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Research Station

Science FINDINGS

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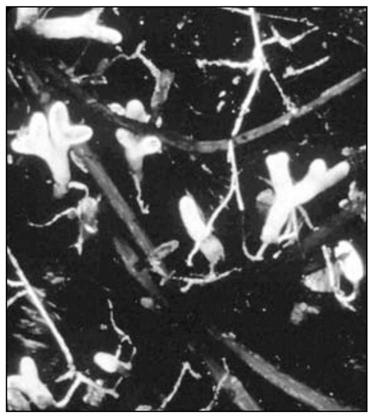
INSIDE

"Science affects the way we think together."
Lewis Thomas

SEARING THE RHIZOSPHERE: BELOWGROUND IMPACTS OF PRESCRIBED FIRES

Mushrooms (left) are the fruit of fungi that form ectomycorrhizas (right). Many fungi only fruit when the ground is moist, making it difficult to study soil ecosystems in dry landscapes. New molecular techniques allow researchers to identify fungal species without the fruit.

"How can I stand on the ground every day and not feel its power? How can I live my life stepping on this stuff and not wonder at it?"

—William Bryant Logan,
Dirt: The Ecstatic Skin of the Earth

Consider forest biodiversity and what comes to mind? Trees, of course. Then, perhaps, plants of lesser stature: shrubs, grasses, flowers, and ferns. And then there is the fauna: the birds, rodents, deer, and bear. But what doesn't leap to mind is the huge variety of organisms living below ground. Nonetheless, soil is home to the bulk of forest biodiversity, and its importance cannot be overstated. It is a complex living system that regulates the livelihoods of all the more familiar, aboveground forest dwellers. For that reason, forest conservation must start below ground and work up. Soil, without a doubt, is the least renewable component of the forest ecosystem.

To Jane Smith, a research botanist at the PNW Research Station in Corvallis, Oregon, out of sight is certainly not out of mind. Smith has been studying soil fungi for years and she is only half joking when she says, "The aboveground forest is simply an appendage of the ectomycorrhizal soil fungi."

This particular group of fungi coevolved with trees, and together they have developed a cooperative arrangement vital to their existence. The fungi grows in a thin sheath around root tips and acquires all its food from the tree—sugars and carbohydrates mainly. In return, the fungi assist the tree in gathering water and provide essential phosphorus and nitrogen that the tree could not acquire on its own. This type of mutually beneficial relationship is termed a symbiosis; and the symbiosis between trees and ectomycorrhizal fungi is one of the most important in nature.

It is not surprising, therefore, that conserving the productivity of soil—its capacity to produce vegetation—is central to the mission of

IN SUMMARY

A century of fire suppression has resulted in dense fuel loads within the dry pine forests of eastern Oregon. To alleviate the risk of stand-replacing wildfire, forest managers are using prescribed fire and thinning treatments. Until recently, the impact of these fuel treatments on soil productivity has been largely unknown. Such information is essential for making sound management decisions about the successful reintroduction of fire to the ecosystem to retain biodiversity of soil fungi and achieve the desired future condition of large ponderosa pines with low fuel loads.

In a recent pair of studies, led by researchers at the PNW Forestry Sciences Laboratory in Corvallis, Oregon, novel molecular techniques were utilized to investigate the response of soil ecosystems to prescribed burning and thinning. The research compared impacts of the season of burn and various combinations of fuel-reducing treatments. Results suggest that overly severe fires can damage soil productivity and that less intense fires can be used to gradually reduce accumulations of fuel. The findings are currently being implemented in decisions about forest management and contribute important new information to the science.

the Forest Service. The agency tries to keep an eye below ground during all management activities, including prescribed fires.

Recently, Smith has been investigating the impacts of prescribed burning on soil productivity on two national forests in eastern Oregon. She is providing helpful information to forest managers and is reminding them that meeting their aboveground objectives is dependant on the fire's impact on the soil. "Ecosystems have different levels of resistance to disturbance," says Smith. "And, it is the interconnected processes, the connections between the above and belowground ecosystems that allow forests to persist."

Fire, whether prescribed or natural, influences soil fungal communities. The specific effect is related to the amount of heat produced, which is a function of the fuel bed. If the layer of needles and organic debris, called duff, has accumulated over many years, and if the duff is dry, then the fire will likely burn hot, killing the root tips and their associated ectomycorrhizal fungi in the soil below. In contrast, when the duff layer is thin or moist, a fire is more likely to burn at lower intensities, meaning the soil fungi will persist.

