Final Report

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Project Title: Pre-settlement fire patterns: records of natural fire or anthropogenic fire use?

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Principal Investigator: Dr. Jason S. Sibold, Associate Professor of Geography, Department of Anthropology, Colorado State University, Fort Collins, CO

Co-author: Lucy Burris, Graduate Student in the Graduate Degree Program in Ecology, Colorado State University, Fort Collins, CO

I. Abstract

Increased wildfire ignition rates from climate change influences on lightning strike frequencies, and increased populations living in wildlands, will interact with climate change to shape future patterns of fire. In regions where natural ignitions are not abundant, increased ignition rates could increase fire occurrence above expectations based on projected future climate alone. Moreover, our lack of understanding on how ignitions influence spatiotemporal patterns of fire limits our ability to separate the influences of anthropogenic fire use from climate influences in fire history records, which play a critical role in our understanding of how climate variability shapes fire regimes over multi-decadal to centennial scales. The goal of this research was to investigate the influence of ignitions (natural and anthropogenic) in shaping spatial patterns in fire occurrence in tree-ring and modern records of fire for western North America and southern South America.

II. Background and Purpose

The role of ignitions as a potential driver of patterns of wildfire is not well understood in comparison to the roles of fuels, weather and climate. For example, fire history investigations, which do not have information on past patterns of ignitions, generally stress the influences of fuels and climate. If the assumption that ignitions are sufficiently abundant as not limit fire occurrence, then fire history records primarily reflect the influences of fuels, climate and weather on fire. Whereas the assumption that ignitions are not limiting to fire is likely valid for some locations, if this assumption is not valid then records of fire history could strongly reflect Native American fire use. Consequently, in systems where ignitions are limiting, temporal variations in fire occurrence resulting from altered land use patterns could be misinterpreted as resulting from climate variability. In the context of using past fire-climate relationships

to help identify the implications of climate change for fire regimes, it is critical to identify the potential confounding influences of ignitions in shaping patterns of fire. The goals of our study were to: 1) develop and test a method to identify potential influences of anthropogenic ignitions on patterns wildfire documented in tree-ring based records of fire history, and 2) use modern records to investigate relationships between wildfires and lightning to test if ignitions are saturated.

III. Study description and location

Assessing anthropogenic signatures in tree-ring records of fire

In the first year of our project we identified two issues with our proposed research design and modified our methods to identify potential influences of Native American land use on fire history records. Specifically, our proposed design was focused on separating climate from potential Native American influences on fire occurrence by comparing regional records of fire history (tree-ring based reconstructions), climate, and Native American land-use evident in the archeological record. The problems with this research design include: 1) there is very limited temporal overlap between the fire history and archeological records, and 2) there are significant difference in the temporal resolution of the records. Tree-ring based fire history records tend to be robust from the 1600s to present. Evidence of earlier (older) fires is difficult to detect because of the death and decay of older trees and removal of evidence by more recent fires. In contrast, archeological records tend to be robust prior to this period and suffer from a rapid decrease in evidence in the 19th century, for unknown reasons. Thus, the period of overlap in the two records is approximately a century, which is not of sufficient length to identify potential anthropogenic influences on fire occurrence. Moreover, the temporal resolutions of fire history and archeological records make comparisons challenging. Specifically, tree-ring based fire history methods provide annual, and in some cases seasonal resolution, while archeological records provide multi-decadal resolution for events that would be expected to influence fire use, significantly limiting our ability to understand the fire consequences of changes.

To address the limitations presented by data limitations, we adopted a space-for-time approach by concentrating on a single widespread event across a large. Specifically, we investigated the spatiotemporal patterns of a well-documented decrease in fire occurrence in western North America and southern South America from the 1780s to the 1840s (hereafter referred to as the "fire hiatus") in the context of potential climate and anthropogenic drivers. Whereas the initiation of the fire hiatus is temporally coincident with a widespread, high-severity smallpox epidemic (Johnson and Larson 1991) and shifting Native American cultural practices (Stephens et al. 2003), most studies focus on broad-scale climate explanations for the decrease in fire (Grissino-Mayer and Swetnam 1997; Kitzberger et al. 2001; Heyerdahl et al. 2002; Sibold and Veblen 2006). To investigate climate and anthropogenic influences on the

fire hiatus, we used existing tree-ring based climate reconstructions (Cook et al. 2004) to develop a network of pyroclimate models (Biondi et al. 2011) for western North America and southern South America. We then compared the modeled frequency of climate conditions that were conducive to fire occurrence identified during the fire hiatus to equal length periods before and after the fire hiatus to test the hypothesis that climate during the fire hiatus was not as conducive to fire occurrence. If the pyroclimate models showed significantly reduced frequency of fire-prone conditions during the hiatus, the models would support the idea that climate was the primary driver of the fire hiatus. In contrast, if there was no difference between the fire hiatus and periods before and after, the models would suggest that non-climate explanations, including potentially changes in rates of anthropogenic ignitions, could have contributed to the period of decreased fire.

