Crossdated Fire Histories (1650 to 1900) From Ponderosa Pine-Dominated Forests of Idaho and Western Montana

Emily K. Heyerdahl, Penelope Morgan, and James P. Riser II






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Abstract

For a broader study of the climate drivers of regional-fire years in the Northern Rockies, we reconstructed a history of surface fires at 21 sites in Idaho and western Montana. We targeted sites that historically sustained frequent surface fires and were dominated or co-dominated by ponderosa pine (*Pinus ponderosa* P. & C. Lawson). Our objective is to report the site-specific fire and site information we did not report in our regional study that might be useful to local land managers for determining such things as Fire Regime Condition Class. We include 23 sites—20 from our regional study (one was reported elsewhere) and another three sampled in the region for other purposes. We crossdated samples from 640 trees to obtain calendar years for each tree ring and hence for 9,691 fire scars. For each site, we report the chronology of surface fires, properties of the fire regime (mean fire interval and intra-ring position of fire scars), and forest type, as well as topography that might be used to extrapolate site-specific fire regimes to unsampled areas.

Keywords: fire scars, dendrochronology, crossdate, ponderosa pine

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Contents

Crossdated Fire Histories (1650 to 1900) From Ponderosa Pine-Dominated Forests of Idaho and Western Montana

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Introduction

The Northern Rocky Mountains of Idaho and Montana west of the Continental Divide have a diversity of forest types distributed across a wide range of topography and a long history of forest wildfires (Arno and others 1995; Barrett and others 1991; Brunelle and others 2005; Heyerdahl and others 2008; Kipfmueller 2003; Morgan and others 2008; Pierce and others 2004; Power and others 2006; Smith 1983). To infer the climate drivers of fire in dry forests over the past several centuries, we reconstructed a history of surface fires from fire scars on trees at 21 sites in this region. While the results of this study are useful for managing fire, we recognize that land managers and other researchers also need site-specific details of fire history that we did not publish with our regional-scale analysis (Heyerdahl and others 2008). For example, site-specific fire regimes properties, such as mean fire interval, can be used to understand how fire regime may have changed on a particular site over the past century by determining a Fire Regime Condition Class (Hann and others 2003). Site-specific chronologies of fire can also be related to other aspects of a site's history, such as tree demography and the history of human use of the site. Finally, details of site-specific fire histories and the sites from which they were sampled may be used to extrapolate fire regimes from sampled to similar unsampled areas.

The objective of our broader study was to obtain annually accurate histories of surface fire occurrence across Idaho and Montana to identify regional-fire years and infer their climate drivers (Heyerdahl and others 2008). To meet this objective, we targeted small sites with many, well-preserved fire scars in dry forests; in other words, those dominated or codominated by ponderosa pine. We obtained annually accurate fire dates by crossdating, which can assign the exact calendar year to tree rings and hence fire scars (Stokes and Smiley 1968). Prior to our study, no accurately dated fire histories had been published for this region.

Our objective here is to provide site-specific histories of surface fire that can be used for land management or additional research. We report on 20 of the 21 sites we used in our broader study of climate drivers—details of the remaining site were reported elsewhere (Jones 2005). In addition, we report on three sites that were sampled in this region for other purposes. For each site, we report both the chronology of surface fires and estimates of time-averaged properties of the fire regime, as well as site location, forest type, and topography. We describe our methods in a single section that applies to all sites but provide details of each site in a separate section of the results.

Methods

To obtain a multicentury record of widespread surface fires across the region, we targeted sites that were historically dominated or codominated by ponderosa pine and historically sustained frequent surface fires (fig. 1). We identified potential sites from land managers' knowledge of the locations of old fire-scarred trees. From these, we selected sampling sites distributed across the region that had numerous old trees with many well-preserved fire scars (table 1). We recognized old living trees by their form (Huckaby and others 2003). However, old dead trees were more common and included logs, snags, and the eroded stumps of trees harvested in the late 1800s or early 1900s (fig. 2).

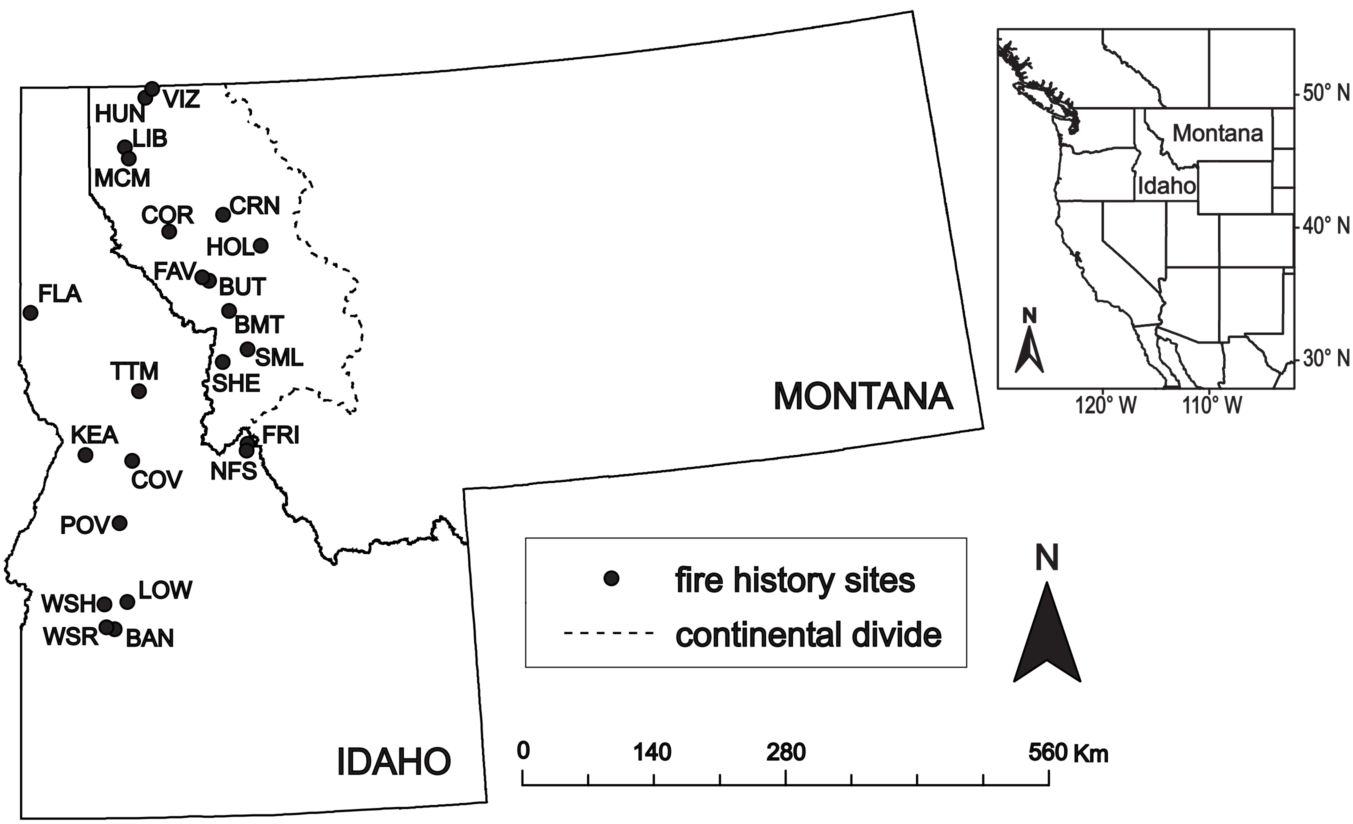


Figure 1—Locations of the crossdated fire history sites we report, all of which lie west of the Continental Divide. More information about these sites is provided in tables 1 and 2.

Table 1—Fire history sites sampled in the Northern Rockies. All Universal Transverse Mercator (UTM) coordinates are relative to the 1927 North American Datum (NAD27) and lie within UTM zone 11, except FRI, HOL, NFS, and SML, which are in zone 12.

Site code	Site name	National forest or other land ownership	Forest Service District	UTM-easting	UTM-northing
BAN	Bannock Creek	Boise	Idaho City	597544	4850698
BMT	Blue Mountain	Lolo	Missoula	719195	5189423
BUT	Butler Creek	Lolo	Ninemile	697722	5221845
COR	Corona Road	Plum Creek Timber, Inc.	—	655529	5273953
COV	Cove Mountain	Nez Perce	Red River	616031	5030319
CRN	Crane Lookout	Flathead	Swan Lake	723019	5308852
FAV	McCormick Creek	Lolo	Ninemile	690341	5225251
FLA	Flannigan Creek	privately owned	—	507761	5187758
FRI	Friedorf Gulch	Salmon-Challis	North Fork	270312	5047852
HOL	Holland Lake Road	Flathead	Swan Lake	300447	5257153
HUN	Hunter Point	Kootenai	Rexford	629785	5416599
KEA	Keating Ridge	Nez Perce	Clearwater	566466	5036515
LIB	Sheldon Flats	Kootenai	Libby	608194	5363358
LOW	Lowman Research Natural Area	Boise	Lowman	610871	4879692
MCM	McMillan Mountain	Kootenai	Libby	612232	5351832
NFS	North Fork Salmon River	Salmon-Challis	North Fork and Salmon	238511	5048425
POV	Poverty Flat	Payette	Krassel	602628	4963601
SHE	Sheafman Creek	Bitterroot	Stevensville	712400	5135045
SML	Sawmill Creek Research Natural Area	Bitterroot	Stevensville	277705	5147868
TTM	Twenty-Three Mile Bar	Nez Perce	Moose Creek	623282	5103917
VIZ	Sophie Lake	State of Montana	—	637160	5425698
WSH	Wash Creek	Boise	Emmet	586202	4877171
WSR	Warm Springs Ridge	Boise	Idaho City	588741	4852895

Figure 2—Dead trees can yield accurate dates of fire occurrence if they are crossdated. For this study, we sampled mostly stumps (a and b), logs (c), and snags (d). One stump retained a record of 32 different fires despite being quite eroded (b). Photo credits: James P. Riser II (a and b), Carly E. Gibson (c), and Marc H. Weber (d).

At the 20 sites we sampled for our regional study, we used a chain saw to remove fire-scarred partial cross sections from living trees, snags, logs, or stumps that had the greatest number of visible, well-preserved scars (Arno and Sneck 1977). Our goal was to sample roughly 30 trees over an area of roughly 75 acres. From living trees, we removed a single, small partial cross section from one side of the catface to reduce the impact of sampling on tree mortality (Heyerdahl and McKay 2001, 2008). From dead trees, we removed one to nine partial or complete cross sections (average 1.6 samples per tree) from different heights, sides of the catface, and/or catfaces, when present, because fire scars from all of the fire years recorded on a tree cannot always be captured in a single sample (Dieterich and Swetnam 1984). For each tree, we recorded species and location (using a handheld global positioning system receiver). This information is not reported here but is publicly available from the International Multiproxy Paleofire Database (see the following For More Information section). Of the three sites sampled for other purposes, Bannock Creek (BAN) was sampled in a similar manner by others (Brown and others 2005). We sampled Twenty-Three Mile Bar (TTM) for a study of the effects of 20th century fire exclusion on forest structure and composition (reported as site TW in Keeling and others 2006) and so targeted 20th century rather than historical fires. North Fork Salmon River (NFS) was sampled by John Sloan and others from the Salmon-Challis National Forest for another study. They sampled several hundred living trees that were generally near roads. We report here on only 52 of the trees from NFS, which we selected because they had multiple, well preserved fire scars.

We sanded the samples from all 23 sites until the cell structure was visible with a binocular microscope. We assigned exact calendar years to tree rings using visual crossdating. Crossdating is the process of matching climatically driven patterns of wide and narrow rings or other ring features, such as latewood width, from trees within sites and among sites across the region to identify and account for missing and false rings (Stokes and Smiley 1968). We were able to crossdate because the high-frequency, or year-to-year, variation in ring width of the trees we sampled was determined in part by year-to-year variation in climate, which was generally homogeneous across the region (Meko and others 1993). For example, most of our samples had narrow rings during the years 1632, 1695, 1721, 1744, 1869, and 1889, all years of summer drought across the region (Cook and others 2007; for visualizations of tree-ring reconstructed regional drought during these years see http://www.ncdc.noaa.gov/cgi-bin/paleo/pd04plot.pl). Year-to-year variation in ring-widths was similar among the ponderosa pine, western larch (*Larix occidentalis* Nutt.), and Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco) trees that we sampled. Slowly varying trends in ring width, such as those generated by stand dynamics, occurred in our samples in addition to the year-to-year variation that was driven by climate but did not affect our ability to crossdate. To crossdate the samples we removed from both living and dead trees, we visually compared the patterns of year-to-year variation in ring widths on each sanded sample to a master chronology (in other words, a bar chart of average ring widths from many trees sampled for other studies in the region). For some trees (15 percent), we were initially unable to visually match the ring-width patterns on the samples to the master chronology, so we measured the width of the rings and statistically compared them to the master chronology. This statistical comparison suggested possible dates for the rings on our samples, which we then verified on the wood to obtain final, exact calendar years for every tree ring.

To determine the year of fire occurrence, we noted the calendar year in which each scar was formed. We identified fire scars as discontinuities between cells, within a ring or along a ring boundary, where the cambium had been killed but not mechanically damaged, followed by overlapping and curled rings (Dieterich and Swetnam 1984). In addition, we obtained a small amount of supporting evidence of surface fires (6 percent of dates) from eroded fire scars (those for which much or all of the overlapping, curled woundwood rings were destroyed by subsequent fires or decay). We noted non-recording years, those which have a crossdated tree ring but no information on fire history, either because the tree had not scarred yet or because the outer edge of the catface was eroded due to subsequent fire or decay (Grissino-Mayer 2001). We also noted the position of each scar within the annual ring in which it occurred (earlywood, latewood, ring boundary, or unknown) as an indication of the season during which the fire burned. In this region, the season of cambial dormancy (in other words, the period represented by the ring boundary) spans 2 calendar years: from the time the cambium stops growing in the summer of one year until it resumes growth the following year. For this study, we assigned ring-boundary scars to the *preceding* calendar year because most modern fires in this area occur in the summer or fall (Schmidt and others 2002). However, scars from a given fire can have a range of intra-annual positions because the timing of radial growth varies across the landscape (Fritts 1976) and fires may burn for several months. For three fires (one each at Hunter Point (HUN), NFS, and Wash Creek (WSH)), scars occurred in the earlywood of most trees but on the preceding ring boundary of some. We inferred that the scars in both positions were created by a single fire burning early in the growing season and therefore, assigned the ring-boundary scars (18 scars total) to the *following* calendar year; in other words, the same year as the earlywood scars. We could not determine the intra-ring position of every scar because some of them occurred in very narrow rings or were obscured by decay or insect galleries. We report the distribution of fire scars by intra-ring position only for ponderosa pine trees because there were too few scars from other species to characterize their distribution. We did not combine these few scars with the ponderosa pine scars because cambial phenology varies among species (Fritts 1976), hence fire-scars created at the same time may vary in intra-ring position among trees of different species (Heyerdahl and others 2007).

In a separate chapter for each site, we present (i) the amount of fire evidence, the tree species sampled, and the size of the sampling area, (ii) the chronology of fire (in a fire chart and in a table listing fire dates and evidence of fire), (iii) some properties of the fire regime (fire intervals and intra-ring position of fire scars), and (iv) two vegetation classifications. To estimate the size of the sampling area at each site, we used a geographic information system to map tree locations and compute the area inside the smallest convex hull enclosing crossdated trees. Fire charts have long horizontal time lines indicating the length of record for each tree and short vertical lines indicating years when that tree had evidence of fire (fire scars or eroded fire scars; Grissino-Mayer 2001). On the fire chart, the chronology of fire and general features of variation in fire occurrence through time can be observed along the horizontal lines and the synchrony of fire across a site can be observed by noting the number of vertical lines with evidence of fire during a given year. We summarized fire regimes over the period from 1650 to 1900 at most sites, but over the period from 1750 to 1900 at one site (Poverty Flat, POV) because the trees we sampled there were not recording fire before 1743. We estimated fire intervals at each site by compositing the fire-scar dates from all trees at that site into a single record of fire occurrence (Dieterich 1980) and computed the intervals between years in which a fire scarred two or more trees. However, we do not report mean fire intervals for three sites because fire-scarred trees were sampled over a very large area (28,352 acres at NFS; table 2) or there were too few intervals (five and eight intervals at TTM and Lowman Research Natural Area (LOW), respectively). We classified most of our sites by environmental site potential (EsP) and biophysical setting (BpS, Comer and others 2003; LANDFIRE 2006). Both classifications are based on topography, soils, and parent material. EsP categories are named for the vegetation that could potentially occupy a site in the absence of disturbance. BpS categories are named for the vegetation that could potentially occupy a site in the presence of the disturbance regime sustained by that site in the past. We report the EsP and BpS categories that dominated a 50-m radius circle around the center point of each site. We do not report a site classification for NFS because it was sampled over too large an area (28,352 acres) for a single category to be meaningful.

Results

The 23 sites lie west of the Continental Divide, between 2,300 and 6,300 feet in elevation on a broad range of aspects and slopes (fig. 1, table 2). Excluding NFS, we crossdated nine to 46 trees (average 27 trees) across an area of 5 to 367 acres (average 72 acres). At NFS, we crossdated 52 trees collected over 28,352 acres. We removed more than one fire-scarred section from nearly 1/2 the dead trees (47 percent). Across all sites, almost all of the crossdated trees were ponderosa pine (627 of 640 trees or 98 percent) because fire scars are well preserved on this resinous species. The remaining crossdated samples were taken from western larch and Rocky Mountain Douglas-fir trees. Missing rings were common at all sites. In addition to the 640 trees we crossdated, we sampled 48 trees that we excluded from further analyses because we could not crossdate them.

Our fire-scar record contains little information about 20th century fires because very few of the trees we sampled had rings or scars from the 20th century. We sampled many more dead than living trees (85 versus 15 percent, respectively) and selected sites that were not burned by 20th century fires because modern fires often destroy the record of past fire by consuming dead trees and existing scars on living trees. Only 10 percent of the tree rings we sampled were formed in 1900s. Of these, most were from NFS (34 percent of the 20th century rings), Cove Mountain (COV; 14 percent), and Sawmill Creek Research Natural Area (SML; 12 percent).

We categorized the EsP of most sites (73 percent) as Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest with the remaining sites distributed among four other categories (table 3). We categorized the BpS of most sites (64 percent) as Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir (8 sites) or Northern Rocky Mountain Ponderosa Pine Woodland and Savanna (6 sites) with the remaining sites distributed among four other categories (table 4).

Table 2—Characteristics of sites sampled, amount of fire evidence collected, and file names in the International Multiproxy Paleofire Database (IMPD). Number of fire scars is for the entire period of record at each site and includes all the scars dated from samples on each tree. More than one sample was removed from many trees.

Site code	Number crossdated fire-scarred trees	Number fire scars	Number eroded fire scars	Sampling area (acres)	Elevation (feet)	Aspect	IMPD file name
BAN	24	314	9	69	4,526	east	usban001
BMT	36	758	25	82	3,962	east to southeast	usbmt001
BUT	38	817	23	5	4,748	south	usbut001
COR	26	417	38	7	4,002	various	uscor001
COV	25	264	22	30	5,756	south	uscov001
CRN	18	239	7	45	3,695	west	uscrn002
FAV	17	261	10	367	3,854	south-southwest	usfav001
FLA	25	556	26	69	3,198	various	usfla001
FRI	31	374	19	116	5,018	various	usfri001
HOL	19	206	20	94	4,051	flat	ushol001
HUN	25	290	25	77	2,575	south-southeast	ushun001
KEA	22	237	11	10	5,076	south-southeast	uskea001
LIB	29	546	68	89	2,304	southwest, nearly flat	uslib001
LOW	9	77	12	57	4,772	various	uslow001
MCM	32	512	44	20	2,822	west	usmcm001
NFS	48	313	9	28,352	6,232	various	usnfs001
POV	33	285	22	45	4,362	various	uspov001
SHE	41	507	42	35	4,879	northeast	usshe001
SML	32	220	17	109	5,232	south and northwest	ussml001
TTM	12	50	2	106	2,460	south	usttm001
VIZ	46	1,463	51	32	2,558	various	usviz001
WSH	25	480	43	77	3,419	various	uswsh001
WSR	27	505	32	37	5,034	southwest	uswsr001
Total	640	9,691	577				

Table 3—Dominant environmental site potential (EsP) within 50 m of fire-history sites, as mapped by LANDFIRE. EsP categories are named for the vegetation that could potentially occupy a site in the absence of disturbance. We do not report EsP for NFS because it was sampled over too large an area for a single vegetation category to be meaningful (28,352 acre).

Site code	EsP code	EsP name
BAN	1053	Northern Rocky Mountain Ponderosa Pine Woodland and Savanna
BMT	1045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
BUT	1045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
COR	1045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
COV	1045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
CRN	1045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
FAV	1045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
FLA	1045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
FRI	1166	Middle Rocky Mountain Montane Douglas-Fir Forest and Woodland
HOL	1159	Rocky Mountain Montane Riparian Systems
HUN	1045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
KEA	1045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
LIB	1045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
LOW	1045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
MCM	1045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
POV	1166	Middle Rocky Mountain Montane Douglas-Fir Forest and Woodland
SHE	1045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
SML	1045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
TTM	1047	Northern Rocky Mountain Mesic Montane Mixed Conifer Forest
VIZ	1045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
WSH	1045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
WSR	1053	Northern Rocky Mountain Ponderosa Pine Woodland and Savanna

Table 4—Dominant biophysical setting (BpS) within 50 m of fire-history sites, as mapped by LANDFIRE. BpS categories are named for the vegetation that could potentially occupy a site in the presence of the historical disturbance regime at that site. We do not report BpS for NFS because it was sampled over too large an area for a single vegetation category to be meaningful (28,352 acres).

Site code	BpS code	BpS name
BAN	10530	Northern Rocky Mountain Ponderosa Pine Woodland and Savanna
BMT	10451	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir
BUT	10452	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Larch
COR	10451	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir
COV	10530	Northern Rocky Mountain Ponderosa Pine Woodland and Savanna
CRN	10453	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Grand Fir
FAV	10530	Northern Rocky Mountain Ponderosa Pine Woodland and Savanna
FLA	10451	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir
FRI	11660	Middle Rocky Mountain Montane Douglas-fir Forest and Woodland
HOL	11590	Rocky Mountain Montane Riparian Systems
HUN	10451	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir
KEA	10530	Northern Rocky Mountain Ponderosa Pine Woodland and Savanna
LIB	10451	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir
LOW	10451	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir
MCM	10451	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir
POV	11660	Middle Rocky Mountain Montane Douglas-fir Forest and Woodland
SHE	10530	Northern Rocky Mountain Ponderosa Pine Woodland and Savanna
SML	11390	Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland
TTM	10453	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Grand Fir
VIZ	10451	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir
WSH	11390	Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland
WSR	10530	Northern Rocky Mountain Ponderosa Pine Woodland and Savanna

SHE (Sheafman Creek) Bitterroot National Forest, Stevensville Ranger District

In 2004, we removed fire-scarred partial cross sections from 42 trees (41 ponderosa pine and one Douglas-fir) over a sampling area of 35 acres (fig. 1, table 2). Most of these trees were dead when sampled (93 percent stumps, logs, or snags). We were able to crossdate samples from 41 of these trees (98 percent), from which we identified 507 fire scars and 42 eroded fire scars (fig. 3).

