatment area size, the condition of forest stands around the treatment area, time since treatment, and many other factors (Chambers and Germaine 2003). Relatively little monitoring of wildlife responses to restoration thinning has been done, but among the most apparent of responses seen in areas monitored so far is a marked increase in butterfly use of thinned and burned areas in 1.5/3 treatment areas at Mount Trumbull, probably because of increased light levels (Waltz and Covington 2004; Meyer et al. 2001). Other studies have found an increase in fledging success among western tanagers, plumbeous vireos, and western bluebirds in treated areas at Mount Trumbull, though the bluebird fledglings also had a higher rate of parasitism by nest parasites (Battin 2003; Germaine and Germaine 2002). Mule deer tended to use a combination of thinned and unthinned areas (Chambers and Germaine 2003). Wild turkey roosting behavior was not noticeably affected by treatments, and turkeys did use thinned areas for foraging (Martin et al. in press).

Social Issues:
Aesthetically, these treatments can represent a profound alteration of the forest landscape. The dramatic reduction in tree density may result in significant social concerns about thinning, but site appearance improves within a few years as stumps decay, charred wood disintegrates, and understory vegetation recovers. In the Fort Valley area social considerations were among those that led to the development of the 2/4 and 3/6 replacement rates.

Costs

Restoration costs vary widely, but researchers at the ERI estimate as a very rough guideline that it costs anywhere from $250 to $1,000 per acre to conduct the thinning work for a 1.5/3 restoration treatment. Prescriptions leaving more replacement trees may require additional thinning in a few more years. Prescribed burning of slash piles, and subsequent broadcast burning, also presents costs. In Fort Valley, slash pile and broadcast burning cost an average of $250 per acre. At Mount Trumbull, treatment costs have totaled about $700 per acre, not including the cost of native seed for understory regeneration at $80 to $150 per acre. Whether treatment costs can be offset in whole or in part by the value of wood removed varies with local conditions.

Discussion

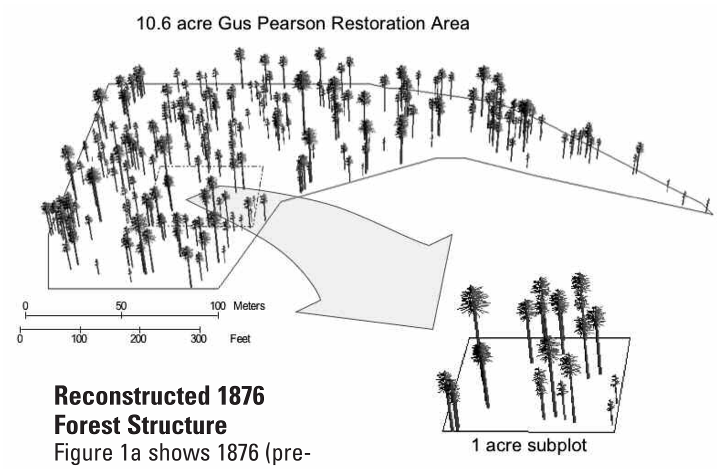
This treatment strives to use the self-sustaining conditions present before Euro-American settlement as a template for future conditions. It aims to create a forest structure that allows ecological processes, especially low-severity fire, to shape the ecosystem into the future. As a result, stand-replacing fire and severe bark beetle outbreaks should be rare in treated stands in the future. It is important to emphasize the key role that fire must play in future maintenance: without regular fires, thinned stands are likely to once again become dense with small trees.

The degree of thinning chosen has a number of important consequences. A lighter degree of thinning, such as that represented by the 2/4 or 3/6 replacement rates, may be more socially acceptable in some places. Managers may also choose to retain more trees in some areas in order to provide habitat for wildlife species that might find 1.5/3 stands too open—or to provide options for future timber harvests. However, retaining more trees provides less protection against crown fires than using the 1.5/3 replacement rate. In addition, retaining more trees may necessitate a future entry to thin more trees, with associated impacts on soils and the potential for spreading invasive species.

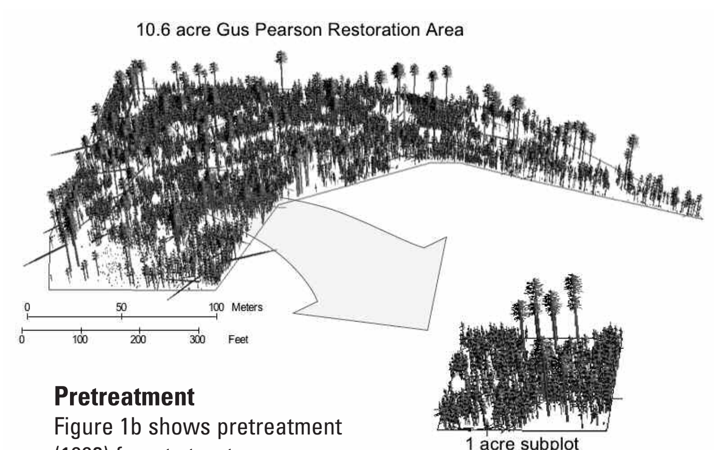
The degree of thinning, and the selection of specific trees for retention, also affects how "clumpy" the resulting stand will be. Choosing replacement trees from a radius of 60 feet around presettlement evidence indicators generally allows for the retention of larger trees, but because the replacement trees can be more widely spread the resulting stand often consists of rather evenly spaced trees rather than clumps. Choosing replacements closer to presettlement evidence signs can create a stand with a mosaic of small clumps and openings that is believed to be characteristic of presettlement forest stands in many areas (White 1985).

