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Prescribed Burning and Big Trees: Can We Do It Without Killing the Trees?

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Joint Fire Science Program

Fire Science Brief

RESEARCH SUPPORTING SOUND DECISIONS

Youth Conservation Corp crews from the Susanville Indian Rancheria rake away litter and duff from a tree.

Prescribed Burning and Big Trees: Can We Do It Without Killing the Trees?

Summary

At first glance, it may seem that large diameter ponderosa and Jeffrey pine trees would be well-equipped to handle prescribed fire, especially low-intensity burns. They have thick bark and sturdy root systems, and have been around a long time. However, managers have found these high-value trees often die several years after prescribed burning, and researchers want to know how managers and planners can more readily protect these trees.

With years of little to no fire, duff accumulation around many of these trees is unprecedented, and some researchers have proposed that burning this deep duff can increase the risk of death to large trees. Raking the duff away from the trees has been proposed to mitigate this problem, but others have argued that raking can harm the trees. Sharon Hood and her colleagues examined the effects of raking versus prescribed burning on large diameter ponderosa and Jeffrey pine trees. They found that raking takes little time, does no harm, and may help trees exposed to prescribed burns. They also found that raking appeared to protect trees from red turpentine beetle attacks, which in turn, later seemed to protect those trees from attacks by primary bark beetles like Jeffrey and western pine beetles. Raking is an important management option when large, high value ponderosa and Jeffrey pine trees may be at risk in prescribed fires.

Key Findings

- Raking in this experiment does not appear to increase tree mortality.
- Raking may help decrease cambium injury by removing the potential for smoldering duff at the tree base.
- It takes 2–3 people about six minutes per large tree to rake two feet away from the tree's base, down to mineral soil.
- Raking lowered the probability of red turpentine bark beetle attacks in this study; specifically on ponderosa and Jeffrey pine trees in northern California.
- Raking duff away from trees with fire scars is imperative for these trees to survive a fire.

Introduction

There is a common perception that large diameter ponderosa and Jeffrey pine trees are well-equipped to handle prescribed burning—especially low intensity management burns. They have thick bark, sturdy root systems and it would seem that they should generally be resistant to prescribed fire, especially low intensity fire.

Researchers and managers are finding large-diameter tree mortality related to prescribed burns.

But more evidence is cropping up to suggest otherwise. Researchers and managers are finding large-diameter tree mortality related to prescribed burns. Ponderosa pine trees, according to a handful of recent reports, are showing signs of mortality after burning. In the Grand Canyon and Crater Lake National Parks, for instance, mortality was higher for large diameter trees after burns than trees in unburned areas.

Sharon Hood is a Forester at the Rocky Mountain Research Station (RMRS), Fire Sciences Lab in Missoula, Montana. Her colleague, Sheri Smith, Regional Entomologist, USDA Forest Service, Forest Health Protection, had a specific experience that helped cement the pair's interest in understanding this kind of mortality. Smith was working on a forest protection project in Northern California—the goal was to restore a stand of trees, including old growth ponderosa pine. They planned to use a low intensity burn to remove fuel and open up the stand. Smith says, "Initially, the burned areas look pretty good and managers walked away thinking all was good, but several years later the large trees began to die." They were "alarmed," says Hood, "because the plan backfired, and the very trees they wanted to survive ended up dying."

After this experience, Hood worked with Smith—as well as James Reardon (Forester, RMRS Fire Sciences Lab) and Danny Cluck (Entomologist, Forest Health Protection)—to write a Joint Fire Science Program (JFSP) proposal designed to help understand the reasons for large diameter tree mortality in these situations. Why were these trees susceptible to mortality? This question is particularly important to managers and planners who use prescribed burns as a matter of course in areas with high-value, large diameter trees.

Hood says, "We suspected the duff had a big role in tree mortality. Burning deep duff around the tree's base can cause cambium injury."

Still, she says, "Some work had suggested that raking the duff away from trees might cause injury (e.g., to the root system). We wanted to know exactly what would damage or help conserve these trees. Also, no one really had a clear idea of how much time it would actually take to rake the duff. We knew managers and planners needed this information, too."

Another point of interest is that the amount of duff accumulation around many of these trees is unprecedented. It seemed very likely to Hood and her colleagues, that such large amounts of smoldering duff around the base of these old trees could be a cause of significant mortality. "Long-term smoldering can cause high soil heating above 60°C, the temperature required to kill living tree tissue," says Hood.

