

SHORT-TERM EFFECTS OF PRESCRIBED FIRE IN GRAND FIR-WHITE PINE-WESTERN HEMLOCK SLASH FUELS

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ABSTRACT

Experimental burns were conducted on 36 plots in mixed conifer logging slash in northern Idaho, under varying fuel loadings and moisture conditions. This paper reports the immediate effects of these burns on the forest floor, the woody fuel complex, and the plant community, and includes recommendations to managers for using prescribed fire in this forest type. Much of the shallow layer of duff was consumed exposing mineral soil under the full range of burn conditions; however, the deep pockets of rotten wood in the forest floor retained moisture throughout the burning season, and were largely intact after fire. Most (70%, or an average of 31 tons/acre) of the large woody fuel was retained. Planted Douglas-fir, western larch and white pine had greater average height growth on burned units than on unburned. Natural regeneration of grand fir and western hemlock was taller with greater average annual increment on unburned units than on burned units. There were more grand fir seedlings on unburned units, but more hemlock seedlings on burned units.

Keywords: prescribed fire, fire effects, duff, fuel, regeneration.

INTRODUCTION

Prescribed fire is an important management tool for reducing fuels and fire hazard following timber harvest, for site preparation, and for manipulating vegetation. Prescribed fire may have a significant role in maintaining a healthy forest while meeting other management objectives. Prescribed fire has been used in the cedar-hemlock-white pine forests of the Inland West with varying degrees of success since the early 1900s (Davis and Klehm 1939). However, today land managers are faced with increasing constraints in using prescribed fire. Smoke emissions, visual concerns, site protection and site productivity are all issues that need to be addressed in using prescribed fire. It is important in the face of these concerns to develop our knowledge about fire effects and our skills in prescribing and meeting objectives through prescribed burning.

To help meet this information need, a study was initiated in 1984 by the Intermountain Experiment Station's Fire Effects Research Work Unit to quantify the effect of prescribed fire in grand fir-white pine-western hemlock (*Abies grandis*-*Pinus monticola*-*Tsuga heterophylla*) slash fuels. This paper reports

the effects of 36 prescribed burns on the forest floor, the fuel complex and the plant community, and provides recommendations to managers for using prescribed fire in this forest type.

STUDY AREA AND DESIGN

The study is located on the Deception Creek Experimental Forest, which is on the Fernan Ranger District, Idaho Panhandle National Forests. The site is a steep (50-80%), north-facing slope at 3000-4000 feet elevation. Habitat type is western hemlock/Queencup beadlily (*Tsuga heterophylla*/*Clintonia uniflora*-*Clintonia uniflora* phase) (Cooper et al. 1987).

Forty-four experimental units were established in a series of small strip clearcuts and alternating clearcut-seed tree strips. Units were harvested using a skyline yarding system. In twelve of the units fuel loadings were reduced by yarding unmerchantable material (YUM treatment) greater than 6 inches in diameter to the tops of the units where it was made available to firewood cutters, resulting in lighter fuel loadings and additional duff and soil disturbance. Four of the YUM units were burned in the spring (June) and four in the fall (August or September); four were reserved as unburned controls. Of the units that did not receive a YUM treatment, nineteen were burned in the spring, nine in the fall, and four were unburned.

SAMPLING

In each of the burn units, woody fuels were inventoried before and after burning, using a planar intersect method (Brown 1974). On a subset of 18 units, consumption of large woody material was also sampled by circling 60 logs with wire. Wires were measured to determine preburn circumference, then cinched up and measured to determine postburn circumference. Moisture contents of duff, 0- to 1/4-inch twigs, 1/4- to 1-inch twigs, and large woody material were sampled on the day of the burn. A detailed description of fuel sampling methods is provided in Reinhardt et al. (1991).

On each unit, 40 one-meter-square microplots were established and permanently marked. Before and after burning, coverage of duff, mineral soil, large woody material, herbaceous plants, subshrubs and shrubs was estimated. Duff spikes were placed at the corners of these microplots with their heads flush with the duff surface for measuring duff consumption and residual duff depth.

