Palaeobotanist 50 (2001) : 133-140
0031-0174/2001/133-140 $2.00

Fire History and Fire Climatology along a 5° Gradient in Latitude in Colorado and Wyoming, USA

PETER M. BROWN[1] AND WAYNE D. SHEPPERD[2]

[1]*Rocky Mountain Tree Ring Research, Inc., 2901 Moore Lane, Fort Collins, CO 80526 USA.*
Email: pmb@rmtrr.org
[2]*USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO 80526 USA.*

(Received 15 January 2000; revised version accepted 10 December 2001)

ABSTRACT

Brown PM & Shepperd WD 2001. Fire History and Fire Climatology along a 5° Gradient in Latitude in Colorado and Wyoming, USA. Palaeobotanist 50(1) : 133-140.

We reconstructed fire chronologies covering the past four to six centuries from fire scars recorded in tree-ring series from 18 sites in the central Rocky Mountains of Colorado and Wyoming. Sites are located in forests containing predominately *Pinus ponderosa*. Median fire-free intervals in fire chronologies are related to latitude, with shorter intervals in southern stands than those in the north. However, strength of this relationship varied through time, with a stronger latitudinal gradient in fire frequency from 1600 to 1800 than from 1700 to 1900. Variability in fire frequency with time may be related to strength of regional climate gradients. Seasonality of fire scars also varied across the latitudinal gradient, from predominately early season fires in the south to late season fires in the north. Superposed epoch analysis of fire years with annual variability in Palmer drought severity indices shows that fire years throughout the gradient were dry, but those in the south were preceded by wet years. This result suggests that fuel amounts may have been limiting in southern forests where fire intervals were shorter, and that longer intervals in the north permitted fuel buildup between fires. All chronologies show a general cessation of fire scars beginning in the latter nineteenth century, coincident with widespread Euro-American settlement of the western US.

Key-words—Chronology, Fire, Forest, USA.

संयुक्त राज्य अमरीका के कोलेराडो एवं वायोमिंग प्रान्त में 5° अक्षांश प्रवणता पर अग्नि का जलवायुविक इतिहास तथा जलवायुविज्ञान

पीटर एम. ब्राउन एवं वेन डी. शेपर्ड

सारांश

हमने कोलेराडो एवं वायोमिंग के मध्य प्रस्तरी पर्वतश्रेणियों के 18 स्थलों की वृक्ष वलय श्रेणियों में अंकित पाँच क्षतचिन्हों (स्कार), जो विगत चौथी एवं छठी शताब्दी के हैं, से अग्नि कालानुक्रम का पुनर्सृजन किया। स्थल प्रमुखतः *पाइनस पॉण्डीरोसा* की प्रमुखता वाले वनों में स्थित हैं। अग्नि कालानुक्रम के माध्य अग्नि अन्तराल उत्तरी खड़ों (स्टैण्ड) की अपेक्षा दक्षिणी खरों में लघुतर अन्तरालों से युक्त अक्षांश से सम्बन्धित हैं, तथापि कालानुसार इस सम्बन्ध की तीव्रता भिन्न-भिन्न होती जाती है। सन् 1700 ई. से 1900 ई. के अन्तराल की अपेक्षा सन् 1600 ई. से 1800 ई. के मध्य अग्नि आवृत्ति में अक्षांश प्रवणता अधिक है। कालानुसार अग्नि आवृत्ति में भिन्नता क्षेत्रीय जलवायुविक प्रवणताओं से सम्बन्धित हो सकती है। दक्षिण में प्रमुखतः प्रारंभिक मौसमी अग्नि से उत्तर में अन्तिम मौसमी अग्नि तक अग्नि क्षतचिह्नों की मौसमिकता भी

भिन्न-भिन्न है। पामर अनावृष्टि भयावहता सूचकांक में वार्षिक भिन्नता से युक्त अग्नि वर्षों के अध्यारोपित युगीन विश्लेषण से प्रदर्शित होता है कि सम्पूर्ण प्रवणता के दौरान अग्नि वर्ष शुष्क थे, किन्तु दक्षिण में यह स्थिति आर्द्र वर्षों के पश्चात आई। इस परिणाम से प्रस्तावित होता है कि दक्षिणी वनों के ईंधन की मात्रा सीमित हो सकती है, जहाँ अग्नि अन्तराल संक्षिप्त थे तथा उत्तर में दीर्घावधिक अन्तरालों के कारण अग्नियों के मध्य ईंधन निर्मित होता रहा होगा। सभी कालानुक्रम सामान्यतः उत्तरवर्ती उन्नीसवीं शताब्दी के प्रारंभ में अग्नि क्षतचिन्हों का अवसान प्रदर्शित करते हैं, जो पश्चिमी अमरीका के दूर-दूर तक फैली हुई यूरो-अमरीकी बस्तियों के सम्पाती हैं।

संकेत शब्द—कालानुक्रम, अग्नि, वन, संयुक्त राज्य अमरीका.

