FUEL REDUCTION IN LODGEPOLE PINE STANDS IN BANFF NATIONAL PARK

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ABSTRACT

Over the last decade fire managers in Banff National Park have embarked on a comprehensive fuels management program of which one aspect has been fuel reduction treatments near structures or facilities (e.g., homes, campground, hotels). These treatments included the reduction of dead and down woody surface material (e.g., logs, branches, twigs), removal of coniferous understory trees, pruning, and overstory thinning. Detailed measurements of all flammable material above mineral soil were made at four plots within the treated areas and four plots in stands immediately adjacent to the treatments. The fuel treatments resulted in a 3-, 4-, and 6-fold decrease in crown bulk density, stand density, and dead and down woody material, respectively. The change in surface fuel loading caused a 50% reduction in the potential surface fire intensity. Based on Van Wagner's theories, the likelihood of crown fire initiation was significantly reduced and the rate of spread required to sustain continuous crowning rose almost 4 times.

INTRODUCTION

Within Canada the practice of fuels management is becoming increasingly important as fire and resource managers seek proactive ways to reduce the threat of wildfire to people, property, and natural resources. Of the three variables that determine forest fire behavior (i.e., fuels, weather, and topography), altering the forest fuels is the only way to influence the fire behavior potential of a stand or area. Fuels management is formally defined as the planned manipulation of forest vegetation to decrease the intensity and rate of spread of a wildfire (Merrill and Alexander 1987). The need for fuels management is based on the realization that although fire suppression is effective in the vast majority of wildfire situations (e.g., 90-95% of the time), it is neither physically nor economically possible to control all wildfires.

Pyne et al. (1996) identifies three types of fuels management: fuel reduction, fuel conversion, and fuel isolation. This study focuses specifically on fuel reduction, which consists of actions taken to decrease the total amount of fuel in a given area. Fuel reduction procedures can also change the fuel arrangement within a stand which may further alter forest fire behavior potential. Fuel reduction can include the removal of dead and down woody material (e.g., logs, branches, twigs), removal of ladder fuels (e.g., understory coniferous trees and low branches on trees), and thinning of the overstory. These actions reduce the likelihood that a stand will support the initiation and spread of high intensity crown fires that are difficult to control.

Fuels management has been practiced for centuries. In North America, aboriginal peoples used planned fires to manage their surroundings for ecological and protective purposes (Lewis 1982). In parts of Europe, grazing and the extensive collection of forest fuels have almost completely eliminated fire from many forested areas. In the United States formal fuels management programs have existed since the 1930s, and there are currently many localized projects being conducted in high value areas (Pyne et al. 1996). Fuels management has also become a very significant part of the land management and fire management practices in Australia in both wildland-urban interface areas as well as valuable plantations (Foster 1976).

Although many operational fuels management projects are being conducted there have been only a few studies that have attempted to evaluate the impact of such treatments on the fuel complex (e.g., Benson 1982, Wakimoto et al. 1988, Kalabokidis and Omi 1998). The purpose of this study was to measure the change in fuel loading and stand structure resulting from fuel reduction activities in lodgepole pine stands within Banff National Park and estimate the impact of these treatments on forest fire behavior potential.

METHODS

Study Area and Treatments

The Town of Banff (latitude: 51.18°N, longitude: 115.57°W, elevation: 1397 m) is within Banff National Park which is located at the eastern edge of the Canadian Rocky Mountains. Between 1988 and 1998 several fuel reduction projects were conducted in and around the Town of Banff as part of a comprehensive fuels management strategy for the area (Hirsch and Pengelly 1998). Two of these sites, one at the Tunnel Mountain campground and one at the Two Jack Lake campground, were selected for this study because they are representative of the lodgepole pine/buffaloberry (*Pinus contorta var. latifolia/Sherperdia canadensis*) forest that is commonly found in the valley floor benchlands and extensively effected by fire (Holland and Coen 1982).

A total of 54 ha were treated at the two sites between 1988 and 1993. Treatments involved hand falling with chainsaws and tree-length line skidding to a landing for limbing and bucking. Surface fuels were piled and burned during the winter.

Measurements

Detailed measurements of all flammable material above mineral soil were made at a total of 8 plots. Four plots were in the treated stands (Figure 1) and four were located immediately adjacent to the treatment areas in stands representative of the pre-treatment forest (Figure 2). General locations for the plots were recommended by Parks Canada staff to ensure adequate coverage of the range of conditions of the treatment area and the pre-treatment vegetation. The specific location of each plot and the orientation of the initial transect were randomly selected. Data collection techniques were similar to those used by White (1985) who conducted an extensive fuel loading study of various ecosites in the entire park. Each plot consisted of three 30-m transects (Figure 3) arranged as an equilateral triangle. The slope of each transect was measured and photos were taken of the initial line. Six specific types of fuels measurements were made at each plot.

