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Fire Severity in Intermittent Stream Drainages, Western Cascade Range, Oregon

Abstract

We quantified fire severity patterns within intermittent stream drainages in a recently burned area of the central western Cascades, Oregon. Aerial photographs were used to estimate post fire live canopy cover within streamside and upland zones on the southeast and southwest-facing slopes of 33 watersheds. Live canopy cover did not differ significantly between streamside and upland zones in the watersheds. Fire severity data obtained from aerial photographs were highly correlated with fire severity data obtained in the field in six of the watersheds, confirming that aerial photograph estimates of live canopy cover reflected actual conditions on the ground. While previous studies indicate that fire severity may be lower along perennial streams, the results of this study suggest that fire severity in intense events may be similar between intermittent stream channels and adjacent upland areas. At the landscape scale, differences in fire severity along streams of different sizes may influence the mosaic of post fire vegetation and contribute to overall structural diversity in forests of mountainous landscapes. Fire regime information obtained in this and related studies may be used to guide forest management activities that are modeled after natural disturbance processes and seek to balance commodity production and ecosystem protection.

Introduction

Contemporary ecologists agree that natural disturbance events occurring over various spatial and temporal scales are integral components of ecosystems (White 1979, Pickett and White 1985, Sprugel 1991, White et al. 1999). Information about the historic frequency, severity, and spatial extent of such disturbance events can be applied to landscape management (Agee 1993, Hunter 1993, Morgan et al. 1994, Swanson et al. 1994, Engstrom et al. 1999). Based on the assumption that species have adapted to a certain range of ecosystem conditions created by natural disturbance regimes, the concept of managing an ecosystem within its range of natural variability is being explored as a way to increase the potential for sustaining native species across a broad range of habitat types (Morgan et al. 1994, Swanson et al. 1994, Engstrom et al. 1999).

In the Pacific Northwest, federal forest management objectives include both ecosystem protection and timber production. The Northwest Forest Plan employs a system of static reserves, corridors, and habitat management prescriptions for matrix lands to protect an array of terrestrial species thought to depend upon late successional forest habitat, to protect aquatic ecosystems, and to provide a sustainable supply of timber (USDA and USDI 1994). Riparian reserves, which consist of zones of uncut forest along streams of all sizes, are an integral component of the Northwest Forest Plan. These reserves, which are intended to protect streamside areas, concentrate timber management in the upland areas between buffers and result in spatial segregation of old and young forest stands.

An alternative strategy for meeting the broad objectives of the Northwest Forest Plan involves using natural disturbance regime information to guide forest management activities (Cissel et al. 1999). In Douglas-fir (*Pseudotsuga menziesii*) dominated forests of the central western Cascades of Oregon, fire has historically been the dominant natural disturbance agent and a primary determinant of forest structure and composition (Agee 1993, Weisberg 1998, Weisberg *In Press*). Understanding the range of natural variability within

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this landscape, therefore, is contingent upon an understanding of fire regime characteristics.

Intermittent stream drainages are a predominant structural element of mountainous landscapes in the Pacific Northwest. Variation in fire severity at the scale of these small watersheds may contribute significantly to remnant tree densities and overall habitat heterogeneity (Romme 1982, Morrison and Swanson 1990, Turner et al. 1994, Kushla and Ripple 1997, Taylor and Skinner 1998, Keeton 2000). Patterns of fire severity in these small watersheds, however, are poorly understood. The central objective of this study was to quantify fire severity patterns within the watersheds of intermittent streams in a recently burned area in the central western Cascades.

Documented fire regime characteristics for the watersheds of perennial streams suggest that fire severity is lower in riparian zones than in adjacent uplands (Camp et al. 1997, Wimberly and Spies 2001, Skinner 2002). Riparian-associated landforms and vegetation conditions are thought to mitigate fire severity (Camp et al. 1997, Impara 1997, Kushla and Ripple 1997, Taylor and Skinner 1998, Keeton 2000, Wimberly and Spies 2001, Skinner 2002, Lee and Smyth 2003). Higher humidity, lower solar heating, the effects of cold air drainage, hydric soils, abundant herbaceous and deciduous vegetation, and higher moisture content in both living and dead woody fuels may all contribute to apparently lower fire intensity and severity in these areas (Romme 1977, Romme and Knight 1981, Agee et al. 2002). Because intermittent stream channels in the study landscape are generally steeper and less often associated with humid riparian zones and deciduous trees, however, we predicted that proximity to the stream channel does not mitigate fire severity within these small watersheds.

