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Fire and Fuel Accumulation in a Giant Sequoia Forest

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ABSTRACT– Studies of downed woody fuel and of litter and duff accumulation in the sequoia (Sequoiadendron giganteum (Lindl.) Buchh.)- mixed conifer forest of Kings Canyon National Park in California showed that prescribed burning removed much of the fuel which had accumulated during the 60 years of fire suppression. Within seven years after prescribed burning, fuel was sufficient to support a fire.

Giant sequoias represent a fire-climax community whose stability depends on frequent burning (Rundel 1971, Hartesveldt et al. 1975). Before the coming of European man to the area in the late 1850s, low-intensity ground fires burned throughout the sequoia-mixed conifer forests of the southern Sierra Nevada with a frequency thought to have been as often as seven to nine years (Kilgore 1973a). With the initiation of suppression policies in the early 1900s, fire was virtually eliminated in most groves of giant sequoia, and reproduction of this species decreased while that of the more shade-tolerant white fir *(Abies concolor* [Gord. and Glend.] Lindl.) increased. Accumulation of ground fuels increased the risk of potentially destructive wildfires. In recent years it has become apparent that if sequoia groves are to be maintained as naturally functioning ecosystems, fire will have to be reestablished (Kilgore 1972).

To accomplish this objective a prescribed burning program was instituted in the sequoia groves of Kings Canyon National Park in 1969. The immediate goal was to reduce the heavy ground fuels *(fig. I)* that had accumulated during 60 to 70 years of protection, and to control the thickets of small trees that were filling in the once open forest floor *(fig. 2).* It was anticipated that when these purposes were accomplished natural fires could again be allowed to burn. Since the inception of the program in 1969, more than 1,600 acres have been burned by prescription in the Redwood Mountain Grove of the park. Burning is usually conducted in the fall when temperature, relative humidity, fuel moisture, and wind speed and direction are judged to be suitable. To date these fires have reduced the accumulated ground fuels and have removed many of the small trees (Kilgore 1973b). This paper provides information on the rate and amount of accumulation of new fuel after prescribed burning.

The Study

The main study area was along the ridge of Redwood Mountain at an elevation of about 6,600 feet, within the largest existing grove of giant sequoia. Associated tree species include white fir, sugar pine *(Pinus lambertiana* Dougl.), ponderosa pine *(Pinus ponderosa* Laws.), incense-cedar *(Calocedrus decurrens* [Torr.] Florin), and Pacific dogwood *(Cornus nuttallii* Aud.).

All sites sampled within this area had been burned during the fall with moderately intense fires that had consumed most of the downed woody material. Fuel was sampled in areas that had: (1) no record of burning, (2) been burned the preceding week, and (3) been burned one, four, or seven years previously. The sampling, conducted between 1974 and 1976, was carried out on the same plots for the unburned, immediate postburn, and one-year postburn on a follow-through basis. Nearby plots which had been burned in 1969 and 1972 provided the data for the four- and seven-year-old burns.

To measure downed woody fuel, transects 50 feet in length were randomly located at each study site. The number of surface twigs and branches that intersected the transect was tallied along the first six feet; diameter classes were 0-0.25 and 0.26-1.0 inch. The number of intersections of branches one to three inches in diameter was tallied along the first 10 feet. All downed branches and logs larger than three inches in diameter were individually measured and recorded along the entire transect. These data were then converted to tons per acre according to the system proposed by Brown (1974). Depths of litter and duff combined were taken at preestablished distances along each transect. The litter and duff layer was defined as including all intact and partially decomposed needles, as well as partially buried woody fuels less than 0.25 inch in diameter. The measurements were converted to tons per acre (Agee 1973). From 20 to 60 fuel

transects and 120 to 210 combined litter and duff depths were read for burns of each age. Sample sizes were still larger for unburned sites.

Fuel Buildup

It is evident from *table 1* that the fires consumed most of the downed woody material. Woody fuels increased slightly during the first year after a burn and considerably during four and seven years' time. Relative rates of accumulation were greatest in the smaller size classes.

After seven years all fuels under three inches in diameter had nearly returned to preburn levels. While fuels greater than three inches in diameter showed considerably larger total accumulations than the smaller size classes at all points in time, even the seven-year accumulation was well below that found in an unburned forest. The relative rate of return to pre- burn fuel levels decreased with increasing fuel size.