Dead and Down Woody Fuels – Dead and down fuels

Figure 1. Photograph of an untreated stand at the Tunnel Mountain campground near the town of Banff.

Figure 2. Photograph of a fuel reduction treatment area at the Tunnel Mountain campground near the town of Banff.

were sampled using the line intersect method (Van Wagner 1982) following the layout described in McRae et al. (1979). Fuel loads were calculated using the constants derived by Delisle and Woodard (1988).

Duff and Litter Fuels – Square (30 by 30 cm or 0.09 m^2) duff and litter sub-plots were located 1m outside of the plot perpendicular to the 5 m point on each transect. Litter consisted of needles, leaves, and very small twigs; it did not include grass or other herbaceous material, which was measured separately. Duff comprised the fermentation (F) and humus (H) layers of decomposed organic materials present above mineral soil. Litter and duff depths were measured at the Four Corners of the sub-plot. The litter and each 2-cm layer of duff was collected and oven-dried at 105 °C for 24 hours to determine their oven-dry weight. The bulk density (kg/m^3) for the litter and an overall bulk density for the duff were determined by dividing the oven-dry weight by the average depth of the fuel. Bulk densities were also calculated for each 2-cm layer of the duff. Additional measurements of duff and litter

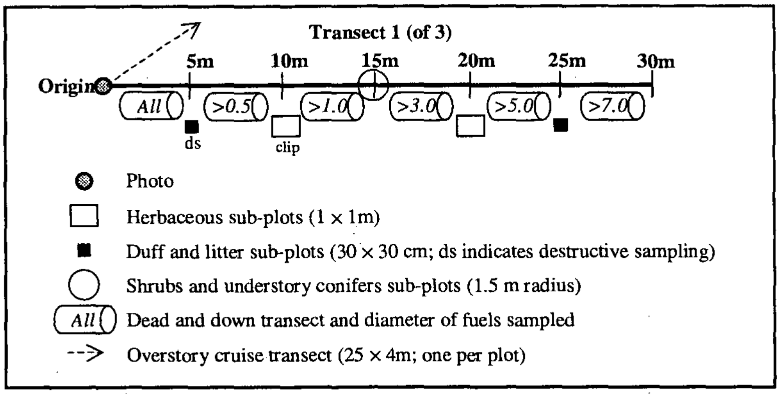

Figure 3. Measurements made on each side the triangular sampling

depths were made adjacent to the 25-m point on each side of the transect.

Herbaceous Fuels – Herbaceous fuels were measured in 1 by 1 m sub-plots located 1 m outside of the plot adjacent to the 10-m and 20-m transect points. Percent cover for three classes of herbaceous material (i.e., grass, bearberry (*Arctostaphlos uva-ursi*), and other herbs) were visually estimated. At the 10-m transect point, each category of herb was clipped and bagged. Material was oven-dried and used to calculate herbaceous fuel loading.

Shrub and Understory Coniferous Fuels – Shrubs and conifers less than 3 m in size were measured using circular, 1.5-m radius sub-plots located at the 15-m point of each transect line. Shrub condition (live or dead), species, and basal diameter class were measured for each stem in the plot. An average height and the percent cover (live) by species was also estimated. Species, condition, basal diameter, and height for each understory conifer were also measured. Shrub and understory conifer fuel loadings were calculated using regression functions found in Brown (1976) and Delisle (1986).

Overstory Fuels – Overstory fuels were measured using a 25 by 4 m (.01 ha) transect located in a random direction beginning at the origin of the triangular plot. For each tree in the transect the following information was recorded: species, condition (live or dead), diameter at breast height (DBH), height, height to live crown, height to dead crown, and maximum live crown width (all heights measured to within 0.5 m). These data were used to determine stand density, average crown bulk density, and an estimate of crown closure. Crown bulk density of the stand (kg/m^3) was calculated using average height of the live crown (m) and the total weight of the foliage for all trees in the transect (Van Wagner 1977). Crown fuel weights (kg/m^2) were obtained for individual trees using biomass regression equations from Johnson et al. (1990) and Brown (1978).

RESULTS AND DISCUSSION

Table 1 provides a summary of the stand structure and fuel loading characteristics for the treated and untreated plots. The data shows that on average the treated plots had:

- A four-fold reduction in stand density.
- A three-fold drop in crown bulk density.
- A six-fold decrease in dead and down fuel loading for both the fine fuels (< 7 cm in diameter) and the coarse fuels (> 7 cm in diameter).
- A minor reduction in duff and litter depth.
- A rise in grass loading and percent cover (although the grass load remains a relatively small proportion of the total surface fuel load).
- An increase in average DBH due to the removal of smaller trees.

There was very little change in the average values for tree height, height to live crown, crown width, herbaceous loading, and shrub and conifer understory loading.