INTRODUCTION

FIRES that burn at the base of a tree may kill portions of the vascular cambium and leave distinctive lesions (fire scars) recorded in the tree-ring series (Fig. 1). By crossdating the tree rings using dendrochronological methods, chronologies of past fires may be reconstructed. Fires can be dated to the year they occurred and often to the season by noting positions of fire scars within annual rings and knowing when radial growth begins and ends during a typical growing season. Long sequences of fire scars often are recorded on individual trees because of repeated burns during a tree's life (Fig. 1).

Studies using fire-scar data from lower and middle elevation forests throughout the western US have shown that frequent, low-severity fires were important forest disturbances prior to the twentieth century (e.g., Swetnam, 1993; Swetnam & Baisan, 1996; Barrett *et al.*, 1997; Brown *et al.*, 1999, 2000, 2001; Veblen *et al.*, 2000). Fires were keystone ecosystem processes (*sensu* Holling, 1992) that influenced forest composition and structure, understorey species diversity and productivity, biogeochemical processes, wildlife habitats, hydrology, and other environmental conditions (e.g., Cooper, 1960; Covington & Moore, 1994). Fire cessation occurred in almost all areas beginning the latter half of the nineteenth century or early in the twentieth century because of land use that accompanied European settlement of the West. Settlement brought intensive livestock grazing which removed grass and herbaceous fuels that promoted fire spread and later, beginning in the early half of the twentieth century, fire suppression by land management agencies, such as the US Forest Service.

Here we describe fire histories reconstructed from fire-scar records in 18 sites that occur along a 5° latitudinal

Fig. 1—Fire scars (arrows) recorded in a cross section from *Pinus ponderosa*. Bottom four fire scars are dormant season (between two rings) while uppermost fire scar occurs early in the earlywood.

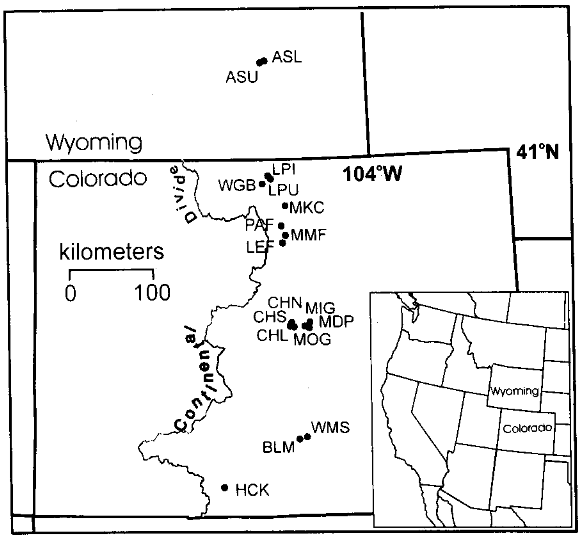


Fig. 2—Locations of 18 Fire History sites in Colorado and Wyoming.

gradient in the Rocky Mountains of Colorado and central Wyoming (Fig. 2). We compare reconstructed fire frequency and fire seasonality to assess shifts in fire-climate relations that occurred along the latitudinal gradient and through different periods covered by the fire chronologies. Our interest is in determining if there are recognizable relations between fire occurrences and variability in regional climate regimes as represented by latitude, and whether or not these relationships remained stable through the period covered by the fire chronologies.

METHODS

We used chainsaws to collect cross sections from fire-scarred trees in montane forests containing predominately *Pinus ponderosa*. Sites range from southern Colorado to central Wyoming along the central Rocky Mountain cordillera (Figs. 2, 3). At each site, we collected cross sections from 10 to 20 trees from forest stands that varied in size from 4 to 20 hectares. Our goal with collection in each site was to reconstruct a comprehensive, long-term fire chronology (Swetnam & Baisan, 1996; Brown *et al.*, 2001). We compiled composite fire chronologies from multiple trees because of the possibility of incomplete fire-scar records on individual trees. It is possible that either a fire that burned at the base of the tree was not recorded at the time of its occurrence or fire scars may have been burned off in subsequent fires or were otherwise erased from a tree's fire-scar record .

Fire-scarred samples were crossdated by matching common patterns of climatically controlled parameters in growth between trees such that absolute dating of tree rings was assured (Stokes & Smiley, 1968). Once tree rings were crossdated on each sample, dates were determined for fire scars. Positions of fire scars within tree rings were also assigned. Dates on individual trees at each site were compiled into fire chronologies and fire frequency was determined using program FHX2 (Grissino-Mayer, 2001).

