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COMPARISON OF CHARCOAL AND TREE-RING RECORDS OF RECENT FIRES IN THE NORTHERN ROCKY MOUNTAINS, KALISPELL, MT, USA

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ABSTRACT

In the Northern Rocky Mountains, climate and vegetation histories have been developed using charcoal and pollen deposits in the sediment of lakes to determine the effect of changing climate on species distribution and disturbance regimes through time. However, few studies have been done on the spatial and temporal accuracy of these charcoal and pollen sediment strata analyses. In this study we created a dendrochronological fire history using fire-scarred trees in the watershed of Foy Lake in the Flathead Valley, MT, to determine the synchronicity between two fire proxies: the watershed's tree fire scar chronology and the dated charcoal in the sediment lake strata. I also compared Foy Lake's charcoal profile to six other tree-ring based fire histories that were developed within 120 kilometers of Foy Lake to evaluate the registry of regional fires in Foy Lake's charcoal sediment fire history. I found that of the 31 fire years shared among tree-ring fire history sites in the region, 12 registered as significant charcoal peaks in Foy Lake. Of those 12 fire years, eight of them took place in the Foy Lake watershed. Also, of the 19 filtered fire years with two or more scars found in the Foy Lake watershed, only seven corresponded with charcoal peaks in the lake with little or no lag time, but fire years with only one scar found matched most and left few charcoal peaks unaccounted for. This study will enable paleoecologists to better interpret charcoal sediment results, assured that local charcoal deposition is likely the primary contributor to a lake's sediment charcoal record. Large fire years that did not occur in the local watershed may not register in the lake strata, and climate inferences from charcoal particle presence in a single lake may be skewed.

INTRODUCTION

Understanding Fire Regimes

Fire plays an integral role in forest dynamics and hydrologic processes, often having devastating short term effects yet promoting long term biodiversity and ecosystem rejuvenation. These processes are an intrinsic part of natural processes and are crucial for the viability of fire adapted terrestrial and aquatic biota (Benda *et al*. 2003, Owens *et al*. 2006). However, it is important to understand natural disturbance interval and intensity to identify unusual (possibly human driven) variation in natural disturbance regimes. As land managers become more aware of the number, size, and complexity (cost) of fire suppression and potential climate change effects on fire, interest in the processes controlling disturbance regimes is emerging. Most research has attributed wildfire changes to cumulative land use effects or climate change. Post-settlement land use, including grazing, logging and effective fire suppression, began in the late 19th and early 20th centuries, altering the natural fire regime in many northern Rocky Mountain ecosystems. Post-logging vegetation growth in combination with fire suppression has led to forest structure changes and accumulation of fuels, causing more frequent and higher intensity fires in the last few decades (Westerling *et al*. 2006). Information on human land use influence is accessible because it occurred suddenly and relatively recently. Because climate change occurs over broad temporal and spatial scales, it is difficult to model its effects on disturbance regimes, but increased temperatures, decreased precipitation, and subsequent drought in the Western United States has corresponded to an increase in size and severity of large fires (Pierce and Meyer 2008, Whitlock *et al* 2008). In combination with human land use, fire exclusion, and changing climate, vegetation composition and structure in many areas has changed, leading to altered disturbance intensity and interval which can increase the risk of geomorphic events such as mass wasting, erosion, floods, and desertification. From an anthropocentric point of view, these regime shifts could further increase the vulnerability of human resources, property, and life. Appropriate land management is an important component in mitigating the consequences of changing climate or consequences of past land management activities, and knowing how to plan forest management depends on understanding processes that drive disturbance and forest development.

Fire History Reconstruction

To gain a better understanding of the potential fire regime changes due to climate variation, many researchers have been working to grasp the size, intensity, and frequency of past forest fires. In the Northern Rockies there are two primary methods for developing proxy evidence of fire: Dendrochronological studies, which are temporally and spatially precise, and paleoecological studies which analyze charcoal sediment deposited in lakes, fens, alluvial fans, etc. (Whitlock *et al*. 2008) Dendrochronological evidence consistently extends our knowledge of forest disturbance back about 500 years in the Northern Rocky Mountains (NOAA NCDC International Multiproxy Paleofire Database, accessed 12 Feb 2012), providing precise (annual) spatial and temporal evidence of fire in a particular area. On some fire scars it is even possible to determine the season in which the fire occurred (Falk *et al* 2011, Baison and Swetnam 1990). Another form of proxy evidence of fire has been reconstructions from deposited charcoal strata in lakes, fens, alluvium etc. Many researchers have developed fire histories based on dating the deposited charcoal throughout the Northern Rocky Mountains (Brunelle *et al*. 2005, Higuera *et al*. 2010, Pierce and Meyer 2008, Power *et al*. 2005, Whitlock et al. 2004). These fire histories provide evidence much further back in time on the multi-millennial scale to climatic eras disparate from present conditions.

Dating lake sediment depositions can answer numerous questions about previous forest composition and structure through charcoal and pollen deposition. Analyzing pollen and charcoal embedded in lake strata is often used to determine shifts in vegetation composition and fire regime. Combining charcoal fire histories with pollen information can lead to inferences regarding climatic variation's impact on landscape forest dynamics (Ali *et al*. 2009). Fire interval and intensity can be reconstructed back thousands of years depending on site location and charcoal availability. Most charcoal studies have primarily used C^{14} and Pb_{210} methods (in combination with known varve comparison) to determine the dates of lake charcoal (Power *et al*. 2005, Whitlock *et al*. 2004). Dating charcoal using these methods can be subjective, however, because stratigraphic data in sediments can be formed from a range of spatial scales over multiple years (Lynch *et al*. 2004). Whitlock *et al*. (2004) state that lake sediment fire reconstruction have decadal accuracy at best. Some studies sought to resolve imprecision in charcoal sediment by comparing the charcoal strata to dendrochronological evidence from fire-scarred trees in the surrounding areas. This has proven to be effective in numerous studies, (Brunelle *et al*. 2005, Clark 1990, Higuera *et al*. 2010, Whitlock *et al*. 2004) but has aroused questions about the spatial scope and temporal accuracy of lake charcoal based fire histories. The purpose of this study is to compare one lake's charcoal sediment fire history to seven fire histories developed from tree fire-scars in northwestern Montana to better understand the spatial resolution of charcoal sediment fire histories and the rate of charcoal deposition based on proximity to the fire event.

Methods

Study area

Foy Lake is located in northwestern Montana in the Flathead Valley approximately eight kilometers southwest of the city of Kalispell and about 15 kilometers northwest of Flathead Lake, the dominant geographic feature of the Flathead Valley (Figure 1). The Flathead Valley is located just south of the U.S.-Canadian border, in the northern U.S. Rocky Mountains, and extends approximately 130 kilometers in a north to south orientation. The Mission and Swan ranges border the valley to East and the Salish Mountains to the West. The valley has a diverse pattern of climate, disturbance, and land use that lends itself to various vegetation communities across environmental gradients.