"Aboveground ecosystem recovery after a fire is directly linked to the survival of the ectomycorrhizal fungi that reside in the surface layers of mineral soil and organic matter," explains Smith.

BELOWGROUND IMPACTS OF FUEL REDUCTION

Ponderosa pine forests throughout the West are in trouble. For a century now, forest managers have been excluding the wildfires that once burned through the understory every 5 to 15 years. The absence of frequent fire has permitted dense young trees and shrubs to crowd the understory; in addition, the flammable duff layer has built up atop the forest ground.

Decreasing fuel loads to lower the risk of stand-replacing wildfires has become a priority for forest managers. Prescribed fire is often the way they go about it.

There is much to consider when planning and managing a controlled forest fire; it is a job best suited to the efficient multitasker. A first priority is obviously to keep the fire within a perimeter. Then there is the smoke to worry about. And whether the fire is consuming enough of the fine fuels—it must be hot, but not too hot. A delicate balance is needed to kill the small trees while protecting the desirable old growth. Conserving soil productivity is just one, among many, of the responsibilities of the burn boss.

Smith and her colleagues are engaged in two studies designed to help managers find this balance. One is outside of Burns, Oregon, on the Malheur National Forest where managers are interested in the seasonality of prescribed burning. (Are spring season fires ecologically different from fall-season fires?) The other study is approximately 200 miles to the northeast near Enterprise, Oregon, in the Wallowa-Whitman National Forest, where managers and researchers are comparing the efficacy of thinning, prescribed burning, and thinning before burning.

Both studies are ongoing multidisciplinary projects that are making significant advances in our understanding of fire ecology and management. Smith's contributions—not surprisingly—are focused below ground. "My objective was to assess the impacts of prescribed fire and thinning on factors influencing soil productivity. That meant looking at duff, fine root biomass, and ectomycorrhizal fungi," she explains.

Measuring duff before and after the fires gives Smith an indication of the amount of heat that is transferred into the rhizosphere, which is the soil zone that surrounds the roots of plants. By monitoring fine root biomass, she estimates changes in the tree's ability to acquire nutrients from the soil. Similarly, by quantifying the fire's impact on fungal diversity, Smith can gauge the short- and potential long-term effects on soil productivity.

Smith removes multiple soil cores of mineral soil, about 4 inches deep, before and after the fuel-reduction treatments. Then she must identify the impossibly small fungi living on the fine root tips within those soil cores—not an easy task.

Prescribed fire is an important tool for forest managers working in dry ponderosa pine forests.

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TECHNOLOGY MEETS MYCOLOGY

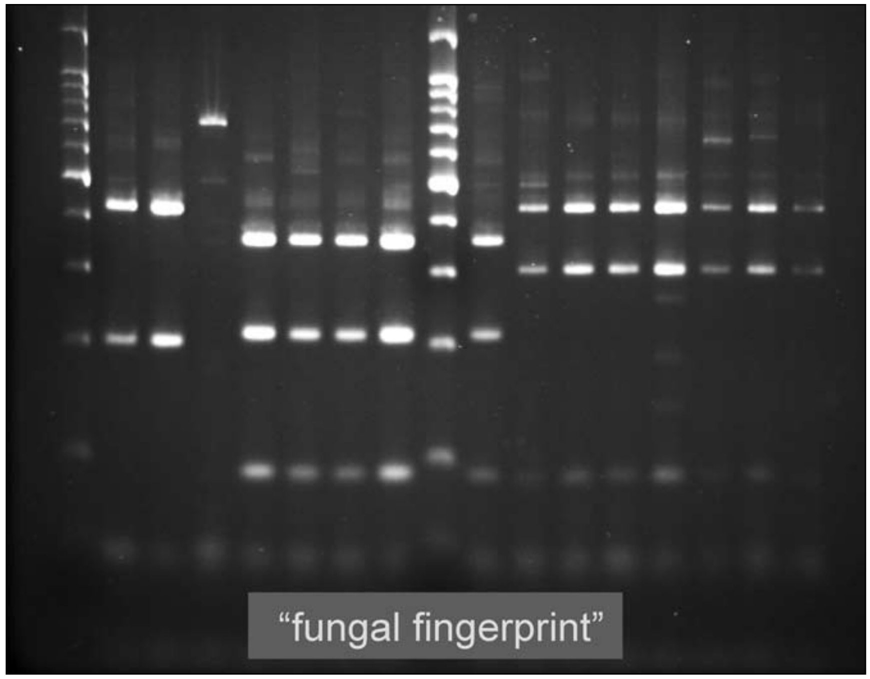
Most of the time, identifying different ectomycorrhizal fungi species by eye is near to impossible; that is, unless they're fruiting. That's why, traditionally, studying soil fungi was constrained to periods when truffles or mushrooms—the fungal fruit—could be collected. But here's the catch, many fungi only fruit when the ground is moist. That means, in dry regions, fungi might not fruit for years, or ever. Not surprisingly therefore, scientific understanding of soil ecosystems in arid landscapes, such as those found east of the Cascades, is woefully inadequate.