But there was little evidence available for exactly how raking or duff burning affected large diameter trees. So Hood and her team received JFSP funding to begin to answer these questions.

Getting set: A plan to assess effects of raking and burning on big trees

"With prescribed burning," says Hood, "one of our priorities is to keep large, old trees." Forests under management by the Sierra Nevada Framework in California have restoring fire and maintaining and enhancing old growth as key goals. The team knew they wanted an experiment that would help managers and planners in their quest to restore fire while lowering the risk of mortality to these high-value trees.

"We designed an experiment that allowed us to measure the effect of raking versus not raking, as well as burning versus not burning," says Hood. That way the researchers could tease apart whether raking actually harms trees, or if raking away the duff protects trees exposed to fire.

"We designed an experiment that allowed us to measure the effect or raking versus not raking, as well as burning versus not burning," says Hood.

"Besides that," she adds, "we measured the amount of time it took to do the actual raking, so planners have a real idea of what kind of 'person power' this actually requires."

Long-term goals included measuring the effects of the different treatments on ponderosa and Jeffrey pine tree vigor, mortality, and bark beetle susceptibility. "The concern we had about tree mortality is a long-term

concern," says Hood. The researchers only measured trees bigger than 25 inches in diameter, and they intend to monitor them for years. Large trees like this may take years to die if a prescribed fire is going to affect them this way.

Another factor weighed on the teams' intentions for their experimental design: bark beetles. The researchers tried to avoid beetle-infected trees. They wanted to get as clear a picture as they could of the effects of raking and burning, without the complicating factor of beetle infestation. That said; they later did look to see if any treatments affected tree susceptibility to beetle attack.

With a clear intention to learn how to protect large, high-value trees in the midst of management goals calling for prescribed burning, the team needed an experimental design that could clear up the conflicting impacts of raking, burning, and beetles in eastside northern California pine stands.

Implementing the plan

The team used two study areas in the Lassen National Forest (LNF) in northern California. The sites had not burned in at least 100 years, and were dominated by ponderosa and Jeffrey pine. White fir were also spread through the sites, and made up the bulk of the midstory. A neighboring—no-burn—area served as a control and raking-only treatment. The burn units were thinned, with the slash distributed evenly prior to treatments. The slash in one of the units was then masticated (the "masticated unit"). Another site—located at Lassen Volcanic National Park (LVNP, also in northern California)—was also dominated by ponderosa and Jeffrey pine with an open understory and natural fuels.

To set things up, the team randomly picked trees—ponderosa pine and Jeffrey pine—at least 25 inches in diameter for which there was no evidence of beetle infestation. The trees were then "paired" based on species and similar size, vigor class, and close proximity to each other. Within each pair, one of the trees was randomly assigned the raking treatment. But if one of the pair had a fire scar, that tree always got the raking treatment because earlier evidence showed a higher risk of mortality for trees with fire scars. "Those scars are a direct way for fire to enter the tree and kill it," says Hood.

Fire scars on trees are highly flammable and hard to extinguish once ignited. Raking duff away and out of a scar reduces the chance that the scar will ignite and burn out the center of the tree.

Months before the prescribed burns, a crew of 2–3 people raked the trees. They raked down to mineral soil, and pulled duff about two feet way from each tree. They measured the amount of time it took to rake. They also inserted duff pins near the trees that were not raked so they could measure how much duff burned during the fire treatments. To measure soil heating, the crew installed thermocouples in the soil near some of the unraked trees.

Fire details

The LVNP site was prescribed burned on June 14–15, 2005. Duff moisture was around 101 percent. The site was a fuel model 9 (Anderson 1981) that burned as a low-intensity surface fire with some individual small tree torching. They measured a rate of spread at about 33 feet per hour with average flame lengths less than 2 feet. The fire burned in fairly mild weather, with low winds and temperatures ranging from 60–70°F over both days, and Relative Humidity (RH) ranging from 23–40. However, a strong Pacific storm entered the area the day after the burn which caused a dramatic drop in temperatures and increased the RH. By the evening of June 16 it was raining steadily, and turned to snow during the night. By the morning of June 17 about 1 inch of snow blanketed the study area.

Fire crews igniting the study site at Lassen Volcanic National Park.

