Fire Science Brief
RESEARCH SUPPORTING SOUND DECISIONS

The Teakettle Experiment set out to determine the ecological effects of prescribed burning, two levels (understory and overstory) of mechanical thinning, and the combined treatments on forest health and restoration goals. Photo shows USDA Forest Service crew overseeing a controlled burn. Credit: Malcolm North.

A Tale of Teakettle: Fire is Key to Restoring Forests

Summary

Prescribed fire and mechanical thinning have long been used as management tools in fire-excluded forests. Until recently, however, little coordinated data existed on the ecological effects of thinning versus fire. Malcolm North and a large team of scientists working in mixed-conifer stands at the Teakettle Experimental Forest in California, examined how a range of ecosystem functions responded to commonly used fuels treatments. They found that fire is the key to restoring forest health, and thinning is best viewed as a tool for controlling fire intensity and extent.

Collectively the different research studies at Teakettle found that fire can "jump start" many ecosystem process while the additional slash and litter produced by thinning alone may actually "stall" the same processes. In current fire-excluded forests, soil moisture is the most limiting resource. Fire exclusion has also significantly changed mortality with insects, disease, and water stress selectively killing larger trees in a clustering pattern. With a broad range of studies, coordinated in a common experimental design, research at Teakettle can provide a valuable, synthesized understanding of how fire and mechanical fuels treatments affect forest health.

Key Findings

Sources: Malcolm North and *The Teakettle Experiment: Fire and Forest Health* DVD (for a free copy go to http://teakettle.ucdavis.edu)

- Many ecosystem processes in fire suppressed mixed-conifer forests can be “jump started” with fire.
- In fire excluded forests with high tree densities, low soil moisture can limit most ecosystem processes.
- If thinning occurs without prescribed fire, the slash and litter can contribute to additional fire risk as well as reduce understory diversity and regeneration.
- Historic mixed-conifer stands (those with active fire regimes pre-1865) had few trees, and equal number of all sizes, and more large trees than currently exist in old-growth forests.

Introduction

Mechanical thinning has become an important tool for managers who want to restore forest ecosystem function to more closely resemble the forest prior to the era of fire exclusion. Yet until recently, there were few studies of whether thinning really helped achieve the goal of forest restoration. What are the different effects of thinning versus prescribed burning on forest ecosystems?

Forest structure has shifted substantially from what it was a hundred years ago and many forests are now at high risk for stand-replacing wildfire. Forests have become choked with smaller, fire-prone species of trees that serve as “ladders” to the overstory canopy, increasing the risk of crown fires; they have large accumulations of litter than can burn hot and easily kill older, otherwise healthy trees; and the smaller, fire-prone trees are typically not of much financial value.

Photos showing an example of the same stand of mixed-conifer forest and giant sequoias in the Mariposa Grove, Yosemite National Park before (1890s) and after (1970s) fire exclusion. Credit: National Park Service.

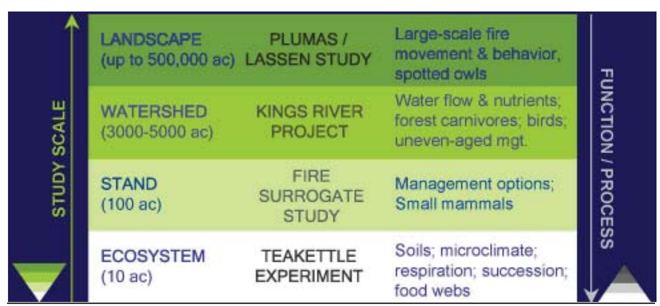
Research supported by the Joint Fire Science Program at the Teakettle Experimental Forest in California’s Sierra Nevada, provides insight into the value and role of fire in mixed-conifer forests.

Malcolm North is a Plant Ecologist with the USDA Forest Service at the Pacific Southwest (PSW) Research Station. North, along with a crew of more than 2-dozen other scientists and graduate students, wanted to determine the relative importance of thinning versus burning in relation to forest health. The experiment grew out of a key question raised in the Sierra Nevada Ecosystem Project: Critical Findings Section, 1996, pp 4-5, *Although silvicultural treatments can mimic the effects of fire on structural patterns of woody vegetation, virtually no data exist on the ability to mimic ecological functions of natural fire. . .*”