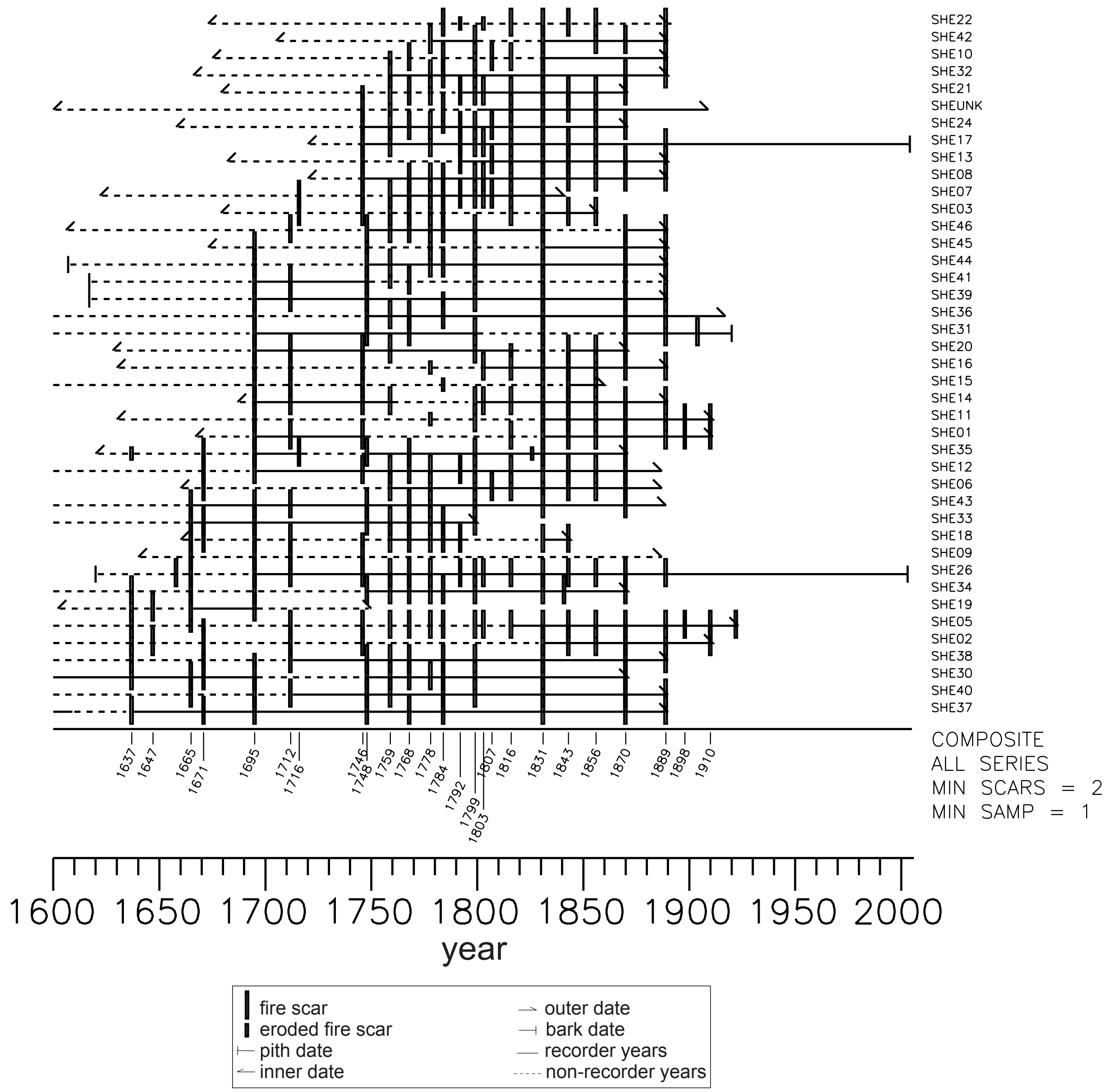


Figure 3—Fire chart for SHE. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

From the composite fire-scar record of 21 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 35-acre sampling area every 11 years on average (range 2 to 30 years; fig. 4, table 5) and these fires scarred an average of 71 percent of the sampled trees that were recording (range 19 to 100 percent). We were able to assign an intra-ring position to approximately ½ (54 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, about ¼ were created by fires burning when the cambium was dormant (26 percent ring-boundary scars; fig. 5). The remaining scars were created during the growing season, and most of these were formed late in that season (23 percent in the earlywood versus 51 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest (code 1045; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Ponderosa Pine Woodland and Savanna (code 10530; Comer and others 2003).

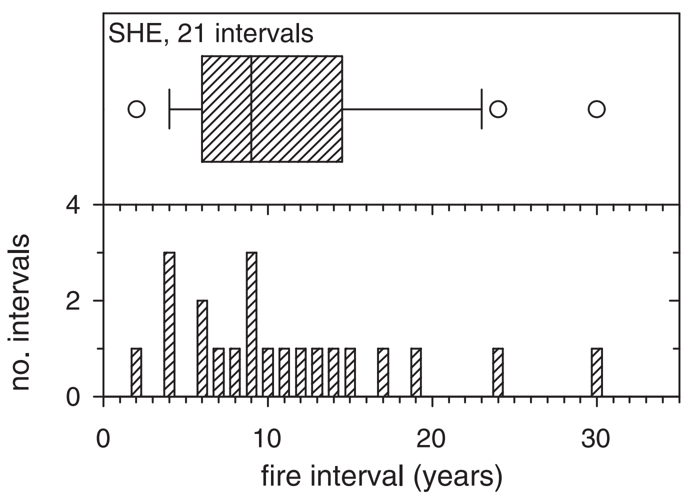


Figure 4—Composite fire intervals for SHE, determined as the intervals between years with fire scars on two or more trees over the 35-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10th to 90th percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 5—Fire years with scars on two or more trees at SHE.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1571	2	0	2	100	.
1594	3	0	3	100	23
1637	7	1	7	100	43
1647	2	0	4	50	10
1665	9	1	10	100	18
1671	8	2	10	100	6
1695	24	1	24	100	24
1712	16	0	21	76	17
1716	3	0	16	19	4
1746	17	2	25	76	30
1748	14	1	21	71	2
1759	21	3	27	96	11
1768	21	0	28	79	9
1778	20	2	28	79	10
1784	18	3	29	76	6
1792	8	1	26	38	8
1799	28	0	31	90	7
1803	8	1	26	35	4
1807	5	0	26	19	4
1816	17	1	30	60	9
1831	37	1	38	100	15
1843	19	0	34	56	12
1856	20	0	33	61	13
1870	30	0	33	91	14
1889	24	0	25	96	19
1898	3	0	9	33	9
1910	4	0	8	50	12

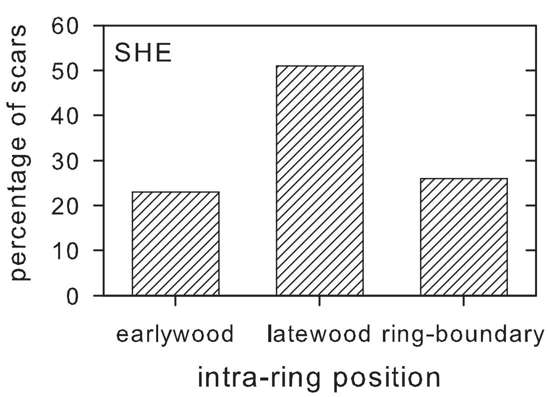


Figure 5—Intra-ring position of fire scars on ponderosa pine trees at SHE during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

SML (Sawmill Creek Research Natural Area) Bitterroot National Forest, Stevensville Ranger District

During the 13th Annual North American Dendroecological Fieldweek in 2003, we removed fire-scarred partial cross sections from 35 trees (34 ponderosa pine and one Douglas-fir) over a sampling area of 109 acres (fig. 1, table 2). Many of these trees were dead when sampled (60 percent stumps, logs, or snags). We were able to crossdate samples from 32 of these trees (91 percent), from which we identified 220 fire scars and 17 eroded fire scars (fig. 6).

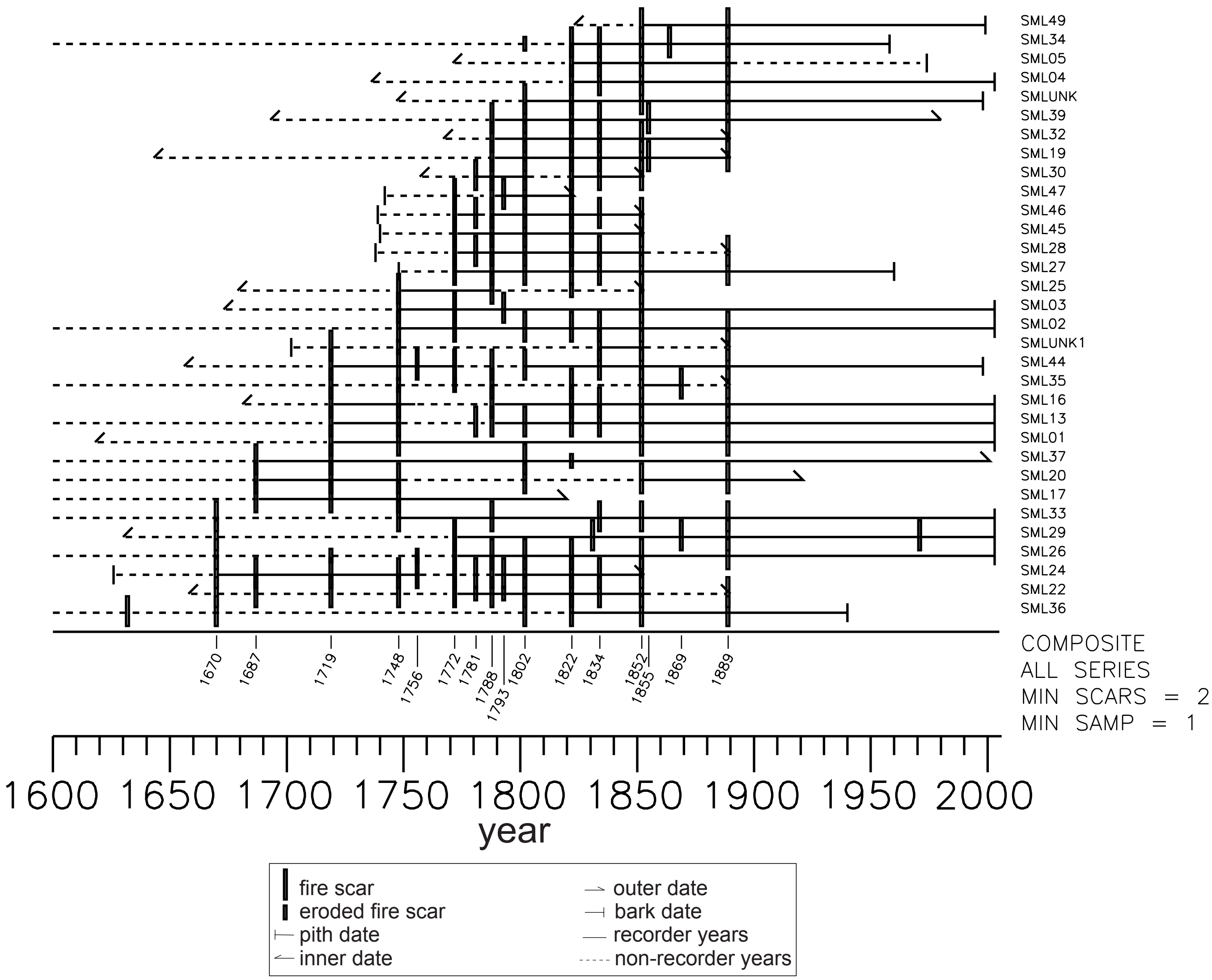


Figure 6—Fire chart for SML. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

From the composite fire-scar record of 15 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 109-acre sampling area every 15 years on average (range 3 to 32 years; fig. 7, table 6) and these fires scarred an average of 67 percent of the sampled trees that were recording (range 9 to 100 percent). We were able to assign an intra-ring position to approximately ½ (52 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, nearly ½ were created by fires burning when the cambium was dormant (43 percent ring-boundary scars; fig. 8). The remaining scars were created during the growing season, and most of these were formed late in that season (21 percent in the earlywood versus 36 percent in the latewood). Preliminary results from this site were reported in Gayton and others (2006). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest (code 1045; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland (code 11390; Comer and others 2003).

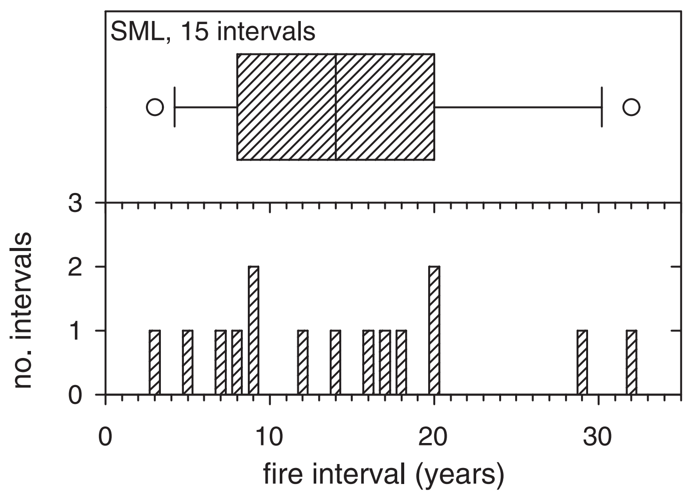


Figure 7—Composite fire intervals for SML, determined as the intervals between years with fire scars on two or more trees over the 109-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10th to 90th percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 6—Fire years with scars on two or more trees at SML.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1670	6	0	6	100	.
1687	5	0	5	100	17
1719	11	1	11	100	32
1748	12	2	13	100	29
1756	2	1	9	33	8
1772	12	1	17	76	16
1781	5	1	17	35	9
1788	18	0	24	75	7
1793	3	1	21	19	5
1802	19	1	25	80	9
1822	21	2	27	89	20
1834	18	0	26	69	12
1852	27	0	30	90	18
1855	2	0	22	9	3
1869	2	0	22	9	14
1889	23	0	25	92	20

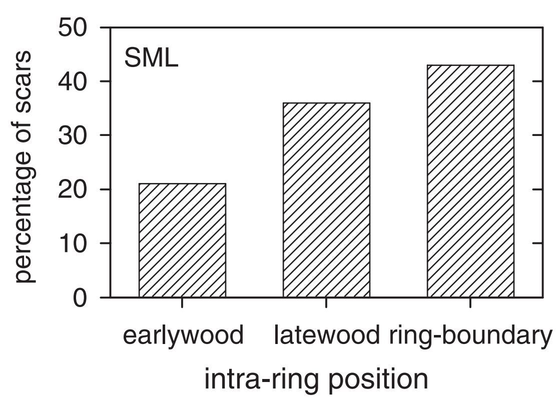


Figure 8—Intra-ring position of fire scars on ponderosa pine trees at SML during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

BAN (Bannock Creek) Boise National Forest, Idaho City Ranger District

In 2005, under the direction of Peter Brown, Penelope Morgan, and Elaine Kennedy Sutherland, members of the 15th Annual North American Dendroecological Fieldweek removed fire-scarred partial cross sections from 30 ponderosa pine trees over a sampling area of 69 acres (fig. 1, table 2; Brown and others 2005). We crossdated samples from 24 of these trees, those with the greatest number of well-preserved scars, from which we identified 314 fire scars and nine eroded fire scars (fig. 9). From the composite fire-scar record of 26 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the

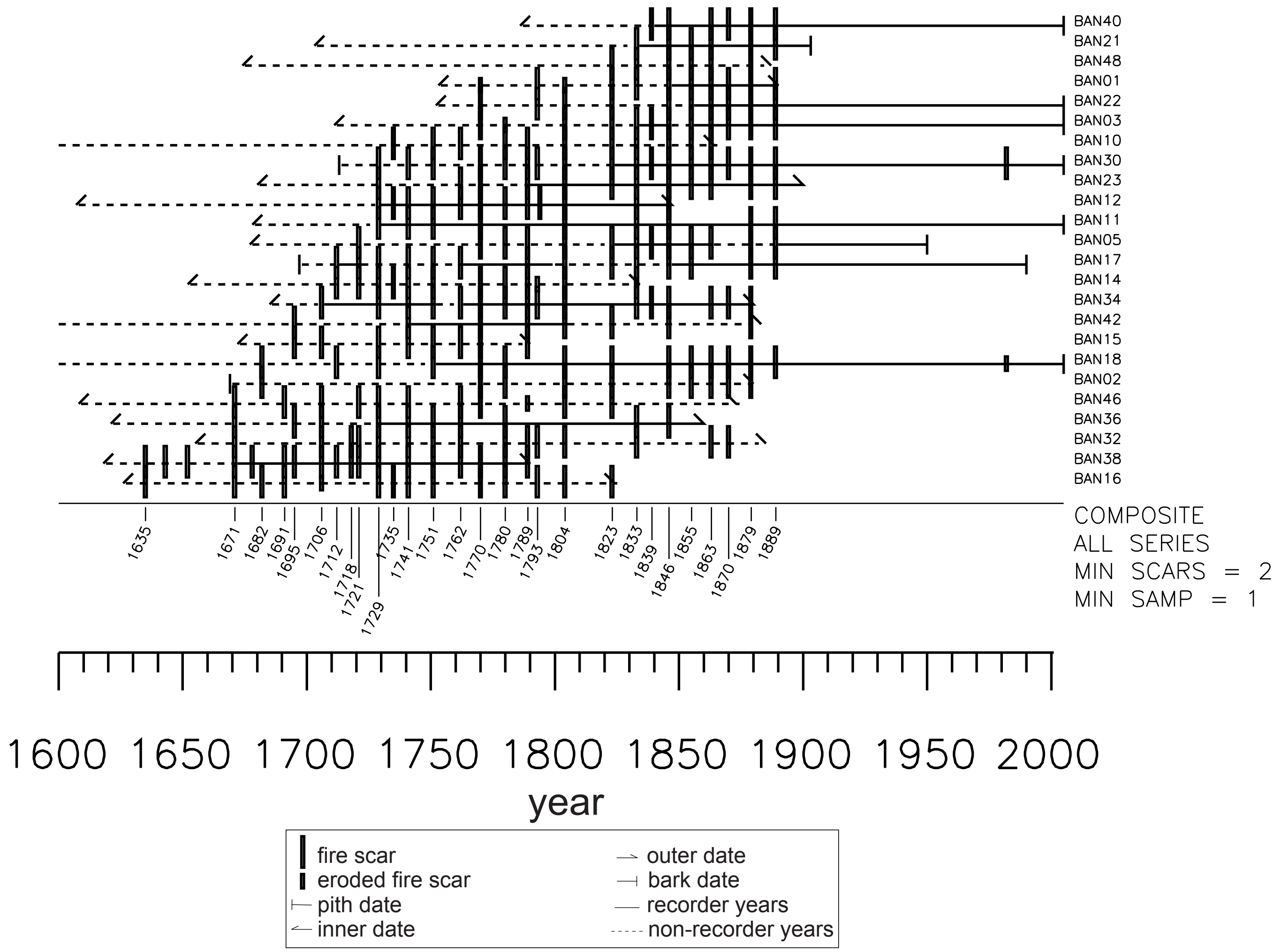


Figure 9—Fire chart for BAN. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

69-acre sampling area every 8 years on average (range 3 to 19 years; fig. 10, table 7) and these fires scarred an average of 85 percent of the sampled trees that were recording (range 45 to 100 percent). We were able to assign an intra-ring position to nearly ½ (46 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, nearly ½ were created by fires burning when the cambium was dormant (46 percent ring-boundary scars; fig. 11). The remaining scars were created during the growing season, and most of these were formed late in that season (12 percent in the earlywood versus 42 percent in the latewood). Samples were also removed from this site for a previous study but were not crossdated (Steele and others 1986), and these samples were subsequently destroyed. The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Ponderosa Pine Woodland and Savanna (code 1053; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Ponderosa Pine Woodland and Savanna (code 10530; Comer and others 2003).

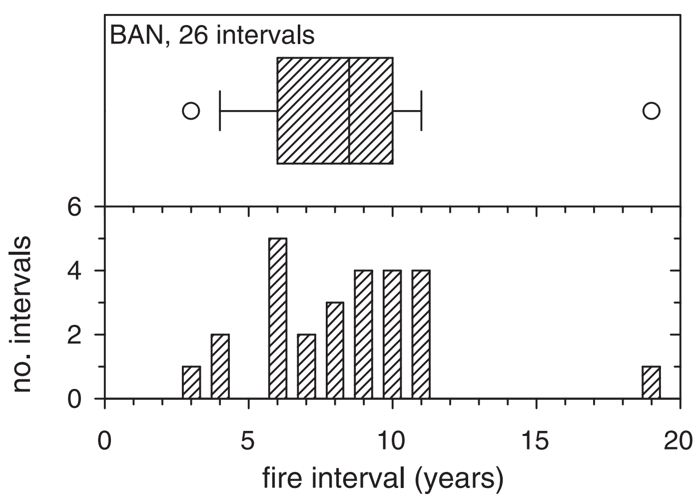


Figure 10—Composite fire intervals for BAN, determined as the intervals between years with fire scars on two or more trees over the 69-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10th to 90th percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 7—Fire years with scars on two or more trees at BAN.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1635	2	0	2	100	.
1671	5	0	5	100	36
1682	3	0	4	75	11
1691	3	0	3	100	9
1695	4	0	4	100	4
1706	6	1	8	100	11
1712	4	0	5	80	6
1718	2	0	4	50	6
1721	6	0	7	86	3
1729	14	0	14	100	8
1735	4	0	8	50	6
1741	13	0	13	100	6
1751	13	0	14	93	10
1762	10	0	13	77	11
1770	16	1	18	94	8
1780	12	1	15	87	10
1789	12	1	15	87	9
1793	6	1	13	54	4
1804	17	1	18	100	11
1823	14	0	18	78	19
1833	15	0	16	94	10
1839	5	0	11	45	6
1846	18	0	18	100	7
1855	12	0	16	75	9
1863	14	0	16	88	8
1870	9	0	13	69	7
1879	15	0	15	100	9
1889	11	0	11	100	10

Figure 11—Intra-ring position of fire scars on ponderosa pine trees at BAN during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

LOW (Lowman Research Natural Area)
Boise National Forest, Lowman Ranger District

In 2004, we removed fire-scarred partial cross sections from 11 ponderosa pine trees over a sampling area of 57 acres (fig. 1, table 2). All of these trees were dead when sampled (stumps, logs, or snags). We were able to crossdate samples from nine of these trees (82 percent), from which we identified 77 fire scars and 12 eroded fire scars (fig. 12). From the composite fire-scar record of 8 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 57-acre sampling area every 29 years on average (range 14 to 47 years; fig. 13, table 8) and these fires scarred an average of 92 percent of the sampled trees that were recording (range 50 to 100 percent). We were able to assign an intra-ring position to about 1/3 (36 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, most were created by fires burning when the cambium was dormant (75 percent ring-boundary scars; fig. 14). The remaining scars were created during the growing season, and all of these were formed late in that season (0 percent in the earlywood versus 25 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest (code 1045; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir (code 10451; Comer and others 2003).

