Soil Temperatures Related to Prescribed Burning in Ponderosa Pine Stands in Yosemite Valley that Include California Black Oak

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Abstract.-Prescribed burning has been actively carried out in Yosemite National Park since the early 1970’s. In the past 2 years an effort has been made to identify an unseen effect of burning, namely soil temperatures. Fires in both giant sequoia (Sequoiadendron giganteum [Lindl.] Buchholz) and mixed-conifer stands and ponderosa pine stands (Pinus ponderosa Dougl. ex Laws.) have been documented thoroughly. In two of the ponderosa pine stands burned, California black oak trees (Quercus kelloggii Newb.) were present. Soil temperatures measured near the bases of these two trees reflect quite different heat fluxes. Heat did not penetrate through the soil where the black oak tree fuels dominated the microsite. In another case, the oak tree was smaller, and the litter fuels from the surrounding pines dominated composition of the forest floor. Heating on that site was substantially greater and at much lower depths. A preponderance of oak leaves in the total makeup of the forest floor appears to reduce the combustibility of the forest floor, hence the resulting decreased soil heating.

INTRODUCTION

Since European settlement of much of the West in the late 1800’s and the development of fire exclusion policies in the early 1900’s, major changes in the way fire interacts in many ecosystems have occurred. Fuel buildup and a flush of young trees cause hazardous conditions to exist where once natural fires kept these elements in check.

For over 20 years now, prescribed fire and prescribed natural fire management programs have been part of the ponderosa pine and sequoia-mixed conifer ecosystems in Sequoia, Kings Canyon, and Yosemite National Parks (Kilgore 1981, Bancroft et al. 1985, Parsons and Nichols 1986).

Many questions have surfaced regarding both objectives and methods as a result of the National Park Service’s (NPS) prescribed fire program. The general goal in the NPS burning program is "to maintain or restore natural fire regimes to the maximum extent possible so that ecosystems can function essentially unimpaired by human interference." In 1986 a panel was assembled "to evaluate the effectiveness of the NPS fire management program in the sequoia-mixed conifer forests of the Sierra Nevada" (Christensen et al. 1987, Parsons 1990). Different areas in the Parks have been burned almost every year to reduce heavy surface fuels and to reintroduce fire to its natural role in these ecosystems. Fire history data in a number of forms indicate the existence of periodic fires in all temporal phases of managed ecosystems (Kilgore and Taylor 1979, Tweed 1987). Reinitiating of the ecological fire process is deemed necessary for the long-term maintenance of such ecosystems (van Wagendonk 1983, Parsons et al. 1986).

A number of recommendations were made as a result of the panel's review of the National Park's burning programs in the Sierra Nevada (Parsons 1990). One was to continue and expand research on the many aspects of fire effects on the giant sequoia-mixed conifer ecosystem. One question raised relates to the use of fire for restoration of an ecosystem when fuels surrounding the trees are perceived to be "unnaturally" or unusually heavy because of the long-term exclusion of fire. The specific concern is that temperatures might be elevated in the soil and on the tree boles sufficiently to cause damage to root and cambial tissue.

Our research in both Parks centers on documenting temperatures in the soil rooting zone and in tree cambiums during prescribed fires in black oak, giant sequoia, sugar pine, and ponderosa pine stands. Soil and cambium temperatures have been studied as well in ponderosa pine stands in Arizona using a thermocouple temperature-monitoring system developed for that specific purpose (Sackett and Haase, in press). Prescribed fires in the Parks have been studied since 1981.


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METHODS

Before each burn, six soil temperature monitoring probes were installed at depths ranging from the soil and duff interface to 22 inches below the soil surface in sequoia-mixed conifer stands and 12 to 18 inches in ponderosa pine stands. Six to ten sites were established on each burn at locations that represent the different depths of forest floor in which the fire is burning.

As the forest floor is ignited, flaming combustion skims off the top litter layer of newly accumulated organic material. As flaming combustion diminishes on the forest floor, glowing combustion continues in the older, more tightly compacted duff layers. An ash layer forms as combustion progresses and acts as an insulation barrier to heat escape. Heat penetration in the soil continues during the glowing combustion phase, often for days.

On sites where soil temperature is monitored, consumption of forest floor fuels has almost always been complete regardless of moisture contents of duff. If environmental conditions allow forest floor material to ignite, all the material will be consumed over the course of the fire in sequoia-mixed conifer stands. The same has been shown to be true where forest floor duff layers are heavy in ponderosa pine stands.

Probes that monitor cambium temperature were also installed in giant sequoia, sugar pine, and ponderosa pine trees during selected Park burns. Probes are installed so that the measuring tip is located in the tree cambium at a point half the distance between the soil and the top of the forest floor. Installation of probes is quite easy in pine species, but the extremely thick bark of giant sequoia makes temperature sensing very difficult.

RESULTS

Substantial soil and cambium heating has been documented in various ecosystems with heavy forest floor loadings caused by fire exclusion. In heavy forest floor sequoia-mixed conifer stands (average 70 tons/acre), temperatures average 134°F at 8 inches below the soil surface. Ponderosa pine sites in the Yosemite Valley have been burned where forest floor loadings range from 22 to 70 tons per acre. Under those conditions, soil temperatures average 106 °F at 8-10 inches. Soil temperature approached 96 °F at 14 inches in one case.

In two of the Yosemite ponderosa pine stands California black oaks were present. Both sites were in the Yosemite Valley along the Merced River. In the first stand, a large (39.9 inch d.b.h.), full-crowned oak was growing in a clump of large (39.5 inch d.b.h.) yellow pines, and mixed with incense-cedar (Libocedrus decurrens Torr.). Because of the full crown on the oak, the forest floor composition was dominated by oak leaves. In the second stand, a smaller oak tree (9.1 inch d.b.h.), with a slope to the bole, caused the crown to extend away from the base of the tree. The site was dominated by large (31.6 inch d.b.h.) ponderosa pines, and the forest floor around the oak was hence dominated by pine needle litter.

Temperature traces from the two sites were drastically different from one another, presumably because of the forest floor composition. The preponderance of oak leaves on the first site did not allow the fire to penetrate past the upper, loosely held litter layer. Very little duff was consumed around the oak (13 tons per acre), whereas 15 feet away, the entire forest floor (58 tons per acre) was consumed where the composition was totally ponderosa pine needles, twigs, and bark. Temperature 2 inches below the soil surface near the oak tree only reached 65 °F (fig. 1), whereas surface temperature near the pines exceeded 162 °F. The deepest point at which there was a temperature flux (62 °F) was at 8 inches near the oak. Temperatures elevated to 111 °F at 8 inches below the soil surface near the pines.

At the second site where oak leaves were not a large component in the forest floor near the tree base soil temperatures elevated to 115 °F at depths of 6 inches and to 98 °F at 8 inches below the soil surface (fig. 2). Sixty-one tons per acre of forest floor fuel were completely consumed at 18 inches from the bole where temperatures were measured, and consumption was complete immediately around the bole.

CONCLUSIONS

It appears from the limited amount of data, yet thorough visual examination, that a preponderance of oak leaves in the total makeup of the fuel reduces...
the combustibility of the forest floor, hence reducing soil heating. The reduced combustibility also keeps heating away from the tree boles.

Additional work is needed to quantify the effects of prescribed burning on California black oak growing in association with ponderosa pine.

LITERATURE CITED