Study Area

We examined a portion of the Warner Creek Fire on the Willamette National Forest, 19 km east of Oakridge in the central western Cascade Range of Oregon. In this region, low summer rainfall, easterly winds, and lightning storms create favorable wildfire conditions in late summer and early fall. The Warner Creek Fire was ignited by an arsonist on 10 October 1991 after a prolonged period of hot, dry weather and desiccating winds. Driven by a southwest wind, the fire ran east along the south face of Bunchgrass Ridge, a northwest-southeast trending ridge that roughly bisects the fire area, and north into adjacent drainages. A total of 3,630 ha burned before rain showers slowed and extinguished the fire on 23 October. The fire was actively fought by the USDA Forest Service using aerial retardant drops and backfires (USDA Forest Service 1993). Because suppression efforts were less intensive on the south side of Bunchgrass Ridge, however, we think the effects of suppression activities on fire severity patterns in our study area were minimal.

The study area included the watersheds of 33 intermittent streams incised into the steep, south-southwest face of Bunchgrass Ridge (Figure 1). The average watershed size is 16.2 ha, and elevation ranges from 800-1750 m above sea level. Vegetation of the western hemlock (*Tsuga heterophylla*) zone is dominant in the study area (Franklin and Dyrness 1988). Although western hemlock and western redcedar (*Thuja plicata*) are common, shade-tolerant species in this zone, Douglas-fir maintains dominance in many stands as a result of its longevity relative to the frequency of fires that continually reset succession (Franklin and Hemstrom 1981).

Methods

Aerial photographs were used to quantify patterns of fire severity within the focal watersheds. Because a fire of a particular intensity (e.g., energy released per unit of fire line length) can have different effects on different plant species (Agee 1993). We quantified fire severity in terms of the effect of the fire on Douglas-fir, which is the dominant canopy species in the study area. Aerial photographs of the Warner Creek Fire area taken in 1990, one year before the fire, indicate that the watersheds had nearly complete forest cover before the burn. Fire severity was therefore defined as the percentage of canopy tree cover that survived the fire.

The 33 sample streams and their watershed boundaries were drawn on acetate that overlaid 1:12,000 color aerial photographs taken in 1998. This photo date indicates we sampled both immediate tree mortality and mortality of trees that occurred >7 yr after the fire. Each watershed was divided into four zones defined by landscape position (streamside or upland) and aspect (southeast or southwest-facing slope). The division