Understory vegetation was sampled before harvest and during the first five summers after burning on ten of the units, using permanently marked nested plots (Stickney 1985).

The units were planted with Douglas-fir (*Psuedotsuga menziesii*), western white pine, and western larch (*Larix occidentalis*) in 1985. Natural and planted regeneration was assessed 5 years later by counting seedlings by species, age and height class on each of the 40 microplots in 8 spring burn units, 8 fall burn units, and 8 unburned units.

BURN TREATMENTS

Moisture contents at burn time are summarized in Table 1. Residence time for continuous flaming at an observation point was generally ranged 4-12 minutes. Flame heights were controlled by slow strip ignition. Typical flame lengths were 1.5-10 feet.

No plant cover remained on the burned areas. Nine of the units had discontinuous burns, with 0.5-43% of the area unburned. These unburned patches were the only places with plant cover immediately postfire. Amount of unburned area averaged 4% for spring burns and 0% for fall burns.

Table 1.—Moisture contents at time of burn, percentage by dry weight.

Fuel	Mean June	Mean Aug/Sept	Min.	Max.
Litter-derived duff	16	30	10	40
Deep rotten wood	195	134	80	300
0-1/4 inch	11	12	8	19
1/4-1 inch	11	16	7	25
3+ inch sound	47	46	32	61
3+ inch rotten	83	65	50	111

RESULTS AND DISCUSSION

The Forest Floor

Frequencies of preburn and postburn forest floor depths are shown in Figure 1. Preburn duff depth at Deception Creek averaged 1.5 inches, which is typical of duff profiles in the cedar/hemlock type and warm moist habitat type group of northern Idaho (Brown and See 1981). The duff consisted of a shallow (mean = 0.8 inch) layer of decomposing litterfall interspersed with pockets of rotten wood averaging 5.3 inches deep. The deep rotten wood covered an average of 13% of the forest floor. These pockets of rotten wood are an important source of nutrients and sites of nitrogen fixation and ectomycorrhizal activity (Harvey et al. 1987). Seven percent of the area had no duff. Preburn duff loading averaged 22.6 tons/acre of organic material.

The moisture content of deep pockets of rotten wood in the forest floor was much greater than that of the litter-derived duff layer at the time of the burns. In the fall of 1984, when only 0.3 inch of rain had been recorded since the end of June, moisture contents over 200% were still being observed in these pockets. Average moisture content of litter-derived duff in spring burns was less than in fall burns, while average moisture content of the deep rotten wood was greater in spring burns than fall burns. The

shallow layer dried quickly in the long spring days, while the deep, saturated pockets of rotten wood responded much more slowly to seasonal drought. Moisture content of the entire duff profile was calculated as a weighted average of shallow duff and deep rotten wood moisture, weighted by proportion of area covered by duff type. Moisture content of rotten woody pieces was notably greater than that of sound pieces.

More than half of the duff on the units was burned in both spring and fall burns. An average of 65% of the volume and 61% of the loading, or 14.2 tons/acre was consumed in the spring burns and 62% of the volume and 59% of the loading or 12.8 tons/acre was consumed in the fall burns. The median residual duff depth was 0 on most (56%) of the burned units, and exceeded 0.4 inch on only 2 units. Seventy-five percent of the residual duff loading was rotten wood. The residual rotten wood duff averaged 3.9 inches in depth and residual litter derived duff averaged 0.6 inch. In spite of the large portion of the forest floor with complete duff consumption, residual loading of duff averaged 8.9 tons/acre.

As in other forest types (Brown et al. 1985), duff depth reduction and percentage of duff reduced were negatively correlated with shallow duff moisture and entire duff moisture, indicating as expected that more duff burns when it is dry. This demonstrates that an opportunity exists to manage duff consumption by monitoring duff moisture and prescribing burns to achieve desired duff consumption.