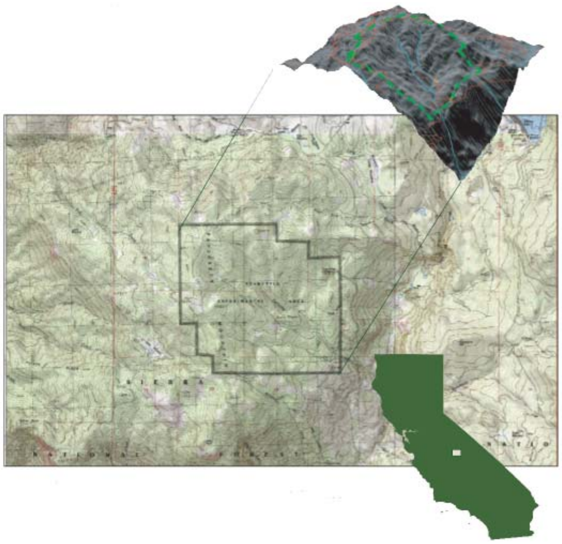
North knew that managers have worked for years to rejuvenate forests like those in the Sierra Nevada. He also knew that prescribed fire and thinning have been two of the major tools used in the effort to restore forest vitality. Yet they are remarkably different.

Thinning is primarily a mechanical way to remove litter, brush, and lower-canopy fuels. While fire does not so much remove vegetation and trees as transform their functions, cycling nutrients and creating snags and logs. Fire has played a central role in forest dynamics for many centuries prior to fire exclusion, so North and many others wondered about the relative importance of prescribed burning versus thinning. Could thinning really contribute to restoring forests’ ecological functions in the same or similar ways as fire?

The scientists chose Teakettle, in part, because mixed conifer is the most common forest type in the Sierra Nevada and present throughout much of the western U.S. Like many western forests, Teakettle’s stands had markedly changed over the last century. Historical accounts and a reconstruction of 19th century forest conditions indicate mixed-conifer forests were open stands with a mix of species, age classes, and many large trees. Today these same forests have an understory choked with litter, logs, and brush, and a high density of small, drought-stressed trees prone to pests and pathogens.



Though there are many other large fire experiments around the nation, including several in California, the Teakettle Experiment is focused upon basic ecological processes (i.e., seral development, water, temperature, light, nutrients and trophic structure), the building blocks within any ecosystem. The focus is to assess how fuel reduction affects forest succession, productivity, diversity and wildlife food webs. Credit: ICE, Department of Environmental Science and Policy, University of California, Davis.



The Teakettle Experimental Forest. Credit: USDA Forest Service.

Lighting the fire: Gathering wisdom from Teakettle's forest

The 3,000 acre Teakettle Experimental Forest, 50 miles east of Fresno, California is managed by the PSW Research Station. The lower half of Teakettle is old-growth, mixed-conifer, a common forest type in the Sierra Nevada and similar to other mixed conifer, stands across the West.

Using tree ring and fire scar data gathered at Teakettle, scientists knew that the historically open stands were maintained by frequent low-intensity fires that occurred every 12–17 years up through 1865. After 1865, fire was virtually erased from Teakettle's forests and a pulse of fire-sensitive trees, white fir and incense cedar, started to grow in the 1880s.

Specifically, scientists working on the experiment wanted to know how thinning might differ from fire in its effect on ecosystem functions and forest succession?

The scientists carefully selected eighteen 10-acre plots, each containing equal amounts of the four "patch" types that characterize mixed conifer: "closed canopy," "shrub," "gap," and "rocky and shallow soils." Researchers had already found all the patch types worked together providing habitat diversity important to mixed-conifer and that ecological processes varied by patch type.

The researchers knew they wanted to compare the untreated "fire-excluded" forest to different treatments designed to help them understand the different ecological effects of fire, thinning and their combination.

Using information from tree ring growth patterns, and a stem map of all the trees (greater than 40,000), snags and logs within the 180 acres of the plots, scientists could reconstruct what the forest looked like in 1865 right after Teakettle's last fire. Stand conditions produced by the different prescribed fire and thinning treatments were compared to the reconstruction of 1865 conditions to assess how each of the fuels treatments did at restoring the forest to an active-fire condition. Scientists also studied how the treatments affected food chains within the forest, soil conditions, and other ecosystem processes to get a better understanding of how the forest functions responded to fuels treatments.