Vegetation in the valley presently consists of agricultural species, mixed conifer, grass and shrublands, and riparian-adapted species. Shaded and moist, low-elevation areas (800 m – 1600 m) typically have overstory vegetation dominated by western red-cedar (*Thuja plicata* Don ex D. Don) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). Where water is readily available for the majority of the growing season, mesic species such as bog birch (*Betula glandulosa* L.) and thinleaf alder (*Alnus incana* (L.)Moench & (Nutt.)Breitung)) are the dominant overstory species. In lower elevation (800 m – 1500 m) areas with limited soil moisture retention, patchy stands of ponderosa pine (*Pinus ponderosa* Lawson and C. Lawson) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.)Franco) create a mosaic landscape. With elevation gain grand fir (*Abies grandis* Douglas ex D. Don) dominates followed by Engelmann spruce (Picea engelmanii) (1500 m – 2000 m) and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.)(1500 m – 2700 m) in the higher elevations of the valley. Lodgepole pine (*Pinus contorta*

Douglas ex Loudon) can also be found in abundance throughout the valley and surrounding mountains between 900-2100 meters in elevation (Power *et al* 2006).

The Flathead valley is typified by a mixed-severity fire regime where elevation, slope, vegetation and climate are the primary driving factors. In the Northern Rocky Mountains, subalpine and lodgepole pine forests experience stand-replacing fire intervals of 50 to 200 years. In moist lower elevation forests where cedar and hemlock are predominant, fires are often stand replacing and can be as infrequent as 75 to greater than 1000 years (USDA Forest Service 2012). This study focuses on the areas around Foy Lake primarily composed of steppe and patchy ponderosa pine and Douglas-fir mixed stand types where the fire interval typically ranges from 50 to 130 years for mixed severity fires, but it is not uncommon for low severity surface fires to occur at 15 to 20 year intervals (Barrett *et al*. 1991). The Foy Lake watershed likely experienced a more frequent fire return interval as a result of Native American burning, creating an open, park-like forest structure (Power *et al* 2006, Barrett and Arno 1982).

Most of the precipitation in western Montana and Idaho comes in the form of winter snow produced by systems that form in the Gulf of Alaska or the Northeastern Pacific Ocean and move east to southeast across the Rocky Mountains. Orographic lift causes vertical movement of air producing heightened condensation and precipitation on the west side of north-south oriented mountain ranges Mock (1996) and Finklin (1983). However, the majority of sediment runoff is associated with summertime convective rain events usually occurring between the months of June and September. According to data recorded at the Kalispell Glacier Airport (1971-2000), average annual precipitation was 39.9 cm. June is typically the wettest month with an average of 5.7 cm, and February is the driest month with 2.5 cm. Temperatures range from -4 °C in November to 27 °C in July (NOAA NCDC NESDIS 2004).

Foy Lake was chosen as study site because there was abundant fire-scarred relict wood available to develop a fire-scar based fire history, and because Foy Lake's lack of inlets or outlets provided a varved, biannual record of charcoal sediment deposits with more accurate fire history profile than those of C14 or Pb_{210} dated sediment cores (Whitlock and Larsen 2001). Foy Lake's first-order watershed is moderate in size but is irregular due to sporadic terrain features and other adjacent lakes and creeks in the vicinity. About half of the watershed to the North and East of the Lake is non-forested (primarily on South-facing slopes), and most of the area has been designated as a state park. Heavy logging took place to the South and West, restricting the total possible sampling area to only about three square kilometers. Due to extensive private development and lack of forest access, sampling was constrained even more and took place adjacent to the lake in patchy ponderosa pine and Douglas–fir stands. The sampling area was restricted to approximately one square kilometer on the hillsides and ridgelines about one kilometer to the south and southwest of the lake (Figure 1).

Field methods

Fire history sampling was designed to maximize the number of fire-scarred tree samples so that I would best represent the fire history of the areas adjacent to Foy Lake. Sampling took place over two field seasons. In July of 2010 I collected fire-scarred relict wood and in August of 2011 I took increment core samples from live trees to cross-date the relict wood collected the year previous. Sampling for fire scars in 2010 consisted of searching the available sampling area using a chainsaw to take cross sections of stumps, downed logs, and other relict woody material with the potential of displaying crossdatable fire scars. I took a targeted sweep approach in areas that would most likely exhibit legible fire scar evidence. This included ridgelines where fires more frequently burn and drier microsites where rot had not degraded the wood to the point of illegibility. In total, I collected 50 crossections or partial crossections. Information was recorded for each sample or group of samples to include estimated diameter at breast height [DBH], scar aspect, hill and slope aspect, sample species, landform, and slope features. In addition, a photo and a global positioning system [GPS] point were taken.

Tree ring chronology. In Aug of 2011 I sampled live trees to develop local tree ring chronologies to be used to crossdate fire-scarred samples. I used an increment borer to remove two cores from each live tree appearently old enough to overlap tree-rings with the dead, fire-scarred samples. This would allow us to develop tree-ring chronologies and accurately crossdate the fire scars that were collected (Stokes and Smiley 1968). The sampling strategy is a classic one, employed to maximize common (climate driven), and species specific tree-ring variability (Fritts 1974). To capture the variability in tree-ring widths, I sought live trees living on water-limited microsites (Fritts 1976). These areas included well-drained soils, ridgelines, and rocky outcrops. Injured or diseased trees, areas of high tree densities, and water drainages were avoided because these factors could change the ring pattern from that of a normal precipitation pattern (Stokes and Smiley 1968, Fritts 1976). In total, I sampled 50 trees to build a tree ring chronology. DBH was recorded and a GPS point was taken for each tree or group of trees. About half of the trees sampled were ponderosa pine and half were Douglas-fir.

Laboratory and Data Analysis Methods

The increment cores and crossections were brought to the Forestry Sciences Laboratory in Missoula, Montana where they were glued for stabilization and sanded to 320 grit so tree rings and fire scars could be seen clearly through a dissecting microscope. Using an Epson 10000 XL large format scanner and the dendrochronological software C-dendro and Coo-Recorder 7.3®

(Cybis Elektronik & Data AB Saltsjöbaden, Sweden), I measured the distances between rings in the chronology cores. Given that the outside ring on each core was the year of collection, I visually skeleton plotted the rings (Stokes and Smiley 1968) and used the statistical software program COFECHA (Holmes 1983) to establish an expectation of each ring's likely width and what ring patterns to expect throughout the life of the tree (Grissino-Mayer 2001a, Stokes and Smiley 1968). Using standard dendrochronological techniques, I was able find several consistent fire scars that were present on two or more trees. Using the program FHX2®, the fire dates were graphically represented (Grissino-Mayer 2001b) (Figure 4).

Composite charcoal data used in Power (2006) was obtained from the author and illustrated using a basic line graph (Figure 2). Although the charcoal fire history extends back thousands of years, only the time frame when fires were found were plotted. Charcoal peaks were determined as a relative percentage of the previous charcoal lull ($\Delta Charcoal/Peak\ Charcoal$). By comparing fire evidence on the landscape to the charcoal volume, I found that peak charcoal was most represented by fire scars when it exceeds the previous lull's volume by at least 40%. This excluded some peaks that may have been influenced by background charcoal. For comparison, six other tree ring derived fire histories were examined from northwestern Montana (National Oceanic and Atmospheric Administration National Climatic Data Center [NOAA NCDC] International Multiproxy Paleofire Database, accessed 12 Feb 2012)(Figure 3), and filtered fire years (scars found on two or more samples) were then overlaid with charcoal quantities, represented as vertical red lines (Figures 8-13). Two graphs were constructed to compare the Foy Lake charcoal record to filtered (two or more scars found) and unfiltered (only one scar found) fire-scar records from the Foy Lake watershed (Figures 4 and 5). A graph was also developed to represent fire years that were shared by at least two of the seven sites (Table 1 and Figure 6).

