Characterizing Fire Frequency and Fire-Climate Links in a Central Idaho Ponderosa Pine Forest

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ABSTRACT

Dendroecological methods were used to select and analyze fire scarred trees in central Idaho. Twenty four trees and stumps with multiple fire scars were cross-dated to identify the year and season of fire occurrence, referenced to a master chronology developed from increment cores from live trees in the area. Fires were frequent in the area, with Weibull mean fire return interval of 8 years. Fire scar locations indicated that fires occurred primarily in the late summer and fall, which was consistent with fire occurrence data records. Fire scars were absent from all trees after 1890, likely corresponding to rapid settlement of the area around Idaho City beginning in 1862, and active fire suppression some time in the early 1900's. Fire occurrence was strongly correlated with Palmer Drought Severity Index, and Pacific Decadal Oscillation.

INTRODUCTION

Frequency and intensity of fire plays an important ecological role in many plant communities in the Intermountain West. The relationship of fire to climate, pest epidemics and land use has shaped the structure and composition of many ponderosa pine (*Pinus ponderosa)* forest types. Reconstructions of historical fire regimes can reveal important interactions between ecological processes that influence present-day stand dynamics.

This study is part of an effort to quantify the frequency and seasonality of wildfire in a ponderosa pine community in Central Idaho. The work involves the collection, enumeration and crossdating of fire events recorded by tree rings in living and dead trees at two locations on different slope aspects. Numerous studies have used dendroecological methods to establish historical fire frequencies in the Southwest United States, the Colorado front range and elsewhere. However, questions remain about the degree to which models of fire frequency from these areas can be extended to the northern Rockies, where patterns of climate and vegetation differ. A broader study of fire history and interrelationships between fire and climate is currently being conducted across the region. This project will add information for the Bannock creek area of the Boise Experimental Forest in central Idaho.

The climate of the central Idaho is cool and moist, with precipitation falling mainly as rain in the spring and snow in winter months. Summer weather is dominated by high-pressure conditions with orographic precipitation confined primarily to late afternoons. The geology of the Idaho batholith is dominated by granite, and soils are primarily coarse, well drained granitic soils with poor water-holding capacity.

Logging and grazing during the past century has dominated land use in this region. Lightning from convective cells during the dry summer months provide sources of ignition. However, precipitation generally constrains fires to especially dry periods during the summer.

Study Objectives

The primary objective of this project was to characterize the spatial and temporal historical fire regimes in a central Idaho Ponderosa pine forest. A secondary objective was to compare fire frequency data with historical climate data.

METHODS

Field Methods

The study site was selected because of the presence of large living fire-scarred ponderosa pine trees and relict fire-scarred stumps. Standing live, standing dead, and fallen tree boles were examined for multiple fire scars. Trees with multiple scars were selected and sampled to ensure documentation of the most complete fire record. Few living fire-scarred trees were observed. Scarred trees are sampled to obtain representative sequences of fire events (Arno and Sneck 1973). Flat wedges of wood, that included fire scars of intact pith, if present, were extracted with chainsaws. Wedges were removed where scarring and scar condition was optimal. Samples were labeled in the order of removal, and wrapped in shrink-wrap to prevent damage during transport. Samples were taken from northwest and southeast facing slopes. Each sample was geo-referenced using a Global Positioning System for later analysis within a GIS.

Sample preparation

Twenty four sample wedges were removed for crossdating and analysis. Sample wedges were planed and sanded with increasingly fine grit sandpaper (#150, 220, 320). This treatment helped reveal the annual growth rings and fire scar positions. Wedges lacking structural integrity were first glued together with carpenter's glue then resurfaced after the glue solidified.

Lab methods

Skeleton plots were developed for each sample wedge. Constructing skeleton plots is a method for standardizing tree ring sequences for comparison across samples (Stokes and Smiley 1968). These plots record the sequence of wide and narrow rings, with greater focus on the narrowest rings. Individual skeleton plots are combined to generate a master plot, and are crossdated to provide absolute dates for all fire years. The crossdating is aided by comparison with Palmer Drought Severity Index (PDSI) data as well as a previous fire history study conducted by Steele and others (1986). Seasonality of fire events is estimated by position of cell damage within the corresponding annual ring.

The chronological distribution of fires at the sites is described with the Fire History Program (FHX2.0) (Grissino-Mayer 1995). The relationship of climate to fire years is analyzed using the EPOCH program (Grissino-Mayer 1995). Tree-ring indices from the Horse Ridge chronology (Holmes, Adams and Fritts 1986) and the Palmer Drought Severity Index retrieved from the International Tree Ring Data Bank (World Data Center, Boulder, CO) are used as climate indicators in this analysis.

