Joint Fire Science Program

Fire Science Brief

RESEARCH SUPPORTING SOUND DECISIONS

After a stand-replacing fire in the Sierra Nevada, shrubs develop and are then removed so conifers can be planted.
Credit: T. McGinnis, U.S. Geological Survey.

After the Fire: Assessing Post-treatment Effects on Fine Fuels in the Sierra Nevada

Summary

In the mixed conifer forests of the Sierra Nevada, it appears that fire dynamics have changed from predominantly low and moderate intensity surface fires to a greater proportion of larger, stand-replacing fires. To help reduce fuels and speed the restoration process, the Forest Service harvests dead trees and uses herbicides to control early stages of shrubs. But there are concerns about these post-burn restoration treatments and their influence on emerging fine fuels. Some of these treatments have been linked to an increase in annual grass invasions, specifically non-native grasses, which have the potential to significantly alter fuel characteristics, promote repeat fires, and hinder forest regeneration efforts. For that reason, the U.S. Geological Survey ecologists and the University of California, Berkeley foresters—with the support of the Forest Service—conducted a scientific study to determine how logging fire-killed trees and using herbicides affect plant community composition, fuel load, fuel structure, and potential fire behavior in four major fire areas of the Sierra Nevada. By using existing treatments on national forests that have detailed site histories, researchers were able to quantify the effects of restoration treatments on fine fuels over time and to provide the scientific input needed to fine-tune future restoration plans.

Key Findings

- Logging fire-killed trees did not affect shrub cover, non-native grass and forb cover, or non-native species richness.
- Herbicide use significantly reduced the amount of shrub cover and in response to the lower shrub cover; these areas had greater non-native grass and forb cover and non-native species richness.
- Logging fire-killed trees in severely burned forests increased the overall dead and down fuel loading, however, residual fuel loads were not significant enough to affect fire behavior.
- Live fuel loads had the greatest impact on modeled surface fire behavior.
- Fire behavior modeling indicated that most of the young conifers would not survive a new fire within the first 20 years after a stand-replacing fire—regardless of shrub presence or post fire treatment.

An evolving landscape

Fluctuating fire regimes and fuel management practices have had a substantial influence on the fuels and fire behavior of the Sierra Nevada forests.

Here, fire exclusion has led to excessively dense young forests and an over-abundance of surface, ladder, and canopy fuels. While most fires are suppressed, the combination of high fuel loads and extreme fire weather and fuel moisture conditions can lead to severe, fast-moving fires that are virtually unstoppable. Two examples of such fires in the Sierra Nevada include the Stanislaus Fire Complex of 1987 and the McNally Fire of 2002.

Six years after the Star Fire, the U.S. Geological Survey project leader and personnel from the Western Ecological Research Center and the Forest Service visit an herbicide-treated area.

Treatments and fine fuels

Post-fire fuel-reduction treatments are commonly used—but their effects on emerging fine fuels are somewhat of a concern. Researchers have found that after fire, logging of fire-killed trees temporarily increases total available dead fuel loads, but exactly how salvage logging affects fire behavior may vary by site characteristics and the amount of slash that is left on site. After logging in post-fire areas of the Sierra Nevada, conifers are often planted using a standard grid pattern. A drawback of this practice is that young conifer plantations are highly vulnerable to fire.

Shrub removal encourages the growth and survival of conifers in plantations. Yet, by removing shrubs, non-native annual grasses can invade these sites, altering fuel characteristics and promoting repeat fires. In the mid-elevation coniferous forests of the Sierra Nevada, annual grasses provide continuous fine fuels that are generally available for five months each year. Common non-native grasses such as Cheatgrass (*Bromus tectorum*) thrive on recurring disturbances and can increase exponentially after herbicide treatments targeting shrubs.

In severely burned Sierra Nevada coniferous forests, cheatgrass and other non-native species increase when native shrubs are removed, potentially increasing the frequency and extent of wildfires. Credit: Leslie J. Mehrhoff, University of Connecticut.