In fact, when Smith was first planning to study ectomycorrhizal fungi in central and eastern Oregon, there was a general perception that diversity would be low. After all, relatively few types of fungal fruits had been seen in dry ponderosa pine forests. "That would be nice for a change," she thought. "Typically, we are just overwhelmed by the diversity."

Smith brought new technologies to the pine forests. "During the past 10 years, molecular techniques have changed the protocol for identifying fungi" she explains. Fungi can be identified by using only the mycelia associated with tree root tips.

But it's still a tedious process: Soil cores are taken back to the lab where the soil is sieved from the root tips and debris. Then, slowly and methodically, the root tips—often only an eighth of an inch long—along with their colonizing mycorrhizae are sorted by shape and color. "Once you get good, you can quickly pick out the ponderosa pine roots," says Smith.

The root tips are taken to the molecular lab housed in the Corvallis Forestry Sciences Laboratory. Then, thanks to the miracle of Polymerase Chain Reaction, the small amount of fungal DNA surrounding the root tips is amplified (or copied) to several thousand times the original quantity, which is necessary to identify the common gene sequences. Enzymes are then used to cut sequences of the DNA to define what Smith calls the "fungal fingerprint."



Recent advances in molecular biology permit mycologists to identify fungal species by comparing patterns of DNA sequences and fragments to those of known samples.

To use the fingerprint to identify the fungal species, Smith must match it to a known sample taken from a truffle or mushroom. Often, however, there is no matching fruit available—that's just the way it goes in these dry forests. So, in these cases, Smith heads to the Internet and runs the sequence through GenBank, an annotated database of all publicly available DNA sequences built and maintained by the National Institutes of Health. Researchers, like Smith, are constantly uploading new sequences into GenBank, making it more powerful all the time.

After working through the known samples and those identified through GenBank, Smith has a measure of soil fungal diversity. "We typically found 5 to 10 different fungal species within a core and as many as 5 times that within a stand," says Smith. "The prediction of low diversity in dry forests didn't hold up to the molecular techniques."

"The vast majority of species were only found in one core. However, there were also a few that showed up in several stands and even across both study areas," she adds.

☞ KEY FINDINGS ☜

- Fall burning significantly reduced live root biomass and species richness of ectomycorrhizal fungi compared to spring burning for at least 2 years.
- Prescribed fire restoration treatments (burned only; thinned and burned) significantly reduced duff levels, live root biomass, and species richness of ectomycorrhizal fungi compared to nonburned treatments (thinning alone; nontreated control).

THE DANGERS OF DEEP DUFF

It is a common perception that protecting big trees during a controlled fire is a matter of keeping the flames out of the canopy and away from the cambium, the tissue under the bark. But that's not all, as Smith's research has shown: "Pine mortality is often related to root death owing to overheating. And, an important predictor of fine root survival is the depth of duff around large trees before a burn. Therefore, managers might consider raking some of the duff away from the base of large trees prior to burning," she says.

"Belowground effects are directly linked to aboveground effects," say Smith. Meaning, quite simply, if the fire burned hot on the ground, it probably burned hot belowground as well.

Other management recommendations came out of her investigation into the season of prescribed burning. "The fall-season prescribed fires in the study near Burns, Oregon, significantly reduced duff depth, live root biomass, and species diversity when compared to the spring burns," says Smith. "In fact, the spring burn sites and the unburned control treatment had about six times more species of ectomycorrhizal fungi than the fall treatment units."