RESULTS AND DISCUSSION

Historical fire frequency

Initial analysis of both the entire spatial and temporal ranges revealed a Weibull Median Fire Interval of 8.5 years with a mean fire interval of 8.7 years. Ten percent of the trees scarred were statistically analyzed and revealed no change. However, 50 percent of the trees scarred displayed a Weibull Median Fire Interval of 11.5 years and a mean interval of 5.4 years. (See Table 1).

A previous study in this area was conducted by Steele *et al.* (1986) which revealed a mean fire interval of 10.3 years based on 19 intervals, all taken from live trees that were not crossdated. Two of the trees used in the previous study were resampled, however, only one older scar was discovered. Because of greater sampling density, such as sampling remnant wood, the results were varied. As shown below, the data reveals a shorter fire interval from 22 intervals of living and dead trees that were crossdated.

Table 1. Fire frequency analysis for 1700 to 2005.

	Total and 10 percent of trees scarred	50 percent of trees scarred
Intervals	25	19
Mean Interval	8.7 ± 3.34	11.5 ± 5.3
Weibull Median Fire Interval	8.5	11.0
Weibull Upper Exceedence Interval	12.7	17.9
Weibull Lower Exceedence Interval	4.6	5.4
Range	1 to 19	7 to 30

Temporal Examination of Fire History

There are two periods of significance for this area: pre-settlement (prior to 1862) and post-settlement (1863 to the present). Therefore, the fire data was statistically analyzed to determine if there was a difference between these two periods. Because the first fire to occur in the data was 1671, the pre-fire interval was set to 1700 to 1862 and the second interval was set to 1863 to 2005. The results showed a significant difference between the two intervals, with a p-value of 0.0135. The first interval contained 19 fires, while the second contained only four. Additionally, each interval was analyzed to determine fire frequency for all, 10 percent, and 50 percent of trees scarred. See Table 2 below.

Table 2. Temporal Differences in Fire Frequency; pre and post settlement.

	Pre settlement, 1700-1862		Post Settlement, 1863-2005
	Total and 10 percent of trees scarred	50 percent of trees scarred	Total, 10 percent, and 50 percent of trees scarred
Interavals	18	13	3
Median Fire Interval	8.3 ± 3.7	11.0 ± 3.1	8.7 ± 1.5
Weibull Median Fire Interval	7.9	11.0	8.8
Weibull Upper Exceedence Interval	12.7	15.0	10.0
Weibull Lower Exceedence Interval	4.0	7.0	7.3
Range	1 to 19	8 to 19	7 to10

Spatial Analysis of Fire History

An important aspect to any fire regime analysis is scale. As such, three different scales were analyzed for this research: site, cluster, and individual tree. Site information for the spatial analysis was reviewed in Table 1 above.

The fire history of each cluster was analyzed to determine variability between clusters. Clusters of trees were determined by the aspect of sample location. The three cluster groups were located on the east, west, and southwest facing slopes of the watershed. Finally, the variability within the entire site was analyzed. There is no significant difference between fire frequency among the three clusters (See Table 3).

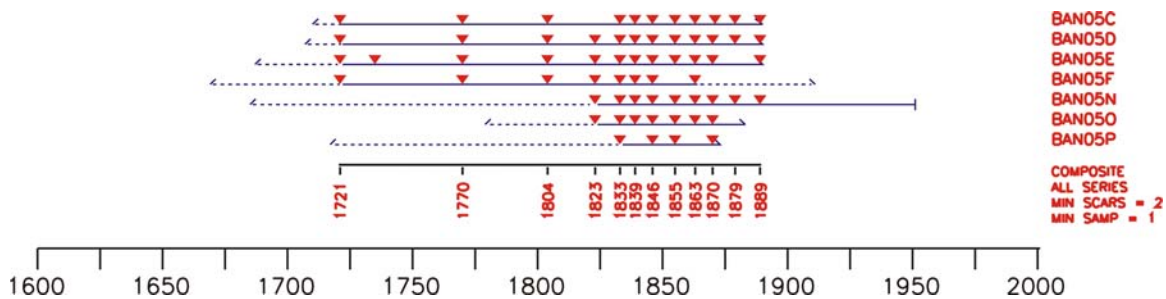
Table 3. Cluster analysis for all and 25 percent of trees scarred.

	Cluster 1 (Easterly)		Cluster 2 (Westerly)		Cluster 3 (Southwesterly)	
	All	25% scarred	All	25% scarred	All	25% scarred
Intervals	22	21	13	13	12	12
Median Fire Interval	9.0 ± 5.7	9.0 ± 5.5	11.0 ± 3.8	11.0 ± 3.8	10.0 ± 12.7	10.0 ± 12.7
Weibull Median Fire Interval	8.7	9.3	12.3	12.3	14.0	14.0
Weibull Upper Exceedence Level	3.5	4.0	7.8	7.8	4.6	4.6
Weibull Lower Exceedence Interval	15.9	16.2	16.8	16.8	29.5	29.5
Range	1 to 30	4 to 30	8 to 19	8 to 19	6 to 44	6 to 44

Vertical distribution of scars along a tree stem

Seven samples from one tree were taken to analyze the variability of fire scars as fires move up the cat face. Each fire burns with different intensity, and the vertical pattern of scarring on a tree stem varies with each fire. Successive fires can burn away previously formed scars. Hence, the section of scar face sampled can then be only a sample of the total scars on a tree. We dissected the scar face of a downed log (Tree 5). Sixteen sections were taken from the tree, starting from the base near the root/shoot boundary (sample “A”) up to the top of the scar face (sample "Q"). Because the tree had been down for some time, some sections were considerably decayed. We surfaced seven sections, crossdated them, and dated the fire scars.