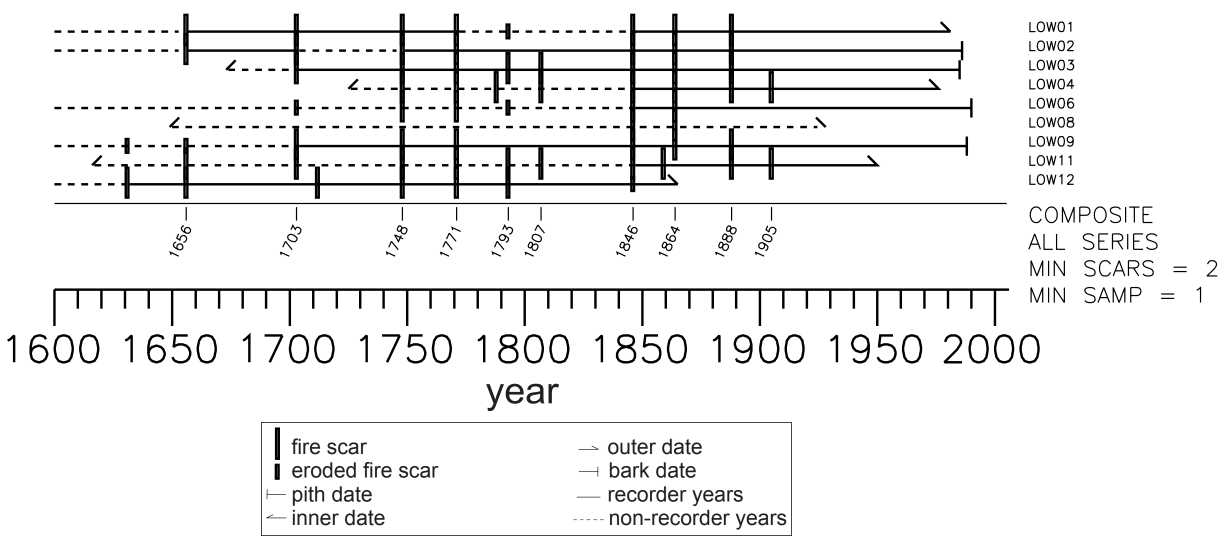


Figure 12—Fire chart for LOW. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

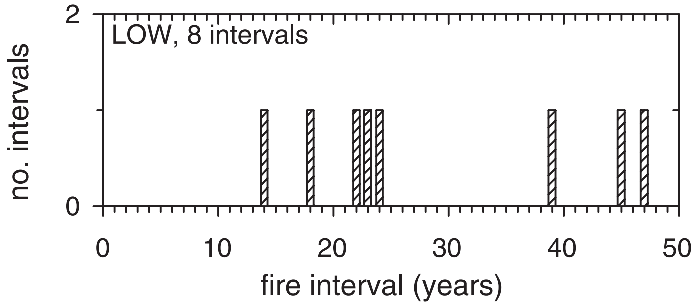


Figure 13—Composite fire intervals for LOW, determined as the intervals between years with fire scars on two or more trees over the 57-acre sampling area during the period from 1650 to 1900. There were too few intervals to create a box plot for this site.

Table 8—Fire years with scars on two or more trees at LOW.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1656	4	1	4	100	.
1703	5	1	6	100	47
1748	8	0	8	100	45
1771	8	0	8	100	23
1793	3	2	5	100	22
1807	3	0	6	50	14
1846	8	1	9	100	39
1864	7	0	9	78	18
1888	6	0	7	100	24
1905	2	0	7	29	17

Figure 14—Intra-ring position of fire scars on ponderosa pine trees at LOW during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

WSH (Wash Creek) Boise National Forest, Emmet Ranger District

In 2004, we removed fire-scarred partial cross sections from 29 ponderosa pine trees over a sampling area of 77 acres (fig. 1, table 2). All of these trees were dead when sampled (stumps, logs, or snags). We were able to crossdate samples from 25 of these trees (86 percent), from which we identified 480 fire scars and 43 eroded fire scars (fig. 15). From the composite fire-scar record of 20 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 77-acre sampling area every 11 years on average (range 1 to 22 years; fig. 16, table 9) and these fires scarred an average of 76 percent of the sampled trees that were recording (range 10 to 100 percent).

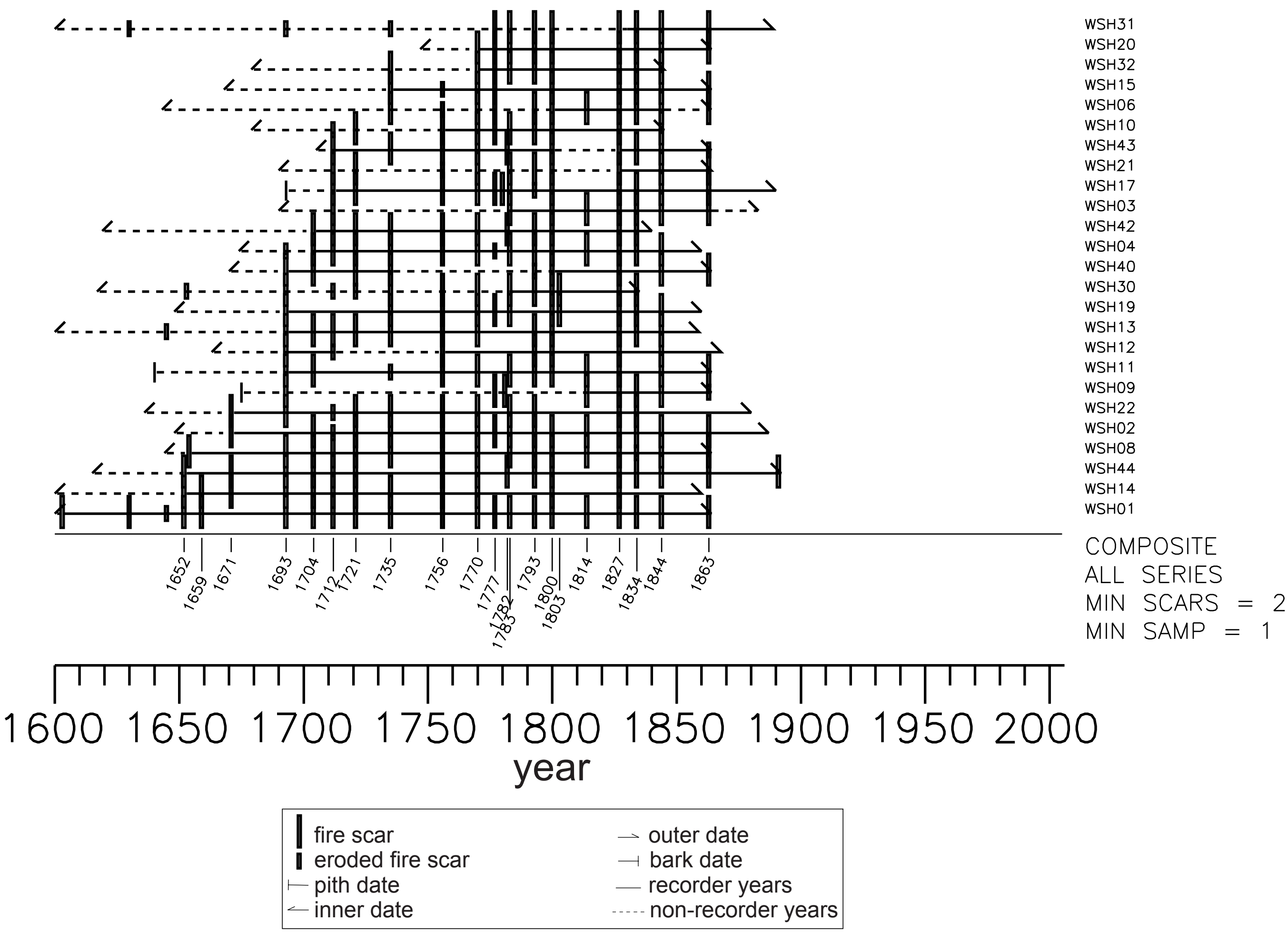


Figure 15—Fire chart for WSH. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

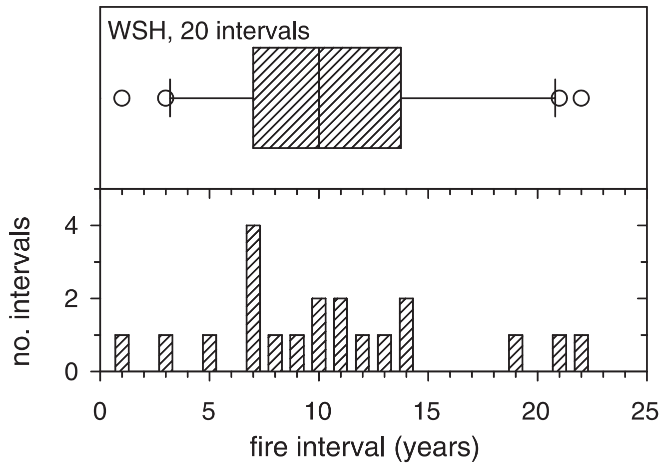


Figure 16—Composite fire intervals for WSH, determined as the intervals between years with fire scars on two or more trees over the 77-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10th to 90th percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 9—Fire years with scars on two or more trees at WSH.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1652	3	0	3	100	.
1659	2	0	4	50	7
1671	4	0	6	67	12
1693	12	2	13	100	22
1704	10	0	13	77	11
1712	11	5	17	94	8
1721	13	1	16	88	9
1735	15	2	18	94	14
1756	16	3	17	100	21
1770	20	0	21	100	14
1777	11	1	21	57	7
1782	3	0	18	17	5
1783	15	0	22	68	1
1793	17	2	23	83	10
1800	23	0	24	96	7
1803	2	0	21	10	3
1814	8	0	22	36	11
1827	25	0	25	100	13
1834	18	1	25	76	7
1844	21	0	23	91	10
1863	13	0	17	94	19

We were able to assign an intra-ring position to about 2/3 (62 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, over ½ were created by fires burning when the cambium was dormant (59 percent ring-boundary scars; fig. 17). The remaining scars were created during the growing season, and most of these were formed late in that season (6 percent in the earlywood versus 35 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest (code 1045; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland (code 11390; Comer and others 2003).

Figure 17—Intra-ring position of fire scars on ponderosa pine trees at WSH during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

WSR (Warm Springs Ridge) Boise National Forest, Idaho City Ranger District

In 2004, we removed fire-scarred partial cross sections from 27 trees (26 ponderosa pine and one Douglas-fir) over a sampling area of 37 acres (fig. 1, table 2). All of these trees were dead when sampled (stumps, logs, or snags). We were able to crossdate samples from all of these trees, from which we identified 505 fire scars and 32 eroded fire scars (fig. 18).

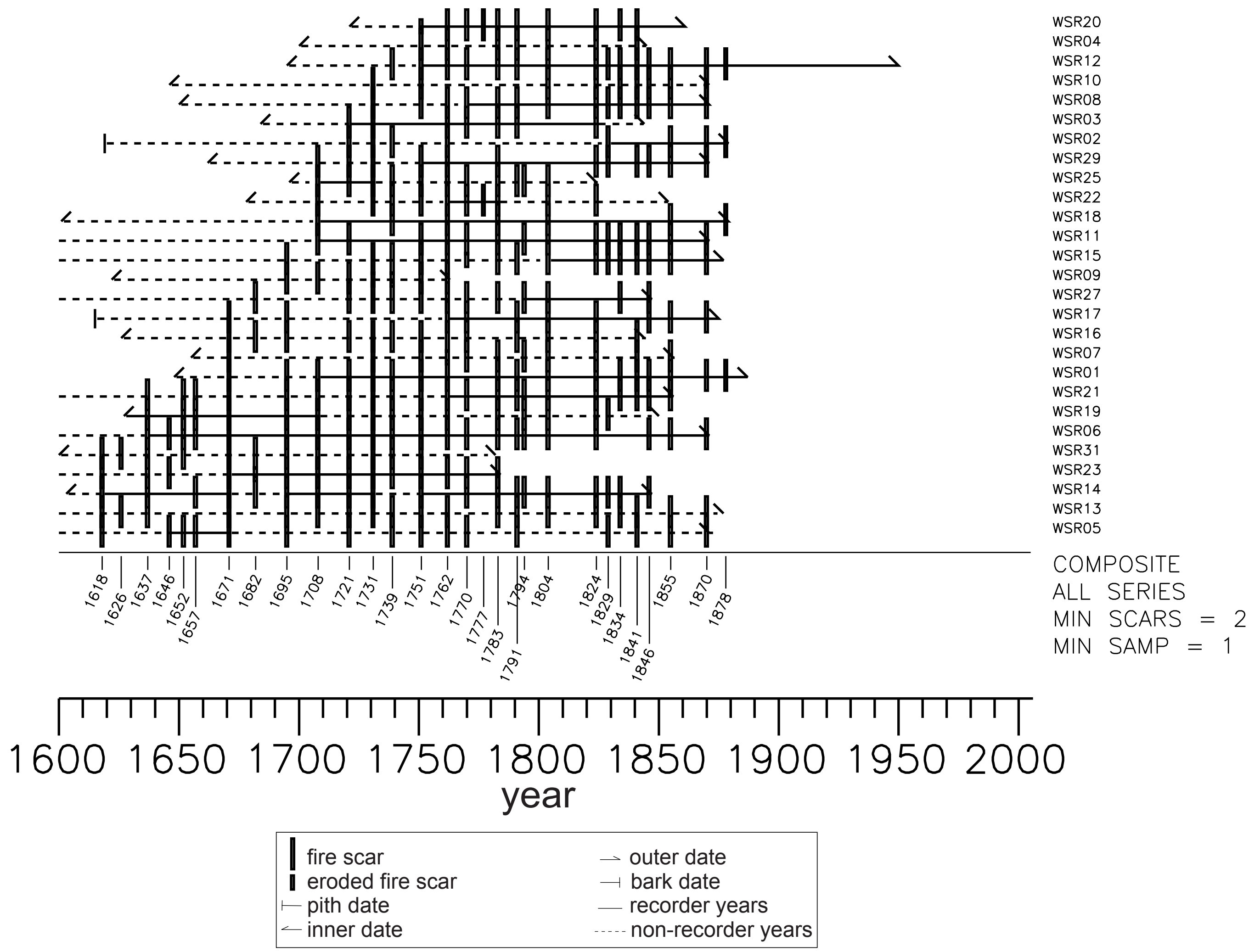


Figure 18—Fire chart for WSR. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

From the composite fire-scar record of 24 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 37-acre sampling area every 9 years on average (range 3 to 20 years; fig. 19, table 10) and these fires scarred an average of 84 percent of the sampled trees that were recording (range 14 to 100 percent). We were able to assign an intra-ring position to about 1/3 (35 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, nearly ½ were created by fires burning when the cambium was dormant (43 percent ring-boundary scars; fig. 20). The remaining scars were created during the growing season, and most of these were formed late in that season (17 percent in the earlywood versus 40 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Ponderosa Pine Woodland and Savanna (code 1053; Comer and others 2003). We placed this EsP in the woodland category (Morgan and others 2008). The dominant BpS is Northern Rocky Mountain Ponderosa Pine Woodland and Savanna (code 10530; Comer and others 2003).

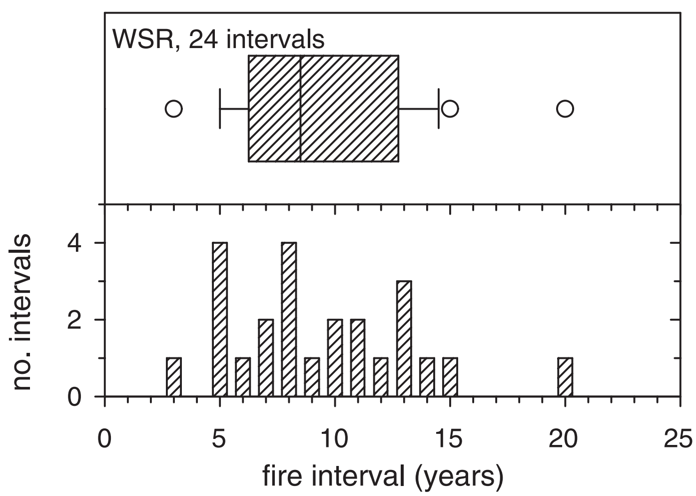


Figure 19—Composite fire intervals for WSR, determined as the intervals between years with fire scars on two or more trees over the 37-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10th to 90th percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 10—Fire years with scars on two or more trees at WSR.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1618	5	0	5	100	.
1626	2	0	3	67	8
1637	7	0	7	100	11
1646	3	0	5	60	9
1652	5	0	6	83	6
1657	5	0	5	100	5
1671	12	0	12	100	14
1682	4	1	7	71	11
1695	13	0	13	100	13
1708	14	0	14	100	13
1721	17	0	18	94	13
1731	19	1	21	95	10
1739	16	1	18	94	8
1751	22	1	25	92	12
1762	23	1	24	100	11
1770	16	1	19	89	8
1777	2	0	14	14	7
1783	20	0	21	95	6
1791	15	0	18	83	8
1794	8	0	16	50	3
1804	20	0	22	91	10
1824	19	0	21	90	20
1829	9	0	16	56	5
1834	11	0	16	69	5
1841	14	0	20	70	7
1846	12	0	15	80	5
1855	15	0	16	94	9
1870	12	0	13	92	15
1878	4	0	4	100	8

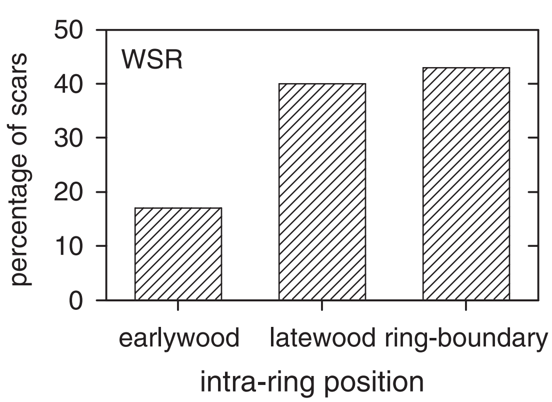


Figure 20—Intra-ring position of fire scars on ponderosa pine trees at WSR during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

CRN (Crane Lookout) Flathead National Forest, Swan Lake Ranger District

In 2005, we removed fire-scarred partial cross sections from 19 ponderosa pine trees over a sampling area of 45 acres (fig. 1, table 2). Most of these trees were dead when sampled (79 percent logs or snags). We were able to crossdate samples from 18 of these trees (95 percent), from which we identified 239 fire scars and seven eroded fire scars (fig. 21). From the composite fire-scar record of 15 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 45-acre sampling area every 16 years on average (range 7 to 31 years; fig. 22, table 11) and these fires scarred an average of 71 percent of the sampled trees that were recording (range 23 to 100 percent). We were able to assign an intra-ring position to nearly ½ (46 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, over ½ were created by fires burning when the cambium was dormant (52 percent ring-boundary scars; fig. 23).