We used several methods to describe and contrast fire frequency and fire climatology in the 18 stands. Fire frequency in each fire chronology was described by the median fire-free interval (MeFI) during periods of adequate sample coverage. Beginning and ending dates for periods of analysis for MeFI were based on a minimum of four trees in the early part of chronologies and when fires ceased in the late nineteenth or early twentieth centuries. We also calculated MeFI for each chronology for periods from 1600 to 1800 and from 1700 to 1900. We chose these two periods to assess possible differences in fire frequency through time as related

Site Name	Site Code	Elevation Range (m)	Latitude (N)/ Longitude (W)	Dominant Overstory Species [a]	Total Trees/Scars [b]
1. Ashenfelder Lower	ASL	1920-1950	42°20·0'/105°23·0	Pipo	12/68
2. Ashenfelder Upper	ASU	1930-1960	42°20·0'/105°24·5'	Pipo	10/52
3. Lone Pine	LPI	2340-2400	40°49·5'/105°27·5'	Pipo, Psme, Pico	11/17
4. Lone Pine Upper	LPU	2380-2410	40°48·5'/105°27·0'	Pico, Pipo, Psme, Potr	8/15
5. Washout Gulch Burn	WGB	2420-2590	40°44·0'/105°40·0'	Pipo, Psme, Potr	17/47
6. Merrill Kaufmann's Cabin	MKC	2090-2200	40°24·0'/105°12·0'	Pipo	18/86
7. Parachute Hill	PAF	2610-2630	40°14·0'/105°28·0'	Pipo, Psme	21/46
8. Mica Mine	MMF	2220-2250	40°09·0'/105°21·5'	Pipo, Psme	16/71
9. Left Hand Canyon	LEF	2600-2630	40°03·5'/105°28·5'	Pipo, Psme	16/41
10. Cheesman Lake North	CHN	2150-2180	39°11·5'/105°16·0'	Pipo, Psme	13/37
11. Cheesman Lake South	CHS	2160-2230	39°09·0'/105°16·5'	Pipo, Psme	17/56
12. Old Tree Cluster	CHL	2150-2180	39°08·0'/105°18·0'	Pipo	23/78
13. Missouri Gulch	MIG	2630-2670	39°08·5'/105°03·0'	Pipo, Psme, Pico, Pifl	8/18
14. Manitou Old Growth	MOG	2380-2390	39°06·0'/105°06·0'	Pipo	9/41
15. Manitou Demonstration Plot	MDP	2390-2410	39°03·5'/105°04·0'	Pipo	26/124
16. Wet Mountains South	WMS	2670-2690	37°55·5'/105°14·0'	Pipo	20/138
17. Black Mountain	BLM	2720-2740	37°51·5'/105°16·0'	Pipo	10/19
18. Hot Creek	HCK	2590-2640	37°17·5'/106°16·0'	Pipo	17/59

[a] Species designations:
Pipo: *Pinus ponderosa*
Pico: *P. contorta*
Pifl: *P. flexilis*
Psme: *Pseudotsuga menziesii*
Potr: *Populus tremuloides*
[b] Numbers of trees crossdated and fire scars recorded

Fig. 3—Sites collected for Fire History studies in Colorado and Wyoming.

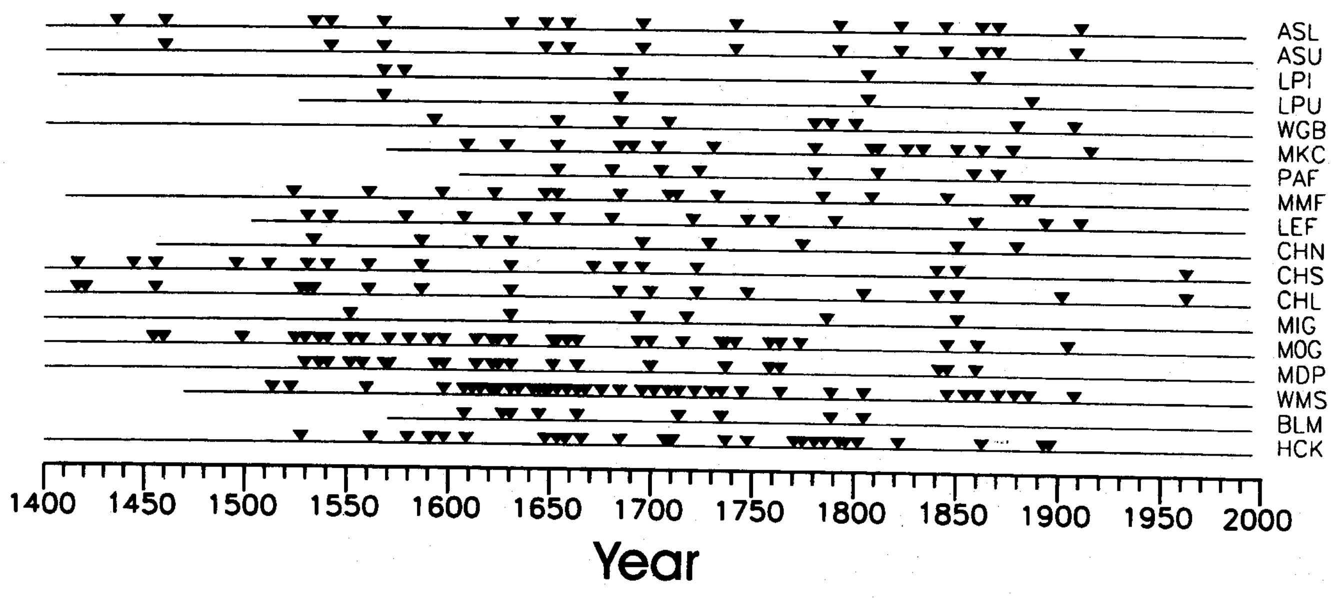


Fig. 4—Summary fire chronologies. Horizontal lines represent time spans of chronologies and inverted triangles represent fire dates.