RESULTS

Fifty samples were collected from the sample site, 25 of which were used in the fire history creation. 50 fire scars were able to be crossdated, and 19 scars indicated fires at more than one location in a given year (Figure 4). Six fire scars were found in more than two locations within the sample area. When determining charcoal volume peaks as a relative percentage of the previous lull in charcoal volume, I found there were 25 charcoal peaks that exceeded the previous lull by at least 40%. When comparing the unfiltered fire scars (only one scar found) in the Foy Lake watershed to the charcoal record only one significant charcoal peak did not have a fire scar within three years of peak charcoal (Figure 6). Of the 19 confirmed fire years (two or more scars found) in the Foy Lake watershed, only seven corresponded to the 25 charcoal peaks in the Lake with little or no lag time, indicating a direct correspondence of only 28% between the two records. Several charcoal peaks were not associated with confirmed fires in the watershed or the lag time to deposition was great enough that the charcoal peak didn’t occur until several years later (Figure 5).

When comparing the regional fire histories to the charcoal quantities, I found that there were 31 fire years that took place at two or more fire history sites, and twelve registered as significant charcoal peaks in Foy Lake (Figure 7). Of the twelve shared fire years that registered as charcoal peaks, eight of them took place in the sample area (Table 1). However, the charcoal peaks after 1600 without confirmed fires in the Foy Lake watershed were represented by fire occurrence in at least one site within 120km of Foy Lake (Figures 8-13). Many of the regional tree-fire histories corresponded well to the charcoal peaks in Foy Lake within three or four years, indicating regional fire drivers. However, the tendency for aerial deposition to occur in the same year of fire occurrence may indicate lack of precision in varved sediment fire histories (Figures 8-13).

DISCUSSION

Charcoal sediment-derived fire histories are imprecise, and based on a set of assumptions made about the accuracy of fire occurrences and the spatial proximity which they represent. Using dendrochronological comparisons, this study was designed to calibrate the ability of a charcoal sediment-based fire history to represent fire events in the northern Rocky Mountains. There are, however, many factors to be taken into account when interpreting the results.

The comparison of charcoal deposits to tree fire-scar evidence yields two types of discrepancies: either 1) a fire is indicated on the landscape with no associated charcoal peak in the lake or 2) a charcoal peak is present in the lake sediment without fire scars indicating fire in the watershed.

One would expect known fire occurrences in the watershed of the lake to correspond with little error (assuming no aerial charcoal deposition) to the charcoal record in the lake strata, but lack of charcoal deposition or a lag time between fire occurrence and charcoal deposition can result from different factors. Sampling around Foy Lake took place in low elevation ponderosa pine and Douglas-fir stands, a forest type that typically experienced low to mixed-severity fires. Though the fire temperature may have been locally high enough to scar a recording tree, it may not have produced much mobile charcoal, or may have left enough understory vegetation to restrict charcoal mobility and hence, deposition. Post-fire charcoal deposition may also have been limited by weather events in the area. McIver (2006), in an extensive study on post-disturbance erosion, found the primary limiting factor in sediment transport to be the occurrence of extreme weather events in the first few years after the fire. Given a weather event, the quantity of sediment transported is a function of disturbance-related vegetation loss, soil hydrophobicity, and lack of water interception. Though the Flathead Valley often receives heavy precipitation in the summer months through extreme convective weather events, drought years typically limit their occurrence, or vegetation may be able to reestablish after a fire, resulting in low sediment transport when charcoal is intercepted by successional vegetation. Knowing when and where particular weather events occurred could explain a lag time or lack of sediment deposition, but weather and climate information in the Flathead valley only goes back to 1890, when this fire-scar record essentially stops.

The second type of discrepancy is due to the conservative nature of fire-scar data and aerially deposited charcoal from regional fires. The fire-scar based fire history at this site does not represent a complete record of historical fires for two main reasons: 1) I was unable to sample much of the watershed because it is in private ownership, and undoubtedly I missed many scarred trees. 2) Fire-scar derived fire history is limited to the presence of datable wood and often later fires will erase (burn) the records of previous fires. However, this is an unlikely source of data limitation in the Foy Lake sampling area due to the forest structure’s tendency toward frequent, low intensity fires (USDA Forest Service 2012).

Aerially deposited charcoal from regional fires can lead to false charcoal peaks. High intensity crown fires produce smaller charcoal particles, often formed from the upper canopy of a tree, and can be transported aerially and deposited in a lake in a nearby watershed (Whitlock and Larsen 2001). This can cause the overestimation of fire frequency in the core-sampled watershed (Hallet and Walker 2000). In a study in British Columbia by Enache and Cumming (2005), significant charcoal deposits were found as far away as 20 kilometers from the fire site. Power *et al.* (2005) made the assumption that because there was a charcoal spike in 1910, and no fire was recorded that year within 10 km of the site, that this was at least the extent of aerial deposition. Though charcoal is known to be aerially transported and deposited, it is hard to know the distance from the lake that a specific fire will deposit charcoal. Though charcoal peaks from Foy Lake correspond to known fire events up to 120km away, it is unknown if fires occurred in closer proximity to the lake in that same year. Though climatic conditions are strong drivers in large fire years (Heyerdahl *et al* 2008), eight of the twelve regionally shared fire years that corresponded to charcoal peaks in Foy lake were also confirmed fires within the watershed (Table 1). This reinforces that climate, though a driving force in forest fire occurrence, may be not be represented by an individual charcoal record as large climate-induced fire years may not register in the charcoal sediment if they did not occur in the local watershed.

Charcoal particle formation and how it relates to particle transportation, buoyancy, morphology, taphonomy, and rates of accumulation have been studied in detail (Swain 1978, Patterson *et al* 1987, Gardner and Whitlock 2001). Analysis of the charcoal sediment deposits can provide information regarding potential source locations and the type of fire (crown, surface, etc.), because they relate directly to temperature and the type of substrate from which it was formed (Lynch *et al*. 2004). The volume of charcoal was the primary emphasis in Foy Lake charcoal analysis, and physical characteristics of the charcoal were not analyzed. As larger particles typically travel a shorter distance than smaller ones, information regarding the source of the charcoal peak could be deduced from this information, and spatial representation of the charcoal sediment fire history could be more clearly defined if physical characteristics are analyzed.

Recommendations for Paleoecology

Though varved sediment records are thought to be the most accurate form of lake strata dating, vegetation, fire history, and climate reconstruction using lake-core samples should be used to indicate climate and forest structure changes at a broad temporal scale regardless of the method of charcoal dating. Foy Lake indicated few charcoal peaks that were strictly associated with airborne deposition, and those regional fires that appear to have been sole contributors through airborne charcoal may actually be a result of sampling limitations in the Foy Lake watershed. When developing fire histories using charcoal sediment, it is important to use multiple fire-scar based fire history sites for comparison to understand regional fire events associated with climatic processes. Comparing charcoal particle size and density to local fire scar histories should help indicate alternate source locations when fire-scar evidence is not present in peak charcoal years.

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FIGURE CAPTIONS AND TABLES

Figures

Figure 1: GPS sampling locations in Foy Lake watershed, Kalispell, Montana.

Figure 2: Charcoal volumes through time Foy Lake Kalispell, MT. Each point indicates a dated sample in the lake sediment core sample.

Figure 3: Tree-scar fire history sites, Northwest Montana. Previously created fire history sites and their distance from Foy Lake.

Figure 4: FHX2 output for Foy Lake watershed fire-scars by sample.

Figure 5: Fire Scar- Charcoal Comparison - Foy Lake (2 or more fire scars confirm the presence of fire in a particular year).