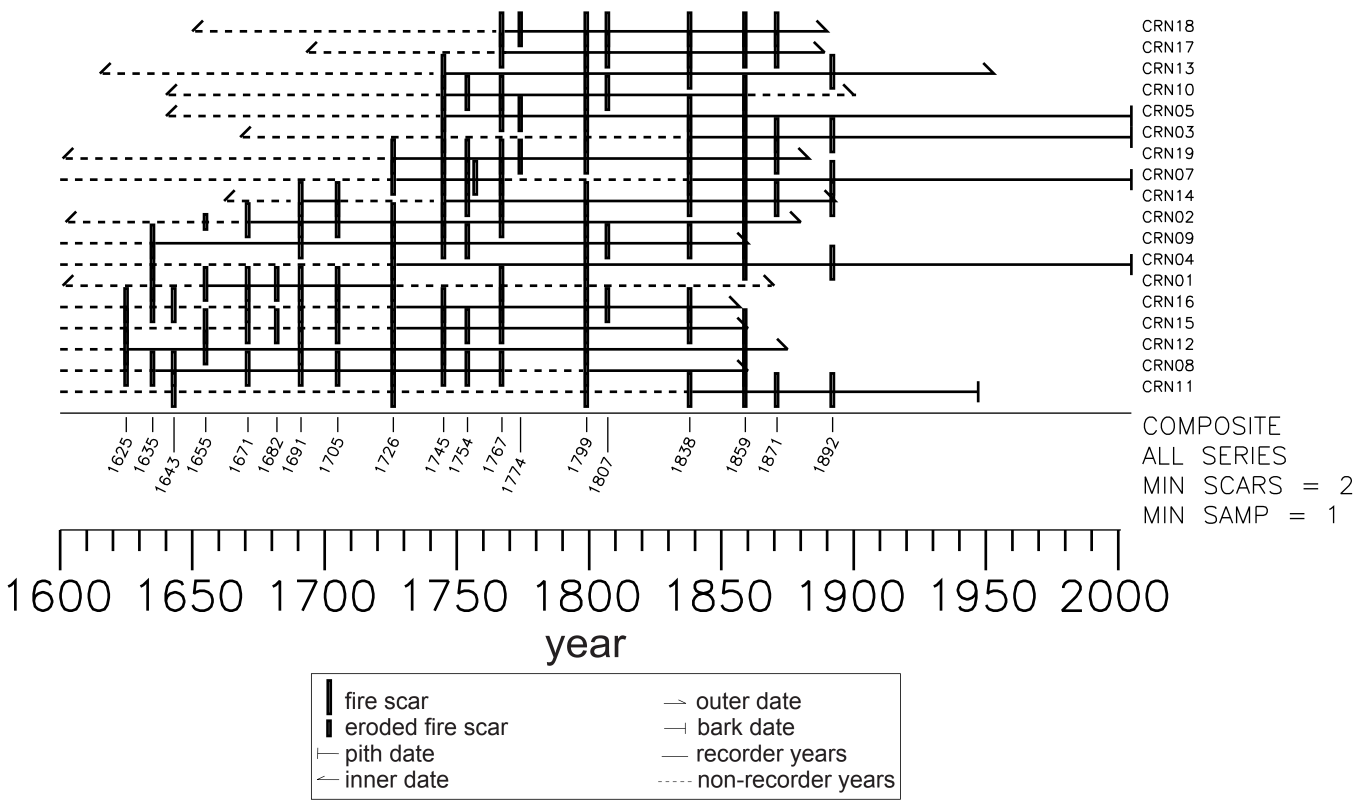


Figure 21—Fire chart for CRN. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

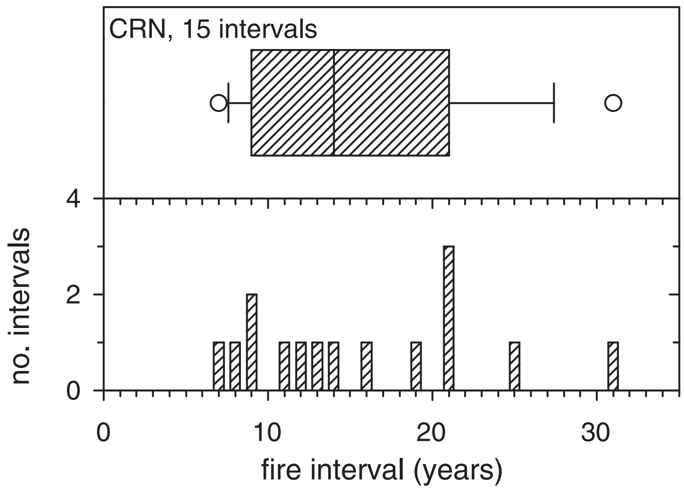


Figure 22—Composite fire intervals for CRN, determined as the intervals between years with fire scars on two or more trees over the 45-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10th to 90th percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 11—Fire years with scars on two or more trees at CRN.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1583	2	0	2	100	.
1625	4	0	4	100	42
1635	5	0	6	83	10
1643	3	0	5	60	8
1655	3	1	5	80	12
1671	5	0	7	71	16
1682	2	0	6	33	11
1691	8	0	8	100	9
1705	6	0	8	75	14
1726	11	0	11	100	21
1745	13	0	14	93	19
1754	7	0	13	54	9
1767	12	0	16	75	13
1774	3	0	13	23	7
1799	17	0	17	100	25
1807	5	0	14	36	8
1838	12	0	17	71	31
1859	15	0	16	94	21
1871	6	0	12	50	12
1892	6	0	7	86	21

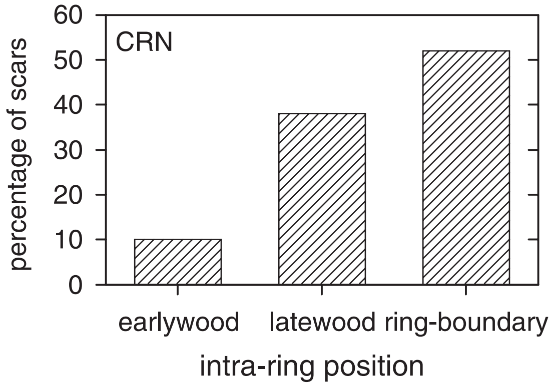


Figure 23—Intra-ring position of fire scars on ponderosa pine trees at CRN during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

The remaining scars were created during the growing season, and most of these were formed late in that season (10 percent in the earlywood versus 38 percent in the latewood). Samples had also been removed from this site for a previous study (Barrett 1998), but those samples were not crossdated and were subsequently destroyed. The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest (code 1045; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Grand Fir (code 10453; Comer and others 2003).

HOL (Holland Lake Road) Flathead National Forest, Swan Lake Ranger District

In 2005, we removed fire-scarred partial cross sections from 22 trees (20 ponderosa pine and two western larch) over a sampling area of 94 acres (fig. 1, table 2). Most of these trees were dead when sampled (95 percent stumps, logs, or snags). We were able to crossdate samples from 19 of these trees (86 percent), from which we identified 206 fire scars and 20 eroded fire scars (fig. 24). From the composite fire-scar record of 14 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 94-acre sampling area every 15 years on average (range 3 to 30 years; fig. 25, table 12) and these fires scarred an average of 82 percent of the sampled trees that were recording (range 50 to 100 percent). We were able to assign an intra-ring position to nearly ½ (44 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, about 2/3 were created by fires burning when the cambium was dormant (68 percent ring-boundary scars; fig. 26). The remaining scars were created during the growing season, and most of these were formed late in that season (3 percent in the earlywood versus 29 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Rocky Mountain Montane Riparian Systems (code 1159; Comer and others 2003). The dominant BpS is Rocky Mountain Montane Riparian Systems (code 11590; Comer and others 2003).

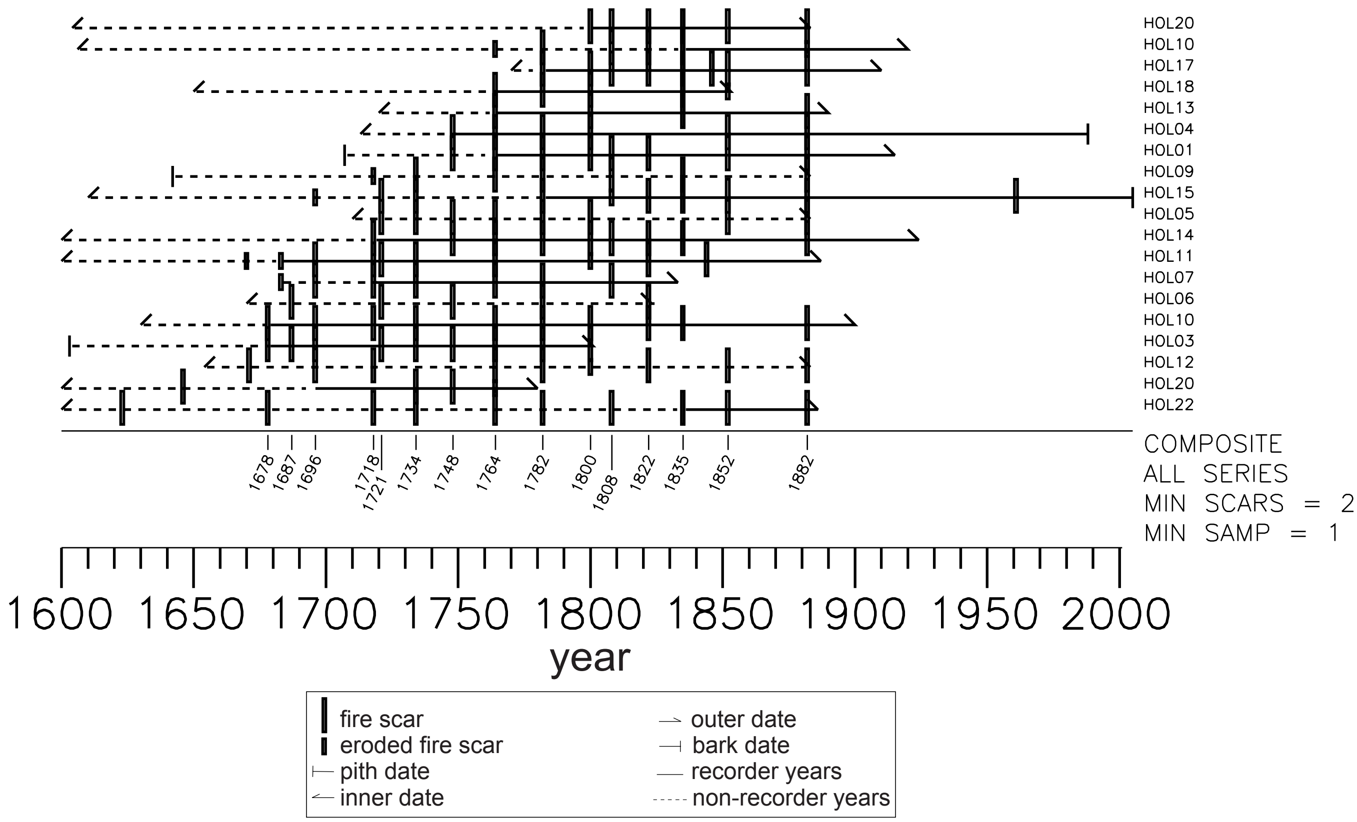


Figure 24—Fire chart for HOL. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

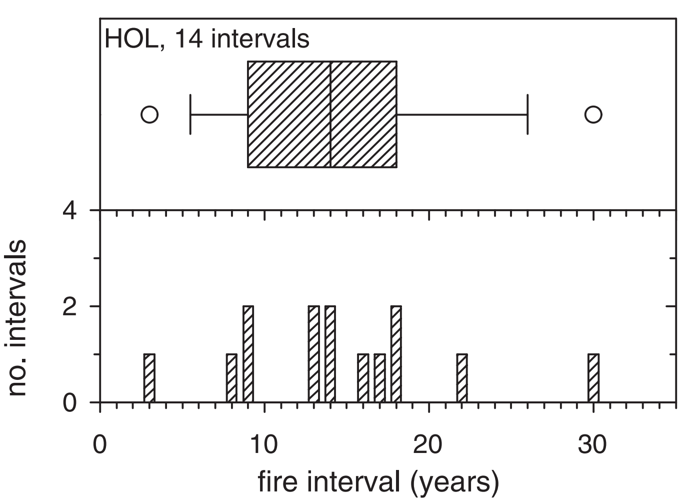


Figure 25—Composite fire intervals for HOL, determined as the intervals between years with fire scars on two or more trees over the 94-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10th to 90th percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 12—Fire years with scars on two or more trees at HOL.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1678	3	0	3	100	.
1687	2	0	4	50	9
1696	5	1	6	100	9
1718	6	1	8	88	22
1721	5	0	9	56	3
1734	9	1	10	100	13
1748	7	0	10	80	14
1764	13	2	14	100	16
1782	15	0	17	88	18
1800	10	2	13	92	18
1808	8	1	14	64	8
1822	10	0	14	79	14
1835	10	0	13	77	13
1852	8	1	14	64	17
1882	12	1	14	93	30

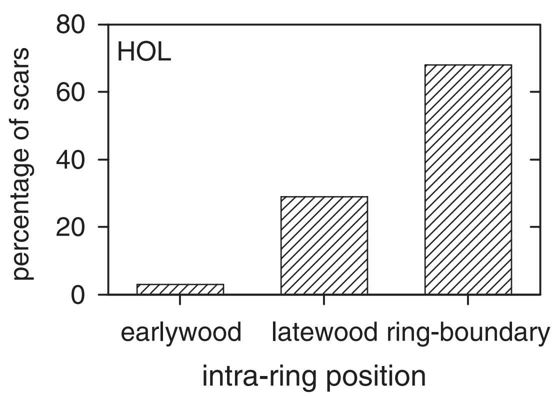


Figure 26—Intra-ring position of fire scars on ponderosa pine trees at HOL during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

LIB (Sheldon Flats) Kootenai National Forest, Libby Ranger District

In 2004, we removed fire-scarred partial cross sections from 29 trees (28 ponderosa pine and one western larch) over a sampling area of 89 acres (fig. 1, table 2). All of these trees were dead when sampled (stumps). We were able to crossdate samples from all of these trees, from which we identified 546 fire scars and 68 eroded fire scars (fig. 27). From the composite fire-scar record of 32 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 89-acre sampling area every 6 years on average (range 2 to 17 years; fig. 28, table 13) and these fires scarred an average of 60 percent of the sampled trees that were recording (range 21 to 100 percent). We were able to assign an intra-ring position to over ½ (60 percent) of

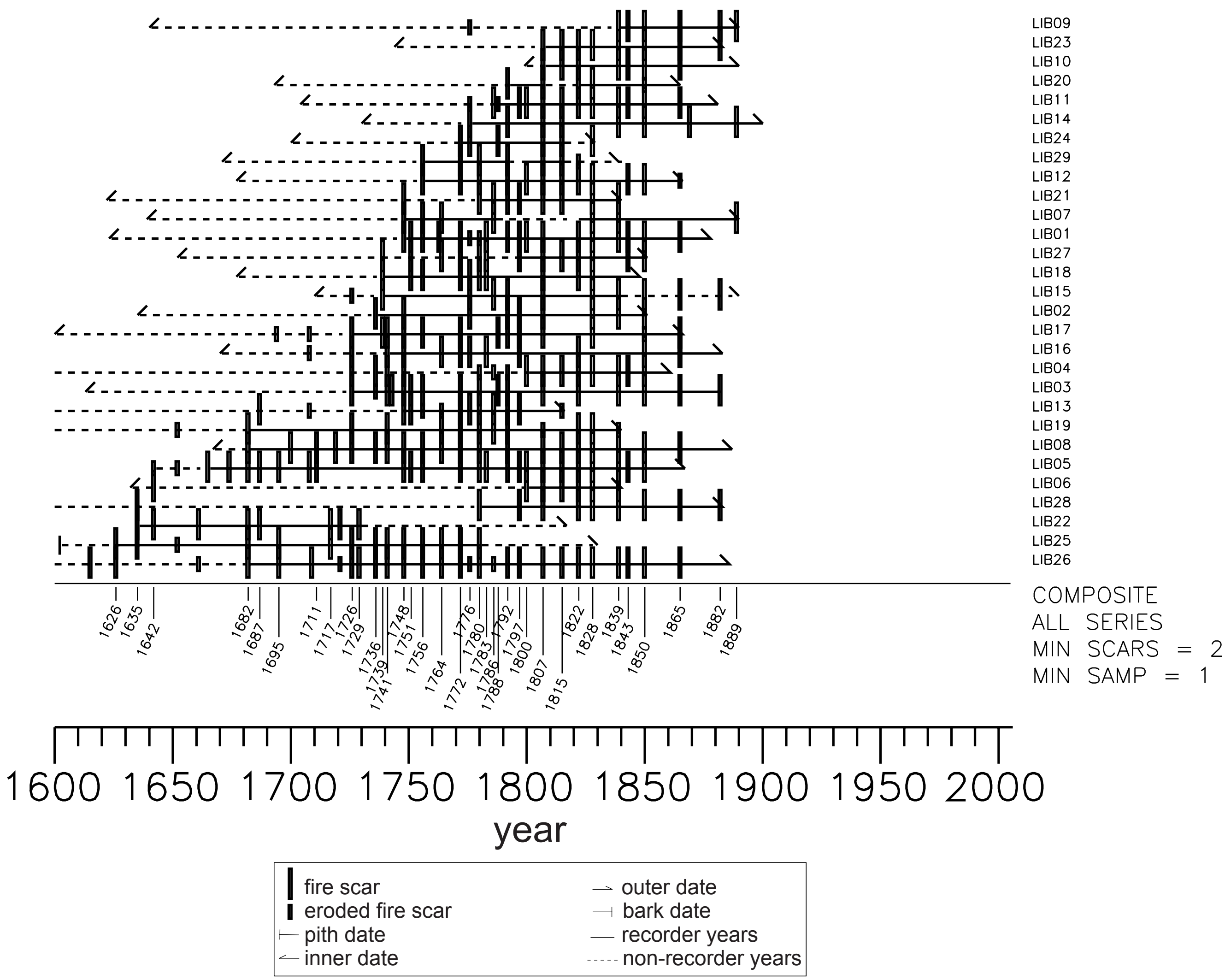


Figure 27—Fire chart for LIB. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, 1/3 were created by fires burning when the cambium was dormant (35 percent ring-boundary scars; fig. 29). The remaining scars were created during the growing season, and most of these were formed late in that season (22 percent in the earlywood versus 43 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest (code 1045; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir (code 10451; Comer and others 2003).

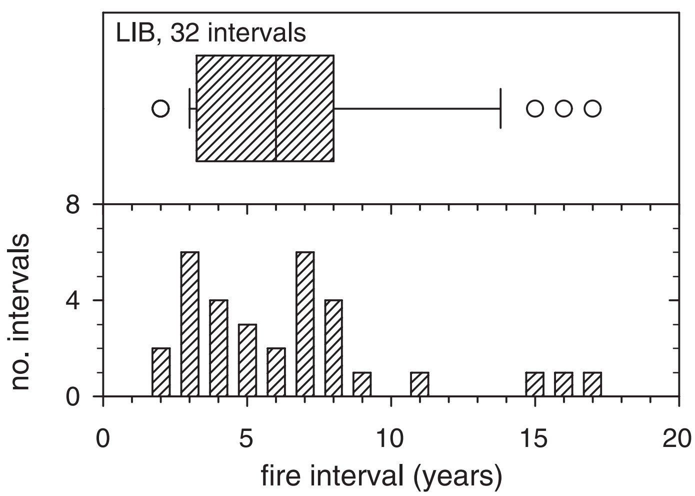


Figure 28—Composite fire intervals for LIB, determined as the intervals between years with fire scars on two or more trees over the 89-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10th to 90th percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 13—Fire years with scars on two or more trees at LIB.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1626	2	0	2	100	.
1635	3	0	3	100	9
1642	2	1	3	100	7
1682	6	0	6	100	40
1687	3	0	7	43	5
1695	3	0	6	50	8
1711	2	0	6	33	16
1717	2	0	6	33	6
1726	8	1	10	90	9
1729	2	0	8	25	3
1736	5	1	9	67	7
1739	4	0	11	36	3
1741	8	0	12	67	2
1748	13	0	16	81	7
1751	6	0	15	40	3
1756	11	1	16	75	5
1764	7	1	17	47	8
1772	15	0	18	83	8
1776	7	4	18	67	4
1780	13	2	21	71	4
1783	5	0	20	25	3
1786	6	2	20	40	3
1788	3	1	19	21	2
1792	15	1	20	80	4
1797	11	0	20	55	5
1800	6	0	23	30	3
1807	22	1	25	92	7
1815	14	1	24	63	8
1822	17	1	23	78	7
1828	20	0	24	83	6
1839	17	1	24	75	11
1843	9	0	20	45	4
1850	17	2	20	95	7
1865	12	1	16	81	15
1882	5	0	11	45	17
1889	3	0	4	75	7

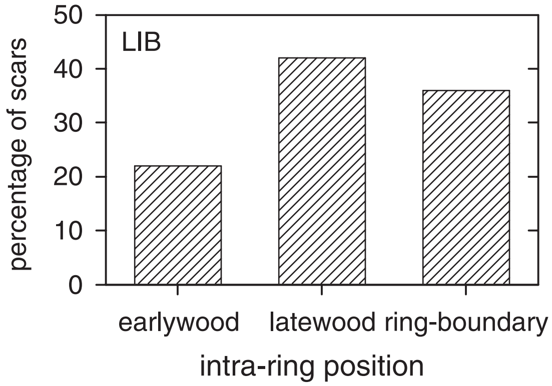


Figure 29—Intra-ring position of fire scars on ponderosa pine trees at LIB during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

MCM (McMillan Mountain) Kootenai National Forest, Libby Ranger District

In 2004, we removed fire-scarred partial cross sections from 33 ponderosa pine trees over a sampling area of 20 acres (fig. 1, table 2). All of these trees were dead when sampled (one log, the rest stumps). We were able to crossdate samples from 32 of these trees (97 percent), from which we identified 512 fire scars and 44 eroded fire scars (fig. 30). From the composite fire-scar record of 19 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 20-acre sampling area every 12 years on average (range 4 to 25 years; fig. 31, table 14) and these fires scarred an average of 78 percent of the sampled trees that were recording (range 25 to 100 percent). We were able to assign an intra-ring position to ½ (52 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, over ½ were created by fires burning when the cambium was dormant (61 percent ring-boundary scars; fig. 32). The remaining scars were created during the growing season, and most of these were formed late in that season (5 percent in the earlywood versus 33 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest (code 1045; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir (code 10451; Comer and others 2003).