Mineral soil exposure averaged 66% based on duff spike data following the prescribed fires, providing a highly desirable conifer seed bed in this forest type (Haig et al. 1941). The thin layer of decomposing litterfall was largely consumed by fire. Mineral soil exposure was highly correlated with percentage of duff reduced. Much of the area where mineral soil was not exposed was incompletely burned pockets of deep rotten wood.

On the microplots, YUM units had less mineral soil exposure after burning and more unburned organic material than no-YUM units, perhaps because the additional yarding treatment disturbed the duff, possibly mixing it with soil, and resulting in less continuous duff burnout. Mineral soil exposure was 41% on

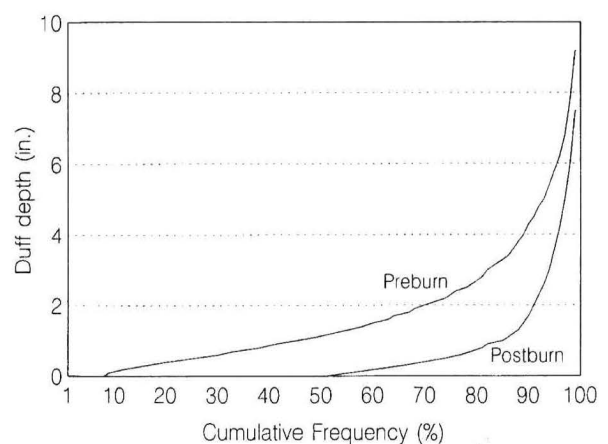


Figure 1.—Pre- and post-burn duff depths at Deception Creek.

YUM units and 56% on no-YUM units based on ocular estimates on microplots, while unburned organic cover was 13% on YUM units and 6% on the no-YUM clearcut strips. This difference was significant at $p = 0.10$.

The Woody Fuel Complex

Preburn downed woody fuel loadings ranged from 28-86 tons/acre. The majority of this (an average of 81% in the no-YUM units) was large (3"+) material.

The fires burned nearly all the small woody fuel. Consumption averaged 94% for 0- to 1-inch fuel and 81% for 1- to 3-inch fuel. Consumption was not related to season of burn or treatment or to measured moisture content of any fuel component. These results indicate that it is difficult to manage or control small woody fuel consumption, and that when fine fuel moistures are in the range of 10-15% nearly total consumption can be expected. Similarly, Robichaud et al. (this proceedings) showed that nearly total consumption of fine fuels can be achieved when moisture contents are near 20%. For most prescribed fire applications it is not necessary to restrict consumption of small woody fuels, and their consumption reduces fire hazard.

Percent consumption of large woody material was more variable than small woody material, averaging 33%. Consumption of large woody material was reduced when these fuels were wet (Brown et al. 1991) and was less in spring burns than fall burns. Opportunities for managing fuel consumption or residual fuel loadings can be greatly expanded by regulating preburn fuel loadings as well as fuel moisture content, as can be seen by examining differences between YUM and no-YUM units (Table 2). For example, if managers are concerned about reducing

consumption to reduce smoke emissions, they can accomplish this in part by reducing preburn loadings through increased utilization. Conversely, if retaining woody debris is important, it may be useful to manage for high preburn loadings as well as burning at higher moisture contents. By considering constraints on large woody fuel consumption or retention early in the planning process, such as in the silvicultural prescription development, managers can give themselves more opportunity to burn under a range of moisture conditions.

Brown and See (1981) report an average of 30 tons/acre of large woody fuels in cedar hemlock forests of the northern Rockies. The median loading was only 12.5 tons/acre. Graham et al. (in progress) report that large woody debris in the forest type could potentially be as high as 250 tons/acre following stand replacement wildfire. The amounts needed to maintain forest productivity after timber harvest in this forest type have been estimated to be in the range of 15-25 tons/acre (Graham et al., in progress). Results of this study indicate that retaining this target residue should not be difficult in prescribed fires if fuel moisture content and preburn fuel loadings are reasonable.