to variations with latitude. Periods overlap because, contrary to many sites in the southwestern US where fire frequency was very high (fires occurring on average every 3 to 10 years in many forests; Swetnam & Baisan, 1996), fire frequency was lower in most sites and there are not enough intervals for calculation of frequency for all stands for non-overlapping 100-years periods. Linear regressions were used to determine significant relationships between latitude and both MeFI and seasonality of fires. Finally, we used superposed epoch analysis (SEA; Swetnam, 1993) to compare fire occurrences to independent tree-ring based reconstructions of Palmer Drought Severity Index (PDSI; Cook *et al.*, 1996). We used SEA to identify patterns between fire years and an eleven-years window of climate values: six years prior to the fire year, the fire year, and four years following. Significant climate departures were determined using mean climate values and variances calculated from 1000 randomly selected event data sets with the same number of fire dates as the tested data. Reconstructed PDSI values from Cook *et al.*'s (1996) grid points 58 (41° N 104·5° W) and 59 (39° N 104·5° W) were selected based on the grid points' proximity to study locations.

RESULTS AND DISCUSSION

Fire Chronologies

We crossdated a total of 272 trees that recorded 1017 fire scars from the 18 sites. Summaries of fire dates in chronologies are shown in Fig. 4. Fire events were recorded at all sites up until the late nineteenth or early twentieth centuries. As in most areas of the western US, few fire scars were recorded at any site during the twentieth century, reflective of changes in land use that occurred with Euro-American settlement.

Typical fire chronologies from four stands in northern Colorado are shown in Fig. 5. As in all stands sampled for this study, many trees were dead at the time of collection. Resinous heartwood of larger *Pinus ponderosa* trees often persists for several decades after tree death and sampling of remnant trees is a means to extend fire (and climate) chronologies to periods before those of living trees. Most fire-scarred cross sections for this study were removed from stumps left from logging. Many low-elevation forests containing *Pinus ponderosa* were heavily logged because of relative ease of access and proximity to population centers on the Colorado Front Range. Other fire-scarred cross sections were collected from standing dead trees (snags) or logs in addition to those from living trees (Fig. 5).

Stands shown in Fig. 5 occur along a gradient in elevation (Fig. 3) and fire was more frequent in the lowest elevation stand (MKC) than in higher elevation stands (PAF, MMF and LEF). Changes in elevation integrate changes in precipitation and temperature that strongly influence both fuel quantity and its ability to burn. Moister and cooler conditions in upper-elevation forests result in fewer years when fuels are dry enough for fire to spread after ignition (Peet, 1981; Swetnam & Baisan, 1996; Brown *et al.*, 2001). While fire frequency generally decreases with elevation, fire severity may increase because of fuel buildups that result from longer intervals between fires and more productive forests at higher elevations.