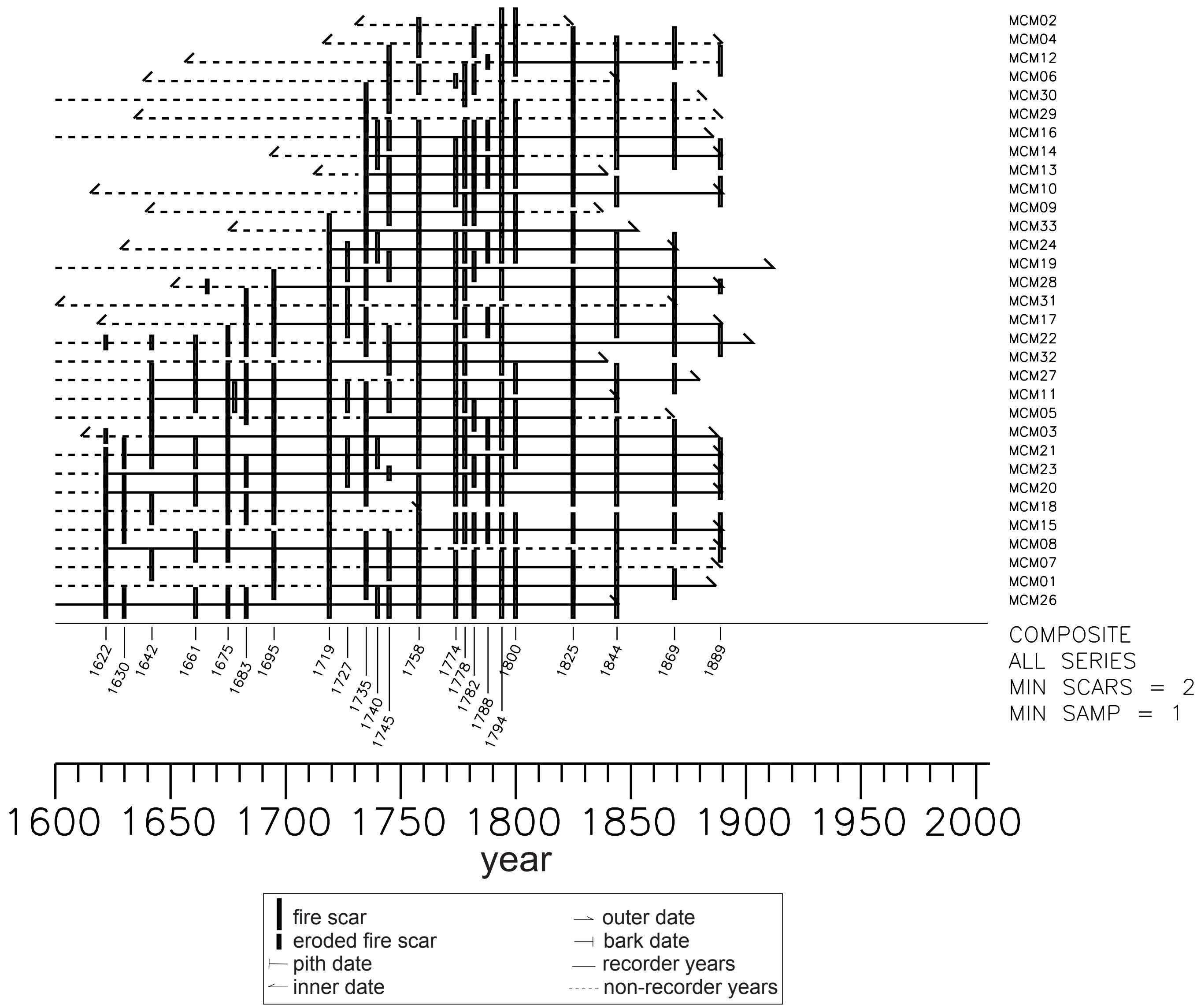


Figure 30—Fire chart for MCM. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

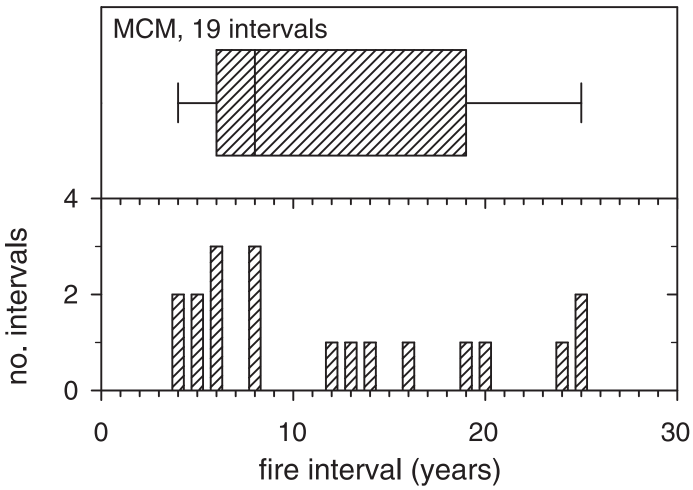


Figure 31—Composite fire intervals for MCM, determined as the intervals between years with fire scars on two or more trees over the 20-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10^{th} to 90^{th} percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 14—Fire years with scars on two or more trees at MCM.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1622	8	3	8	100	.
1630	5	0	7	71	8
1642	7	1	11	73	12
1661	7	1	9	89	19
1675	11	0	11	100	14
1683	8	1	12	75	8
1695	15	0	16	94	12
1719	20	1	20	100	24
1727	6	1	15	47	8
1735	21	0	24	88	8
1740	5	0	20	25	5
1745	14	1	24	67	5
1758	27	1	28	100	13
1774	19	2	24	88	16
1778	14	1	24	63	4
1782	14	0	25	56	4
1788	8	1	23	39	6
1794	25	1	29	90	6
1800	18	0	27	67	6
1825	25	2	28	96	25
1844	23	1	25	96	19
1869	18	1	20	95	25
1889	8	2	12	83	20

Figure 32—Intra-ring position of fire scars on ponderosa pine trees at MCM during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

HUN (Hunter Point) Kootenai National Forest, Rexford Ranger District

In 2004, we removed fire-scarred partial cross sections from 26 trees (21 ponderosa pine and five western larch) over a sampling area of 77 acres (fig. 1, table 2). Most of these trees were dead when sampled (77 percent stumps, logs, or snags). We were able to crossdate samples from 25 of these trees (96 percent), from which we identified 290 fire scars and 25 eroded fire scars (fig. 33). From the composite fire-scar record of 16 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 77-acre sampling area every 14 years on average (range 2 to 27 years; fig. 34, table 15) and these fires scarred an average of 76 percent of the sampled trees that were recording (range 17 to 100 percent). We were able to assign an intra-ring position to approximately ½ (48 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, over ½ were created by fires burning when the cambium was dormant (60 percent ring-boundary scars; fig. 35). The remaining scars were created during the growing season (17 percent in the earlywood and 23 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest (code 1045; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir (code 10451; Comer and others 2003).

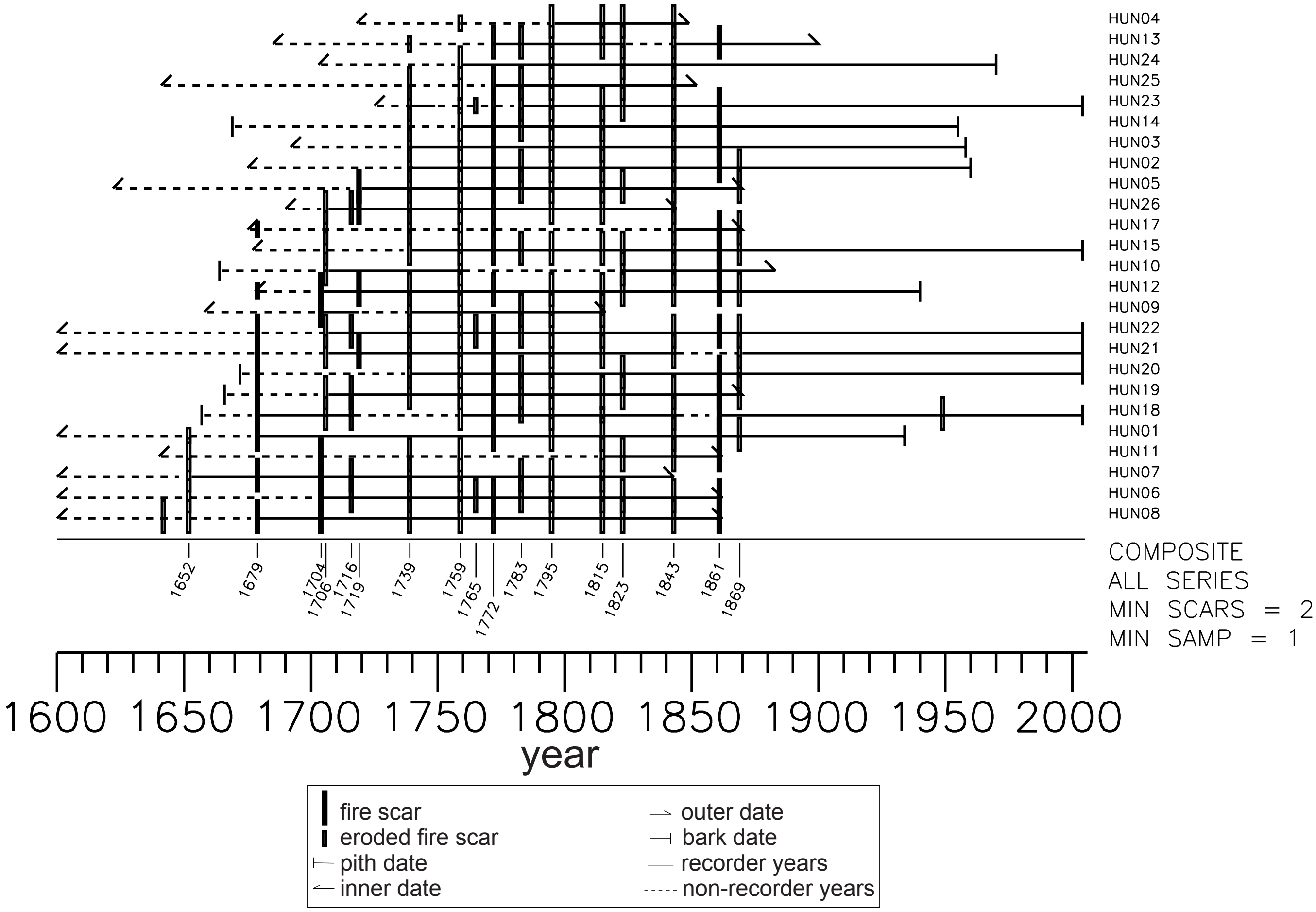


Figure 33—Fire chart for HUN. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

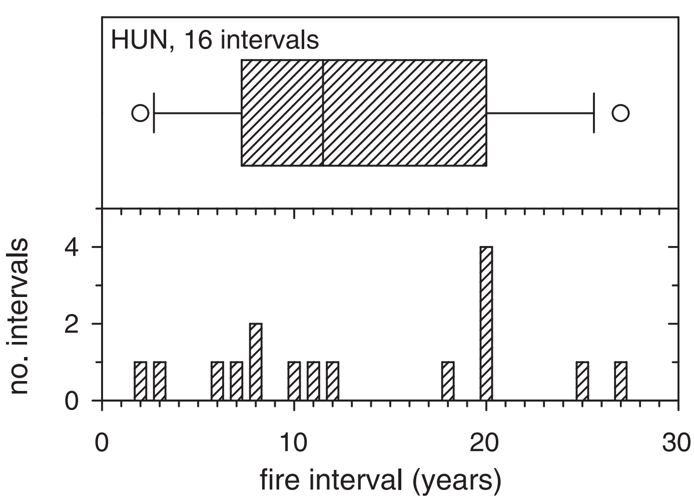


Figure 34—Composite fire intervals for HUN, determined as the intervals between years with fire scars on two or more trees over the 77-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10th to 90th percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 15—Fire years with scars on two or more trees at HUN.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1652	4	1	4	100	.
1679	8	2	9	100	27
1704	6	0	8	75	25
1706	8	0	14	57	2
1716	6	0	12	50	10
1719	4	0	12	50	3
1739	19	1	21	95	20
1759	21	2	22	100	20
1765	2	1	18	17	6
1772	18	1	21	90	7
1783	13	1	21	67	11
1795	22	0	22	100	12
1815	19	1	23	87	20
1823	14	0	23	61	8
1843	22	0	23	96	20
1861	17	0	19	89	18
1869	10	0	17	65	8

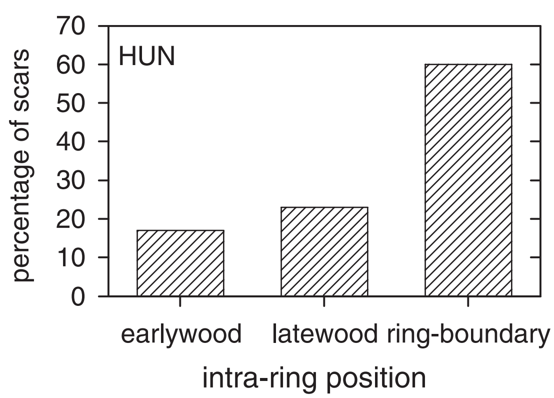


Figure 35—Intra-ring position of fire scars on ponderosa pine trees at HUN during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

VIZ (Sophie Lake) Montana State Land

In 2004, we removed fire-scarred partial cross sections from 48 ponderosa pine trees over a sampling area of 32 acres (fig. 1, table 2). All of these trees were dead when sampled (one log, the rest stumps). We were able to crossdate samples from 46 of these trees (96 percent), from which we identified 1,463 fire scars and 51 eroded fire scars (fig. 36).

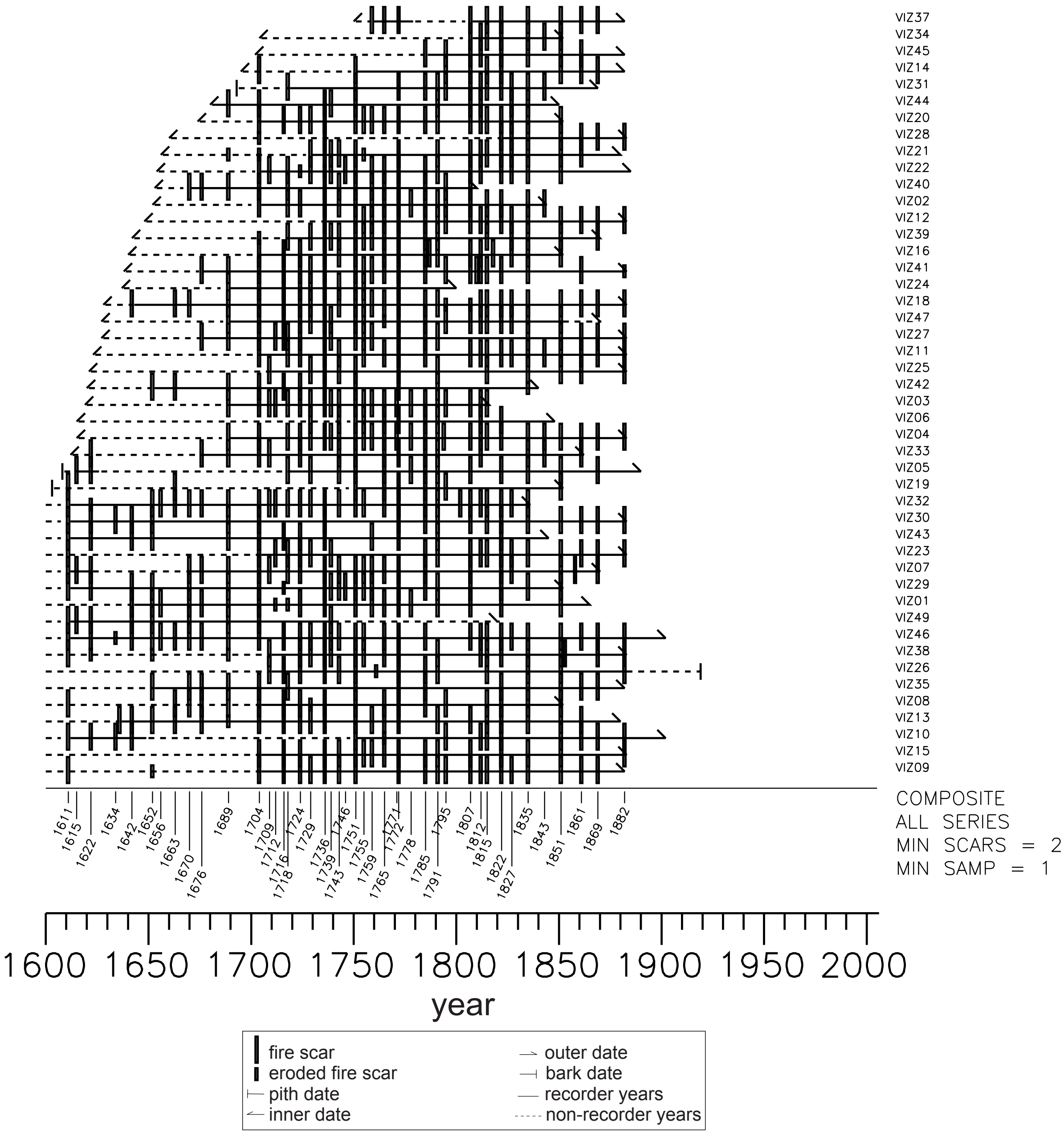


Figure 36—Fire chart for VIZ. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

From the composite fire-scar record of 37 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 32-acre sampling area every 6 years on average (range 1 to 15 years; fig. 37, table 16) and these fires scarred an average of 58 percent of the sampled trees that were recording (range 5 to 100 percent). We were able to assign an intra-ring position to 2/3 (68 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, about one third were created by fires burning when the cambium was dormant (38 percent ring-boundary scars; fig. 38). The remaining scars were created during the growing season, and most of these were formed late in that season (17 percent in the earlywood versus 45 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest (code 1045; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir (code 10451; Comer and others 2003).

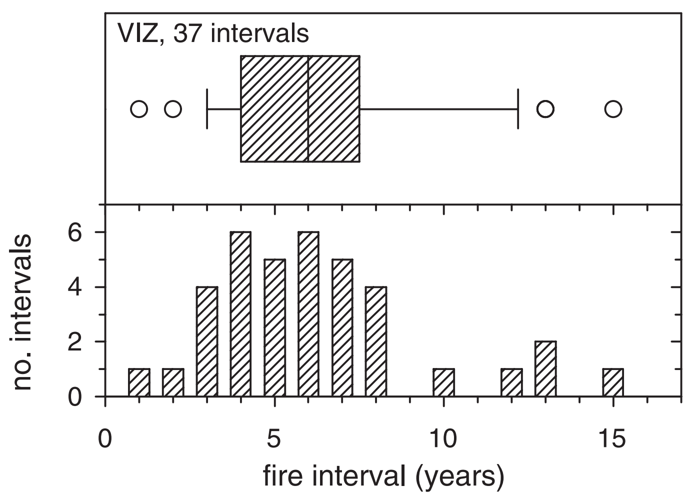


Figure 37—Composite fire intervals for VIZ, determined as the intervals between years with fire scars on two or more trees over the 32-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10^{th} to 90^{th} percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 16—Fire years with scars on two or more trees at VIZ.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1611	13	0	13	100	.
1615	3	0	9	33	4
1622	9	0	10	100	7
1634	2	1	7	43	12
1642	9	0	10	90	8
1652	10	0	11	100	10
1656	3	0	11	27	4
1663	7	0	13	54	7
1670	10	0	14	71	7
1676	11	0	17	65	6
1689	21	0	22	100	13
1704	31	0	31	100	15
1709	8	0	33	24	5
1712	4	0	33	15	3
1716	15	1	33	48	4
1718	14	1	36	42	2
1724	25	1	36	72	6
1729	19	1	38	53	5
1736	32	1	39	85	7
1739	13	0	38	34	3
1743	21	0	38	55	4
1746	2	0	37	5	3
1751	37	0	41	90	5
1755	18	0	41	46	4
1759	18	0	42	43	4
1765	25	2	42	64	6
1771	2	0	42	5	6
1772	35	0	42	83	1
1778	5	0	42	12	6
1785	31	0	42	74	7
1791	30	0	42	71	6
1795	13	0	42	33	4
1807	29	1	43	70	12
1812	23	0	42	55	5
1815	26	0	42	62	3
1822	33	0	42	79	7
1827	17	0	42	40	5
1835	34	1	42	83	8
1843	6	0	40	15	8
1851	33	0	36	92	8
1861	20	0	29	69	10
1869	18	0	26	69	8
1882	14	1	17	88	13

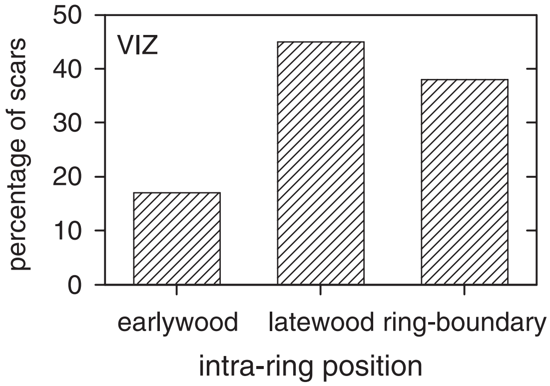


Figure 38—Intra-ring position of fire scars on ponderosa pine trees at VIZ during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

BMT (Blue Mountain) Lolo National Forest, Missoula Ranger District

In 2002, we removed fire-scarred partial cross sections from 39 ponderosa pine trees over a sampling area of 82 acres (fig. 1, table 2). All of these trees were dead when sampled (stumps). We were able to crossdate samples from 36 of these trees (92 percent), from which we identified 758 fire scars and 25 eroded fire scars (fig. 39). From the composite fire-scar record of 37 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 82-acre sampling area every 6 years on average (range 1 to 17 years; fig. 40, table 17) and these fires scarred an average of 51 percent of the sampled trees that were recording (range 8 to 100 percent). We were able to assign an intra-ring position to ½ (54 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, nearly ½ were created by fires burning when the cambium was dormant (42 percent ring-boundary scars; fig. 41). The remaining scars were created during the growing season, and most of these were formed late in that season (16 percent in the earlywood versus 42 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest (code 1045; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir (code 10451; Comer and others 2003).

