Joint Fire Science Program

Fire Science Brief

RESEARCH SUPPORTING SOUND DECISIONS

This study plot at Whiskeytown National Recreation Area was mechanically masticated and burned. Credit: Jennifer Gibson.

Going Underground: Studying Fuel Treatment Effects on the Mycorrhizal Community of Northern California

Summary

On the southeastern edge of the Klamath Mountains in northern California, Whiskeytown National Recreation Area's low elevation plant communities are characterized by an assortment of oaks and conifers with an understory of dense chaparral. Mechanical mastication of shrubs and small trees has become a popular method of fuels management. Although mastication expands the list of options for fire managers, the ecological impacts and long-term effects are virtually unknown. In particular, mechanical mastication essentially rearranges fuels and leaves behind a dense layer of slash on the ground. Burning this debris can potentially heat the soil and adversely affect the roots of woody plants and mycorrhizal fungi. Upper layers of soil are active sites of fine root growth, mycorrhizal hyphae, and nutrient cycling. Mycorrhizal fungi are the primary source for transfer of carbon to underground ecosystems and the transfer of soil nutrients to the trees. It was the goal of researchers to address information gaps on fuel treatments and to examine how mycorrhizal fungi and truffles are affected by mechanical mastication followed by prescribed fire.

Key Findings

- Species richness and community composition of ectomycorrhizal fungi were not dramatically altered by any of the treatments.
- Mechancial mastication improved the species richness and abundance of truffles, with higher numbers for truffles on brush-masticated plots compared to untreated controls.
- Woody debris from mechanical mastication did not reduce the fruiting of truffles.
- Burning of both masticated and non-masticated plots decreased the species richness and abundance of hypogeous fruiting bodies by 90 percent.
- Soil nutrients were not dramatically altered following mechanical mastication and burning.
- Burning of mechanically masticated slash does not harm mycorrhizal communities but does inhibit fruiting of truffles.

Required treatments, unknown effects

Fire managers are often required to reduce fire risk by treating fuels while minimizing potential adverse impacts to cultural and natural resources. Prescribed fire is commonly used, but air quality restrictions and narrow prescription windows have made alternative treatments, such as mechanical mastication, a valuable option for land managers. Using an industrial brush-cutter, small trees and shrubs are masticated, or ground down to the stump, leaving behind a layer of coarse woody debris.

In northern California's Whiskeytown National Recreation Area, prescribed fire has been the primary tool used for ecosystem restoration and risk reduction. As a means of expanding options available to park managers, a number of alternative treatments including chipping, mastication, and understory thinning have been proposed and adopted as a part of the park's revised Fire Management Plan.

While cost-effective and efficient, land managers know little about the potential effects of these treatments on the soil and soil organisms. Thus, researchers used this study to investigate the treatment effects on mycorrhizal and hypogeous fungi in the mixed oak shrubland of Whiskeytown.

The dense, fire-prone vegetation at Whiskeytown must be carefully managed. Credit: Jennifer Gibson.

A remarkable partnership

The bond between roots, plants, and soil may seem straightforward—roots anchor the plant and absorb moisture while the soil provides the essential nutrients needed for growth and survival. But when you add mycorrhizal fungi to the mix, the relationship becomes remarkably interconnected.

The hyphae from these short branched mycorrhizae absorb water and nutrients which they transfer to the host tree. In turn, the tree provides carbon as sugars to the fungi. Credit: Darlene Southworth.

A mycorrhiza is a "fungus-root"—a plant root tip covered with a mantle of fungal cells that extend partway into the root and outward as hyphae into the soil. This symbiotic relationship is mutually beneficial and obligate, that is, necessary to both partners. It is one of the most common and significant symbiotic relationships in the plant kingdom. Living in the upper layers of soil and extending to underground ecosystems, mycorrhizae and fine roots make up an estimated 15 percent of the total weight of the world's plant roots. Mycorrhizae help boost their host plant's ability to capture water and nutrients such as nitrogen and phosphorus, transferring these essential elements to the plant. Plus, the fungi help provide protection against nematode and pathogen attacks. In return, the host plant helps nourish its fungal partner by supplying amino acids,

vitamins, and carbohydrates. In essence, healthy host trees ensure the continuation of their mycorrhizal fungal species, and healthy fungi ensure the survival of host trees.