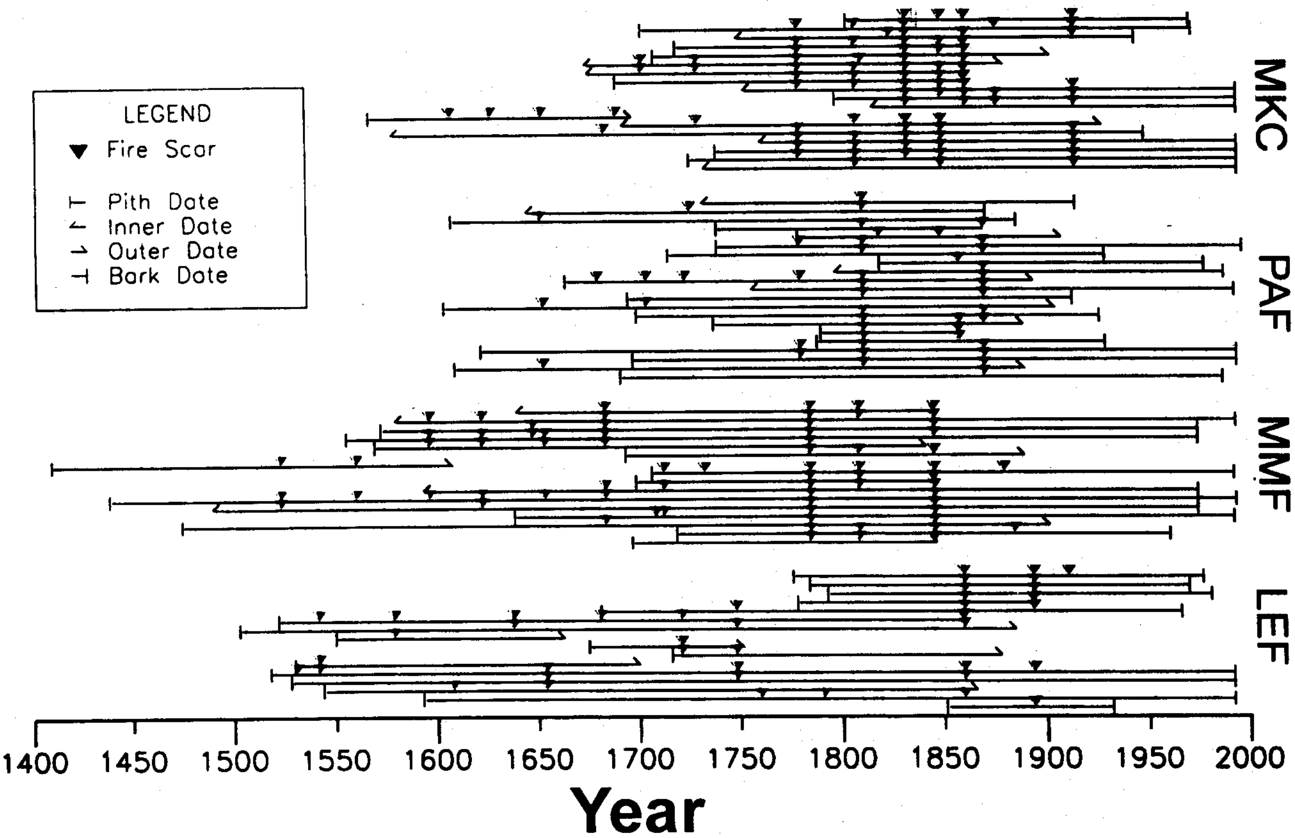


Fig. 5—Composite fire chronologies from four sites in the Colorado Front Range. Sites are arranged from low to high elevation (see Fig. 3).

In several of the higher-elevation areas we sampled for this study, we found evidence of catastrophic crown fires (Brown *et al.*, 1999, 2000). Crown fires likely occurred more frequently and across larger areas in *Pinus ponderosa* forests of our study area than in those of the Southwest because of generally longer intervals between fires (Brown *et al.*, 1999).

In general, we did not find any increase in fire occurrences during the early settlement period of the late nineteenth century as has been found in other fire history studies in central Colorado (e.g., Veblen *et al.*, 2000). This may be the result of either differences in methodologies for developing fire chronologies and/or in locations of stands selected for fire history. Other studies selected primarily living trees for reconstruction of fire history while we collected both living and remnant materials. We have found that living trees in a majority of *Pinus ponderosa* forests in Colorado are relatively young because of past logging that removed larger and older trees. A reliance on living trees that exhibit multiple fire-scar records may bias site selection to areas where fire was more frequent during the early settlement period. Historic records and photographs often document burning that resulted from human ignitions during the settlement period, but we believe that these impacts were limited to specific, more intensively utilized, locations based on fire histories we have reconstructed.

Fire Frequency along the Latitudinal Gradient

While changes in elevation integrate changes in climate regimes at landscape scales (e.g., mountain ranges), changes in latitude integrate changes in climate across larger regional scales. Median fire intervals generally decreased with increasing latitude, although there was a great deal of variability both within and between fire chronologies (Figs.

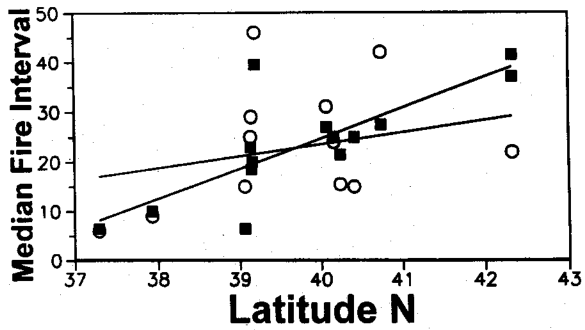


Fig. 6—Box plots of fire interval distributions in fire chronologies. Small boxes are median intervals, large boxes are first and third quartile intervals, and lines are range of intervals in each chronology. Sites are arranged by latitude.

Site	Period of Analysis	No. of Fire Intervals	Median Fire Interval (yr)	Range of Intervals (yr)
ASL	1436-1911	15	26	8 to 74
ASU	1460-1909	12	33·5	8 to 82
WGB	1654-1908	8	29·5	8 to 79
LPI	1568-1861	4	80·5	10 to 122
LPU	1568-1896	3	117	80 to 122
MKC	1609-1878	14	16	3 to 50
PAF	1654-1871	10	21·5	3 to 54
MMF	1524-1885	14	25·5	4 to 52
LEF	1542-1911	13	29	11 to 69
CHN	1534-1880	8	39·5	15 to 76
CHS	1417-1851	15	20	10 to 118
CHL	1325-1851	26	16	3 to 58
MIG	1631-1851	5	64	24 to 79
MOG	1598-1846	10	22·5	2 to 72
MDP	1521-1865	24	7·5	2 to 82
WMS	1514-1908	28	10	4 to 41
BLM	1608-1805	8	19	4 to 54
HCK	1528-1896	26	9·5	2 to 41