The LNF sites were prescribed burned on October 21–22, 2005. Duff moisture was 24 percent. A fuel model 9 best described the thinned unit which burned as a low-intensity surface fire. The researchers measured flame lengths between 0.5–1.5 feet and rates of spread between 130–200 feet per hour. Meanwhile, the masticated unit was a fuel model 8; also a low-intensity surface fire. They measured similar flame lengths as the thinned unit (less than 1 foot), but saw extremely slow rates of spread (less than 15 feet per hour). During the burn the weather was mild, with temperatures ranging from 60–70°F, and RH from 12–28. Winds were low, with gusts up to 10 mph. There was no precipitation on the site for at least 1 week after the fire.

"After the burns," says Hood, "we went back and looked at post-fire vigor, crown and cambium injury, site and tree level fuel consumption, and insect attacks. We assessed for cambium damage in sample trees where bark charring was evident. We sampled four points at the base of each tree to see if the tissue was alive or dead. This was the most reliable way to measure cambium death, because it is very hard to tell just by looking at the bark."

Early answers show raking does no harm, may help

The most vital result of this work concerns raking—it answers outstanding questions about whether raking harms or helps large diameter trees exposed to prescribed burns. In this experiment, raking the duff away from trees did not cause tree mortality, regardless of whether the site was burned. The researchers' results also show that raking can lower cambium injury, especially in sites where there is almost complete consumption of deep duff layers. As for the timing? Hood says, "It takes about six minutes for 2–3 people to rake duff down to mineral soil, two feet away from the bole of a tree." What's more, raked trees in the burned units had lower levels of bark beetle attacks.

Smoldering duff around a raked tree during the prescribed burn.

The researchers found that in general, the level of bark beetle attack was fairly low, but in the burned units there were significantly more attacks by red turpentine beetles on unraked trees, than on raked trees. "Red turpentine beetles are not a primary bark beetle—that is they do not typically kill trees," says Hood, "but we did see that once a tree was attacked by red turpentine beetles, it was much more likely to be attacked by Jeffrey and western pine beetles, which *are* primary bark beetles. So, raking may have a protective effect on trees in terms of later bark beetle attack."

Why is raking so potentially helpful? The answer lies in the duff, which can be a major player in managers' decisions regarding prescribed fire. The potential for whether duff can harm trees is affected by moisture content and duff depth at the tree base. According to their results, the researchers found that the amount of duff to burn depends on duff moisture at the time of the burn and post-fire weather. "We saw that at the LVNP site, the amount of duff that burned was extremely variable, while at the LNF site, almost a hundred percent of the duff burned (recall that at the time of the burn, the duff moisture at LVNP was about 101 percent and LNF it was 24 percent).

The LVNP study site after burning. Danny Cluck and Sheri Smith check for cambium injury around a sample tree.

The researchers state in the JFSP final report that, "Laboratory tests suggests that sustained smoldering of Jeffrey pine duff occurs below 40–50 moisture content and 65–85 percent for ponderosa pine." By measuring moisture content of the duff prior to a prescribed burn, managers can get a better sense of whether smoldering duff is a concern in conserving large diameter trees.

"Also, if duff isn't more than a few inches, then it is not deep enough to cause basal injury even if it does burn completely, says Hood. "These old ponderosa and Jeffrey pine trees have really thick bark, so it does take a lot of duff sitting next to the base to cause the long-term smoldering necessary to kill cambium."

Duff accumulation around a tree base before burning. Deep duff around trees can kill the underlying cambium even through thick bark from long-term smoldering combustion.

Meanwhile, Hood and her colleagues also found evidence that FOFEM—a duff consumption modeling program—does not accurately predict duff consumption when the duff is deep. They write in the JFSP final report, "It is difficult to predict the percent of duff consumption in duff mounds based on pre-fire duff moisture to determine when to burn."

As for how the fire and raking affected tree vigor? "We haven't seen much tree mortality in any of the treatments

yet and I'm not sure we ever will," she says. It is probably a little early to draw any conclusions about whether raking reduced tree mortality in the burned units. The trees with fire injuries may take several years to die. Plus, bark beetles are still attacking some trees, which will cause more tree mortality."