A mycorrhizal community can include more than 40 different fungi within the roots of a single site. One such type of mycorrhizal fungi associated with oaks and pines is that of hypogeous fungi, or truffles. Highly seasonal, truffle production begins in the spring in oak woodlands and in the spring and late fall in conifer forests. Living in the upper few centimeters of soil, hypogeous fungi develop spores underground, however, the sporocarps, or fruiting bodies, do not open to disperse the spores on their own. Instead, the fruiting bodies rely on being eaten and dispersed by small mammals, thus helping to produce the mycorrhizal inoculums needed to help establish seedlings.

Fire and fungi

Since fire is a natural disturbance, most organisms, including mycorrhizal fungi, can effectively adapt. Although the species richness and composition of mycorrhizae may change post-fire, the fungi will most likely survive.

Land managers often use prescribed fire and fuel reduction treatments to mimic the natural fire process. While prescribed fire more closely represents the natural ecosystem processes, mechanical mastication does not. This raises concerns about the impact of these treatments on the physical and biological properties of the soil and on the fungi and fine roots of woody plants. The layer of coarse debris generated by mastication can take a long time to decompose, thus moderating soil temperature and moisture and decreasing aeration. Plus, once the debris is burned, a hot, smoldering fire can potentially destroy the mycorrhizae living in the upper layers of soil.

Prescribed fire can also affect truffle production. If prescribed burning is used at the time of fruiting, truffles may be destroyed, resulting in less food for small mammals and fewer spores for mycorrhizal inoculum.

"Soil microbes and mycorrhizal fungi are extremely important in the maintenance of biodiversity through their effects on community composition and ecosystem processes. Changes to the soil community can have impacts on the plant community which they support," stated Jennifer Gibson, Co-principal Investigator.

Exploring Whiskeytown

Nestled between the Klamath Mountains and the northern edge of the Sacramento Valley in California, Whiskeytown National Recreation Area was the designated site for this study. Not only a popular recreation area for outdoor enthusiasts, but a place of impressive biodiversity, Whiskeytown boasts a complex mix of habitats and species from different climates. Summers are characteristically hot and dry and winters are typically cool, with approximately 60 inches of annual rainfall. The overstory tree canopy consists primarily of conifers and hardwoods such as knobcone pine (*Pinus attenuata*), ponderosa pine (*Pinus ponderosa*), black oak (*Quercus Kelloggii*), and canyon live oak (*Quercus chrysolepis*) and includes a dense shrub community dominated by white leaf manzanita (*Arctostaphylos viscida*) and intermixed with toyon (*Heteromeles arbutifolia*), poison oak (*Toxicodendron diversilobum*), buckbrush (*Ceanothus cuneatus*), and chamise (*Adenostoma fasciculatum*).

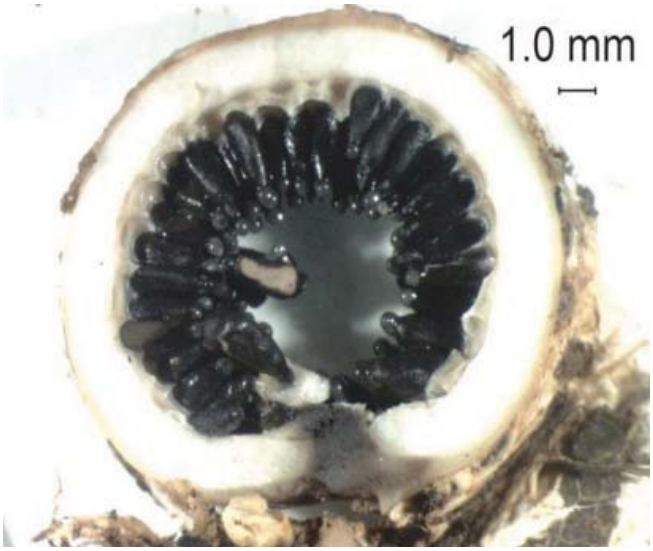
Whiskeytown is not only beautiful, but biologically diverse. Credit: Jennifer Gibson.

For this project, researchers tested three hypotheses to determine how the soil and mycorrhizal and hypogeous fungi would respond to each of the treatment methods. Study sites consisted of pre-defined macro plots that were 1 to 2 acres in size and had been randomly treated using mechanical mastication only, mechanical mastication followed by prescribed fire, prescribed fire only and untreated controls. In November 2002, the macro plots were masticated using a low ground pressure and a rubber tracked industrial brush-cutter. All pole-sized trees were retained but shrubs and small trees that were less than 12 feet in height were masticated to reduce understory density by 60 to 95 percent. Prior to mastication, the vegetation at the study site was characterized as a mix of fuel models 4, 8, and 9. Post treatment, the fuel bed changed drastically, with post treatment fuels best characterized as model 11 logging slash. In comparison to untreated sites, mastication resulted in the conversion of live and dead standing materials into downed woody debris that are now surface fuels. Consequently, woody fuel loading for 1- and 1,000-hour fuel size classes doubled, and 10- and 100-hour fuel size classes more than tripled post mastication treatment.