Fig. 7—Measures of fire frequency calculated for period of analysis

4, 6 & 7). In northern stands, shorter growing seasons coupled with mostly cooler conditions likely resulted in fewer years during which fires were able to occur. There is also a general decrease in elevation along the latitudinal gradient with lower stands in the north than those in the south (Fig. 3). Decreasing stand elevation with latitude is a result of typical biogeography of species resulting from decreasing temperatures and growing season lengths as one moves north (Richardson, 1998). Intervals between fires found in the sites of this study were generally longer than most *Pinus ponderosa* stands of the Southwest US (see summary of 63 sites from Arizona and New Mexico in Swetnam & Baisan, 1996; Brown *et al.*, 2001) and comparable to those found in *Pinus ponderosa*

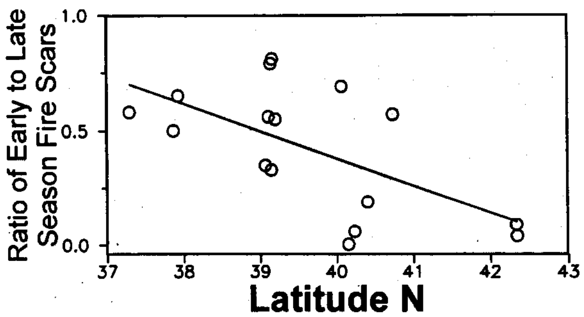


Fig. 8—Median fire intervals (MeFI) by latitude. Squares are MeFI from 1600 to 1800 (MeFI = 6·11 * latitude - 220; $R^2 = 0{\cdot}62$) and circles are MeFI from 1700 to 1900 (MeFI = 2·40 * latitude - 72; $R^2 = 0{\cdot}12$).

forests of the central Rocky Mountains (Brown *et al.*, 1999, 2000; Veblen *et al.*, 2000).

The relationship of decreased fire frequency with increasing latitude was stronger during the period from 1600 to 1800 ($p < 0{\cdot}001$) than it was from 1700 to 1900 ($p = 0{\cdot}21$; Fig. 8). This result highlights instability in fire regimes not only across space but also through time as a result of long-term climate variability. Studies from the Southwest US suggest that climate was less variable on decadal and longer times scales during the seventeenth and eighteenth centuries and, at least in the Southwest, was transitional ca. 1800 to wetter and possibly cooler conditions (Swetnam & Betancourt, 1998; Grissino-Mayer & Swetnam, 2000). It is also likely that generally warmer and likely drier conditions after the end of the little ice age (LIA) of the ~~sixteenth to~~ eighteenth centuries resulted in greater possibility for fires to occur in the more northern stands. Gradients in climate with latitude may have been stronger during the LIA than afterwards, and hence fire occurrences show a stronger gradient in frequency from 1600 to 1800 than from 1700 to 1900. These potential temporal relationships between fire frequency and latitude will be explored with a larger regional dataset from the Southwest (Swetnam & Baisan, 1996; Brown *et al.*, 2001) and northern Rocky Mountains (Brown & Sieg, 1996, 1999; Brown, unpublished data) that spans approximately 13° of latitude.

Latitudinal gradients in fire patterning also are evident in seasonality of fires (Fig. 9) and in relationships with annual drought conditions. Fire scars occurred predominately early in growing seasons in the south and later in growing seasons in the north ($p < 0{\cdot}001$; Fig. 9). Historic and recent fires in the Southwest commonly occurred during the dry period of May and June and before the onset of summer monsoon moisture during July and August (Swetnam & Baisan, 1996). Fires in more northern stands typically occurred in late July, August, and September after grasses and herbaceous fuels cure at the end of shorter growing seasons than those to the south (Brown & Sieg, 1996, 1999). We found no significant variability in fire seasonality in subsets of fire-scar data based on periods of analysis.

Superposed epoch analysis showed that fires in both northern and southern stands occurred predominately during dry years but that fires in the south often were preceded by wet years. Wet years establish abundant grass and herbaceous understories that are the primary fuels for fire spread. A pattern of wet years preceding dry years has been found in other studies from Southwestern forests (e.g., Swetnam & Baisan, 1996; Brown *et al.*, 2001) and suggests that fire spread in stands was limited as much by fuel amounts as by dry fuel conditions. In more northern stands, fuel amounts were not as limiting to fire spread because of generally longer intervals between fires which permitted fuel buildup.

CONCLUSIONS

Variability in fire frequency in the 18 stands of this study document often strong control by climate regimes that occur along the latitudinal gradient. Variability in fire frequency, fire seasonality, and fire timing in relation to annual variability in PDSI can be related to latitude. Fires in northern stands tended to occur less frequently and later in the summer than those to the south. Fires in the south tended to occur after wet periods that permitted buildup of grass and herbaceous fuels. However, changes in land use accompanying Euro-American settlement at the end of the nineteenth century overrode climatic gradients and led to fire cessation in all stands.