LAND MANAGEMENT IMPLICATIONS

- Understanding how mycorrhizal fungi respond to prescribed fire and thinning will assist forest managers in selecting fuel-reducing treatments that maintain critical soil processes.
- Prescribed fires that are too intense can result in a short-term reduction in mycorrhizal species richness and live root biomass and may influence whether managers can maintain stands with large trees and low fuel loads.
- Restoration treatments using combinations of low-severity spring and fall underburning or combinations of seasonal prescribed burning and thinning can be used to reduce duff accumulations and reduce the risk of stand-replacing wildfires.

"However, it was likely the drier conditions in the fall—rather than the season itself—led to the more severe impacts. In this region, burning conditions in the fall differ considerably, and sometimes fall burning can be so light that it appears like the spring burning.

"It may be that to conserve soil productivity, managers will need to burn in the spring or in other moist and cool conditions in order to gradually bring fuel loads down to historical level," says Smith.

Would thinning prior to burning ratchet down the severity? Maybe not. In the study near Enterprise, Oregon, "there were no significant differences in duff depth, live root biomass, or number of fungal species among treatments before prescribed burning and thinning began. After the two burning treatments—burn only and thinning followed by burning—fungal diversity was reduced, as was the live root biomass, and the duff depth," says Smith. And, interestingly, thinning followed by burning had particularly large impacts on soil productivity resulting from the additional pulse fuel in the form of logging debris. But thinning alone increases small-diameter fuels on the ground, increasing the risk for high-intensity wildfire.

Pine mortality is often related to root death from overheating. And an important predictor of fine root survival is the depth of duff around large trees before a burn.

AN EXCITING TIME TO BE WORKING IN DIRT

Compared to the aboveground portion of the forest, we still know very little about the effects of prescribed fire on soil. The landscape-level studies carried out by Smith are some of the first to rigorously use molecular techniques to investigate, in depth, the belowground impacts of prescribed burning. That's probably why Smith's findings have been so well received by soil scientists throughout the region. Since the publication of her work, she has received a host of positive feedback—considerably more than she expected.

One soil scientist wrote: "It is articles like this that help us make the case with District Rangers and other Resource Staff Officers for the need to give greater consideration to specific fire effects during burn prescription development."

Another scientist summed up his response by saying: "A very exciting time to be working in dirt!"

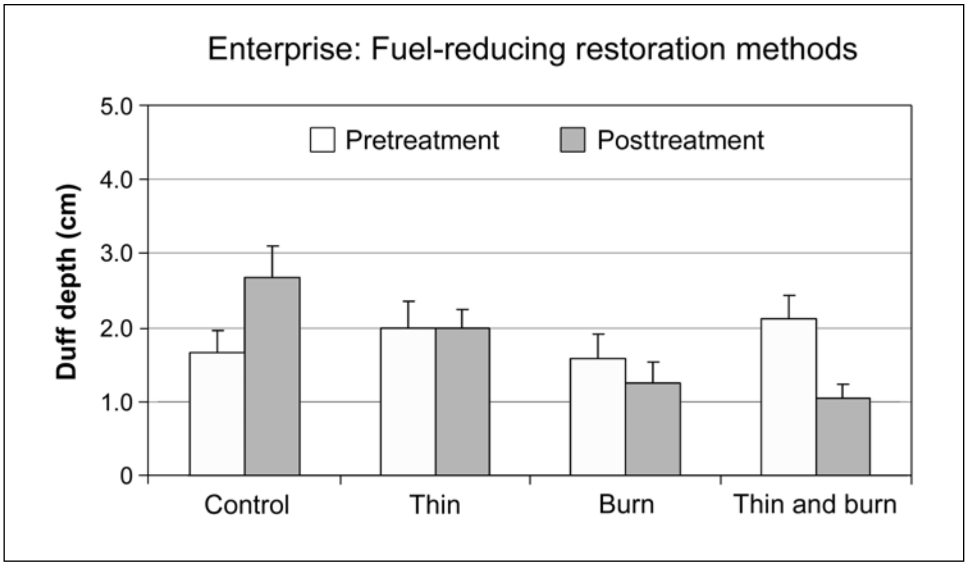
Smith agrees: "There is so much we don't know about the soil resource and so much fundamental science to be done. And the molecular approach opens what has always been a black box. It really is an exciting time to be a soil scientist."