In May 2003, prescribed fire treatments were conducted with drip torches using a combination of strip and spot ignition patterns. During the burns, temperature extremes ranged from 59°F to 71°F, relative humidity ranged from 34 to 73 percent, and wind speeds averaged 2 miles per hour with a maximum wind speed of 6 miles per hour. Moisture readings were very high (0.3–0.4 kPa tension) during the burning period as recorded by a Delmhorst KS-D1 soil moisture tester at reference locations.

In spring 2008, researchers gathered samples of mycorrhizas and soil from the above treated macroplots. Researchers also collected hypogeous fungi by using garden cultivators to rake away duff and leaf litter in the upper four inches of soil, then closely examining the soil to distinguish sporocarps of hypogeous fungi. Further study included

microscopic examination of mycorrhizal roots, DNA identification of mycorrhizas and sporocarps, and statistical comparisons of fungal communities and soil variables.



Formerly known as *Pyrenogaster, Schenella pityophilus* was one of the truffle types observed in this study. Credit: Jonathan Frank.

New answers and further questions

After performing extensive research on the soil, mycorrhizae, and truffles at the various treated and untreated plots, researchers were able to calculate their results. Overall, the community composition and species richness of mycorrhizal fungi were not significantly altered by any of the treatments. Also, soil nutrients at the depth of fine roots and mycorrhizal fungi were not significantly changed due to mechanical mastication followed by burning and soil nutrient composition did not vary among treatments.

Overall, the community composition and species richness of mycorrhizal fungi were not significantly altered by any of the treatments. Also, soil nutrients at the depth of fine roots and mycorrhizal fungi were not significantly changed due to mechanical mastication followed by burning and soil nutrient composition did not vary among treatments.

According to Gibson, "This study provides new and valuable information about organisms we know relatively little about. For land managers concerned with the long-term health and biodiversity of treated areas, they must take into account impacts to soils and soil microorganisms."

Specific results related to each hypothesis are as follows:

Hypothesis 1: Mechanical mastication will lead to greater abundance and species richness of both mycorrhizal fungi and truffles.

Results: Mechanical mastication did not improve or degrade the abundance and species richness of ectomycorrhizas. In addition, there was no change following prescribed burning, in both masticated and unmasticated plots.

Mechanical mastication did improve abundance and species richness of hypogeous fungal sporocarps (fruiting bodies), with higher numbers on brush-masticated plots.

Furthermore, coarse woody debris from mechanical mastication did not reduce the fruiting of hypogeous fungi, which form under and beyond the canopy edge. It appears that the fruiting process was not restricted by competition with wood-rotting fungi and changes in soil surface properties.

"The results of this study indicate that brush mastication does not degrade the habitat for mycorrhizas on roots or for truffle production where the host trees, e.g., oaks, tanoaks, and conifers, remain alive," said Dr. Darlene Southworth, Principal Investigator. She continued, "As researchers, we certainly expected greater changes due to mechanical mastication. Basically, there were none."

Hypothesis 2: Prescribed burning without mechanical mastication will not reduce the mycorrhizal community, but will reduce the abundance and species richness of truffles.

Results: In this study, burning did not affect the ectomycorrhizal community as much as it affected the fruiting of hypogeous fungi. Whether on masticated or unmasticated plots, the use of prescribed fire dramatically reduced the abundance and species richness of truffles by 90 percent. Since truffles offer a number of benefits and are an incremental part of establishing pine and oak seedlings, there are concerns about the serious loss of fungi as a result of these treatments. Today, some species of hypogeous fungi are threatened and endangered, therefore, if truffle loss continues over a period of several years, species extinctions could occur.

Hypothesis 3: Mechanical mastication followed by burning will decrease the abundance and species richness of both mycorrhizal fungi and truffles.

Results: Five years after mechanical mastication followed by prescribed fire, mycorrhizal communities of oaks and pines were not reduced in species richness or altered in species composition. Researchers speculate that because the mastication treatment avoided trees taller than 12 feet, the woody debris under trees may have been less than in dense shrubland. Although depth of woody debris was not part of the experimental design, the preservation of larger trees may have helped to reduce soil heating under tree canopies above the root zone. Then again, soil depth may have helped to insulate the mycorrhizal roots.

