

# Fire Science

RESEARCH SUPPORTING SOUND DECISIONS

## Brief



Seedlings of regenerating trees face site conditions altered by a century of fire exclusion.

## How does a Sierran Forest Grow? Fire, Thinning, and Regenerating Trees

### *Summary*

Excluding fire over the last century has allowed canopy cover to burgeon, to thicken, along with litter depth (dead needles and leaves accumulated on the forest floor), and tree density in western forests. These changes have altered the small scale (microsite) conditions that affect the ability of tree seedlings to establish. This study in a mixed-conifer forest in the Sierra Nevada revealed relationships between established understory trees and microsite quality, and examined the effect of fire, thinning, and shrub cover on seedling establishment. Most of the conifer species grew on microsites with relatively high soil moisture and relatively low direct sunlight. Planted seedlings died in high numbers, particularly in exposed areas. Thinning and burning did not substantially increase the natural abundance of pine seedlings, which have become scarce in these forests. Although shrub cover may initially help regenerating trees survive, few conifer saplings were growing in shrub-dominated patches, possibly because shrubs can be aggressive competitors for soil moisture. The lack of new growth, logs, or snags in many openings suggests that large gaps are hostile environments for tree seedlings.

## Key Findings

- Traditional cool-season burning treatments do not remove enough of the choking thicknesses of small trees, but do kill greater numbers, particularly of incense cedar, than thinning through cutting alone.
- Moderate-severity thinning treatments designed to keep forest habitat at a late stage of ecological development also allows high numbers of shade-tolerant white fir and incense cedar seedlings to thrive, and relatively few Jeffrey and sugar pine seedlings.
- Treatments that maintain a large number of shade-tolerant trees in the overstory will perpetuate stands with dense fuel ladders and few fire-resistant pines. Treatments that remove a large portion of the overstory to promote new stands result in fewer seedlings, with more pine seedlings, but also stimulate shrub growth.
- Combining features of treatments—using prescribed fire to create some open areas, and some moderate-cover areas that benefit wildlife, may meet fuel reduction and fire restoration objectives better than a single approach.
- Treatments may need to be reapplied to prevent dense ladder fuels from regrowing.

## Introduction

Read nineteenth century travelers' descriptions of wandering through open groves of trees in Sierra Nevada forests, and you will do more with your imagination than picture waistcoats, horses, and pocket watches. Along with dress, transportation and technology, mixed-conifer forests, the most common forest type of the Sierra Nevada, have experienced dramatic changes. Harvesting the largest pines over the last century allowed more plants to grow in the understory and midstory, creating opportunities for shade-tolerant and fire-intolerant firs and incense cedars to multiply and reduce gaps in the forests.

The patchy tree canopy filled in. As the structure of the mixed-conifer forest has changed since earlier travelers' tales, and the kinds of tree species present, so has the way the forest behaves. Thick mats of needles and leaves increase on the forest floor. Shrubs, bushes, and small trees, crowded together, create ladder fuels—places where fire can climb from the forest floor, up to the midstory, and into the dense canopy above. With fewer gaps in the canopy, fire can roar into high-intensity crown fires, and spread easily through the nearly continuous upper story.

Our curiosity and examination has led us to understand the importance of restoring fire to ecosystems, but how do those ecosystems respond where fire has been reduced, or excluded, for so long? Can historic forest community

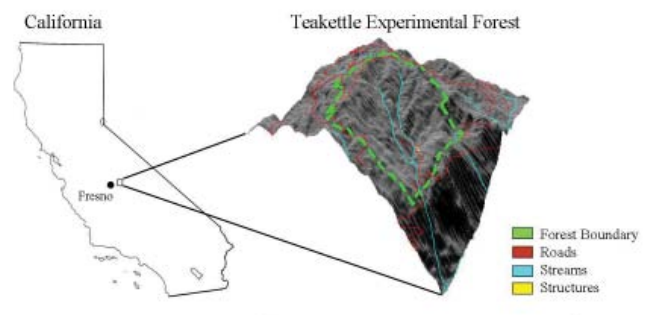


Nineteenth century travelers described open groves in Sierra forests, where navigating, often by car, was easy.

members, such as sun-loving pines, recover to their levels before Euroamerican settlement in the shady, dense stands now found in many landscapes, even when we give them a nudge with our arsenal of treatments? What treatment options, or combinations of treatments, such as thinning by cutting and prescribed burning, are the best? To answer these questions, Andrew Gray, research ecologist with the Forest Inventory and Analysis Program of the U.S. Forest Service's Pacific Northwest Research Station, and his team looked at biological factors, site conditions, and treatment approaches to understand how different species of regenerating trees respond to fire's homecoming.