	No Burn	Burn
No Thin	Control	Burn only
Caspo Thin[a] (Understory thin)	Thin only	Burn and thin
Seed Tree Thin[b] (Overstory thin)	Thin only	Burn and thin

a. Based upon California Spotted Owl or CASPO guidelines (Verner et al. 1992). All trees greater than 10 inches and less than 30 inches are removed.
b. Based upon a common pre-CASPO thinning, leaving 8 large trees per acre approximating a 70 foot x 70 foot space.

The experiment uses a full-factorial design crossing 3 levels of thinning with 2 levels of prescribed burning.

According to North, "Each plot has a grid of sample points where all data were collected before and after the treatments. As a result, data collected by different studies can be compared to assess forest response across ecological disciplines."

Fire and forest health

A central result of the experiment is an understanding of how fire is vital to forest health. Thinning certainly altered the stands so that brush and understory trees no longer contributed to high risk for severe fire, but thinning alone also tended to stall forest processes. The increase in slash and litter on the forest floor from thinning decrease plant diversity, excluded tree regeneration, and slowed soil nutrient cycling. Says North, "Many important ecosystem processes are stalled without fire."

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With data collected in the years prior to the treatments, the scientists could easily see the differences between the "fire-deprived" forest and the prescribed burned forest. Without fire, they found shade-tolerant species like firs and cedars dominated many fire-excluded stands, and limited soil moisture, which slowed decomposition and nutrient cycling, says North, "Water stress is produced by high stem densities from fire suppression and periodic La Niña events. This drought stress also predisposes trees (to mortality), and pest/pathogens (particularly beetles) are the final agent."

Then add fire. Almost everything the scientists measured showed that forest ecosystem functions shift towards a 'healthier' condition in the presence of fire. 'Health' in this case, was judged as moving the forest toward the stand structure, composition and function of a forest with an active fire regime. Soil moisture, vegetation, tree regeneration, microclimate, respiration and decomposition, pests, and foodweb measurements all responded to the addition of fire.

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What's more, fire following moderate understory thinning injected new life into the system. The burns in this study occurred in the fall in order to reduce the risk for serious wildfire. Researchers found that the treatments that combined thinning with fire resulted in 'healthier' ecosystem function. The litter and slash from thinning allowed a more intense fire than would have been possible in fall months, increasing the beneficial ecological effects of the burn.

For example, in thinning/prescribed burn treatments there were significant increases in herbaceous species; an important response given most of the plant diversity, including many rare species, occur in the forest understory. Available nitrogen was also much higher in soils of the thinning/prescribed treatments.

Another intriguing result relates to water. Researchers found that water is the primary influence on ecosystem function in mixed-conifer forests. This included tree regeneration, nutrient cycling, decomposition, and understory diversity. Water in the Sierra Nevada is scarce during the summer months, and forests rely on the previous winter's snow to provide almost all of the soil moisture. In fire-excluded stands, with many small trees competing for limited soil moisture, water was usually the limiting factor for many ecological processes. Thinning significantly reduced the number of small trees increasing water availability. However the forest only benefited from this increase in water if fire was applied to remove slash and thick litter layers which otherwise slow recovery.

Fire-excluded stand at Teakettle. Credit: USDA Forest Service.

Climate, critters, and more

With climate change a major concern worldwide, and to fire management in particular, the researchers wanted to know how carbon storage was affected by their treatments. According to the PSW article, *Restoring Forest Health*, "In plots where thinning had taken place, no change was found at 1 year, but by 2 years post-treatment, CO_2 release significantly increased." The scientists, however found that after fire, tree growth flourished, and trees sequestered carbon. They suspect that with thinning alone, trees don't grow as quickly as they do after fire and therefore don't accumulate carbon as quickly. The slash and litter left on the ground after thinning alone also increased the amount of carbon released into the air because soil microbes, decomposing the residue, release carbon dioxide. "These early findings suggest that in the long run, thinning may contribute more to elevated CO_2 and potential global climate change than prescribed fire."

Researchers were also committed to learning more about northern flying squirrels—the primary prey of the spotted owl—and how they might be affected by the treatments. They found that the flying squirrels' preferred habitat is near creeks or streams that have large trees nearby. The squirrel's main food source, truffles, was always reduced with any treatment, but that, according to publications on the DVD, "understory…cutting and lower intensity fires best retain truffles." They conclude that in the dry southern Sierra, flying squirrels are most abundant near creeks where their food supply, truffles, is also most abundant. The experiments' treatments did not affect the abundance and range of squirrels, perhaps because few riparian trees were thinned or burned.