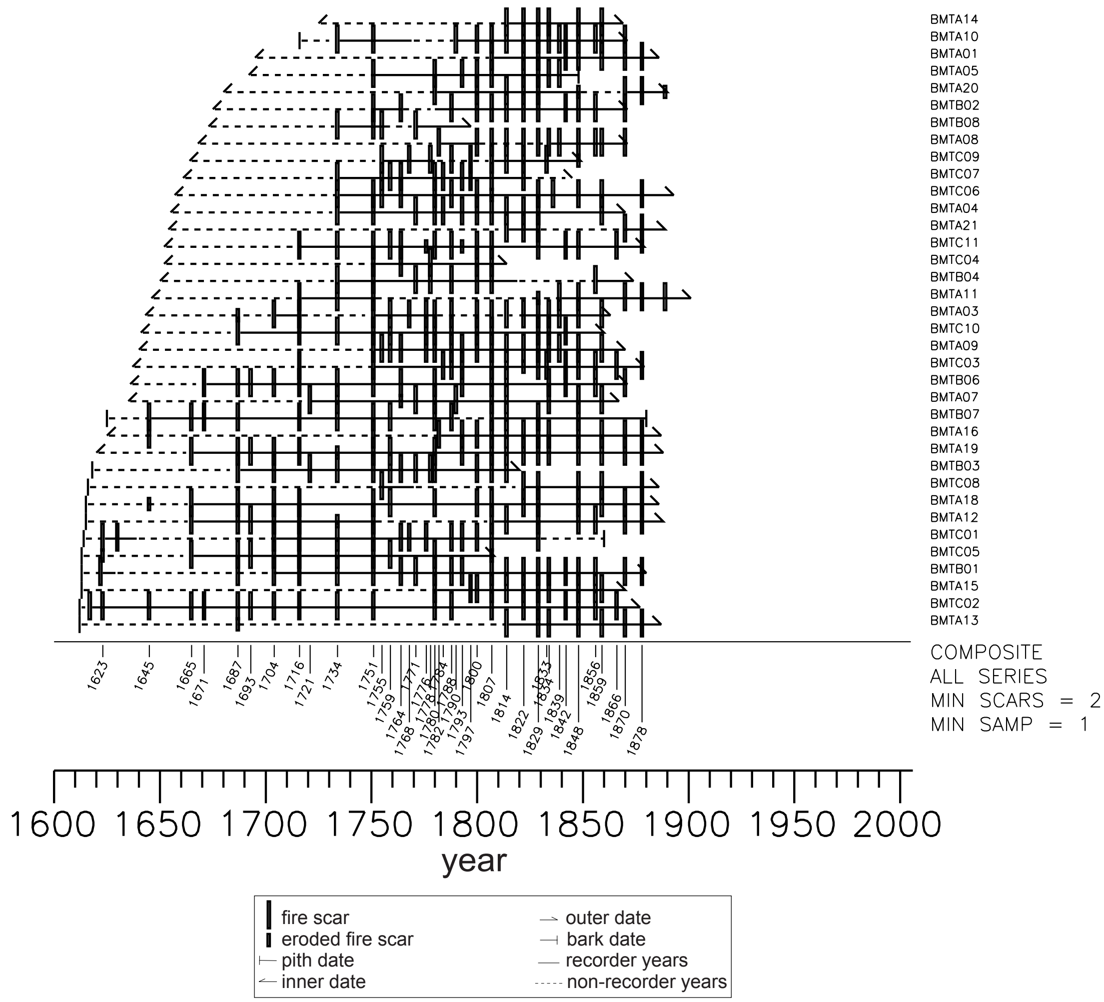


Figure 39—Fire chart for BMT. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

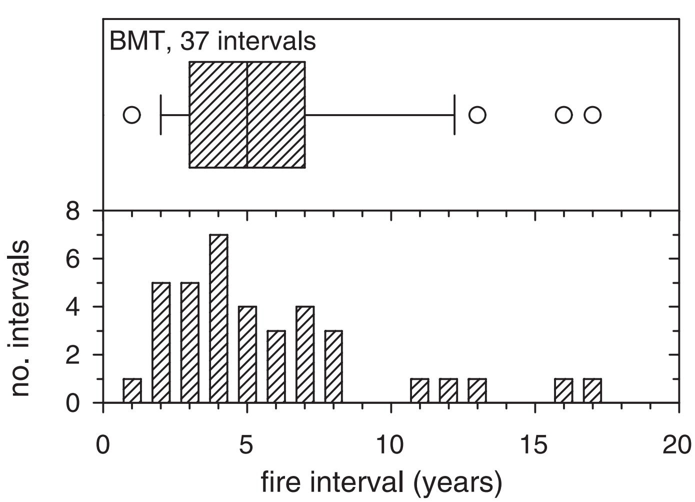


Figure 40—Composite fire intervals for BMT, determined as the intervals between years with fire scars on two or more trees over the 82-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10[th] to 90[th] percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 17—Fire years with scars on two or more trees at BMT.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1623	2	1	3	100	.
1645	3	1	4	100	22
1665	6	0	6	100	20
1671	3	0	7	43	6
1687	10	2	12	100	16
1693	5	0	9	56	6
1704	10	0	12	83	11
1716	14	0	15	93	12
1721	2	0	14	14	5
1734	17	2	20	95	13
1751	25	0	27	93	17
1755	6	0	26	23	4
1759	10	0	25	40	4
1764	10	1	25	44	5
1768	3	0	24	13	4
1771	6	0	23	26	3
1776	4	1	23	22	5
1778	4	0	23	17	2
1780	19	0	26	73	2
1782	2	0	26	8	2
1784	3	0	26	12	2
1788	13	0	28	46	4
1790	2	0	26	8	2
1793	10	1	26	46	3
1797	3	0	26	12	4
1800	18	0	26	69	3
1807	27	2	30	97	7
1814	21	0	31	68	7
1822	20	1	30	70	8
1829	26	1	29	93	7
1833	2	0	26	8	4
1834	14	0	27	52	1
1839	6	0	28	21	5
1842	9	0	28	32	3
1848	22	2	27	89	6
1856	10	0	26	38	8
1859	15	0	26	58	3
1866	3	0	24	13	7
1870	14	0	21	67	4
1878	13	1	15	93	8

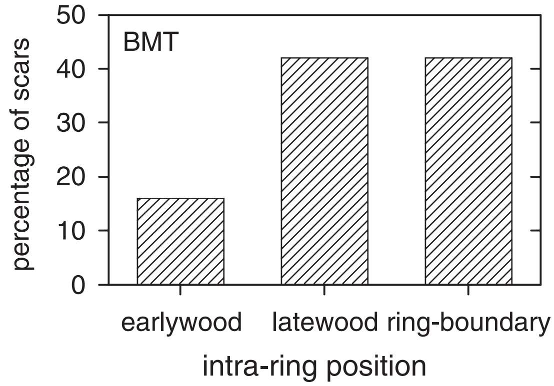


Figure 41—Intra-ring position of fire scars on ponderosa pine trees at BMT during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

BUT (Butler Creek) Lolo National Forest, Ninemile Ranger District

In 2005, we removed fire-scarred partial cross sections from 41 trees (40 ponderosa pine and one Douglas-fir) over a sampling area of 5 acres (fig. 1, table 2). All of these trees were dead when sampled (stumps, logs, or snags). We were able to crossdate samples from 38 of these trees (93 percent), from which we identified 817 fire scars and 23 eroded fire scars (fig. 42). From the composite fire-scar record of 24 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 5-acre sampling area every 8 years on average (range 3 to 23 years; fig. 43, table 18) and these fires scarred an average of 69 percent of the sampled trees that were recording (range 6 to 100 percent). We were able to assign an intra-ring position to approximately ½ (55 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, about ¼ were created by fires burning when the cambium was dormant (27 percent ring-boundary scars; fig. 44). The remaining scars were created during the growing season, and most of these were formed late in that season (16 percent in the earlywood versus 57 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest (code 1045; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Larch (code 10452; Comer and others 2003).

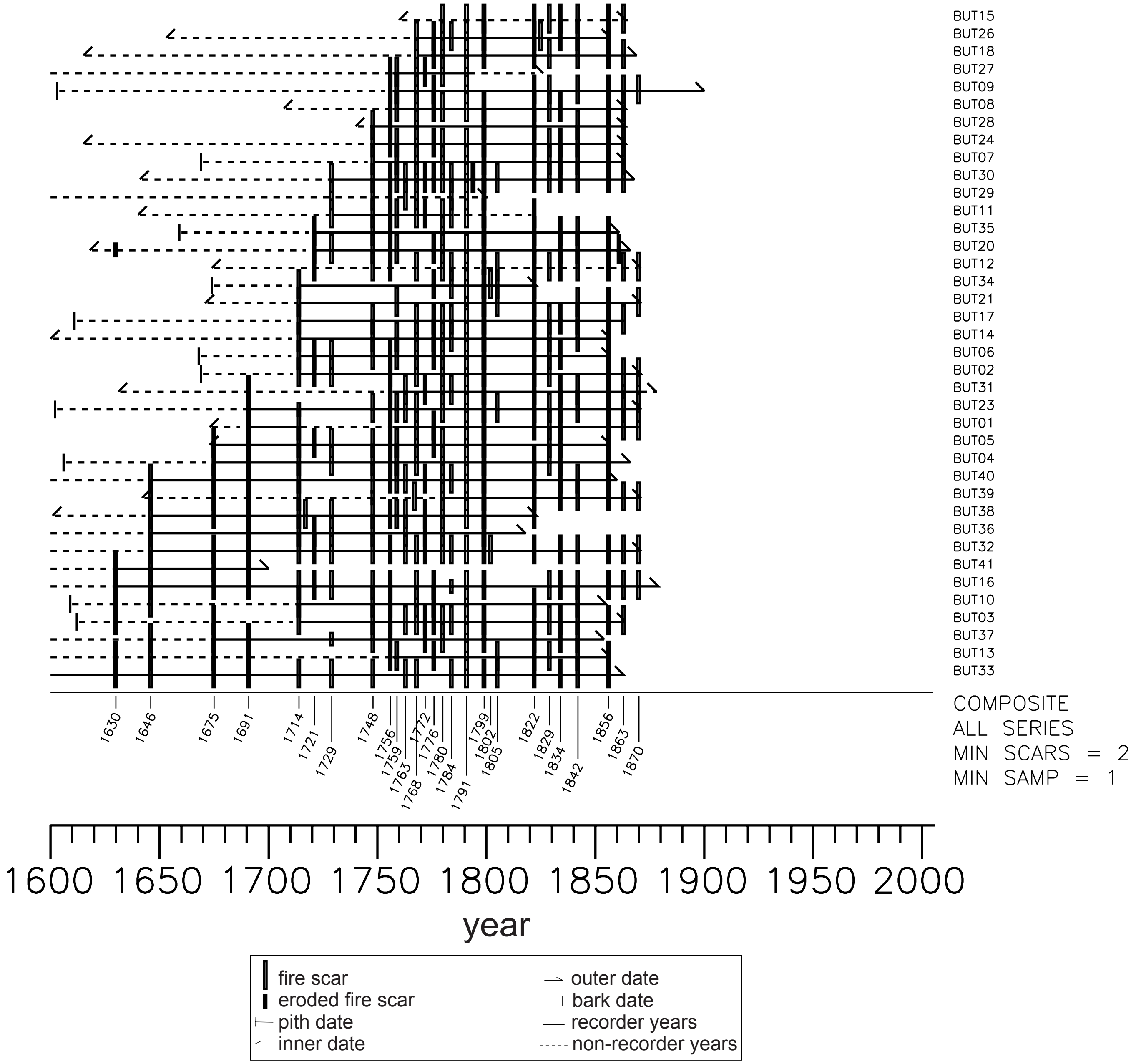


Figure 42—Fire chart for BUT. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

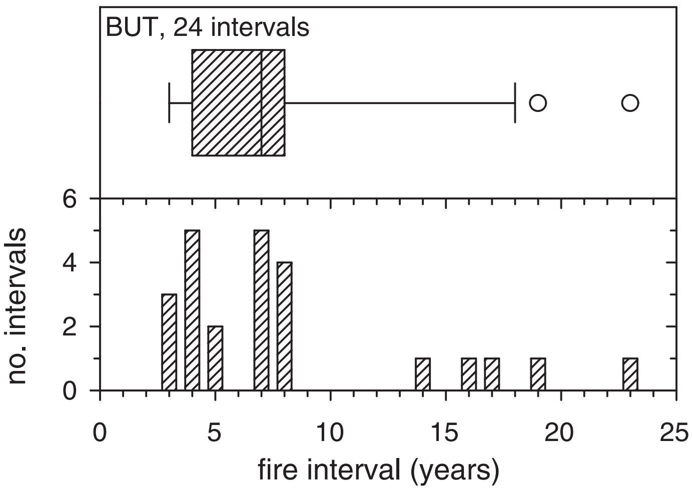


Figure 43—Composite fire intervals for BUT, determined as the intervals between years with fire scars on two or more trees over the 5-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10th to 90th percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 18—Fire years with scars on two or more trees at BUT.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1594	3	0	3	100	.
1630	6	1	7	100	36
1646	11	0	11	100	16
1675	12	0	13	92	29
1691	15	0	15	100	16
1714	18	1	20	95	23
1721	9	0	21	48	7
1729	13	1	23	61	8
1748	24	1	27	93	19
1756	26	0	33	79	8
1759	17	0	31	55	3
1763	10	0	32	31	4
1768	25	0	35	71	5
1772	10	0	33	30	4
1776	17	0	33	52	4
1780	27	0	36	75	4
1784	13	1	36	39	4
1791	33	1	37	92	7
1799	32	1	35	94	8
1802	2	0	32	6	3
1805	7	0	33	21	3
1822	32	0	34	94	17
1829	19	0	31	61	7
1834	23	0	31	74	5
1842	25	0	31	81	8
1856	29	0	29	100	14
1863	17	1	21	86	7
1870	10	0	10	100	7

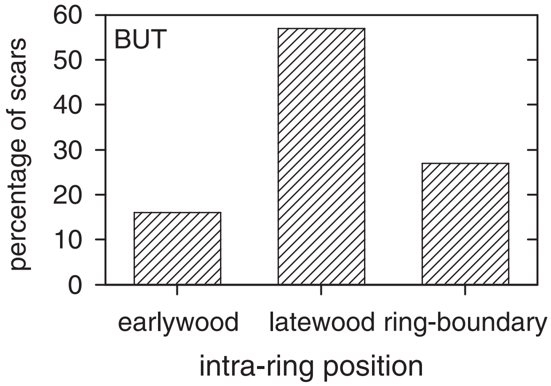


Figure 44—Intra-ring position of fire scars on ponderosa pine trees at BUT during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

FAV (McCormick Creek) Lolo National Forest, Ninemile Ranger District

In 2004, we removed fire-scarred partial cross sections from 18 ponderosa pine trees over a sampling area of 367 acres (fig. 1, table 2). All of these trees were dead when sampled (one log, the rest stumps). We were able to crossdate samples from 17 of these trees (94 percent), from which we identified 261 fire scars and 10 eroded fire scars (fig. 45). From the composite fire-scar record of 16 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 367-acre sampling area every 13 years on average (range 3 to 30 years; fig. 46, table 19) and these fires scarred an average of 78 percent of the sampled trees that were recording (range 38 to 100 percent). We were able to assign an intra-ring position to over ½ (60 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, nearly ½ were created by fires burning when the cambium was dormant (47 percent ring-boundary scars; fig. 47). The remaining scars were created during the growing season, and most of these were formed late in that season (8 percent in the earlywood versus 45 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest (code 1045; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Ponderosa Pine Woodland and Savanna (code 10530; Comer and others 2003).

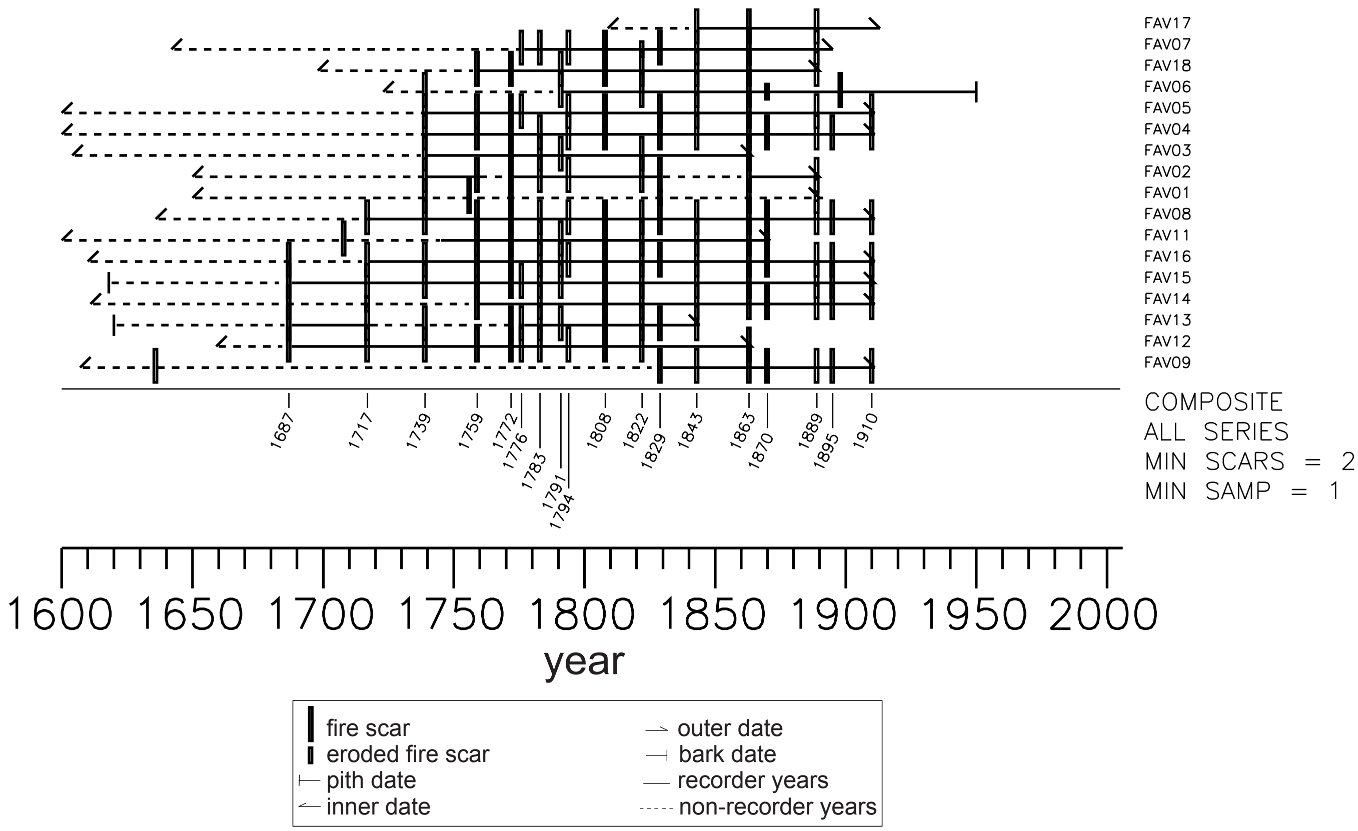


Figure 45—Fire chart for FAV. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

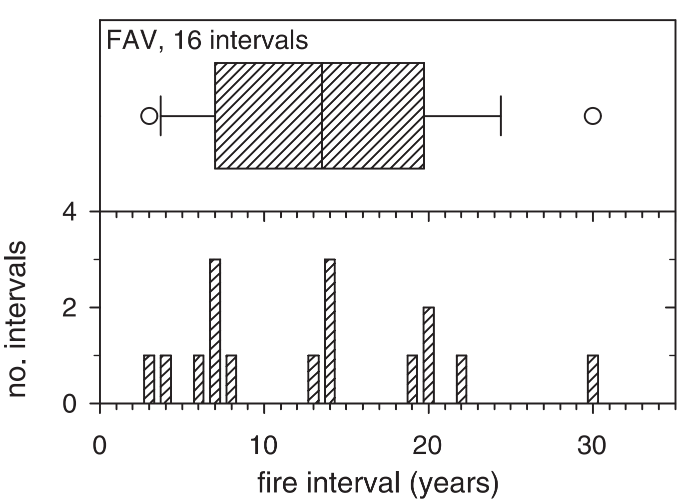


Figure 46—Composite fire intervals for FAV, determined as the intervals between years with fire scars on two or more trees over the 367-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10th to 90th percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 19—Fire years with scars on two or more trees at FAV.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1687	5	0	5	100	.
1717	5	1	5	100	30
1739	11	0	11	100	22
1759	10	0	11	91	20
1772	12	0	13	92	13
1776	5	0	13	38	4
1783	11	0	13	85	7
1791	7	0	14	50	8
1794	7	0	14	50	3
1808	11	0	14	79	14
1822	11	1	14	86	14
1829	8	1	15	60	7
1843	13	0	15	87	14
1863	16	0	16	100	20
1870	6	1	13	54	7
1889	12	0	13	92	19
1895	6	0	9	67	6
1910	7	0	9	78	15

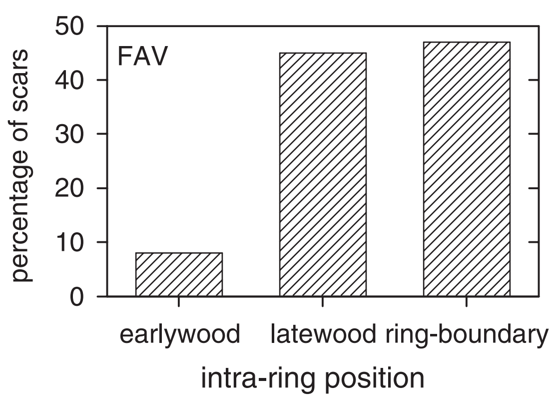


Figure 47—Intra-ring position of fire scars on ponderosa pine trees at FAV during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

COV (Cove Mountain) Nez Perce National Forest, Red River Ranger District

This site was sampled primarily as part of our broader study of the climate drivers of regional-fire years in the Northern Rockies (Heyerdahl and others 2008) but it was also selected to satisfy the sampling needs of a study of the effects of 20th century fire exclusion on forest structure and composition (reported as site MB in Keeling and others 2006). In 2005, we removed fire-scarred partial cross sections from 26 trees (25 ponderosa pine and one Douglas-fir) over a sampling area of 30 acres (fig. 1, table 2). Almost ½ of these trees were dead when sampled (46 percent stumps, logs, or snags). We were able to crossdate samples from 25 of these trees (96 percent), from which we identified 264 fire scars and 22 eroded fire scars (fig. 48).

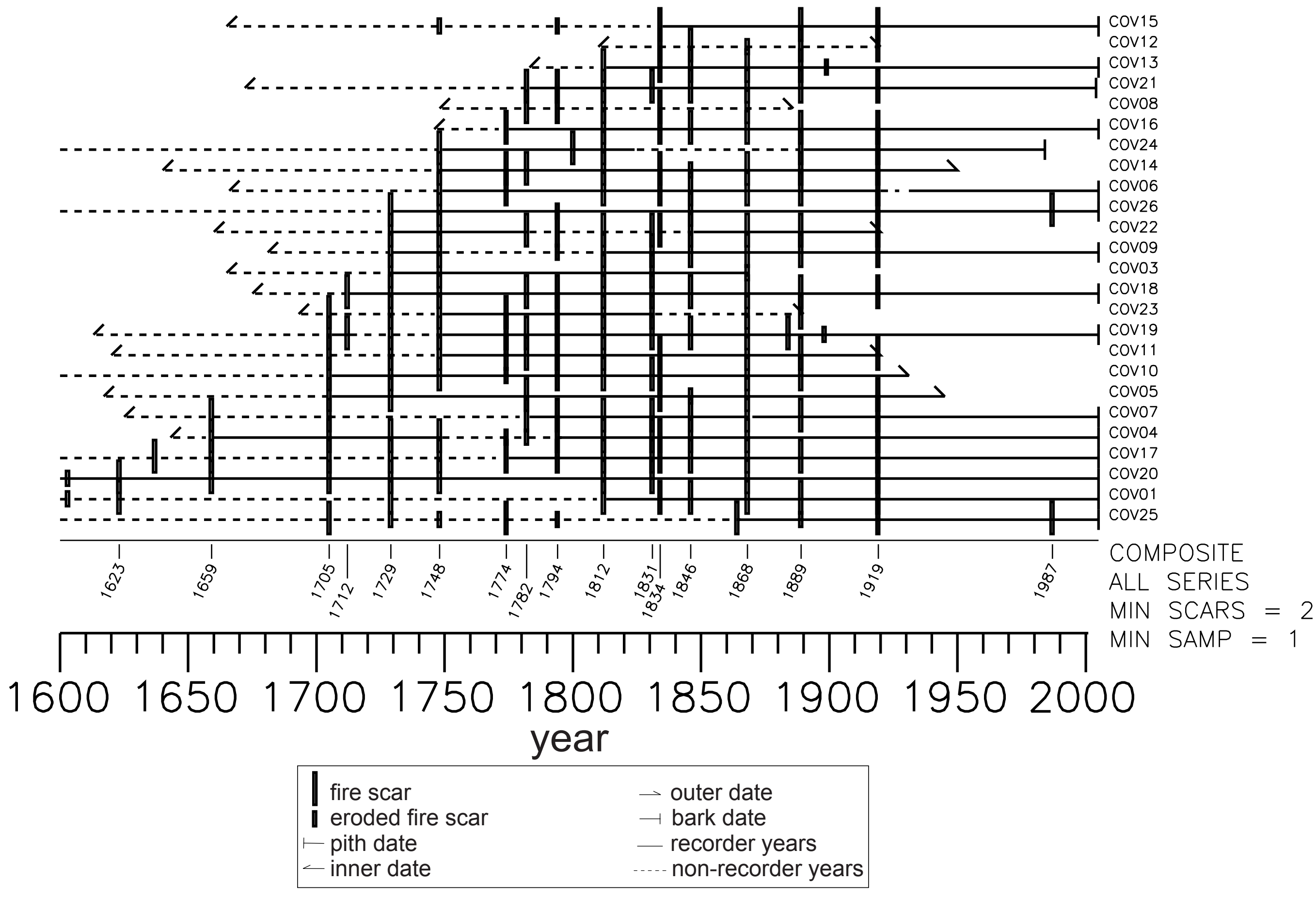


Figure 48—Fire chart for COV. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

From the composite fire-scar record of 13 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 30-acre sampling area every 18 years on average (range 3 to 46 years; fig. 49, table 20) and these fires scarred an average of 79 percent of the sampled trees that were recording (range 33 to 100 percent). We were able to assign an intra-ring position to 2/3 (67 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, nearly ½ were created by fires burning when the cambium was dormant (42 percent ring-boundary scars; fig. 50). The remaining scars were created during the growing season (23 percent in the earlywood and 35 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest (code 1045; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Ponderosa Pine Woodland and Savanna (code 10530; Comer and others 2003).