To examine how post-fire fuel reduction and conifer restoration treatments affect plant community composition, fuel distributions and potential fire behavior, U.S. Geological Survey (USGS) ecologists and University of California, Berkeley foresters embarked on a scientific study in four large fire areas of the Sierra Nevada. By conducting this research, the investigators sought to quantify restoration treatment effects on fine fuels over time to help provide Sierra Nevada foresters and fire managers with the information they need to modify restoration plans going forward. With a greater understanding of the fuel and fire behavior trade-offs associated with forest restoration practices, resource managers can better determine which treatments to use, when, and where.

Study hot spots

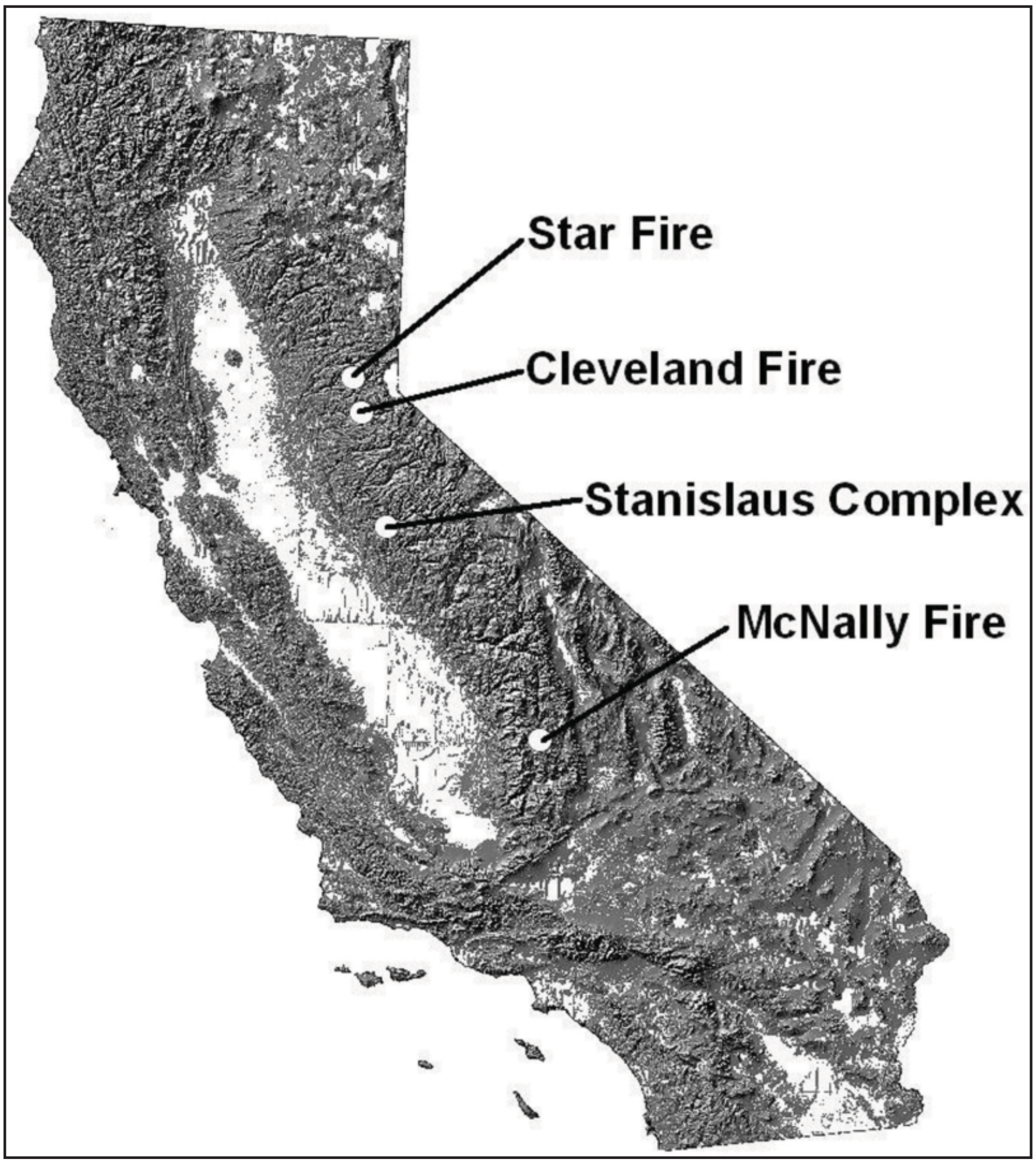
Over the past two decades, hundreds of stand-replacing fires have swept through western Sierra Nevada forests, including four that were the subject of this study: the 1987 Stanislaus Fire Complex, the 1992 Cleveland Fire, the 2001 Star Fire, and the 2002 McNally Fire. These sites were ideal for this study because they not only provided a 20-year perspective on post-fire plant succession, but offered diverse silvicultural and environmental conditions as well. Vegetation types for the region include both dry and moist mixed conifer forest, red fir forest, and post-fire montane chaparral. Some sites were left untreated and other sites were treated with salvage-logging with and without replanting, and salvage-logging followed by conifer planting and herbicide release treatment.