Figure 6: Fire Scar- Charcoal Comparison - Foy Lake (unfiltered): Red vertical lines indicate all of the scars found in the Foy Lake watershed even if only one scar was found and it wasn't able to be confirmed.

Figured 7: Fire Scar- Charcoal Comparison – Shared Fires (filtered). Red vertical lines indicate when fire took place at more than one of the tree-scar fire history site. Blue vertical lines indicate when a regional fire was shared with a scar from the Foy Lake sample area.

Figure 8: Fire Scar- Charcoal Comparison – Corona Road (2 or more fire scars confirm the presence of fire in a particular year).

Figure 9: Fire Scar- Charcoal Comparison – Crane Lookout (2 or more fire scars confirm the presence of fire in a particular year).

Figure 10: Fire Scar- Charcoal Comparison – Griffin Creek (2 or more fire scars confirm the presence of fire in a particular year).

Figure 11: Fire Scar- Charcoal Comparison – McCormick Creek (2 or more fire scars confirm the presence of fire in a particular year).

Figure 12: Fire Scar- Charcoal Comparison – McMillan Mountain (2 or more fire scars confirm the presence of fire in a particular year).

Figure 13: Fire Scar- Charcoal Comparison – Sheldon Flats (2 or more fire scars confirm the presence of fire in a particular year).

Tables

Table 1: Fire years shared at more than one site in the Flathead Valley Region, MT- X indicating fire presence at a particular location.

FIGURES

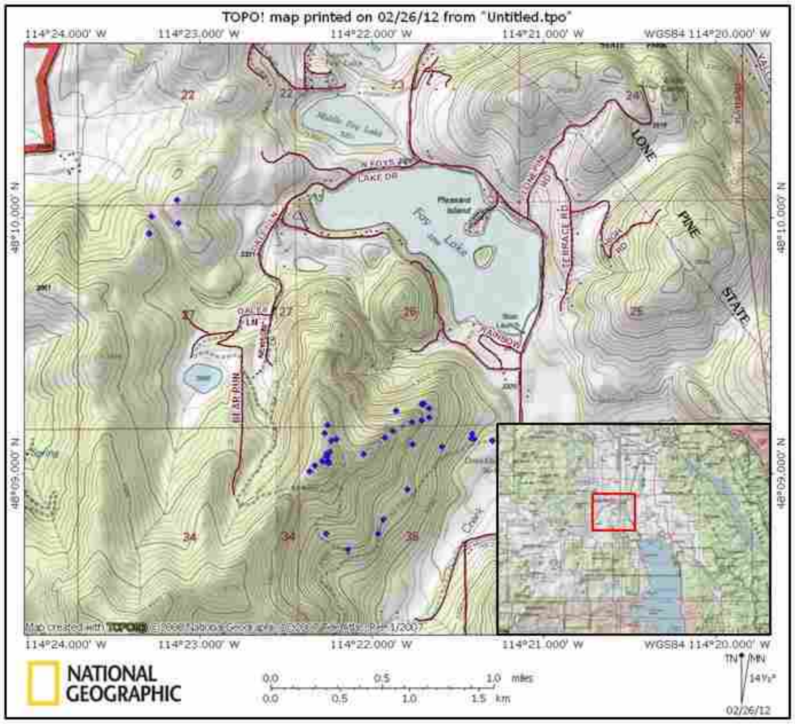

Figure 1: Sampling Points, Foy Lake watershed, Kalispell, Montana.

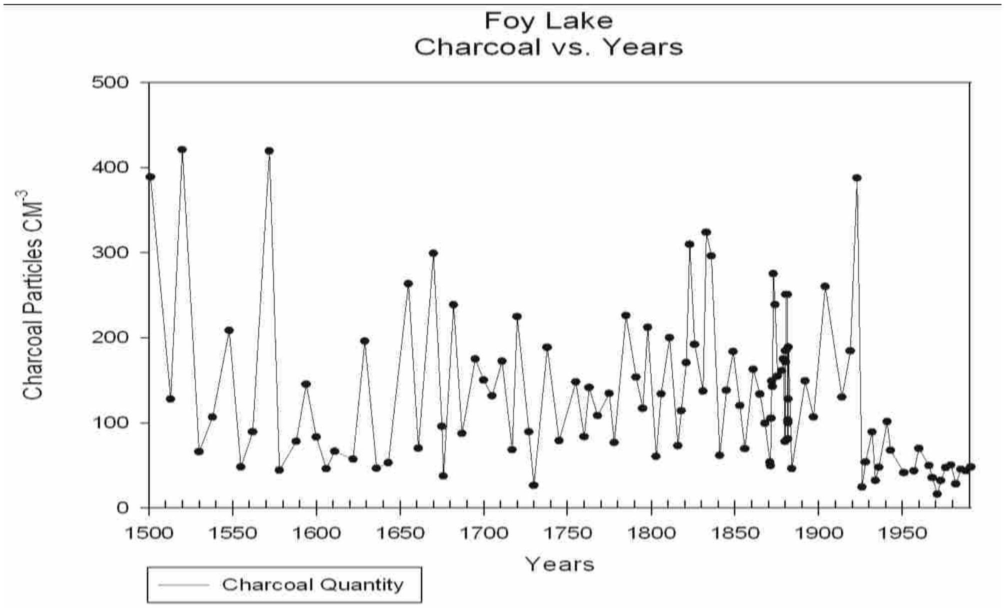

Figure 2: Charcoal volume by year1500-2000.

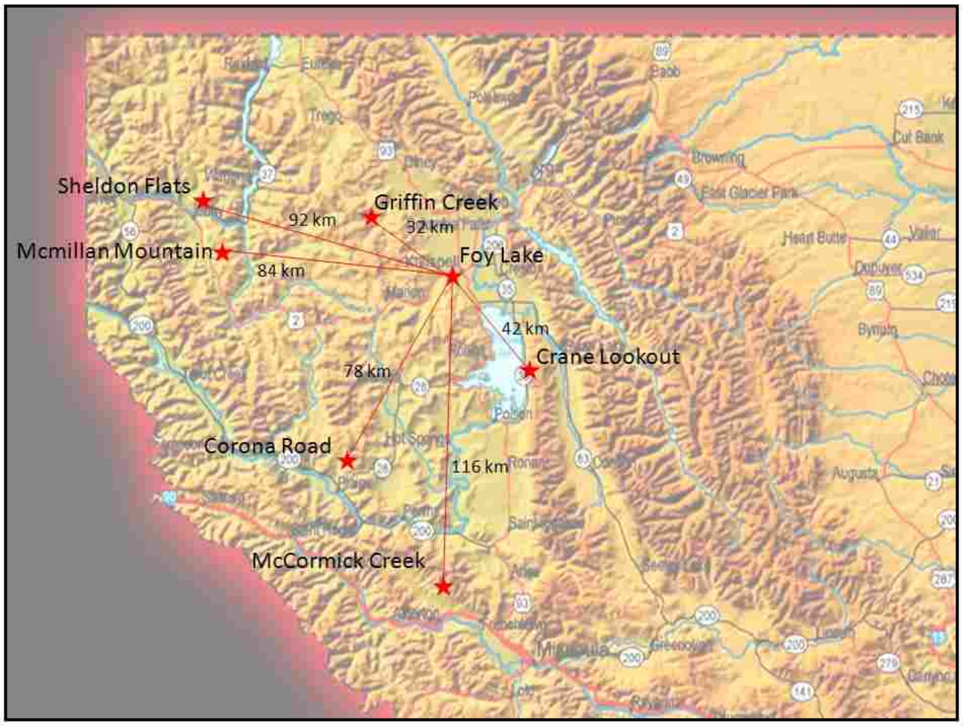

Figure 3: Tree- scar fire history sites and their distances from Foy Lake, Northwest Montana.