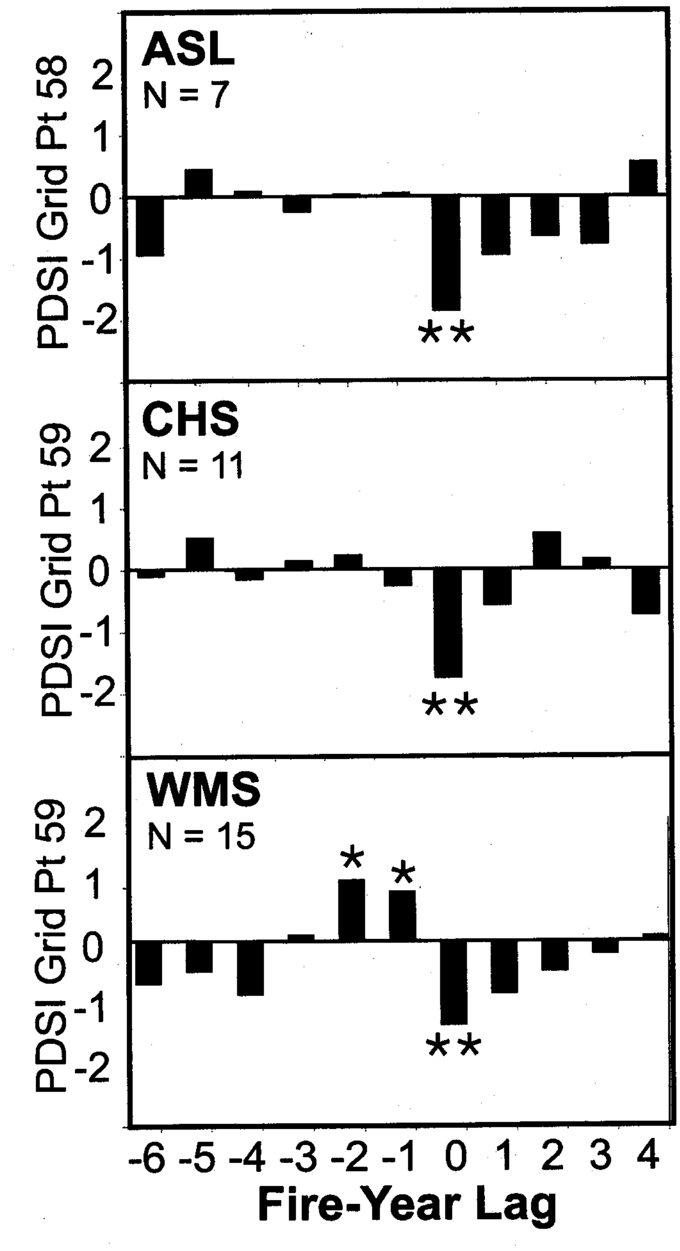


Fig. 9—Ratio of early- to late-season fire scars in fire chronologies by latitude. Ratio in each site is based on fire scars that occur within ring series (i.e., not including dormant season fire scars that occur at the boundary between rings).

Acknowledgements—*E. Bauer, B. Brown, C. Brown, S. Gallup, L. Huckaby, M. Kaufmann, M. Losleben, B. Martin, S. Mata, E. Peterson, C. Woodhouse and R. Wu assisted with field collections. Site LEF was collected during the 1992 North American Dendroecological Fieldweek held at the Mountain Research Station, University of Colorado, Boulder and we thank T. Swetnam for its use. Site MMF and some of the trees at site PAF were developed as part of a field course at the Mountain Research Station in 1995 and we thank C. Woodhouse for sharing these data. Other trees from PAF were collected and analyzed during the 1998 North American Dendroecological Fieldweek, also held at the Mountain Research Station, and we thank M. Kaye and J. Speer for these data. Funding for a majority of this research was provided by the US Forest Service, Rocky Mountain Research Station, Ft. Collins, Colorado. Other funding was provided by the National Science Foundation, Long-Term Ecological Research Program.*

REFERENCES

Barrett SW, Arno SF & Menakis JP 1997. Fire episodes in the inland northwest (1540-1940) based on fire history data. U.S. Department of Agriculture, Forest Service General Technical Report INT-GTR-370. 17 pages.

Brown PM, Kaufmann MR & Shepperd WD 1999. Long-term, landscape patterns of past fire events in a montane ponderosa pine forest of central Colorado. Landscape Ecology 14 : 513-532.

Brown PM, Kaye MW, Huckaby L & Baisan C 2001. Fire history along environmental gradients in the Sacramento Mountains, New Mexico: Influences of local patterns and regional processes. Écoscience 8 : 115-126.

Brown PM, Ryan MG & Andrews TG 2000. Historical fire frequency in ponderosa pine stands in Research Natural areas, central Rocky Mountains and Black Hills, US. Natural Areas Journal 20 : 133-139.

Brown PM & Sieg CH 1996. Fire history in interior ponderosa pine forests of the Black Hills, South Dakota, USA. International Journal of Wildland Fire 6 : 97-105.