Managers of high-value trees may have more room to breath

Given the early but clear evidence that raking does not affect tree mortality, Hood's research essentially offers another tool for prescribed burning in relation to large diameter ponderosa and Jeffrey pine trees. If long-term duff smoldering is a concern, managers now know the amount of time it takes to rake a tree is fairly short, and that raking will not harm the tree. This result gives managers a wider scope of options when implementing burns because if they are waiting for the "right window" to burn (e.g., by waiting for the right moisture content of the duff, weather), raking can open the window wider—the burn may be an option if raking occurs, where it might not be otherwise. It certainly offers a protective measure for large diameter trees. Finally, raking can protect these important trees from attacks of red turpentine beetle—not necessarily harmful themselves. But as precursor beetles to the more deadly Jeffrey and western pine beetles, raking may actually protect these trees from eventual primary beetle attacks.

"When you think about a historical forest," says Hood, "you often don't think about the duff. You usually think about the stand structure, and not so much about the forest floor. But this may actually be extremely important in management today. Historically these forests burned with frequent fires so there was not a lot of duff. But with fire exclusion, there are now unprecedented levels of duff in many areas."

She concludes, "Even though our results are early and we don't know precisely how raking and burning affect long-term tree vitality versus mortality, *we* do know that raking gives people some breathing room to protect trees in those situations where you might have just one chance to get it right."

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So what's next? Hood and her colleagues will continue to monitor the trees for any additional mortality and beetle attacks for the next several years and then publish the final results of their study. They are also going to core the trees in the unburned LNF unit to see if raking reduced tree growth. "We'd like to know if raking caused any stress to the trees, and one way to do that is to see if raked trees have smaller growth rings than the unraked trees since they were raked," says Hood.

She's also writing a literature synthesis on this topic that will pull together all the information around the country about burning in old, long-unburned stands. "What we found in our study, might not be true in other areas, for other species. We'd like for managers to have all the information out there about this in one publication to make it easier for them to decide how to best reintroduce fire into stands while limiting mortality to these high-value trees."

Management Implications

- While raking may not be appropriate for every prescribed burn in old stands of ponderosa and Jeffrey pine, it should be considered a tool managers can use when trying to limit tree mortality from fire.
- Duff can burn for a long time. Raking does not harm trees, and it can reduce the heat load around trees to help protect near their roots and cambium.
- Fire scars are fire vectors. If a stand is going to be prescribed burned, it makes sense to rake large trees with fire scars. This will increase the trees' chances for survival.
- In this experiment, FOFEM did not accurately predict duff consumption or soil heating in areas of deep duff. It should not be used for this purpose.

Further Information: Publications and Web Resources

Final report for this project: Hood, S., J. Reardon, S. Smith, D. Cluck. 2007. Prescribed burning to protect large diameter pine trees from wildfire – Can we do it without killing the trees we're trying to save? JFSP Final Report 03-3-2-04. p. 33.

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Scientist Profiles

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Manager's Viewpoint
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Prescribed Burning to Protect Large Diameter Pine Trees from Wildfire—Can We Do It Without Killing the Trees We are Trying to Protect?

Written By: Paige Houston

Purpose of this opinion piece

Manager's Viewpoint is an opinion piece written by a fire or land manager based on information in a JFSP final report and other supporting documents. This is our way of helping managers interpret science findings. If readers have differing viewpoints, we encourage further dialogue through additional opinions. Please contact Tim Swedberg to submit input (timothy_swedberg@nifc.blm.gov). Our intent is to start conversations about what works and what doesn't.

Problem

Old growth stands of ponderosa pine (*Pinus ponderosa*) landscapes in northern California are reaching high mortality due to prescribed burning used to reduce surface fuels. Often times, the means to reduce these surface fuels require prescribed burning. However, these fuels are at high levels and moisture values are too low to sustain such activity without negative effects. As a result, old growth ponderosa pine are dying. This situation is compounded by the fact that duff depth is increasing over time and space. Therefore, the challenge to reduce surface fuels in and around old growth ponderosa pine and to burn during conditions conducive to preventing mortality confronts land managers today.

Application by Land Managers: How Best to Reduce Duff Depths

The concept and activity of raking duff around old growth ponderosa pine trees before implementing prescribed burning is a management activity that occurs frequently. The research from this project further evaluates methods for accomplishing this activity more effectively. Currently, the biggest challenge for managers is reducing the extensive duff depth prior to the application of prescribed burning—without adverse impacts.

Fire managers understand the importance of integrating the best ecological methods for reducing surface fuels. Thus, they work at trying to calculate duff depth and how best to remove the duff around the bole of tree and drip line. When duff is raked, these accumulations can cause tree mortality—even from low-intensity prescribed fire.