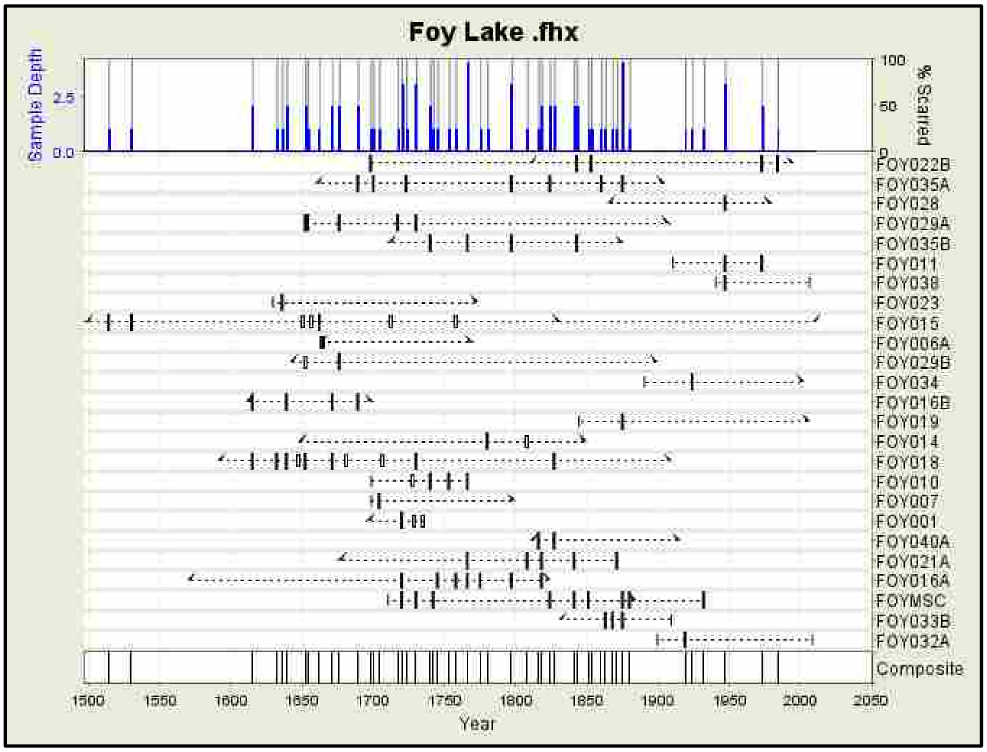

Figure 4: FHX2 output for Foy Lake fire-scars by sample.

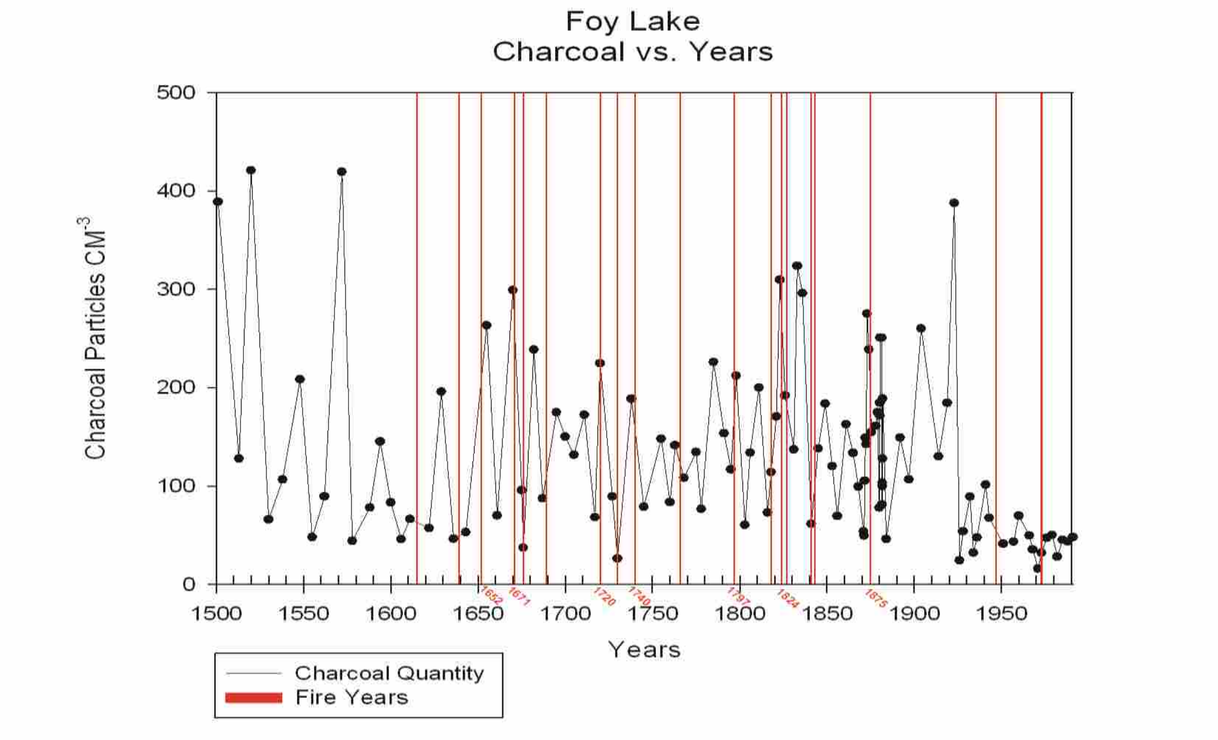

Figure 5: Fire Scar- Charcoal Comparison - Foy Lake (filtered).