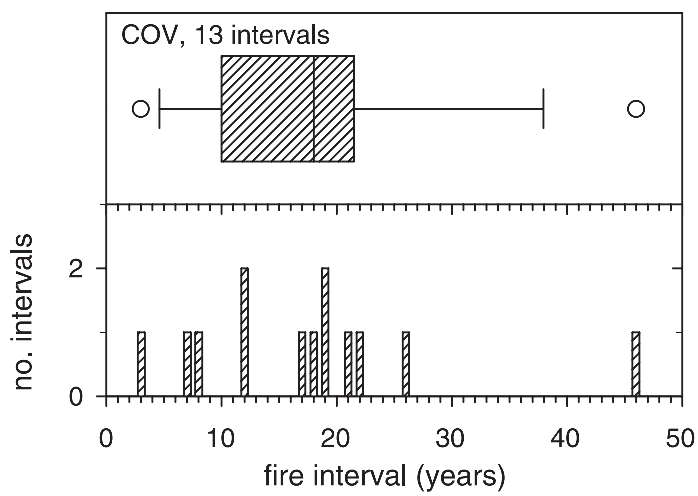


Figure 49—Composite fire intervals for COV, determined as the intervals between years with fire scars on two or more trees over the 30-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10th to 90th percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 20—Fire years with scars on two or more trees at COV.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1543	2	0	3	100	.
1567	2	0	2	100	24
1623	2	0	3	100	56
1659	4	0	4	100	36
1705	10	0	11	100	46
1712	2	0	6	33	7
1729	14	1	15	100	17
1748	15	2	18	100	19
1774	8	2	16	69	26
1782	9	1	18	56	8
1794	11	4	19	84	12
1812	20	0	22	91	18
1831	12	0	20	60	19
1834	14	0	22	64	3
1846	14	2	21	81	12
1868	19	1	23	91	22
1889	17	1	23	78	21
1919	19	0	22	86	30
1987	2	0	15	13	68

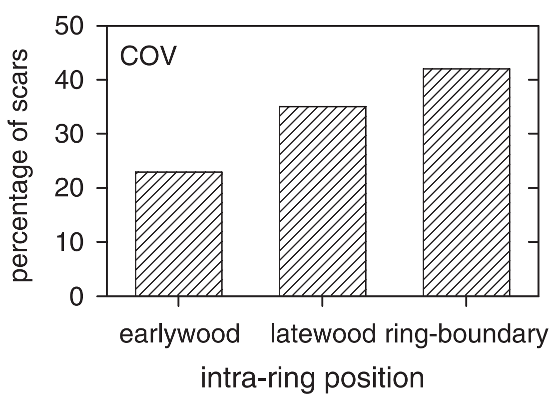


Figure 50—Intra-ring position of fire scars on ponderosa pine trees at COV during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

KEA (Keating Ridge) Nez Perce National Forest, Clearwater Ranger District

In 2004, we removed fire-scarred partial cross sections from 24 trees (23 ponderosa pine and one Douglas-fir) over a sampling area of 10 acres (fig. 1, table 2). All of these trees were dead when sampled (stumps, logs, or snags). We were able to crossdate samples from 22 of these trees (92 percent), from which we identified 237 fire scars and 11 eroded fire scars (fig. 51). From the composite fire-scar record of 16 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 10-acre sampling area every 14 years on average (range 3 to 26 years; fig. 52, table 21) and these fires scarred an average of 74 percent of the sampled trees that were recording (range 20 to 100 percent).

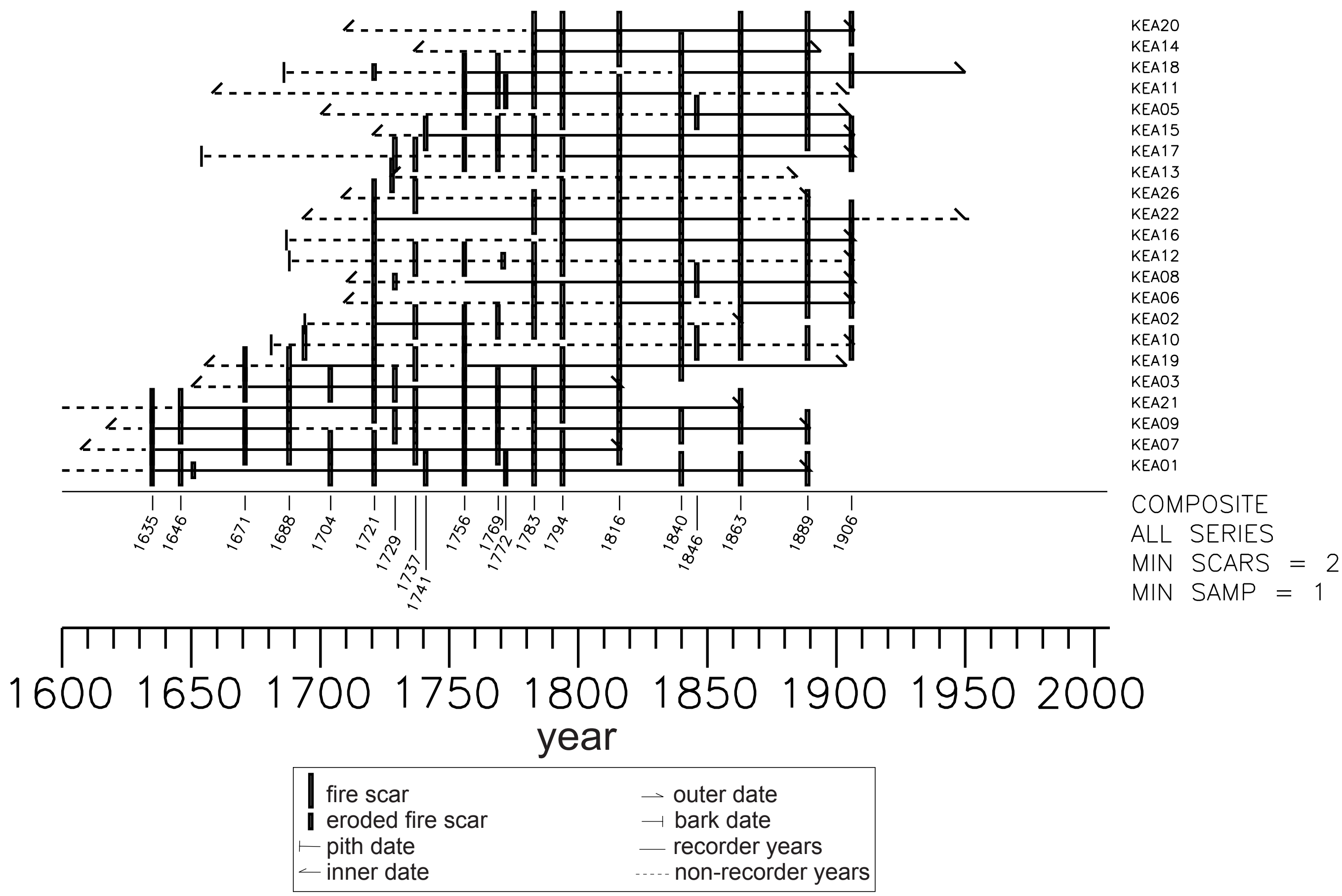


Figure 51—Fire chart for KEA. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

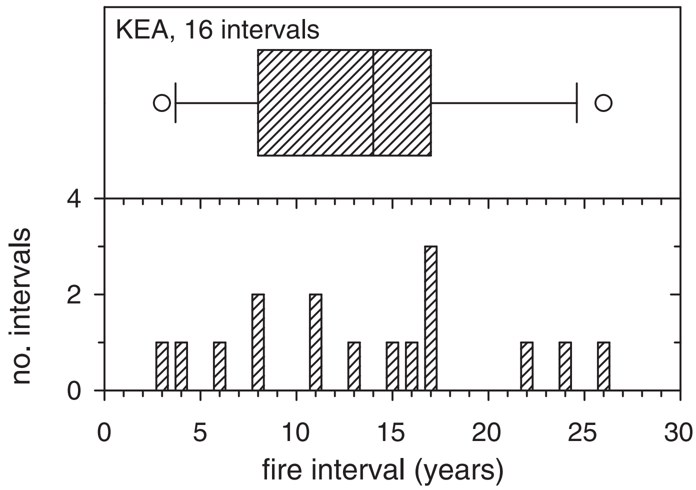


Figure 52—Composite fire intervals for KEA, determined as the intervals between years with fire scars on two or more trees over the 10-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10^{th} to 90^{th} percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 21—Fire years with scars on two or more trees at KEA.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1635	4	0	4	100	.
1646	3	0	4	75	11
1671	4	0	6	83	25
1688	5	0	6	83	17
1704	3	0	5	60	16
1721	13	1	13	100	17
1729	3	1	8	50	8
1737	8	0	11	73	8
1741	2	0	7	29	4
1756	12	1	15	100	15
1769	9	0	13	77	13
1772	2	0	10	20	3
1783	16	1	17	100	11
1794	17	0	20	85	11
1816	20	0	21	100	22
1840	18	0	20	95	24
1846	3	0	14	21	6
1863	19	0	20	95	17
1889	13	2	17	88	26
1906	10	0	10	100	17

We were able to assign an intra-ring position to nearly ½ (44 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, over ½ were created by fires burning when the cambium was dormant (56 percent ring-boundary scars; fig. 53). The remaining scars were created during the growing season, and most of these were formed late in that season (9 percent in the earlywood versus 35 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest (code 1045; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Ponderosa Pine Woodland and Savanna (code 10530; Comer and others 2003).

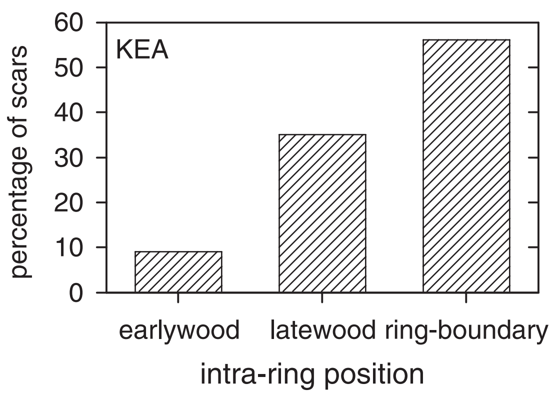


Figure 53—Intra-ring position of fire scars on ponderosa pine trees at KEA during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

TTM (Twenty-Three Mile Bar) Nez Perce National Forest, Moose Creek Ranger District

In 2005, we removed fire-scarred partial cross sections from 12 ponderosa pine trees over a sampling area of 106 acres (fig. 1, table 2). One- half of these trees were dead when sampled (6 snags). We were able to crossdate samples from all of these trees, from which we identified 50 fire scars and two eroded fire scars (fig. 54, table 22). This site was sampled as part of a study of the effects of 20th century fire exclusion on forest structure and composition (reported as site TW in Keeling and others 2006), hence the relatively short record. The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Mesic Montane Mixed Conifer Forest (code 1047; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Grand Fir (code 10453; Comer and others 2003).

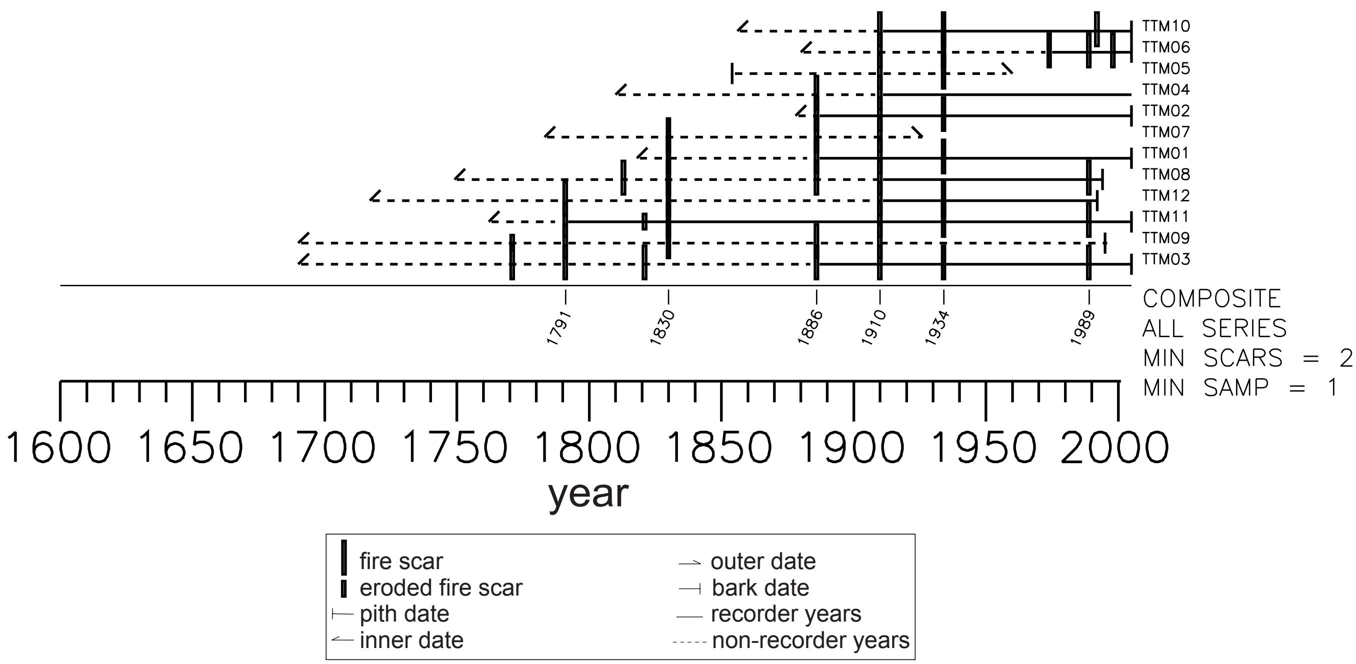


Figure 54—Fire chart for TTM. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

Table 22—Fire years with scars on two or more trees at TTM.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1791	4	0	4	100	.
1830	6	0	6	100	39
1886	7	0	8	100	56
1910	12	0	12	100	24
1934	8	0	10	80	24
1989	4	0	9	44	55

POV (Poverty Flat) Payette National Forest, Krassel Ranger District

In 2004, we removed fire-scarred partial cross sections from 34 trees (33 ponderosa pine and one Douglas-fir) over a sampling area of 45 acres (fig. 1, table 2). All of these trees were dead when sampled (stumps, logs, or snags). We were able to crossdate samples from 33 of these trees (97 percent), from which we identified 285 fire scars and 22 eroded fire scars (fig. 55). From the composite fire-scar record of 10 intervals over the analysis period (1750 to 1900), a fire occurred somewhere in the 45-acre sampling area every 12 years on average (range 3 to 26 years; fig. 56, table 23) and these fires scarred an average of 68 percent of the sampled trees that were recording (range 8 to 100 percent). We were able to assign an intra-ring position to nearly ½ (47 percent) of the scars that were formed during the analysis period (1750 to 1900). Of the scars to which we could assign an intra-ring position, about 1/3 was created by fires burning when the cambium was dormant (30 percent ring-boundary scars; fig. 57). The remaining scars were created during the growing season (36 percent in the earlywood and 34 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Middle Rocky Mountain Montane Douglas-Fir Forest and Woodland (code 1166; Comer and others 2003). The dominant BpS is Middle Rocky Mountain Montane Douglas-fir Forest and Woodland (code 11660; Comer and others 2003).

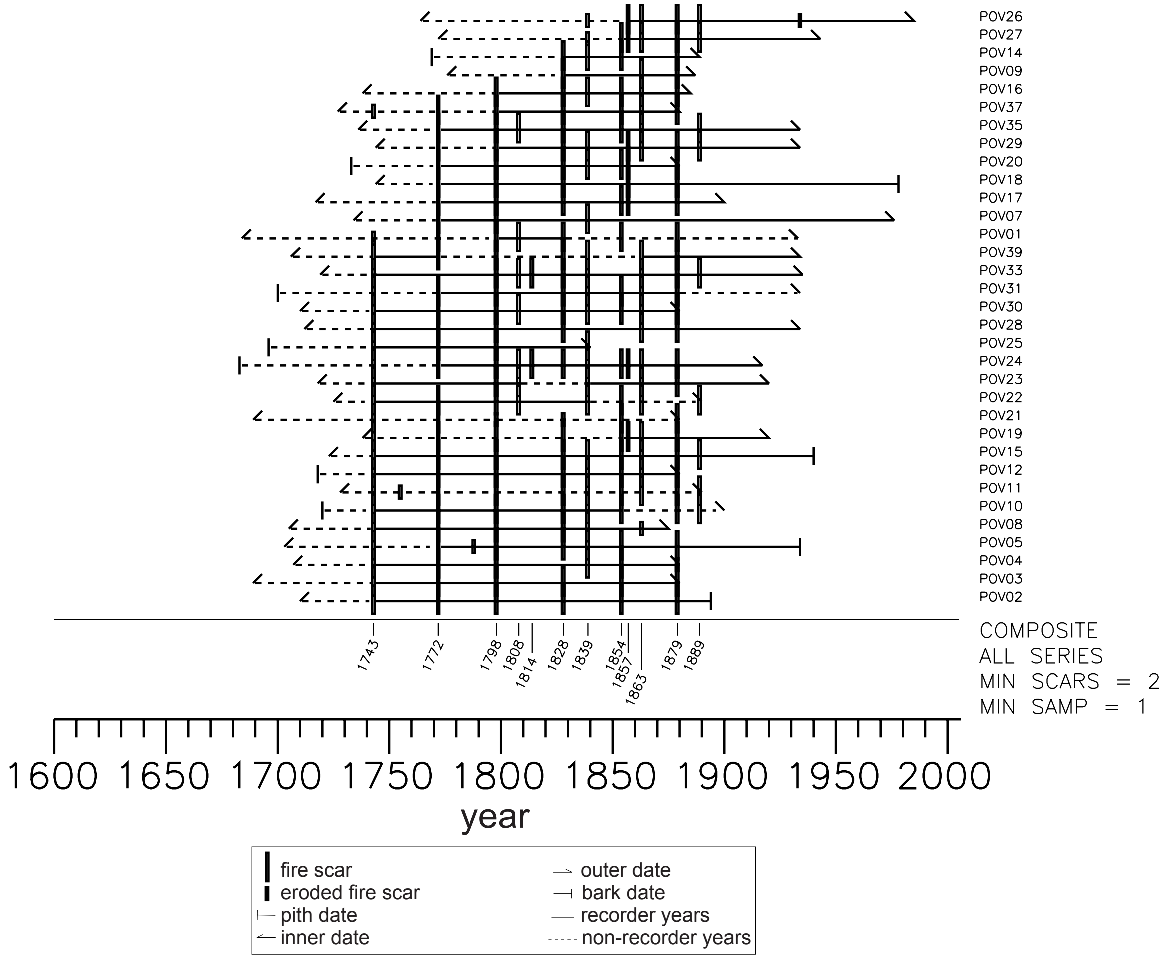


Figure 55—Fire chart for POV. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

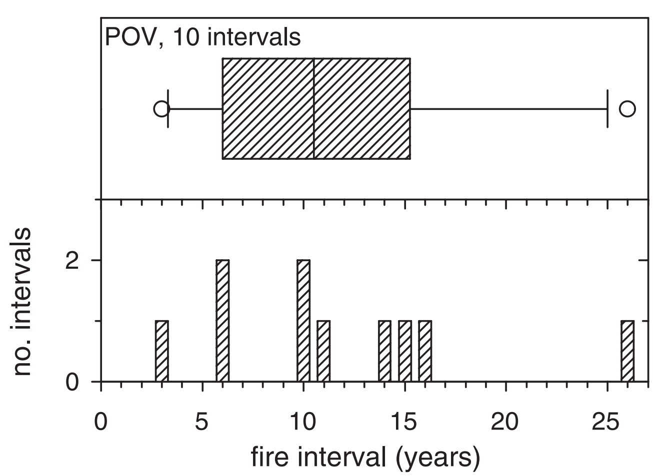


Figure 56—Composite fire intervals for POV, determined as the intervals between years with fire scars on two or more trees over the 45-acre sampling area during the period from 1750 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10th to 90th percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 23—Fire years with scars on two or more trees at POV.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1743	20	3	20	100	.
1772	26	0	28	93	29
1798	28	1	28	100	26
1808	7	0	25	28	10
1814	2	0	24	8	6
1828	25	1	29	90	14
1839	20	2	28	79	11
1854	22	0	30	73	15
1857	8	0	26	31	3
1863	19	1	29	69	6
1879	27	1	30	93	16
1889	9	0	19	47	10