"Essentially, all life depends upon the soil ... There can be no life without soil and no soil without life; they have evolved together."

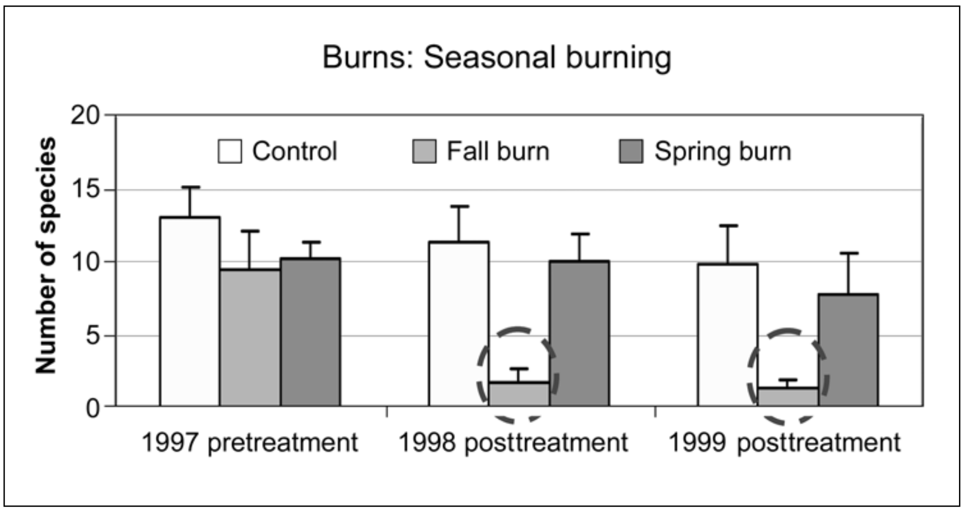
—Charles E. Kellogg,
USDA Yearbook of Agriculture, 1938

WRITER'S PROFILE

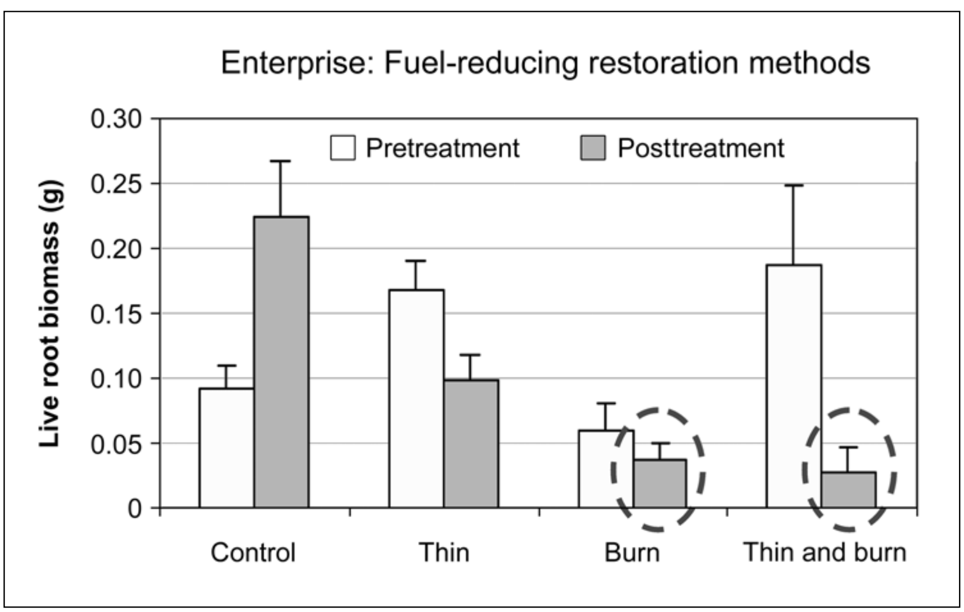
Jonathan Thompson is an ecologist and freelance writer. He lives in Corvallis, Oregon.



Both treatments with burning reduced duff levels compared to the nonburned treatments.



Fall burning reduced mycorrhizal species compared to spring burning for at least 2 years.



Both fuel reduction treatments with burning reduced live root biomass compared to the control.

FOR FURTHER READING

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