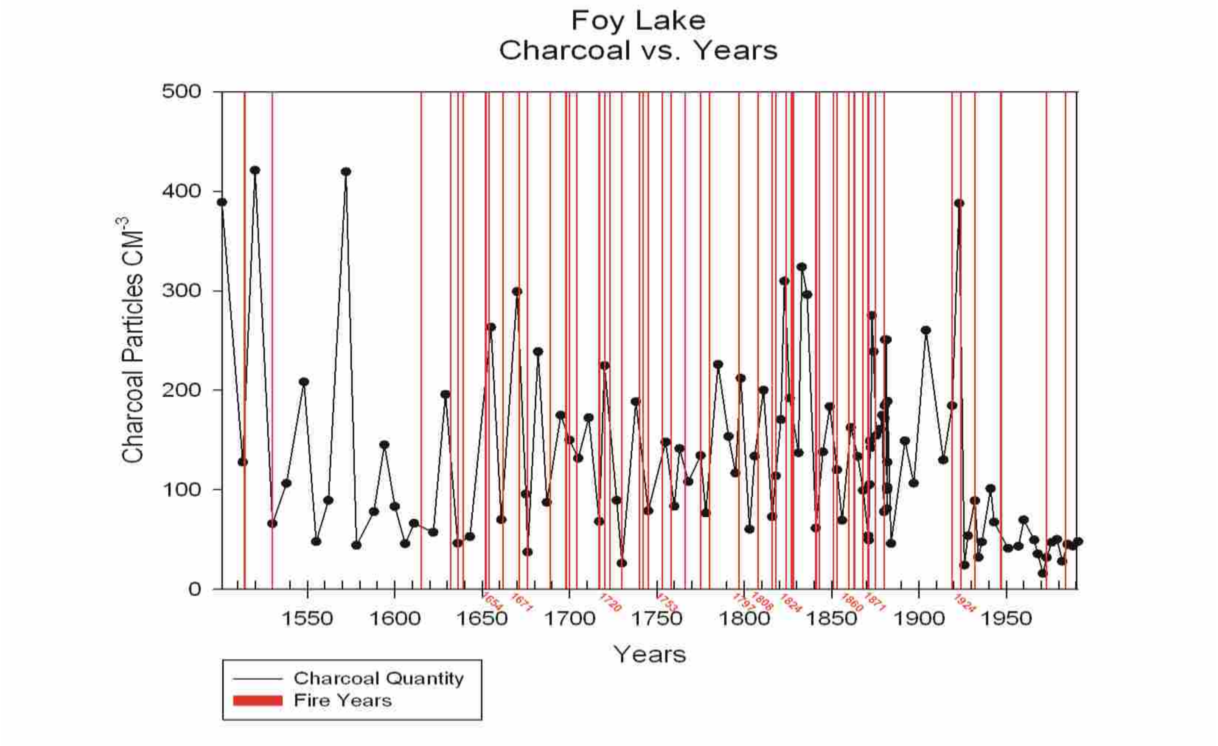

Figure 6: Fire Scar- Charcoal Comparison - Foy Lake (unfiltered).

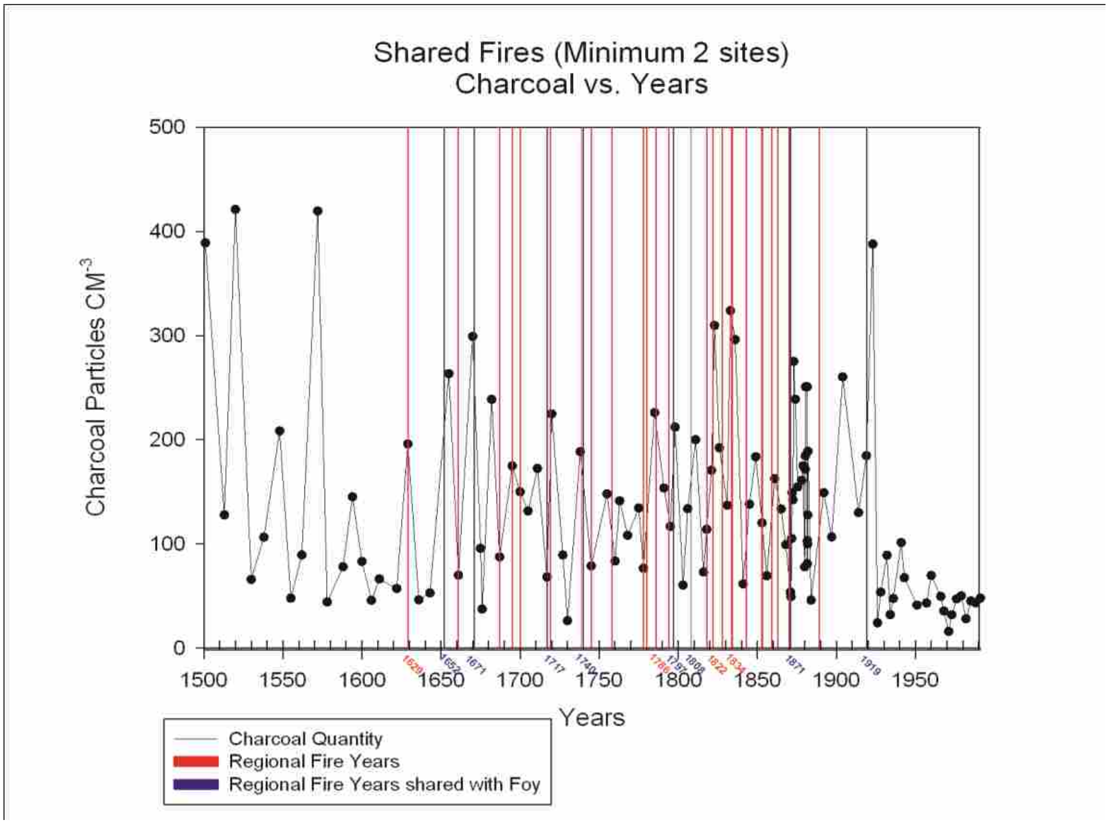

Figure 7: Fire Scar- Charcoal Comparison – Shared Fires (filtered).

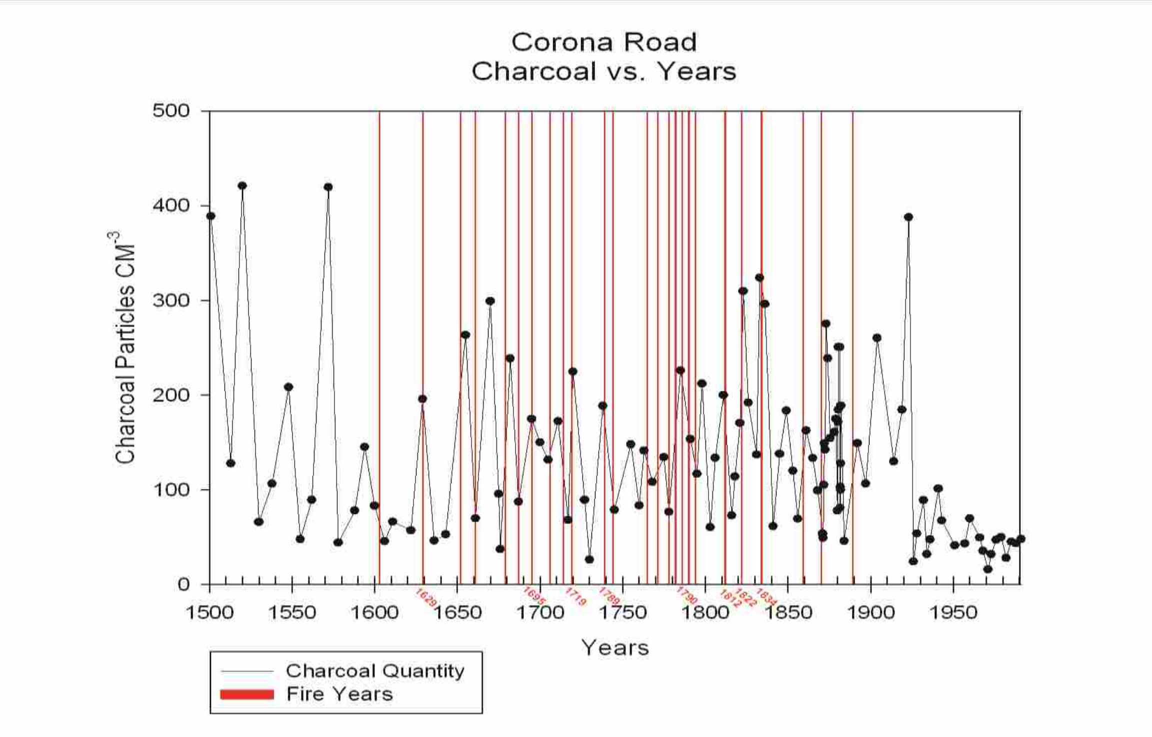

Figure 8: Fire Scar- Charcoal Comparison – Corona Road (filtered).