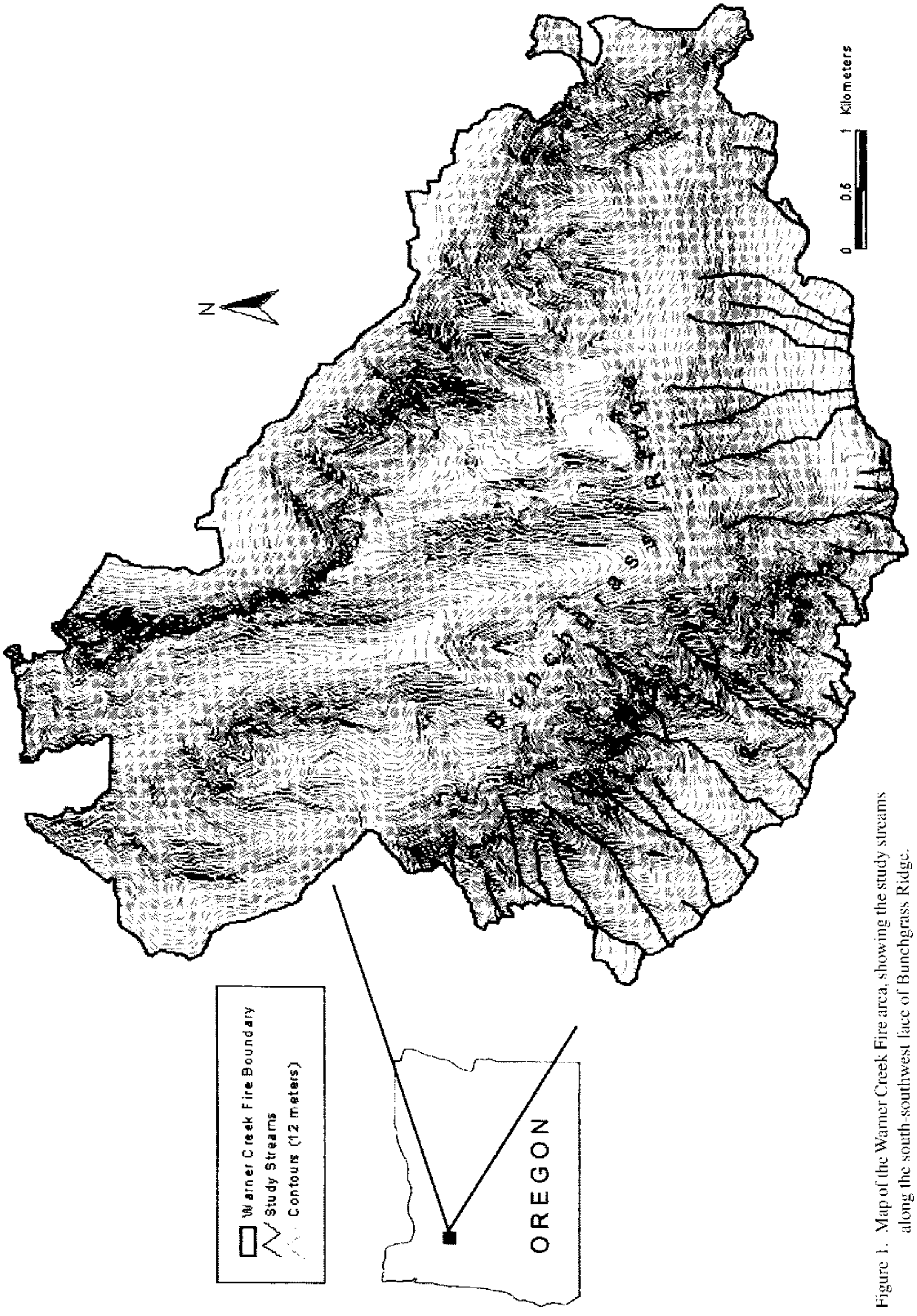

Figure 1. Map of the Warner Creek Fire area, showing the study streams along the south-southwest face of Bunchgrass Ridge.

between the streamside and upland zones was drawn halfway between the stream channel and the ridgeline so that the zones would be large enough to visually estimate live canopy cover on the 1:12,000 aerial photographs. This resulted in individual zones covering slope distances of ~50-100 m. Using a Stratex-prism mirror stereoscope with 4x binoculars, percent post-fire live canopy cover in each of the four watershed zones was visually estimated within 10 equal intervals ranging from 0-100% (e.g., 0-10%, 11-20%, etc.). The mid-point of each interval was used in statistical analyses (e.g., 0-10% = 5%, 11-20% = 15%, etc.). The direct and interactive effects of landscape position (streamside v. upslope) and aspect (southeast v. southwest-facing slope) on live canopy cover were tested using two-way analysis of variance (ANOVA) on the arcsine square-root transformed data (Zar 1999, SAS Institute 1995). The level of significance was set at $P = 0.05$.

To test the accuracy of the aerial photograph interpretation, fire severity data obtained from aerial photographs were compared with fire severity data obtained in the field. Six of the study watersheds (totaling ~103 ha, or 19% of the area sampled) were randomly selected for ground-truthing. Percent live canopy cover was calculated in the field using a Moosehorn densitometer (Garrison 1949). Each watershed was divided into a 10 x 10 m grid, and a canopy reading was taken at every grid intersection. At each point, the canopy was open if live canopy filled less than half of the squares visible in the Moosehorn grid, and closed if live canopy filled half or more of the squares. Field data were collapsed into the four watershed zones used in the aerial photograph analysis, and the percentage of closed canopy points within each zone was calculated to obtain an estimate of live canopy cover within each zone. We tested for a correlation between live canopy cover calculated from field data and live canopy cover estimated from aerial photographs for each watershed zone using Pearson product-moment correlation (Zar 1999, SAS Institute 1995). The level of significance was set at $P = 0.05$.