Table 2 shows that nearly 92 percent of the weight of the litter and duff layers was consumed. Both depth and weight of litter and duff increased steadily during the years following burning. After seven years these values were slightly less than half of that which had accumulated during more than 60 years of fire exclusion.

The total accumulation of all ground fuels, including both woody material *(table I)* and the litter and duff layer *(table 2)* was 85.0 tons per acre in the unburned forest. Burning reduced the amount to 9.3 tons. This value gradually increased to 45.0 tons per acre over the next seven years.

Although not specifically measured, many small trees killed by the burning were still standing seven years later. They represent a significant fuel source to be considered when planning for future reburns.

Table 1. Accumulation of downed woody material per acre.

Time since fire	Size class (inches)			
	0-0.25	0.25-1	1-3	3+
	Tons			
Unburned[1]	0.257	1.872	3.040	50.72
Immediate postburn	.101	.258	.476	6.11
1 year	.116	.380	.635	6.46
4 years	.503	1.373	1.177	9.19
7 years	.404	1.764	2.323	27.38

'Unburned for more than 60 years; exact date of last burn unknown.

Table 2. Litter and duff accumulation following different periods since burning.

Time since fire	Depth	Weight per acre
	Inches	*Tons*
Unburned'	*1.9 ± 0.31*	*29.1 ± 3.6*
Immediate postburn	.2 ± 0.1	2.4 ± 0.6
1 year	.3 ± 0.1	4.2 + 1.6
4 years	.7 ± 0.1	10.3 ± 1.4
7 years	.9 ± 0.1	13.1 ± 2.0

'Unburned for more than 60 years; exact date of last burn unknown.

Implications for Fire Managers

The information presented here documents the effectiveness of prescribed burning in eliminating the majority of the accumulated ground fuels in the sequoia-mixed conifer forests of Kings Canyon National Park. It also quantifies the rate of fuel accumulation for the first seven years after a burn. Data of this sort represent the first step towards refining and expanding the park's program of prescribed burning. They also provide an indication of how soon an area can or should be reburned.

Since the unburned forest in the present study had accumulated fuel for over 60 years, the amount probably was considerably higher than that commonly found under a more natural fire regime of seven to nine years. And while this 60-year accumulation was al- most completely consumed during the first burn there was a considerable increase in ground fuels during the next few years. The explanation, at least in part, appears to be that many young trees (mainly white fir up to 20 inches in d.b.h.) had come in during the period of suppression (Kilgore and Sando 1975). When they were killed by the fire, their falling needles, twigs, and branches built up ground fuels rapidly. The total accumulation (woody material plus duff and litter) of 22.5 tons per acre found four years after burning and 45.0 tons per acre after seven years would, depending on the prescription used, be sufficient to carry a second relatively hot fire. As such young, fire-susceptible trees are thinned out in successive burns, the rate of ground fuel buildup should decrease.

To fully understand the rate of fuel accumulation both under a natural fire cycle and during long periods of suppression, it will be necessary to experimentally reburn areas two, three, or even four times. These burns should be conducted at various frequencies and prescriptions. For example, portions of both the seven- and four-year-old burns could now be re- burned. Such experimentation would help to evaluate the effectiveness of different prescriptions in removing the existing, unnatural buildup of heavy fuels.

Once heavy accumulations have been removed, the interval between subsequent burns could be set by nature. Eventually, naturally ignited fires may be able to resume their role m the giant sequoia ecosystem. €

Figure 1*. Buildup of ground fuels, young white fir, and sugar pine following 60 years of fire suppression.*

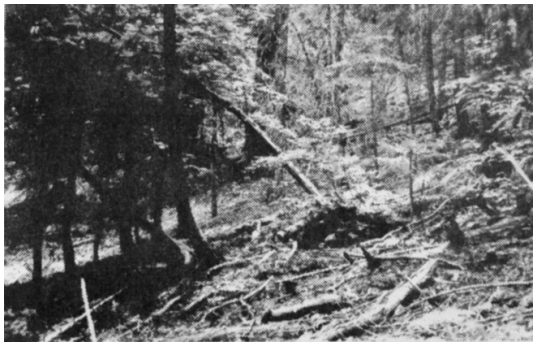

Figure 2. *Abundant growth of young white fir and dogwood in an area protected from fire since the early 1900's.*

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