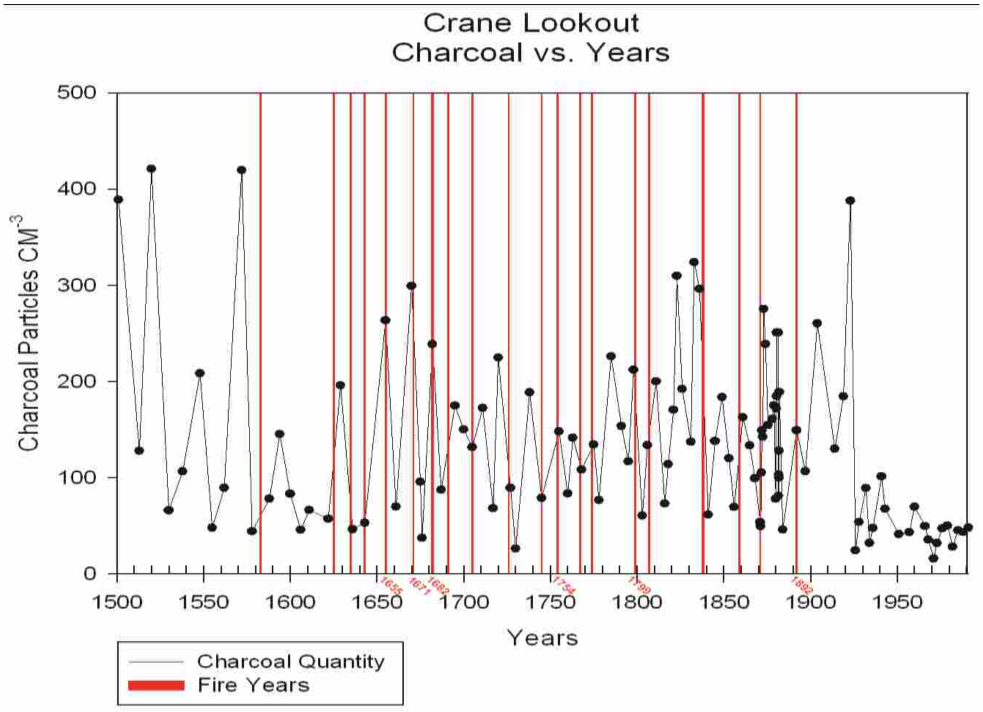

Figure 9: Fire Scar- Charcoal Comparison – Crane Lookout (filtered).

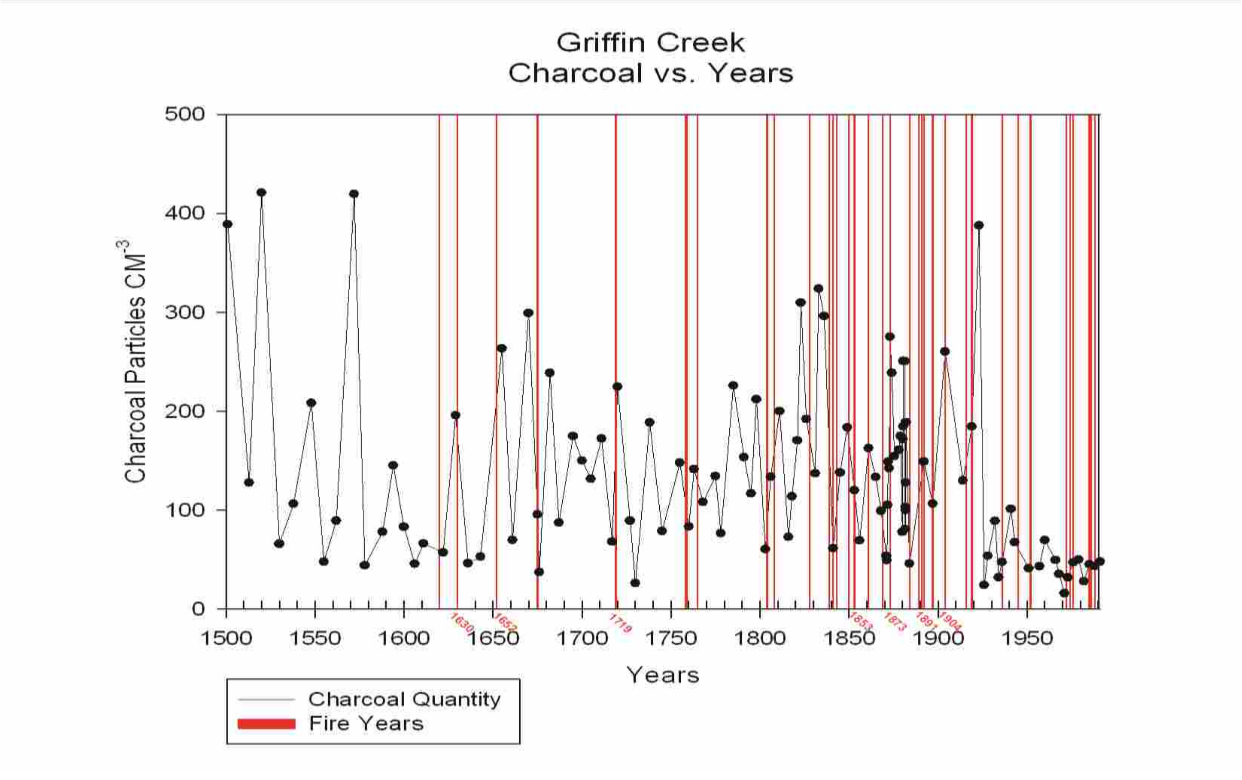

Figure 10: Fire Scar- Charcoal Comparison – Griffin Creek (filtered).

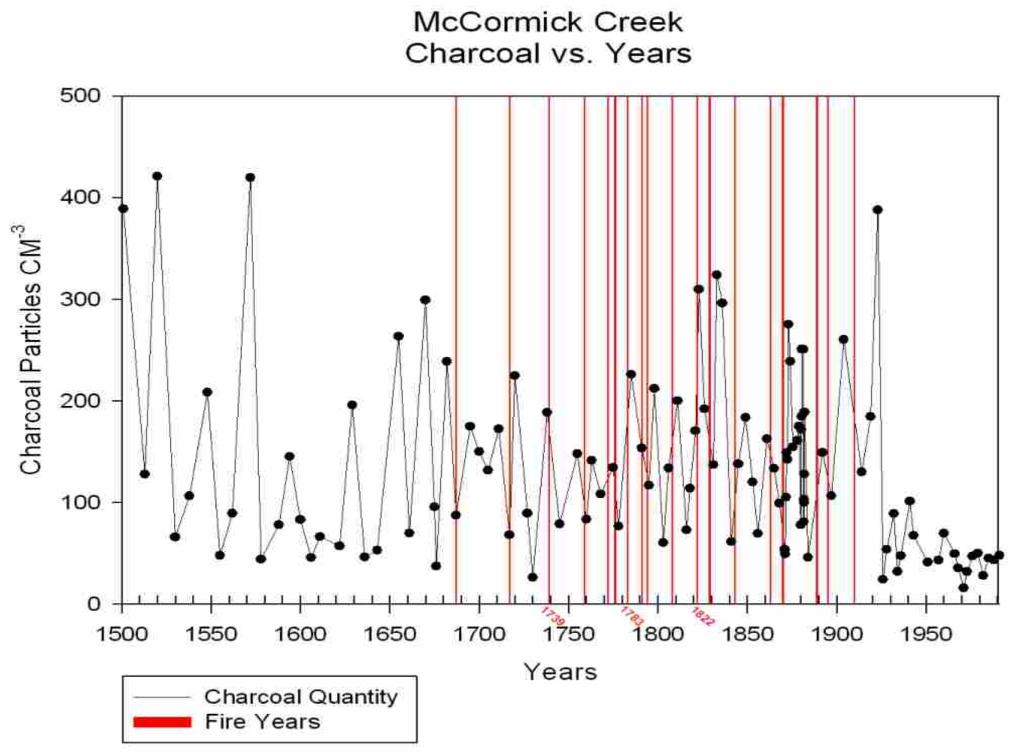

Figure 11: Fire Scar- Charcoal Comparison – McCormick Creek (filtered).