## Some like it hot, some like it cold...

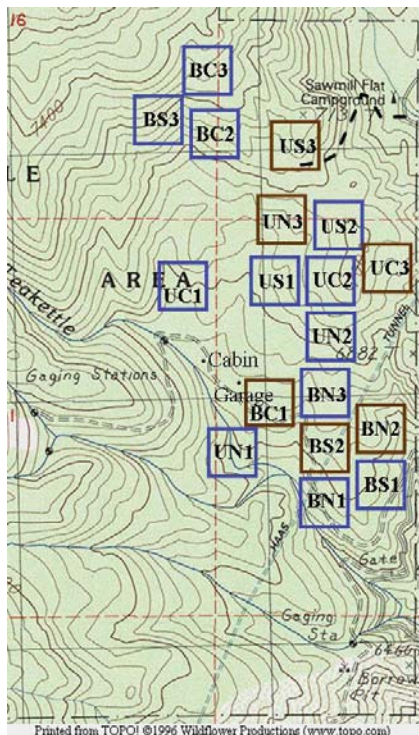
...some like it in the shade where they can take hold. Like the nursery rhyme about pea's porridge, each tree species has its preferences for the ecological stew that promotes and sustains it. In order to understand the recipe, Gray and his team designed their study to examine the relationships between established tree seedlings of different species and light, soil moisture, shrub cover, and litter cover—the dominant factors influencing species composition and the abundance of regenerating species—before they could examine how fire and thinning treatments changed seedling growth and survival.



The Teakettle Experimental Forest, where this study was located, lies within the Sierra National Forest—in a Mediterranean type climate area where different species of conifer grow.

Forty-five miles east of the agriculturally intense area of Fresno, California, high in the Teakettle Experimental Forest located within the Sierra National Forest, Gray and his team established their study area. White fir and incense cedar dominate this mixed-conifer forest, though sugar pine and Jeffrey pine, the largest trees, tower above. In the understory, red fir, California black oak and bitter cherry add to the compositional mix, adding structure in the middle. To study the numbers and types of seedlings, and their relation to their Mediterranean climate type environment, the researchers collected data from 18 10-acre plots located from 6,200 to 8,530 feet in elevation. The researchers counted every seedling and sapling in micro-plots, and measured the tallest of each species, noting whether it was growing in litter, the forest floor, woody debris, mineral soil or rock. They also measured the amount of direct or indirect sunlight and soil moisture. All measurements were taken before treatment, and for several years afterward.

Because prescribed fire and thinning by cutting are commonly used in our management efforts to reduce fire severity and in the hope that burning will promote fire-resistant species such as pine, the scientists tested how regenerating trees of different species responded to restoration treatments. With managers concerned about air quality and risks from prescribed burning, the researchers wanted to answer how much thinning by cutting alone could accomplish, without prescribed fire, in reducing fuels and in altering forest structure, and thus shape the future composition of Sierran mixed-conifer forests.



The study area was designed to test two levels of burning and three levels of thinning treatments. Burn treatments included no burn (U), and understory burn (B). Thinning treatments included no thinning (N), understory thinning (C), and overstory shelterwood thinning (S). Combinations of treatments were tested.

Treatment areas were split between those receiving prescribed burning, and those remaining unburned. The treatment areas were further divided into three thinning treatments in which plots were not thinned; were thinned in the understory by removing mid-level plants; or had the overstory thinned by removing the tallest trees in the canopy (shelterwood). Thin and burn treatments removed more understory trees than thinning alone. Removing the canopy trees (shelterwood), reduced densities the most.



Bare ground forest.



Shrub patch forest.



Closed canopy forest.

After treatments, the researchers examined how treatments affected seedling and sapling survival and growth plus the natural regeneration of tree seedlings. They also studied how treatments changed the three dominant land cover types: bare ground, shrub-dominated, and closed-canopy forest. In each treatment, they sowed seeds of five species in each cover type and examined seed germination and seedling survival for two years.