Current conditions play an important role in making decisions about thinning intensity: a thinned stand with some remnant old "yellow" pines will look unlike one that lacks large, old trees, and may play a different ecological role. As always, local conditions and objectives should dictate replacement rates and thinning methods.

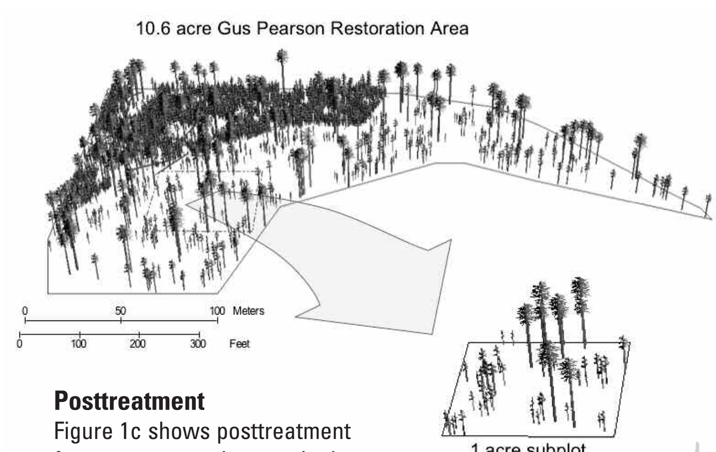
Figure 1. Simulation depicting results of this thinning treatment, with a 1.5/3 replacement rate, as implemented at the Gus Pearson Natural Area.



Reconstructed 1876 Forest Structure
Figure 1a shows 1876 (pre-disturbance) forest structure, as reconstructed through dating of trees living in 1992 and analysis of nonliving woody material.



Pretreatment
Figure 1b shows pretreatment (1992) forest structure.



Posttreatment
Figure 1c shows posttreatment forest structure; the area in the upper left corner is an untreated control. Actual tree locations are shown.

Table 1. Difference in selected ecological parameters between control areas and areas thinned to three different tree densities.

PARAMETER	CONTROL	1.5/3	2/4	3/6
Tree vigor and health	Often declining due to heavy competition for water, light, and nutrients	Improved for at least seven years after initial thinning (Kolb et al. 2001; Wallin et al. 2004); some danger of mortality during intense prescribed fire (Jerman et al. 2004)	Likely to improve due to reduced competition; some danger of mortality during intense prescribed fire (Jerman et al. 2004)	Likely to improve due to reduced competition; some danger of mortality during intense prescribed fire (Jerman et al. 2004)
Herbaceous vegetation	Often low in richness and cover, due to tree density and heavy deposits of fallen needles	Both native and nonnative species increase in richness and cover (Abella and Covington 2004; Huffman and Moore 2004; Moore and Deiter 1992)	Response intermediate between 1.5/3 and control treatments (Abella and Covington 2004)	Response similar to 2/4 thinning (Abella and Covington 2004)
Fuel loading	Heavy crown fuels and "ladder fuels"; little herbaceous growth, but heavy loading of pine needles	Very light loading of crown fuels; vigorous herbaceous regrowth should promote surface fires (Fulé et al. 2001; Waltz et al. 2003)	Light loading of crown fuels; vigorous herbaceous regrowth should promote surface fires (Fulé et al. 2001)	Intermediate loading of crown fuels; some herbaceous regrowth should promote surface fires (Fulé et al. 2001)
Fire behavior	Can be extreme; high susceptibility to crown fire (Fulé et al. 2001)	Very low likelihood of crown fire (Fulé et al. 2001)	Moderate likelihood of crown fire (Fulé et al. 2001)	Likelihood of crown fire intermediate between 2/4 treatment and control (Fulé et al. 2001)
Hydrology	Stand-replacing wildfire can cause severe erosion and downstream sedimentation (Baker 2003)	Water outflow slightly higher than in control areas (Kaye et al. 1999)	Not measured	Not measured
Wildlife	Depends upon individual species needs and patch dynamics (Chambers and Germaine 2003)	Increase in butterfly use and in fledging rates of some passerine birds (Waltz and Covington 2004; Battin 2003; Germaine and Germaine 2002)	Not measured, but results likely mixed depending upon species and patch dynamics (Chambers and Germaine 2003)	Not measured, but results likely mixed depending upon species and patch dynamics (Chambers and Germaine 2003)

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