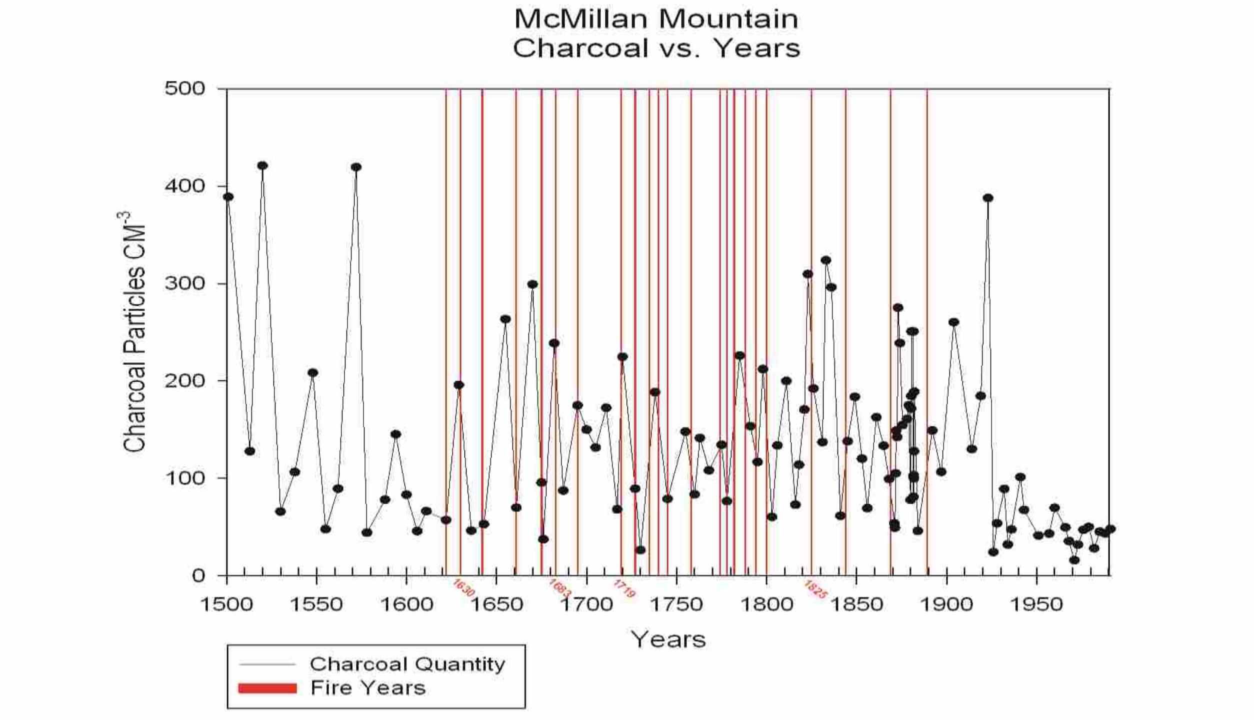

Figure 12: Fire Scar- Charcoal Comparison – McMillan Mountain (filtered).

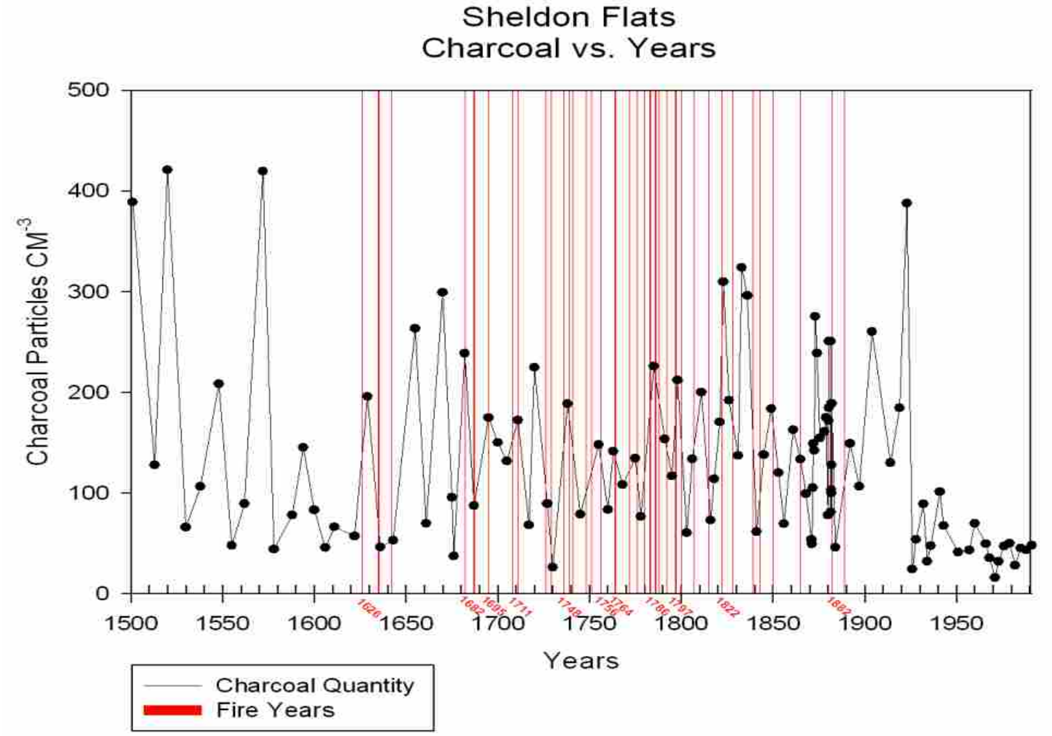

Figure 13: Fire Scar- Charcoal Comparison – Sheldon Flats (filtered).

TABLES

Shared Fire Years	Foy Lake (Unfiltered)	Griffin Creek	Corona Road	McMillan Mountain	Crane Lookout	McCormick Mountain	Sheldon Flats
1629		X	X				
1652	X	X	X				
1661			X	X			X
1671	X				X		
1687			X			X	X
1695			X			X	X
1700	X						X
1717	X					X	X
1719		X	X	X			X
1739			X			X	X
1740	X			X			
1745	X				X		
1758	X	X		X			
1778	X	X	X	X			
1780	X						X
1786			X				X
1794			X	X		X	
1797	X						X
1808	X	X				X	
1818	X	X					
1822			X			X	X
1828	X	X					
1834		X	X				
1843	X	X				X	X
1853	X	X					
1859		X	X		X		
1863	X					X	
1870			X	X			
1871	X				X		
1889		X	X	X		X	X
1919	X	X					

Table 1: Fire years shared at more than one site in the Flathead Valley, MT.