Results

Aerial photograph data revealed no significant difference in live canopy cover between streamside and upland zones on either the southeast or southwest-facing slopes of the sampled watersheds (Figure 2). We observed a significant correlation between live canopy cover calculated from field data and live canopy cover estimated from aerial photographs in each of the four watershed zones (Pearson product-moment correlation: $r = 0.95$-0.98, $N = 6$, $P < 0.005$).

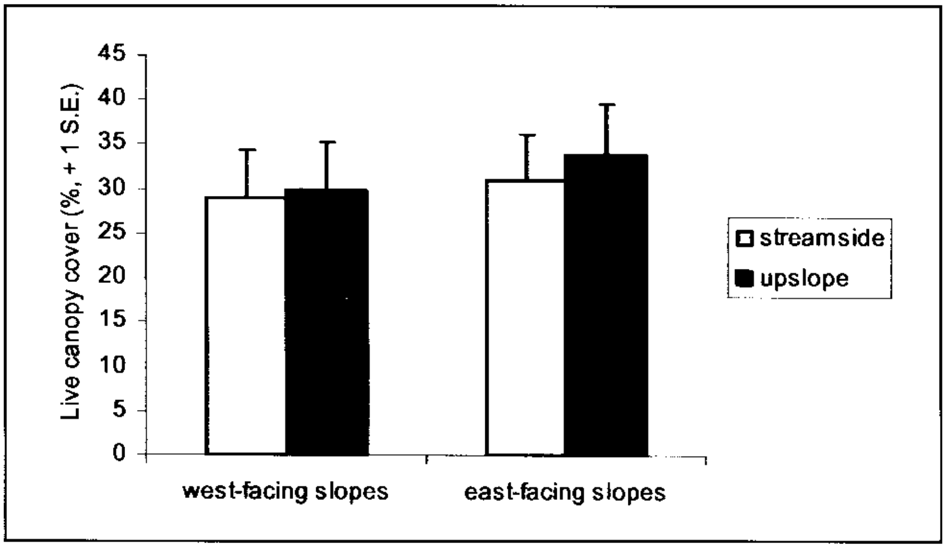

Figure 2. Mean live canopy cover (+ 1 standard error) estimated from aerial photographs in streamside and adjacent upland zones on southeast and southwest-facing slopes within the watersheds of 33 intermittent streams in the Warner Creek Fire study area, July 2000.

Discussion

Fire Severity within Watersheds

The watersheds included in this study are located in steep, south-facing, dissected terrain where vegetation composition and environmental conditions are similar along the stream and on the adjacent uplands. Solar radiation is high in the study area and, by late summer, soil and fuel moisture are extremely low. The potential for intermittent stream drainages such as these to mitigate fire severity may be reduced by a lack of microclimate and foliar moisture characteristics associated with riparian vegetation and landforms common along larger, lower-gradient streams. The extent to which fire severity is reduced along stream drainages in general, therefore, may depend on the size of the stream and the degree of differentiation between riparian and upland fuel conditions. At the landscape scale, differences in fire severity along streams of different sizes are likely to influence the mosaic of post fire vegetation and contribute to overall structural diversity in forests of mountainous landscapes.

The correlation between fire severity data estimated from aerial photographs and fire severity data obtained in the field was significant, confirming that aerial photograph estimates of live canopy cover reflected actual conditions on the ground. Although there may have been some delayed mortality between the fire year (1991) and the year the aerial photographs were taken (1998), we assumed no significant change in live canopy cover between 1998 and 2000, when field sampling was conducted.

Potential Management Implications

An alternative strategy for meeting the broad objectives of the Northwest Forest Plan involves using fire regime information to guide the location, frequency, and intensity of forest management activities (Cissel et al. 1999). This strategy is based on the assumption that species have adapted to a certain range of ecosystem conditions brought about by natural disturbance regimes, and that human activities that maintain ecosystems within this range may increase the potential for sustaining ecological processes and native biological diversity. The results of this study demonstrate that some fire-related disturbance occurs in the riparian zones of steep, intermittent streams on south-southwest facing slopes in the western Cascades. It may therefore be appropriate to consider permitting some human disturbance in some riparian zones of managed landscapes in this region, provided other critical riparian zone functions, such as shading and large woody debris inputs, are appropriately distributed in time and space at the landscape scale. Modeling silvicultural practices after natural disturbance processes may contribute to landscape diversity and increase the likelihood of balancing commodity production and biodiversity conservation.

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