Analysis of modern lightning-wildfire relationships

We also investigated relationships between natural wildfires and lightning strikes on Federal lands in the conterminous western US for the period 1994-2007 (Fig. 1). We used fire (http://wildfire.cr.usgs.gov/firehistory/data.html) and lightning databases (National Lightning Detection Network) to investigate if wildfire initiation is associated with 1) increased frequency of lightning strikes, and 2) lightning strikes that discharge more energy (strikes with long continuing current, multiple strokes, or high first stroke peak current)(Latham and Schielter 1989; Latham and Williams 2001). Because of the high spatial variability of lightning density across the western U.S. (Huffines and Orville, 1999), we investigated wildfire-lightning relationships for individual ecoregions (EPA Level 3 Ecoregions; http://www.epa.gov/wed/pages/ecoregions/level_iii_iv.ht) to identify potential spatial variations in relationships. To identify the importance of lightning density and strike characteristics in the initiation of fire, we compared patterns of lightning that fell close to (<5 km) wildfire locations for five-day periods before, during and after fire initiation. If lightning strikes were significantly more frequent during the fire initiation period, this would imply that wildfire initiation is contingent on increased lightning strikes. In contrast, if strike frequencies were not higher during fire initiation periods this would indicate that fire initiation is not contingent on increased rates of lightning above baseline levels and that fuel conditions (structure and moisture) are the overriding influence on fire occurrence. Likewise, if strikes during the fire initiation period discharged more energy as compared to strikes before and after fire initiation, this would indicate that wildfire initiation requires abnormally high-energy strikes. If strikes coincident with fire initiation were not unique in their characteristics, then we can conclude that in general strikes have sufficient energy to initiate wildfires.

IV. Key findings and management implications

Assessment of tree-ring records of fire

The results of the pyroclimate models suggest that the fire hiatus (~1782-1842) was potentially a result of climate and anthropogenic changes. More specifically, in general the pyroclimate models only support the notion that climate during the fire hiatus was not conducive to fire occurrence for the last two decades of the period (~mid-1820-1842). In contrast, climate conditions in the first few decades of the fire hiatus do not appear to be unique as compared to periods before and after the fire hiatus. A potential explanation for the initiation of the widespread, abrupt decline in fire in the 1780s is a well-documented smallpox outbreak that significantly reduced Native American populations in both western North America (Fenn 2001) and southern South America (Casanueva 1991) in the early to middle 1780s. In the context of fire management, this suggests that while much of our fire management attention is focused on climate, weather and fuels, changes in ignition (anthropogenic or natural) could play a critical role in shaping future patterns of wildfire. Consequently, concerns surrounding development in the wildland urban interface (WUI) should not be limited to the potential hazard these communities face from wildfires but also include the potential source of ignitions that they represent.

Wildfire-lightning-fire relationships

Our analysis of wildfire-lightning relationships from 1994-2007 demonstrates that high-energy strikes are not required to initiate wildfires, however, in many areas fire initiation is associated with increase lightning frequencies. More specifically, overall in the western US lightning strike densities were approximately four times higher during fire initiation periods as compared to before and after fire initiation. However, this relationship varied significantly by ecoregion. Fire occurrence in ecoregions close to the west coast (e.g. Coast Range, Sierra Nevada, and Klamath Mountains) where lightning strikes are relatively infrequent, is strongly associated with increased frequencies of lightning. In contrast, ecoregions where lightning is abundant (e.g. the Southwest) fire initiation was not associated with increased frequency of lightning.

These results have implications for interpreting fire history records as well as the sensitivity of wildfire occurrence to altered patterns of ignitions. In the context of fire history records, the spatial patterns of wildfire-lightning relationships suggest that Native American fire use would have had varying potential to influence fire occurrence. Specifically, in west coast systems, where the ratio of strikes to fire occurrence is low, fire occurrence can be considered sensitive to anthropogenic ignitions. Consequently, it is possible that fire history records strongly reflect Native American land use patterns in addition to the influences of climate variability. In contrast, in the Southwest, where strikes are abundant and a small percentage of strikes initiate wildfires, fire occurrence is likely less sensitive to anthropogenic sources of ignition and fire history records would be expected to more strongly reflect the influence of climate influences on fire. This also implies that the potential for increased amounts of ignitions from increased frequencies of lightning projected under climate change (Price and Rind 1994), and increased human ignitions from populations increases, especially in wildland areas,

could increase the number of fires along the west coast above what would be expected based on climate projections alone.

V. Relationship to other findings

Our pyroclimate assessment of the ~1780-1840 fire hiatus identified in many tree-ring based reconstructions of fire history throughout western North America and southern South America suggests that climate was not unique at the start of this period. Whereas climate conditions undoubtedly played a role, the pyroclimate models suggest that climate was a stronger contribution factor in the later half of the period. The abrupt initiation is more temporally and spatially correlated with the 1780s smallpox epidemic (Johnson and Larson 1991), which suggests that reduced Native American sources of ignition played a role in the fire hiatus.

Our investigation into wildfire-lightning relationships using modern records expands upon work by Dilts et al. 2009, that demonstrated that lightning density is a significant driver of spatial patterns of wildfire at the landscape scale. Our results indicate that the energy discharge associated with individual lightning strikes is not an important influence on the initiation of wildfires are not in agreement with laboratory experiments and field observations that suggest that strikes with long continuing current, multiple strokes, or high first stroke peak current are important in initiating wildfires (Latham and Schielter 1989; Latham and Williams 2001).

VI. Future work needed

Because of the challenges created by differences in archeological and fire history records, investigations focused on Native American fire use influences on past fire appear to be limited. Whereas there might be some specific sites with good overlap of the two record types, differences in temporal resolution make detailed examinations unlikely.

In contrast, there are abundant opportunities to further develop our understanding of the role of lightning in shaping patterns of wildfire. Of specific interest would be the development of models that would incorporate fuel conditions (characteristics and moisture), and weather in addition to lightning to investigate potential thresholds in wildfire-lightning relationships.

VII. Deliverables

Deliverable	Status
Peer-review publication focused on wildfire-lightning relationships and implications for fire management.	This paper is currently undergoing an informal review and will be submitted for publication shortly.
Peer-review publication focused on identifying the potential role of Native American fire use in shaping patterns of wildfire in tree-ring based records of fire history. This paper also illustrates the application of pyroclimate models to help identify anthropogenic signatures in records of fire and stresses the management implications.	This manuscript is in the final stages of preparation and will be sent out for an informal review shortly.

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