When duff is raked, these accumulations can cause tree mortality—even from low-intensity prescribed fire.

This study defines the fuel loading thresholds across a multivariate landscape both before and after prescribed burning. It also takes into consideration the effects on old growth ponderosa pine and this species' survival in raked versus unraked areas. The research revealed that very little change in reduction in mortality occurred between the unraked and raked trees (Hood 2007).

Science experts believe that decades of fire suppression produced ecosystems that will need many treatments over a period of years and that small adjustments are better than one large adjustment. While fire managers already knew this, this particular study provides new insights into how small these initial adjustments need to be implemented—for instance, simply raking an individual tree.

Small, Incremental Steps

The study promotes the idea that management objectives and site conditions should be the influencing factors for how to apply this management activity of raking (Hood 2007). Other scientists agree that fire managers will need to recognize how fire will influence unpredictability across some stands and how this level of unpredictability can impact old growth ponderosa pine trees (Harrington 2007).

The amount of time it would take to conduct the management activities of raking around trees would serve as the driving factor for determining whether or not this activity would be economical. For the most part, this depends on site conditions and how long it would take to rake around one tree. If sites exhibit heavy amounts of deep duff layers in addition to surrounding fuel loads, it would take an average of 16 minutes for one person to clear out an area of one tree (Hood 2007). Land managers already figure such variables into their planning phases—especially when old growth protection is the objective. Therefore, if protecting old growth is the primary objective, taking small incremental steps will pay off in the long run.

The Smoldering Effect

When prescribed burning is the application tool, the variable that concerns scientists is the burning material's residence time. Thus, the timing of prescribed burning on sites of heavy duff layers may warrant further investigation. If duff moistures exhibit low moisture values, burning under these conditions will lead to mortality in the roots and basal girdling (Hood 2007). In addition, Hood (2007) states that long-term smoldering can actually raise the soil temperature to above 60°C. If temperatures are above this gradient for long periods of time, the smoldering effect will cause damage to ponderosa tree roots and cambium, and even possible death to living tree tissue (Hood 2007). Other scientists, however, suggest that ponderosa pine develop root systems that extend to levels where protection from soil heating—even from low-intensity fires—in combination with moisture amount in residing fuels will prevent mortality (Fitzgerald 2005).

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In theory, increased moisture values may contribute to longer residence time, thus triggering higher mortality. While raking will allow managers increased burning windows, each site will have its own set of parameters. When setting these parameters for determining duff consumption rates as they pertain to mounds of duff, managers shouldn't rely on the computer model FOFEM (First Order Fire Effects Model). Reinhardt does reflect that within the FOFEM

User's Guide, in order to run predictions, the assumption is that if fire is applied, the model assumes a homogenous occurrence and does not address mounds of duff (1997). Hence, outputs may not reflect accurate soil heating because moisture values will be skewed.

Insect Attack

This study also provides information regarding the relationship and impact of insect attack on trees during prescribed burning. It explored the possibility that when old growth ponderosa pine trees were raked and prescribed burning was applied, insect attacks were reduced (Hood 2007). Inversely, with trees that were not raked and prescribed burning was applied, insect attacks from the red turpentine beetle increased (Hood 2007).

Obvious reasons exist for conducting raking methods that land managers will have to consider for themselves when weighing this practice's benefits and risks. The ongoing research into the feasibility of such methods will be very useful. This management tool, used quite frequently, is more economical in some areas. Overall, this study addresses some additional new concerns for land managers to consider before applying prescribed fire in ponderosa pine sites.

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Manager Profile

Paige Houston is the Regional Aviation Training Specialist at the Northern Rockies Training Center in Missoula, MT. She has 22 years experience in fire management across several USDA Forest Service regions, and a few years with the USDI Bureau of Land Management. She currently serves as a primary Division Group Supervisor on the Northern Rockies Type 1 Incident Management Team and instructs a variety of fire and leadership courses in northwest Montana, at the Wildland Fire Apprentice Academy, and with the National Smokejumper Association. She spent eight years with the Bitterroot and Lolo hotshot crews and worked two seasons with the Alaska Smokejumpers.

She has several more years of experience in other primary firefighter and fuel management positions, including a season with the rappellers out of Chelan, WA. She's a graduate of the University of Montana where she received a degree in resource conservation.

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