The Plant Community

Trees

Natural regeneration was primarily grand fir and western hemlock. Western white pine, western larch, and Douglas-fir seedlings were present but not frequent. Regeneration of these species may have been hampered by inadequate seed supply. Five years after the burns, more grand fir seedlings were found on unburned units but more western hemlock seedlings were found on burned units (Table 3). These results are similar to those

Table 2.—Average preburn and residual fuel quantities, and the range of observed percent consumption for spring and fall burns. Values are tons/acre except duff depth is inches. YUM refers to units in which unmerchantable material was yarded to the top of the units, reducing fuel loadings.

Fuel	Preburn Mean	Residual Mean	Percent Consumed		
			Mean	Min.	Max.
Spring					
Duff depth	1.9	0.66	65	29	80
Duff	23.2	9.0	61	27	85
0-3 inch	11.4	1.4	87	31	98
3+ inch YUM	29.9	22.3	22	0	36
3+ inch no-YUM	55.6	34.7	39	18	64
Fall					
Duff depth	1.7	0.64	62	43	93
Duff	21.6	8.8	59	42	92
0-3 inch	12.7	1.6	86	3	99
3+ inch YUM	36.1	21.9	39	7	53
3+ inch no-YUM	48.0	33.1	30	0	54

reported by Haig et al. (1941), who found that western hemlock germinates over 10 times better than grand fir on burned over surfaces, and that grand fir germinates better on duff than on burned surfaces.

Table 3.—Natural regeneration of grand fir and western hemlock 5 years after treatment on burned and unburned units. Seedlings over 5-years-old (advance regeneration) were excluded from analysis.

	Burned	Unburned
Grand fir		
Average annual height increment (meters)	0.04	0.07
Density (seedlings/acre)	1902	2145
Western hemlock		
Average annual height increment (meters)	0.02	0.04
Density (seedlings/acre)	14691	4290

Although the differences in seedling establishment between burned and unburned units were statistically significant, ample regeneration of both species was present on both burned and unburned plots. No differences were found between spring and fall burns.

Seedlings of both species had greater annual height increments on unburned plots than on burned plots. Characteristics of the forest floor did not appear to influence height increment of either species. Height increment of both species was uncorrelated with amount of mineral soil or residual organic material on the microplots. It was positively correlated with percent plant cover, perhaps indicating that the difference between growth on burned and unburned plots could be because the burned plots were too exposed for these shade tolerant species. Foiles et al. (1990) report that early growth of grand fir is favored by moderate shade.

The 5-year-old planted seedlings of western white pine, western larch, and Douglas-fir were taller on the burned plots than the unburned plots (Table 4). As with the natural regeneration, height growth was not correlated with presence or absence of duff or organic material on the microplots. There was, however, a negative correlation between seedling height growth and plant cover on the microplots. The contrast in results between natural regeneration and planted seedlings may be due to differences in shade tolerance between species. Haig et al. (1941) reported that

Table 4.—Height of planted seedlings 5 years after planting.

	Height (meters)	
	Burned	Unburned
Western larch	1.06	0.86
Western white pine	.69	.59
Douglas-fir	.56	.49

2-year-old larch seedlings were approximately twice as tall on burned sites as on scarified mineral soil or duff covered soil. Douglas-fir seedlings were also taller on the burned seedbeds. Schmidt et al. (1976) found that greater height growth of western larch seedlings on burned seedbeds than on mechanically scarified or untreated seedbeds persisted for at least 17 years. They attributed the increased growth on burned sites to reduced vegetative competition, more light and more available nutrients.

Understory Vegetation

The understory plant response was monitored on 10 units. One group of five units was a moderate fall burn, with duff consumption averaging 0.8 inch, and 57% mineral soil exposure. The other group of five units was burned in June under drier conditions. Duff consumption averaged 1.3 inches, and mineral soil exposure averaged 73%.