## Trees, seeds and seedlings

To understand how new seedlings get started, you need to know how many seeds are produced, which in turn depends on how many adult trees there are. The researchers counted cones on adult trees every fall, and measured the number of seeds falling into critter-proof seed traps. Although mature trees of the different species had similar numbers of cones in a good year, most of the seeds in the traps were white fir. Even in the overstory thins, where white fir cover was reduced by two-thirds, twenty-nine white fir seeds fell on each square foot in a good seed year. Overall, ten times as many seeds of white fir and incense cedar were counted versus Jeffrey and sugar pines. What the scientists weren't able to measure was all the pine cones that were clipped from the trees by squirrels and chipmunks before the trees could shed their seed. Although these rodents bury most of the seeds in caches, the low number of germinating pines the researchers found suggests most of the seeds were eventually eaten. Every naturally-regenerated pine the team found was in a clump from a forgotten cache.

## The place's the thing



Lower numbers of pines in the understory compared to their numbers in the overstory suggests pines may decline in undisturbed forests.

If the seeds make it to the ground and survive the winter without being eaten by birds or rodents, or rotted by fungi, the biggest challenge to becoming an adult happens within the first few weeks after germination. "As soon as the snow melts in late spring and the seeds germinate, the seedlings are in a race against time," Gray explains. "They need to grow their roots quickly before the upper soil layers dry out

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during the typically dry Sierra summers." The soil can be dried out directly, by evaporation, or indirectly, by the roots of shrubs and adult trees. Survival can be harder in areas with heavy litter, because litter dries out faster than soil and also gets hotter in the sun. Seedlings need enough sunlight to help them grow roots and leaves, but too much sunlight can lead to desiccation and death. This often means that a narrow range of moisture, light, and ground conditions are "just right" for seedling survival, and the optimal conditions are different for different tree species. Gray and his team found that 90% of germinating seedlings had died in their first month in shrub patches, but the rate was 80% in other areas of the thinned forest. The seedlings that survived their first couple of years had found just the right location.

## Wanting water

Soil moisture was so important to the number of understory tree species growing, the scientists feel the lack of moisture may be an important factor that limits regenerating trees in mixed-conifer forests. All regenerating tree species, the scientists found, were more abundant in areas with greater soil moisture. Across the spectrum of water needs, incense cedar preferred the wettest sites, Jeffrey pine the driest, and the other conifers in the middle. At the depths that seedlings rooted, soil moisture was higher in the overstory thinned plots than in the understory thinned plots, while the unthinned plots were the driest. Areas with shrubs were less wet than areas without; by late-summer, soil moisture in the burn areas was higher in the open patches of bare ground than in areas where shrubs were growing. The scientists measured sound waves from controlled impacts they administered in one plot, and found that depth to bedrock varied substantially. The wettest soils and areas of highest tree volume were in the areas with the deepest soils.

Because of the nature of the ecosystem's Mediterranean climate, most moisture falls as snow in the winter months when trees regenerate in later seasons, they must rely on the moisture holding ability of the soil for their needs, and less competition from other plants taking up moisture. Benefits and adversities exist often simultaneously: "In early postfire years before accumulation of forest floor and litter, seedlings germinating in open burned areas have the advantage of greater moisture availability and release from competition, but must contend with greater exposure to the sun and increased air temperatures," Gray explains, "Seedlings germinating in the shade of ceanothus or manzanita shrubs appear to initially benefit from the shade, but must compete for soil moisture, especially later in the summer, with the result that few seedlings survived where shrub density was high." However, not every summer in the Sierra is equally parched—a few midsummer rain storms can lead to trees surviving the crucial seedling stage in areas where they might not otherwise have established.

## Censoring sun

High levels of direct sunlight were harmful to shade-loving red fir, white fir and incense cedar. Planted seeds died in high numbers in the exposed areas where thinning and burning had been applied, and also in the open bare ground patches that had not been treated. The exposure and high temperatures at the ground level appeared to dry the seedlings out until they died. Jeffrey pine was the toughest of the tree seedlings, and survived better in the exposed overstory thin plots than in the other treatments. Sugar pine was the most flexible, and was able to get started in shady and exposed areas. But what is good at one stage, may not necessarily be the best at another—shade was better for regenerating trees as seedlings established, but as the seedlings matured, they benefited from light levels that would have killed them earlier in their growth. Sugar pine, Jeffrey pine and California black oak, the scientists explain, tend to be less shade-tolerant as they mature and would probably require much more sunlight to be able to grow to overstory heights.