Although the results from this study help provide greater insight into the effects of fuel reduction treatments on the mycorrhizal community, researchers feel that there are still many unanswered questions. Further investigation of the following questions could provide managers with the information they need to plan for and implement treatment methods that are ecologically favorable:

- Is inhibition of truffle fruiting a direct consequence of soil chemistry changes with fire or an indirect consequence of soil heating and drying due to removal of vegetation?

- How does depth of masticated woody debris affect hypogeous fungal fruiting? What depths created by mechanical mastication of dense shrubs inhibit fruiting?
- What size (specifically related to scale) of unburned tree islands would preserve rodent populations and hypogeous fruiting?
- Are there soil treatments which promote the recovery of hypogeous fungi, following mechanical mastication and prescribed fire?
- What are the rare rodents and fungi found in fuel reduction areas?
- What are the long-term impacts on soil microorganisms in sites which have been repeatedly treated over a long period of time?
- Are there cumulative impacts on soil microorganisms from multiple mechanical and prescribed fire treatments?

Treatment recommendations

There is something very special about the relationship between mycorrhizal fungi and their host trees—something worth preserving. To help support the long-term health and biodiversity of these underground soil communities, researchers recommend the following treatment options:

- Retain trees greater than 12 feet in height in mechanical mastication treatments, since the root tips of virtually all oaks and pines are colonized by mycorrhizal fungi. Ensuring survival of host trees will help ensure the survival of the mycorrhizal community.
- Vary prescribed fire treatments in size and severity so that patches of host trees remain. These patches will support truffle production, and hence, food for small mammals, and spores to inoculate tree roots.
- Apply mastication to vary surface fuel loading (i.e., the depth of mastication slash) throughout the treatment unit to help lower fire behavior indices and severity results.
- Apply prescribed fire to mastication treatments when the fuel moisture of masticated materials is moderate, not low. Masticated fuelbeds experience much different fire behavior than untreated vegetation. Prescriptions must consider the differences in expected behavior and subsequent severity where retention of overstory or residual trees is desired.

Management Implications

- Retain trees greater than 12 feet in height in mechanical mastication treatments and larger overstory trees to reduce soil heating above the tree root zone.
- Vary the level of mastication intensity.
- Apply prescribed fire when the fuel moisture of masticated materials is moderate.
- Retain mycorrhizal host tree species such as pines and oaks.

"The above strategies would also provide for a more spatially heterogeneous effect across the treatment area, which would thus provide a diversity of conditions in which underground organisms can find refuge," stated Gibson.

Further Information: Publications and Web Resources

Darlene Southworth's Web page:
www.sou.edu/biology/faculty/Southworth.htm

Joint Fire Science Program Project 05-2-1-87 Final Report:
http://www.firescience.gov/projects/01B-3-3-27/project/01B-3-3-27_final_report.pdf

Whiskeytown National Recreation Area Website:
http://www.nps.gov/whis/index.htm
and http://www.nps.gov/whis/naturescience/fireecology.htm

Scientist Profiles

Dr. Darlene Southworth earned a BS and MS in Botany at University of Michigan, and a PhD in Botany from the University of California, Berkeley. She taught biology at Southern Oregon University for 22 years and taken sabbaticals at the University of Melbourne, Australia, and University of Siena in Italy. As professor emerita for 10 years, Darlene has carried out research with undergraduate students on the mycorrhizal fungi associated with oaks, their dispersal by small rodents, and the types of mycorrhizas on oaks growing in serpentine soils.

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An Ecologist with the National Park Service at Whiskeytown National Recreation Area, Jennifer Gibson has diverse experience working for the U.S. Fish and Wildlife Service's California Condor Recovery Program, as well as for Channel Islands National Park and The Nature Conservancy's Santa Cruz Island Preserve. Currently, she coordinates research and monitoring in Whiskeytown, manages exotic, rare, and forest restoration projects, and actively works with fire managers on wildland and prescribed fires. She has her BS in Biology from University of California, Santa Barbara and MS in Ecology from San Jose State University. Jennifer's education emphasized population dynamics, ecological monitoring, experimental design, and multivariate analysis.

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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.

The information in this Brief is written from JFSP Project Number 05-2-1-87, which is available at www.firescience.gov.

An Interagency Research, Development, and Applications Partnership

JFSP *Fire Science Brief* is published monthly. Our goal is to help managers find and use the best available fire science information.

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