Immediately after the burns there was no plant cover on these units. The first season postfire plant cover averaged 35% on the more severely burned units and 58% on the moderately burned units. The difference in plant cover by severity diminished rapidly over the 5-year-period. By the fifth year after burning there was substantial plant cover (about 60% on all units) consisting of a number of herbs and shrubs.

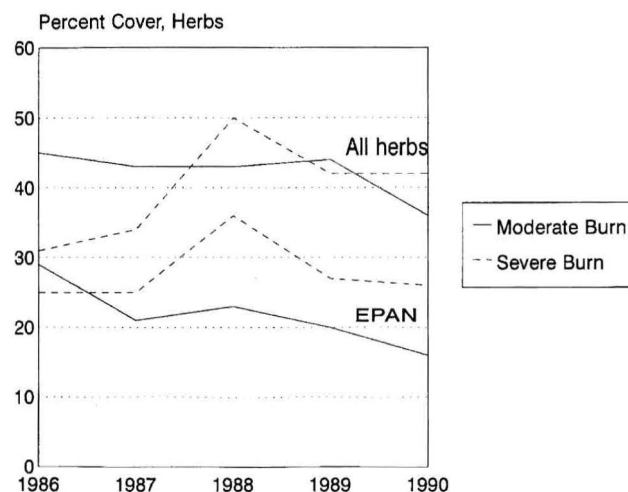


Figure 2.—Percent cover of fireweed (EPAN) and all herbaceous plants on moderately and severely burned units for 5 years following treatment.

The majority of the herbaceous cover was fireweed (*Epilobium angustifolium*) over the 5-year-period (Figure 2). Herbaceous cover was fairly similar in the moderately burned and severely burned sites. Other herbs that were consistently present were fairy bell (*Disporum hookeri*), and several species of sedge (*Carex*).

Shrub species included Rocky Mountain maple, mountain lover, thimbleberry, and huckleberry (*Acer glabrum*, *Pachistima myrsinites*, *Rubus parviflorus*, and *Vaccinium globulare*). Shrub

cover was initially substantially greater in the moderate burn group (Figure 3), presumably because of greater recovery from surviving underground plant parts, but this difference decreased substantially over the 5-year-sample period.

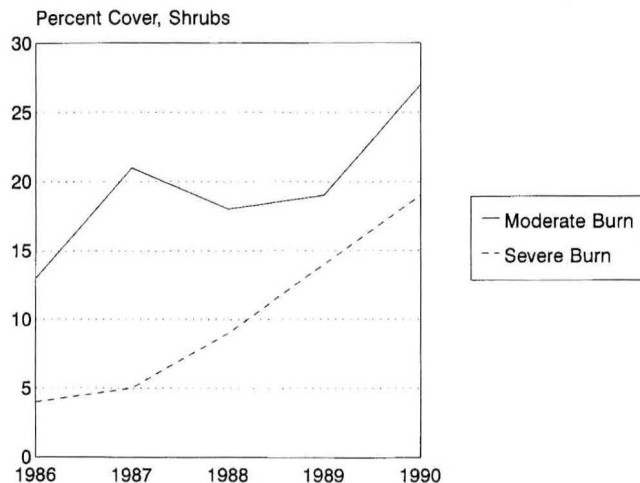


Figure 3.—Percent shrub cover on moderately and severely burned units for 5 years following treatment.

CONCLUSIONS

These prescribed fires were conducted under a broad range of operational conditions, and indicate that in this productive forest type managers have a range of opportunities to use prescribed fire. Under the full range of burn conditions most of the small woody fuels were consumed considerably reducing fire hazard and a substantial portion of mineral soil was exposed providing optimum sites for natural regeneration. Large woody fuels were retained in varying degrees depending on moisture content and preburn quantities, and were generally well within recommended amounts for maintaining forest productivity. YUM treatments can expand the range of management opportunities for treating fuels with prescribed fire while controlling smoke emissions. In addition, large amounts of rotten wood in the forest floor were preserved, maintaining an important source of nutrients and locations for microbiological processes.

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