During this study, researchers examined how plant succession and post-fire treatments affected fuel loads, fuel structure, and vegetation structure, and probable mortality of regenerating conifers from future fires. Researchers also evaluated how treatments influenced fuel loads by size class and used three fire modeling programs to predict potential surface and crown fire behavior.

In addition, the researchers determined the effects of logging of fire-killed trees and post-fire herbicide treatments on shrub cover, native and non-native grass and forb cover, the number of species present and available dead surface fuel loads.

Logging vs. herbicides

Compared to findings on herbicide use, logging fire-killed trees had little to no effect on non-native species cover or species richness. This treatment did not affect shrub cover, and few non-native species were found beneath shrubs. Logging fire-killed trees did temporarily increase the overall dead down fuel loading in severely burned forests, however, the residual fuel loads were not substantial enough to alter modeled fire behavior in logged stands. Instead, live fuel loads appeared to have the greatest effect on modeled surface fire behavior.



As indicated above, four major fire areas were studied in the western forests of the Sierra Nevada.

Sierra Nevada west side post-fire study locations (2006-2008), treatments and sample size

Fire	Year of fire	Location (lat, long)	Treatment name	Post-fire treatments included	N^a	N^b
McNally	2002	36.1° N, 118.3° W	Untreated	None[1]	145	19
			Logged	Logging fire-killed trees[1]	90	19
Star	2001	39.1° N, 120.5° W	Untreated	None	152	13
			Logged	Logging fire-killed trees[1]	50	12
			Herbicide	Logging fire-killed trees, herbicides targeting shrubs[2]	88	14
Cleveland*	1992	38.7° N, 120.4° W	Untreated	None	12	4
			Logged	Logging fire-killed trees[3]	24	20
			Herbicide	Logging fire-killed trees, herbicides targeting shrubs[4]	113	31
Stanislaus**	1987	37.9° N, 120.0° W	Untreated	None	57	6
			Logged	Logging fire-killed trees[5]	25	7
			Herbicide	Logging fire-killed trees, herbicides targeting shrubs[2, 6]	78	20
			Masticated	Shrubs shredded and scattered[2]	17	3

[1]Very few sites also planted with conifers.
[2]Also planted with conifers.
[3]Most sites also planted with conifers.
[4]Also planted with conifers and most conifer plantations were thinned.
[5]Few sites also deep-tilled and planted with conifers.
[6]Most sites also deep-tilled.
*Includes areas that burned once (1992), twice (1959 and 1992), and three times (1959, 1992 and 2001)
**Includes the Hamm, Larson and Paper fires.
N^a: Sample size of native and alien grass and forb cover and 1-h fuel load.
N^b: Sample size of other samples.


An untreated area after the 2002 McNally Fire. Credit: T. McGinnis, U.S. Geological Survey.