The level of change in the fuel loading and stand structure will have a direct impact on the likelihood of crown fire initiation and spread. According to Van Wagner

Feature	Untreated stands	Treated stands
Stand density (stems/ha)	2825[a]	650[b]
Tree height (m)	14.2	14.3
Diameter at breast height (cm)	14.5	19.8
Height to live crown base (m)	7.7	7.5
Crown width (m)	2.7	3.0
Crown bulk density (kg/m^3)		
Foliage	0.26	0.07
Foliage and twigs < 1cm	0.82	0.29
Understory conifer biomass (kg/m^2)	0.11	0.02
Shrub[c] biomass (kg/m^2)	0.42	0.68
Herbaceous biomass (kg/m^2) and Cover		
Grass	0.02 (19%)	0.07 (47%)
Bearberry	0.02 (13%)	0.01 (13%)
Other herbs	<0.01 (4%)	<0.01 (5%)
Dead and down fuel loading (kg/m^2)		
Fuels < 3 cm diameter	0.16	0.06
Fuels 3–7 cm diameter	0.86	0.10
Fuels > 7 cm diameter	1.17	0.21
Litter		
Bulk density (kg/m^3)	38.5	49.6
Depth (cm)	1.4	0.5
Duff		
Bulk density (kg/m^3)	161.8	183.8
Depth (cm)	5.4	4.1

Table 1. Average fuel loading and stand structure measurements for the treated and untreated stands.
[a] 69% were lodgepole pine and 31% were white spruce.
[b] 92% were lodgepole pine, 4% were white spruce and 4% were Douglas-fir.
[c] Dominant shrubs were buffaloberry, wild rose (*Rosa acicularis*), alder (*Alnus* spp.), and common juniper (*Juniperus communis* L.).

(1977) crown fire initiation is dependent upon three factors: surface fire intensity, live crown base height (LCBH), and foliar moisture content (FMC). Assuming all other factors remain constant, the reduction in the surface fuel loading in the treated stands would cause a decrease in the surface fire intensity and thereby lower the chance of crown fire initiation. For example, if it is assumed that all the understory conifer, herbaceous materials, dead and down fuel less than 3 cm, and the litter[1] are consumed in the flaming zone of a head fire this would mean that the total amount of fuel consumed would change from 0.85 kg/m^2 in the untreated areas to 0.41 kg/m^2 in the treated stands. Entering these values into Byram's (1959) fire intensity equation, and assuming 18,000 kJ/kg as the low heat of combustion and a head fire rate of spread of 10 m/min, the surface head fire intensity would decrease from 2550 kW/m to 1230 kW/m. The former would be a high intensity surface fire that could initiate crowning in trees with a live crown base height of 6m or less[2]. The latter would be a low to moderate intensity surface fire and the live crown base height would have to be 3.5 m or less for crowning to occur. Although not modelled here, the removal of the coniferous understory would also increase the gap between the surface fuels and crown fuels making crown fire initiation more difficult. Conversely, the reduction in stand density may allow greater wind penetration into the stand which could increase surface spread rates.

With respect to sustaining the spread of a continuous (or active) crown fire, Van Wagner (1977) theorized it is dependent upon two inversely related factors: crown bulk density (CBD) and rate of spread. He suggests that for a given CBD there is a critical minimum rate of spread (R_o) that must be exceeded in order to main-

[1] Litter fuel loading was obtained by multiplying the litter's average bulk density by its mean depth.
[2] The critical surface fire intensity needed to initiate crowning equals $[0.01*LCBH*(460+(26*FMC))]^{1.5}$ (Van Wagner 1977, Alexander 1988). This example is based on a FMC of 100%.

tain a continuous flame front. Alternatively, for a given rate of spread there exists a critical minimum crown bulk density below which continuous crowning could not be sustained. Therefore, thinning the overstory will reduce the CBD, which means a higher rate of spread is required to sustain crowning. Higher spread rates will require more extreme weather conditions that occur less frequently, so thinning will in effect reduce the likelihood that the treated stands will sustain active crowning. Based on Van Wagner's (1977) equation[3] and using only foliage to calculate CBD, the untreated sites yield an R_o of 11.5 m/min while in the treated stands a R_o of 43 m/min is necessary to sustain continuous crowning. Combining these results with historical fire weather/danger frequency data would allow a further quantification and analysis of the change in the likelihood of sustaining active crowning.

SUMMARY

The fuel reduction projects conducted in Banff National Park significantly altered the fire behavior potential of the treated stands. On average, there was over a 6-fold decrease in the dead and down and understory coniferous fuel loading between the treated and untreated areas as well as a 3-fold reduction in crown bulk density. As a result of these and other less significant changes in the fuel loading and stand structure, crown fire initiation will be more difficult and the rate of spread needed to sustain crowning will be considerably higher in the treated stands.

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[3] $R_o = 3.0/CBD$.

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