## Thinning sets the stage

Studying how seedlings germinated and grew in different light and soil moisture conditions helped the scientists understand why different species did better in some treatments than in others. Although doing the thinning treatments killed a substantial number of seedlings and saplings, seedling regeneration after 3 years resulted in higher numbers of seedlings than before thinning. There were over ten times as many white fir and incense cedar seedlings as there were sugar and Jeffrey pine, but their abundance varied by treatment. White fir and incense cedar did much better in the shadier understory thins while Jeffrey pine did best in the sunnier overstory thins. Sugar pine did equally well in both kinds of thins. Add prescribed fire to the mix, and things change dramatically. The fire killed more seedlings and saplings than thinning alone, particularly of incense cedar which tolerates being banged around during thinning. By consuming much of the litter layer, fire created an ideal seedbed for seedlings. The number of white fir and incense cedar seedlings increased after burning in the shadier understory thins, but basically returned to pre-treatment levels in the burned overstory thins. In contrast, both sugar and Jeffrey pine increased dramatically in the burned plots, particularly in the sunnier overstory thins.

If the goal is to increase pine regeneration and suppress fir and cedar, Gray offers, the burning treatment with overstory shelterwood thinning was the most effective treatment option of those studied. However, these forests were probably always a mix of open and dense patches, so perhaps an intermediate type of thinning combined with fire could meet goals for restoration and maintenance of wildlife that require old-growth structure. Reducing the number of mature, seed-producing white fir and incense cedar, while

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## Management Implications

- Managers should consider that leaving a high density of mature white fir and incense-cedar trees following thinning and burning treatments may be undesirable in the long run as this will promote high densities of shade-tolerant understory trees which could suppress pine regeneration and create fuel ladders into the overstory.
- While thinning was able to create most of the desired structure in the stands, burning the thinned areas did important work by killing understory saplings, consuming most of the fuels left by thinning, and leaving a mineral seedbed conducive to pine regeneration and the establishment of a rich herbaceous understory. Managers should consider restoration goals when using thinning, or thinning plus burning treatments.

retaining mature pine and possibly planting pine also, may help move these forests towards more open stands with a more even mix of species. Although the experiment will need to be followed over time to tell for sure, the scientists explain, it is possible that the dense regeneration of shrubs in the open, burn treatments may help keep tree density relatively low. It is also possible, once fuels have been reduced and fuel ladders removed, that a return to the approximately 15-year fire interval of the early 1800s may be all that is required to maintain a diverse forest with a low probability of succumbing to an intense wildfire. Wandering Sierran Forests could once again be a roomy experience.

## Further Information: Publications and Web Resources

- Gray, A.N.; Zald, H.S.J.; Kern, R.A.; North, M. 2005. Stand conditions associated with tree regeneration in Sierran mixed-conifer forests. *Forest Science* 51(3): 198-210. <http://teakettle.ucdavis.edu/FS%20manuscripts/Stands%20conditions%20and%20tree%20regeneration.pdf>
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## Scientist Profiles

**Andrew N. Gray** is a Research Ecologist with the Forest Inventory and Analysis program of the USDA Forest Service PNW Research Station and courtesy faculty in Oregon State University's Forest Science department. His research interests include fire ecology, stand dynamics, biogeography, and forest history.



Andrew Gray can be reached at:  
USDA Forest Service PNW Research Station  
3200 SW Jefferson Way  
Corvallis, OR 97331  
Phone: 541-750-7252  
Email: agray01@fs.fed.us

## Collaborators

**Malcolm North**, Research Ecologist, USDA Forest Service, Pacific Southwest Research Station

**Harold Zald**, Ecologist, Oregon State University

**Ruth Kern**, Ecologist, California State University, Fresno

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John Cissel  
Program Manager  
208-387-5349  
National Interagency Fire Center  
3833 S. Development Ave.  
Boise, ID 83705-5354

Tim Swedberg  
Communication Director  
[Timothy\\_Swedberg@nifc.blm.gov](mailto:Timothy_Swedberg@nifc.blm.gov)  
208-387-5865

Writer  
Lisa-Natalie Anjorian  
[lisa@toteachhisownmedia.com](mailto:lisa@toteachhisownmedia.com)

Design and Layout  
RED, Inc. Communications  
[red@redinc.com](mailto:red@redinc.com)  
208-528-0051

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