A treated area where fire-killed trees were logged after the 2002 McNally Fire. Credit: T. McGinnis, U.S. Geological Survey.

Herbicide use appeared to have greater consequences. With herbicide application, more space opened up to allow for the expansion of total grass and forb fuels (combined native and non-native grasses and forbs), potential drivers of rapid fire spread when dry. Non-native species richness was also greater in herbicide areas than logged areas, with 12 times more non-native species in the Cleveland Fire area and 5 times more in the Stanislaus Fire Complex area.

"This study quantifies changes in fuel structure associated with different post-fire management treatments. It illustrates the trade-offs in passive versus intense post-fire fuel treatments. Intense treatments such as herbicides may enhance non-native herbaceous species and increase fire risk during the first two decades after fire. Passive treatments allow natural seral stages of shrubs to develop and these suppress highly combustible herbaceous growth and thus minimize the risk of repeat fires, but at a potential cost of higher fire hazard later in succession," stated Jon Keeley, Principal Investigator.

Fire modeling results indicated that very few young conifers would survive a reburn in the first two decades after a severe stand-replacing fire, whether in successional shrub fields or shrub-free conifer plantations.

According to Tom McGinnis, Co-Principal Investigator, "These findings should alert managers to some of the risks associated with shrub removal after stand-replacing fires; non-native species, which are not prevalent in shrub fields, increase as a result of disrupting natural succession."

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Future opportunities

Further research is needed to track the longevity of post-fire logging slash, including decay rates based on physical properties of wood and site conditions. The researchers urge the development of fire behavior models for young closely-spaced conifers in the western U.S. as well as crown fire spread models for small and large conifers, shrubs, and mixtures of shrubs and trees—essential functionality that does not exist in today's fire modeling programs.

Management Implication

- Knowing that shrub removal increases non-native species and does not increase the chance of young conifer survival after a reburn, managers can better plan where fire prevention is most critical and where replanting is not worth the risk. For example, conifer plantations near major roads, where both ignitions and non-native seeds are more likely to occur, may not be good investments.

Further Information: Publications and Web Resources

McGinnis, T.W., Keeley, J.E., Stephens, S.L. and Roller, G.B. 2010. Fuel buildup and potential fire behavior after stand-replacing fires, logging fire-killed trees and herbicide shrub removal in Sierra Nevada forests. Forest Ecology and Management 260 (1): 22-35. Post-Fire Treatment Impacts on Fine Fuels in Westside Sierra Nevada Forests Project Website: http://www.werc.usgs.gov/Project.aspx?ProjectID=177

Scientist Profile

Dr. Jon Keeley earned his PhD in Botany and Ecology from the University of Georgia in 1977 and holds an MS in Biology from San Diego State University. He is currently a Research Ecologist with the U.S. Geological Survey, stationed at Sequoia National Park and an adjunct professor in the Department of Ecology and Evolutionary Biology at the University of California, Los Angeles. Prior to this appointment he served one year in Washington, D.C. as director of the ecology program for the National Science Foundation. He was professor of biology at Occidental College for 20 years and spent a sabbatical year at the University of Cape Town, South Africa. He has over 275 publications in national and international scientific journals and books. His research has focused on ecological impacts of wildfires as well as other aspects of plant ecology, including rare plants, rare habitats such as vernal pools, and plant physiology. In 1985 he was awarded a Guggenheim Fellowship and is a Fellow of the Southern California Academy of Sciences and an Honorary Lifetime Member of the California Botanical Society. He has served on the Los Angeles County Department of Regional Planning Environmental Review Board, the State of California Natural Communities Conservation Program (NCCP) Board of Scientific Advisors and the Nature Reserves of Orange County technical advisory committee.

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Tom McGinnis, who designed and implemented this project, is an Ecologist with the U.S. Geological Survey, Western Ecological Research Center. He has been studying fire and plant interactions in the Sierra Nevada since 2001, after finishing his master's degree in Biology at the University of North Carolina, Wilmington.

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