Brown PM & Sieg CH 1999. Historical variability in fire at the ponderosa pine - northern Great Plains prairie ecotone, southeastern Black Hills, South Dakota. Écoscience 6 : 539-547.

Cook ER, Meko DM, Stahle DW & Cleaveland MK 1996. Tree-ring reconstructions of past drought across the coterminous United States: Tests of a regression method and calibration/verification results. *In:* Dean JS, Meko DM & Swetnam TW (Editors)—Tree Rings, Environment and Humanity: Proceedings of the International Conference, Tucson, Arizona, 17-21 May, 1994. Radiocarbon 1996 : 155-169.

Cooper CF 1960. Changes in vegetation, structure, and growth of southwestern pine forest since white settlement. Ecological Monographs 30 : 129-164.

Covington WW & Moore MM 1994. Southwestern ponderosa forest structure: changes since Euro-American settlement. Journal of Forestry 92 : 39-47.

Grissino-Mayer HD 2001. FHX2 - software for analyzing temporal and spatial patterns in fire regimes from tree rings. Tree-Ring Research 57 : 115-124.

Grissino-Mayer HD & Swetnam TW 2000. Century-scale climate forcing of fire regimes in the American Southwest. The Holocene 10 : 207-214.

Holling CS 1992. Cross-scale morphology, geometry and dynamics of ecosystems. Ecological Monographs 62 : 447-502.

Peet RK 1981. Forest vegetation of the Colorado Front Range. Vegetatio 45 : 3-75.

Richardson DM 1998. Ecology and Biogeography of *Pinus*. Cambridge University Press, U.K. 527 pp.

Stokes MA & Smiley TL 1968. An Introduction to Tree-Ring Dating. The University of Chicago Press, Chicago IL. 73pp.

Swetnam TW 1993. Fire history and climate change in giant sequoia groves. Science 262 : 885-889.

Swetnam TW & Baisan CH 1996. Historical fire regime patterns in the southwestern United States since 1700. *In:* Allen CD (Editor)—Fire effects in Southwestern Forests, Proceedings of the 2nd La Mesa Fire Symposium, March 29-31, 1994, Los Alamos, New Mexico. USDA Forest Service General Technical Report RM-GTR-286 : 11-32.

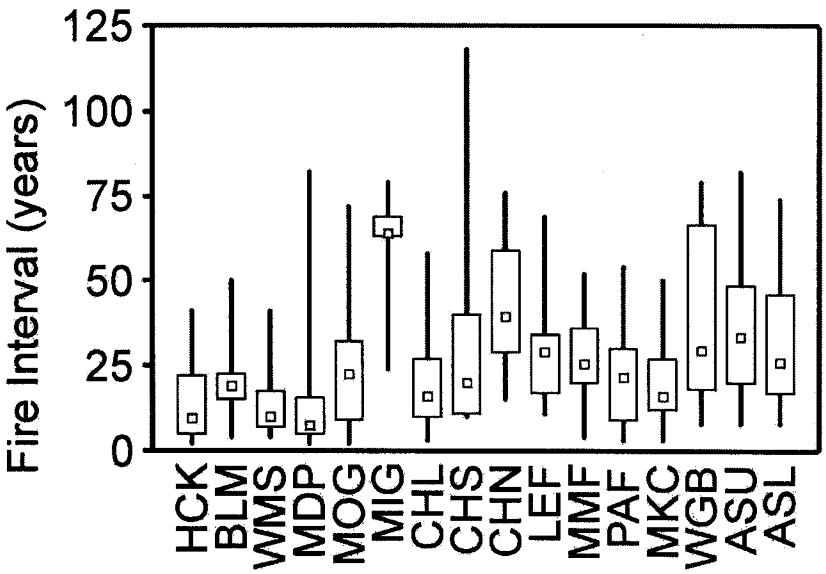
Swetnam TW & Betancourt JL 1998. Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest. Journal of Climate 11 : 3128-3147.

Veblen TT, Kitzberger T & Donnegan J 2000. Climatic and human influences on fire regimes in ponderosa pine forests in the Colorado Front Range. Ecological Applications 10 : 1178-1195.

Errata

P.M. Brown and W.D. Shepperd. Fire History and Fire Climatology Along a 5° Gradient in Latitude in Colorado and Wyoming, USA. The Palaeobotanist 50:133-140 (2001).

Fig 6. – The correct figure was left out of the paper:



Captions for Figs. 8 and 9 are for currently numbered Figs. 6 and 8, respectively.

Correct caption for Fig. 9 – Superposed epoch analysis of departures of PDSI values over an eight-year window around fire years from 1700 to 1900 from three fire chronologies. N is number of fire dates between 1700 and 1900 used in analysis. Fire year lags are: **-6 to -1**, years prior to fire years; **0**, fire year; **1 to 4**, years following fire years. Single asterisks denote years in which departure of actual PDSI from simulated PDSI in SEA were significant at $p < 0.01$ and double asterisks denote years when departure was significant at $p < 0.001$.