(Left) A northern flying squirrel and (Right) its primary food source, a truffle.

According to North, a few other major results of this research include:

- Pine regeneration is most abundant and has its highest survival and growth rate in the heavy thins followed by prescribed burning.
- Residual large overstory fir and cedar are significant sources of natural recruitment pushing stand composition back toward a fire-excluded composition unless pine is planted or prescribed fire is re-applied.
- Initial observations suggest that plots with lower tree densities have less bark beetle activity and damage.
- Decomposition and nutrient cycle rates remain unchanged after thinning only treatments, but increased in thin and burn treatments.
- Soil respiration tended to increase with thinning and decrease with burning.

The tale of Teakettle: Telling the story

North and his colleagues knew they had a lot to share with a very broad community. To that end they put together a rich resource for instructors, students, forest managers, burn officers, and scientists. Their DVD, *The Teakettle Experiment: Fire and Forest Health*, contains many resources for all these audiences.

The DVD has six videos as well as dozens of published papers from the Experiment, presentations, and links to relevant websites in its extensive resource list. The feature video movie is called, Fire and Forest Health. The shorter films are: *Small Mammals and Forest Ecology*; *Climate Change and Forest Management*; *Science and Forest Management*; *Pest, Pathogens and Drought; and Forest Restoration*. Request a copy of this DVD at http://teakettle.ucdavis.edu. Fill out the simple form and click on Order DVD.

Shared vision: Collaboration, consensus and the power of fire

Working together, Teakettles' researchers examined everything from nutrient cycling, to invertebrates, to plants, to nitrogen, to soil respiration, to decomposition and more. The intense focus in one place and coordinated sampling provides a more complete understanding of how fire and thinning fuels treatments, affect a complex web of processes within a forest. Although working at just one location, the combined insights from Teakettle may be widely applicable in other forests.

Scientists enjoying the collaboration and inquiry common to their research interests at Teakettle.

If this assemblage of scientists has reached one over-arching point of consensus, it is that fire is vital to these ecosystems. North says, "There has been so much controversy about thinning, and how big trees can be when logged, but this controversy really puts the cart before the horse. Fire is the most important thing. Thinning is merely a way to control the extent and severity of the burn. It is simply a tool to serve the fire."

Management Implications

Sources: Malcolm North and Restoring Forest Health, PSW.

- Fire is the key to restoring forest ecosystem health. Specifically, this research suggests thinning prescriptions should be designed to serve fire by separating crown base from surface fuels; distributing slash to increase the extent of the surface burn; and removing large fuels, such as logs, which are resting against leave tree boles.
- Thinning alone, even when designed to mimic fire, appears to stall some processes such as nutrient cycling, plant succession, and decomposition and respiration, possibly because of the increase in slash and litter.
- Currently, insects and disease kill more trees than fire. They have become the primary mortality source in fire-excluded forests, and many old-growth trees are at special risk during droughts.
- Thinning can be used as a "tool" to help facilitate the ecological "work" done by fire.
- Thinning should be flexible and leave most fire-resistant pines while keeping some intermediate sized trees.
- To keep an open stand and increase pine presence, repeated prescribed burns and planting pine seedlings may be needed in mixed-conifer stands.

Further Information: Publications and Web Resources

Restoring Forest Health. Science Perspective 7, Summer 2006, Pacific Southwest Research Station. Forest Service, USDA. http://www.fs.fed.us/psw/publications/sp.shtml

The Teakettle Experiment. Fire and Forest Health Interactive Resource Guide. DVD. http://teakettle.ucdavis.edu/index.htm

Wayman, R. and M. North. 2007. Initial response of a mixed-conifer understory plant community to burning and thinning restoration treatments. *Forest Ecology and Management*. 239: 32-44.

Forest Science 51(3) issue Teakettle Research (nine articles).

Scientist Profiles

Malcolm North is a Research Ecologist with the USDA Forest Service at Pacific Southwest Research Station. He is part of the Sierra Nevada Research Center in Davis, CA, and has an affiliate appointment in the Department of Plant Sciences at the University of California, Davis. He is interested in investigating how best to restore fire-suppressed forests and conservation issues of importance to managers in the Sierra Nevada.

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Results presented in JFSP Final Reports may not have been peer-reviewed and should be interpreted as tentative until published in a peer-reviewed source.

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