None of the sections included all scars. Sections D and E (about 25 and 30 cm aboveground) had the most scars (91%), but varied by one scar. By about 35 cm aboveground, fewer and fewer scars were visible on the stem, until by section P (about 100 cm aboveground) only 25% of all scars manifested. Hence, any fire history – particularly those using multiply-scarred trees as a sample – is likely to be a conservative evaluation of fire frequency.



Seasonality

Examining the position of injury within the annual growth ring after a fire can be used to interpret the timing of fire events. The seasonality of fire occurrence can be useful in deriving correlations of past seasonal weather patterns, such as historically dry, warm periods. Of the 168 fire scars examined, 85% occurred in the latewood or dormant positions with in the annual ring. These two seasons usually coincide with late August (Law *et al.* 1999) through May. None of the fire scars occurred in the early or mid earlywood positions (June through early August). These findings agree with previous research by federal agencies which found that 68 percent of all Idaho forest fires from 1982-2005, greater than 200ha in size, (1216-1976 m elevation) occurred after August 1 (Westerling).

Superposed epoch analysis

Superposed epoch analysis (Swetnam 1993) relates fire occurrence to estimates of climate, based on the Palmer Drought Severity Index (PDSI) as well as other climate indices. Our fire data for all and 50 percent of the trees scarred was analyzed against PDSI, Pacific Decadal Oscillation (PDO), Atlantic Multidecadal Oscillation (AMO), El Niño 3 (NINO3) and Southern Oscillation Index (SOI).

As expected we found that climate does have an affect on fire occurrence in central Idaho. PDSI data taken from Cook *et al.* (1999 2004), grid point 70, revealed that fire years are significantly dry ($p<0.001$), while the two years prior were significantly wet ($p<0.05$ for one year prior and $P<0.001$ for two years prior). PDO values taken from D'Arrigo *et al.* (2001, 2005) are positive during fire years and one year prior to the fire ($p<0.001$). AMO (Gray *et al.* 2004), SOI (Stahle *et al.* 1998) and NINO3 (Cook 2000) were not statistically significant.

CONCLUSIONS

Several patterns were evident from the fire chronology. Pre-settlement patterns reveal frequent, low-intensity fires, while post-settlement patterns document fire suppression. Integration of related results provide a clearer understanding of ecosystem interactions; Pandora moth outbreaks may occur during periods of low fire frequency (Speer 1997, Speer *et al.* 1997) and tree initiation pulses apparently respond to different fire frequencies.

Fire years are dry, and often follow one or two wet years. Analysis of climatic relationships to fire frequencies reveals increased drought during and preceding fire, with more favorable climatic conditions prior to fire. Variability in ring width within years, tree ring complacency (low sensitivity to changes in climate), and a small sample size contributed to uncertainty in our fire dates. Small sample size for living trees (>1900 establishment) also limited our interpretation of the post-1900 fire chronology. Increasing sample size of living trees and trees overlapping with the pre-1850 chronologies with post-1850's would permit a more robust account of the fire history for the area.

Our results will be of great interest and utility to natural resource managers. The detailed fire history can be used in mapping Fire Regime Condition Class (www.frcc.gov) across forest landscapes. FRCC is currently used by land managers in federal land management agencies to assess ecological departure from historical fire regime and vegetation conditions, and to prioritize fuels and other management activities accordingly. FRCC has been mapped for the Mores Creek watershed, a 4th code HUC, that encompasses the Boise Basin Experimental Forest. Our sites were assessed as burning frequently (10 to 50 yr MFI) and with low severity (10-30% stand-replacing across the landscape) historically. Their assessment is that the currently, fires are far less frequent (at least 100 yr MFI) and that they currently burn more severely when they do occur (70% stand-replacing across the landscape). The results in a 50-90% departure, and a condition class of 3. Restoring the relative abundance of late seral open forests and the historical fire regimes on all or a portion of the landscape could change the FRCC to class 2 (yellow) or class 1 (green). Local forest managers are experimenting with thinning and burning to protect and enhance the large-diameter, spatially diverse forests.

Our results will also be incorporated into an ongoing research project funded by the USDA/USDI Joint Fire Science Program. In that project, Morgan *et al.* (2005) are identifying regional fire years from fire scars, such as we collected

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