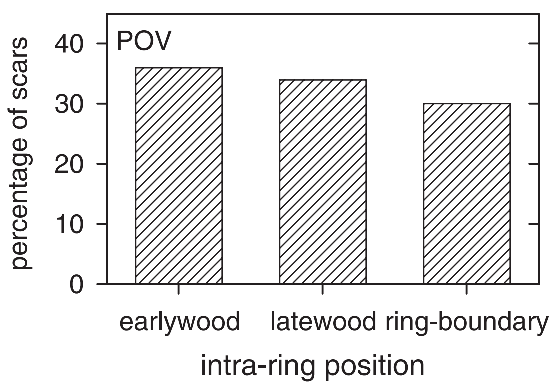
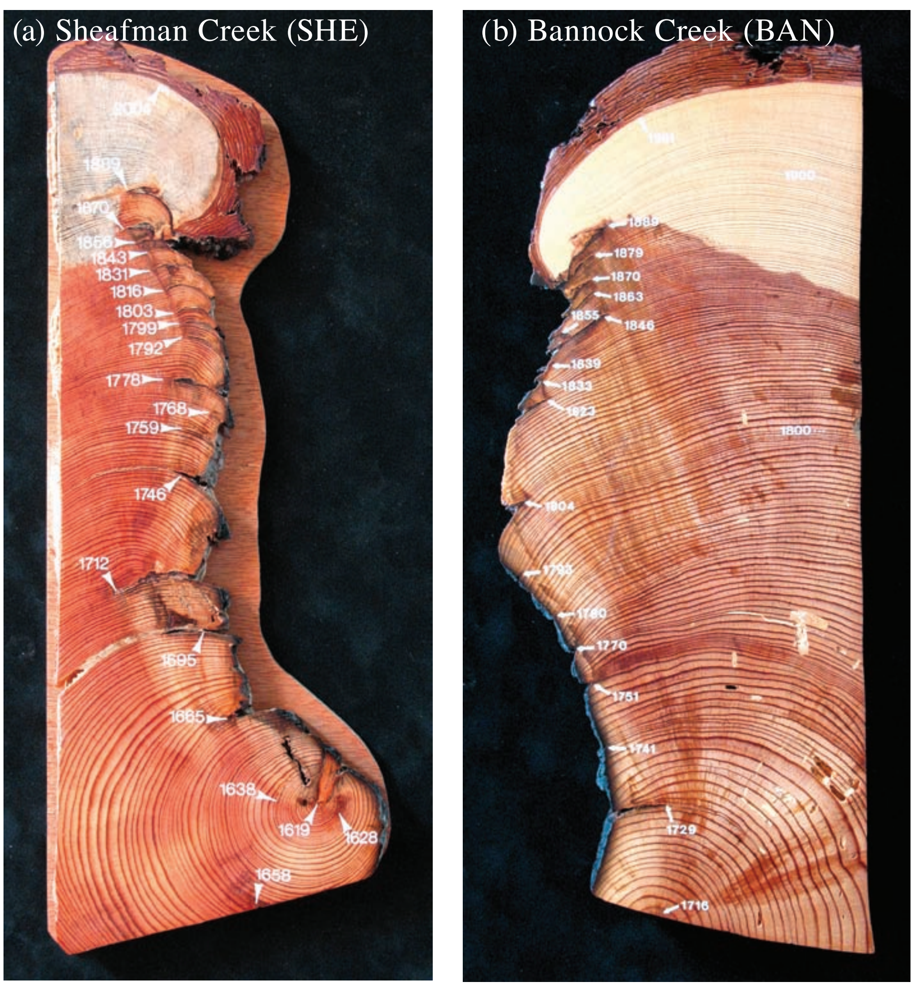


Figure 57—Intra-ring position of fire scars on ponderosa pine trees at POV during the period from 1750 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

NFS (North Fork Salmon River) Salmon-Challis National Forest, North Fork and Salmon Ranger Districts

In 2003, we received fire-scarred samples that had been collected by John Sloan and others from the Salmon-Challis National Forest in 2001 and 2002 near the North Fork Salmon River and the Salmon Front. From the North Fork Salmon River samples, we selected a subset of the best preserved samples with multiple fire scars from 52 trees (51 ponderosa pine and one Douglas-fir) that had the greatest number of fire scars. These trees were distributed over 28,352 acres (fig. 1, table 2) and most of them were living when sampled (88 percent). We were able to crossdate samples from 48 of these trees (92 percent), from which we identified 313 fire scars and nine eroded fire scars (fig. 58, table 24). We did not compute fire intervals because the trees were sampled over such a large area. We were able to assign an intra-ring position to most (66 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, about ½ were created by fires burning when the cambium was dormant (49 percent ring-boundary scars; fig. 59). The remaining scars were created during the growing season (28 percent in the earlywood versus 23 percent in the latewood). We do not report EsP or BpS for this site because it was sampled over too large an area for a single vegetation category to be meaningful.



Two of the crossdated fire-scarred sections that were removed from live trees and reported here. Fire-scar dates are indicated on both samples and the rings for 1800 and 1900 are indicated on the sample from BAN (b). Photo credit: James P. Riser II.

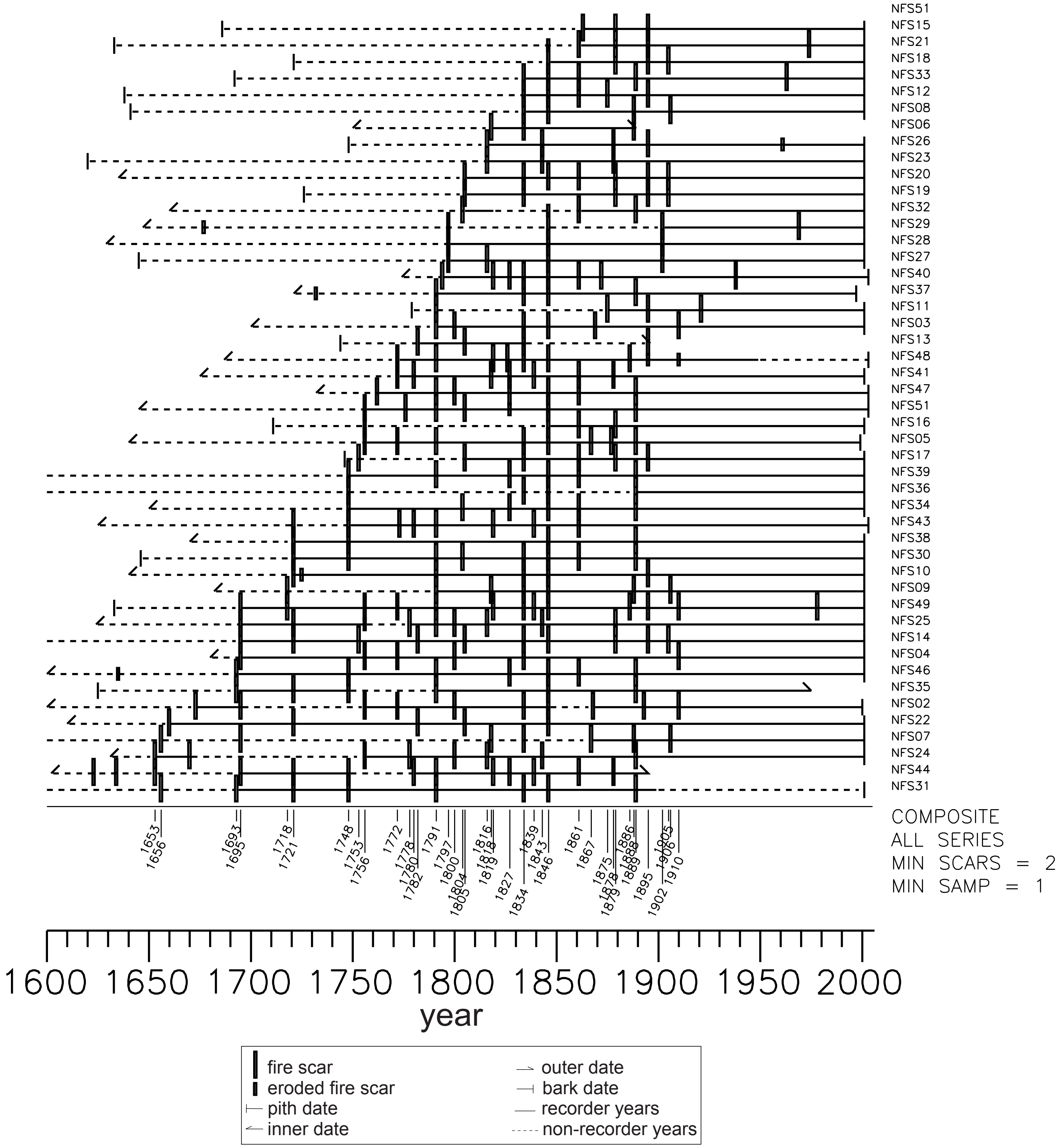


Figure 58—Fire chart for NFS. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

Table 24—Fire years with scars on two or more trees at NFS.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1653	2	0	2	100	.
1656	2	0	3	67	3
1693	3	0	5	60	37
1695	7	0	11	73	2
1718	2	0	10	20	23
1721	10	0	13	92	3
1748	10	0	16	69	27
1753	2	0	14	14	5
1756	7	1	18	50	3
1772	6	0	19	32	16
1778	2	0	20	10	6
1780	3	0	21	14	2
1782	3	0	22	14	2
1791	18	0	27	78	9
1797	3	0	30	10	6
1800	6	0	29	21	3
1804	3	0	30	13	4
1805	7	0	33	24	1
1816	5	0	35	14	11
1818	4	0	37	11	2
1819	5	0	36	14	1
1827	7	1	35	23	8
1834	23	0	40	58	7
1839	4	0	37	11	5
1843	4	0	37	11	4
1846	30	2	41	78	3
1861	16	0	40	40	15
1867	2	0	42	5	6
1875	2	0	44	5	8
1878	4	0	44	9	3
1879	9	0	44	20	1
1886	2	0	44	5	7
1888	4	0	44	9	2
1889	15	0	44	34	1
1895	13	1	44	32	6
1902	3	0	43	7	7
1905	4	0	43	9	3
1906	3	0	43	7	1
1910	4	1	43	12	4

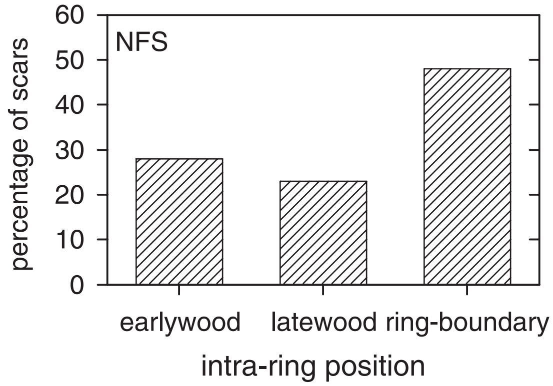


Figure 59—Intra-ring position of fire scars on ponderosa pine trees at NFS during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

FRI (Friedorf Gulch) Salmon-Challis National Forest, North Fork Ranger District

In 2005, we removed fire-scarred partial cross sections from 32 ponderosa pine trees over a sampling area of 116 acres (fig. 1, table 2). All of these trees were dead when sampled (stumps, logs, or snags). We were able to crossdate samples from 31 of these trees (97 percent), from which we identified 374 fire scars and 19 eroded fire scars (fig. 60). From the composite fire-scar record of 19 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 116-acre sampling area every 12 years on average (range 1 to 37 years; fig. 61, table 25) and these fires scarred an average of 62 percent of the sampled trees that were recording (range 17 to 100 percent). We were able to assign an intra-ring position to 1/3 (33 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, over ½ were created by fires burning when the cambium was dormant (55 percent ring-boundary scars; fig. 62). The remaining scars were created during the growing season, and most of these were formed late in that season (12 percent in the earlywood versus 33 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Middle Rocky Mountain Montane Douglas-Fir Forest and Woodland (code 1166; Comer and others 2003). The dominant BpS is Middle Rocky Mountain Montane Douglas-fir Forest and Woodland (code 11660; Comer and others 2003).

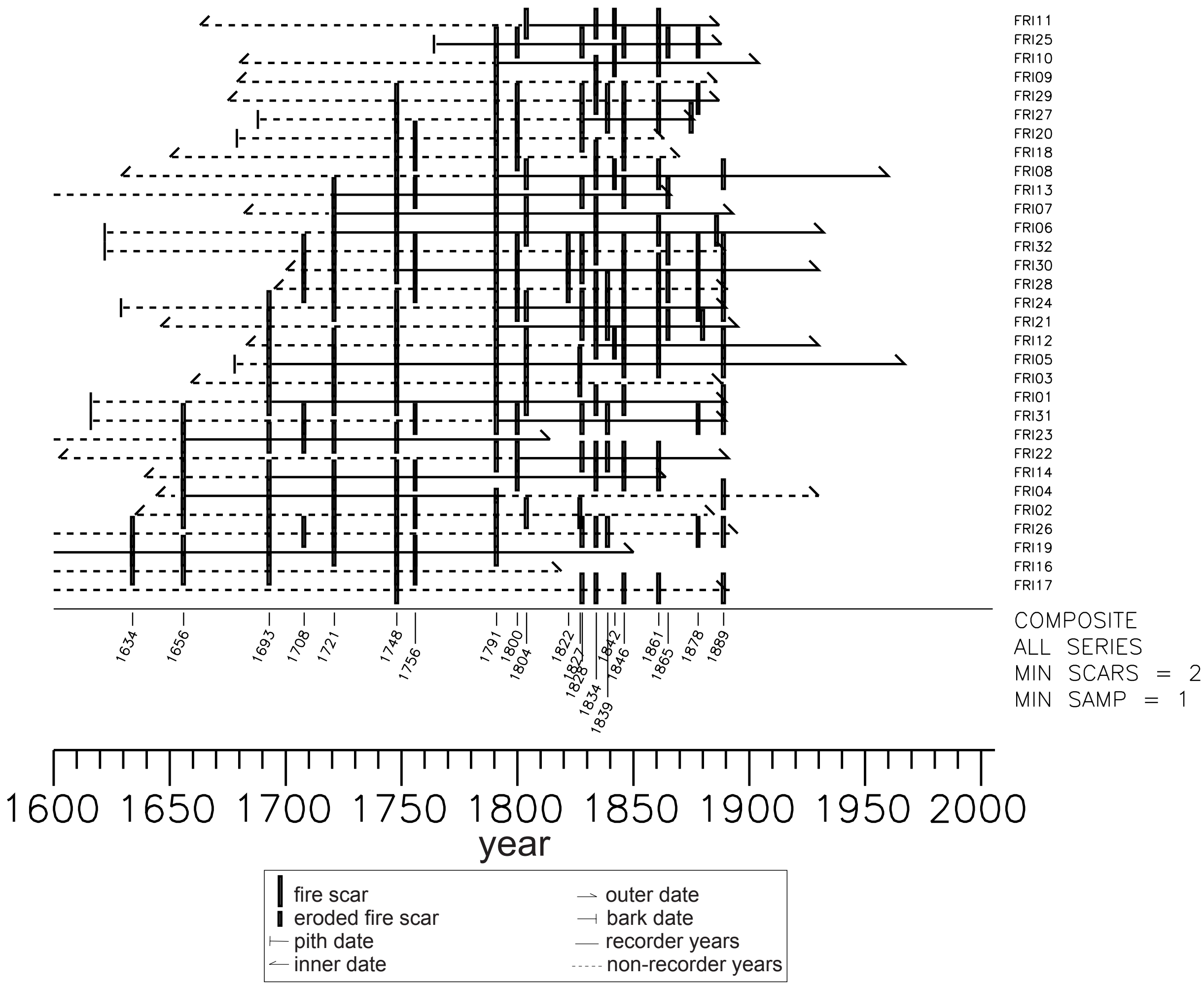


Figure 60—Fire chart for FRI. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

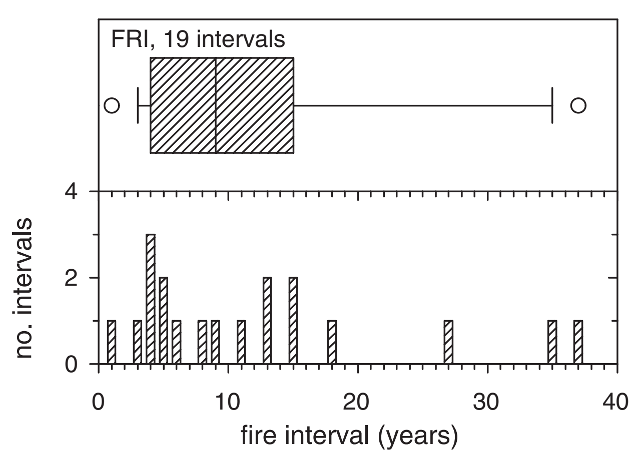


Figure 61—Composite fire intervals for FRI, determined as the intervals between years with fire scars on two or more trees over the 116-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10th to 90th percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 25—Fire years with scars on two or more trees at FRI.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1598	3	0	3	100	.
1634	3	0	3	100	36
1656	8	0	8	100	22
1693	13	0	13	100	37
1708	6	0	11	55	15
1721	17	0	17	100	13
1748	24	0	24	100	27
1756	11	0	17	65	8
1791	24	2	27	96	35
1800	12	0	22	55	9
1804	10	0	20	50	4
1822	3	0	18	17	18
1827	3	0	18	17	5
1828	13	0	22	59	1
1834	17	1	25	72	6
1839	8	0	21	38	5
1842	4	0	18	22	3
1846	17	0	24	71	4
1861	16	0	20	80	15
1865	5	0	19	26	4
1878	8	0	18	44	13
1889	12	0	17	71	11

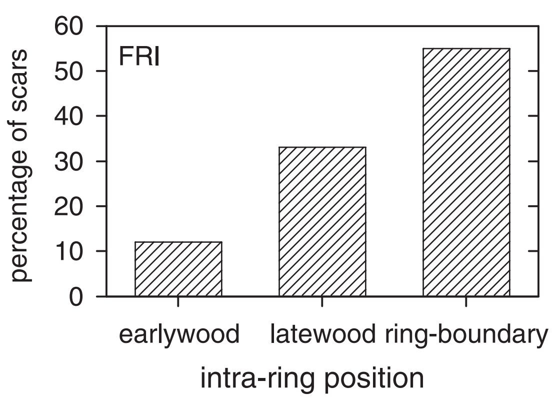


Figure 62—Intra-ring position of fire scars on ponderosa pine trees at FRI during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

COR (Corona Road) Plum Creek Timber, Inc.

In 2005, we removed fire-scarred partial cross sections from 26 trees (23 ponderosa pine and three western larch) over a sampling area of 7 acres (fig. 1, table 2). All of these trees were dead when sampled (stumps or logs). We were able to crossdate samples from all of these trees, from which we identified 417 fire scars and 38 eroded fire scars (fig. 63). From the composite fire-scar record of 22 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 7-acre sampling area every 11 years on average (range 4 to 25 years; fig. 64, table 26) and these fires scarred an average of 75 percent of the sampled trees that were recording (range 27 to 100 percent).

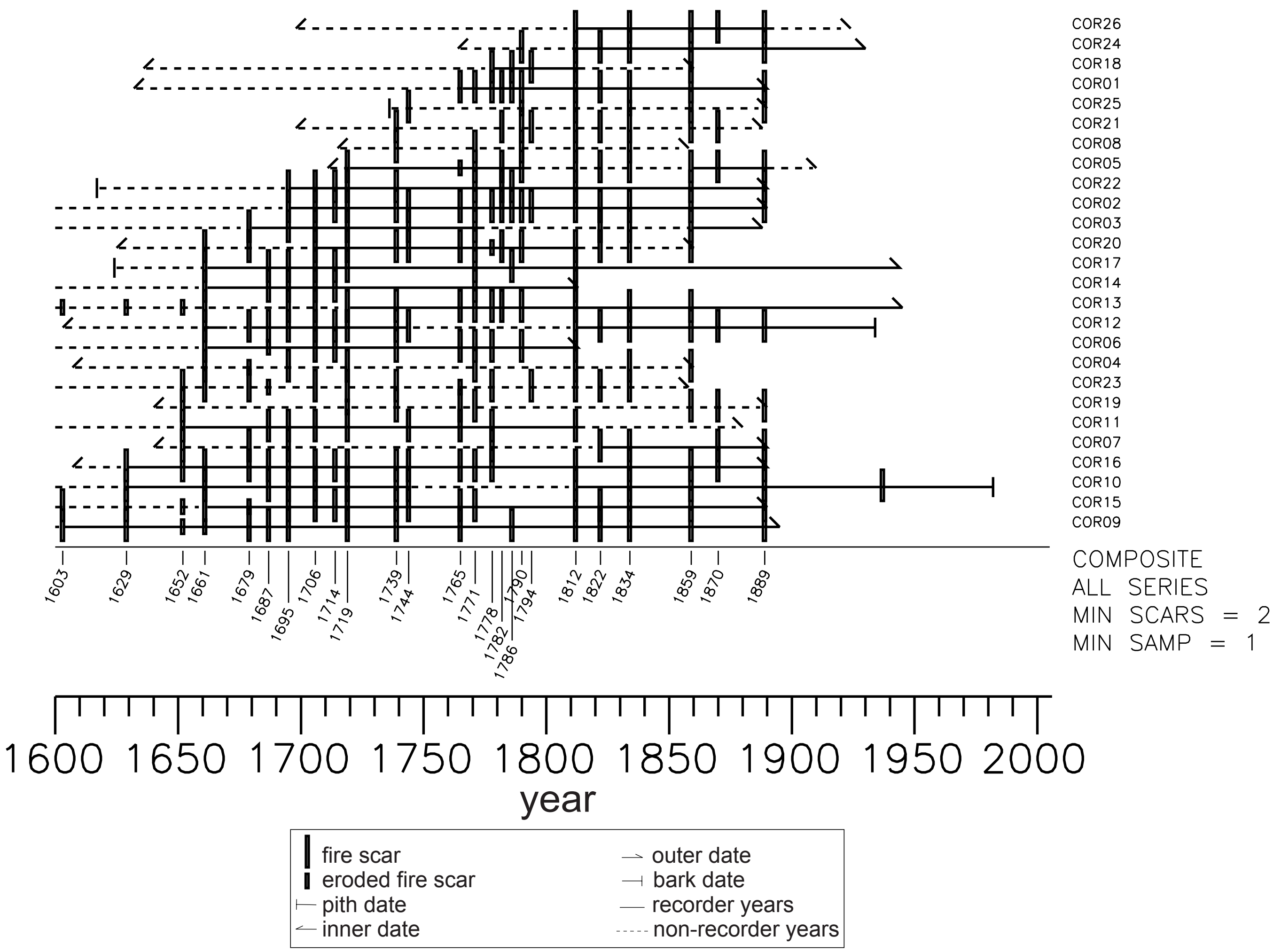


Figure 63—Fire chart for COR. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

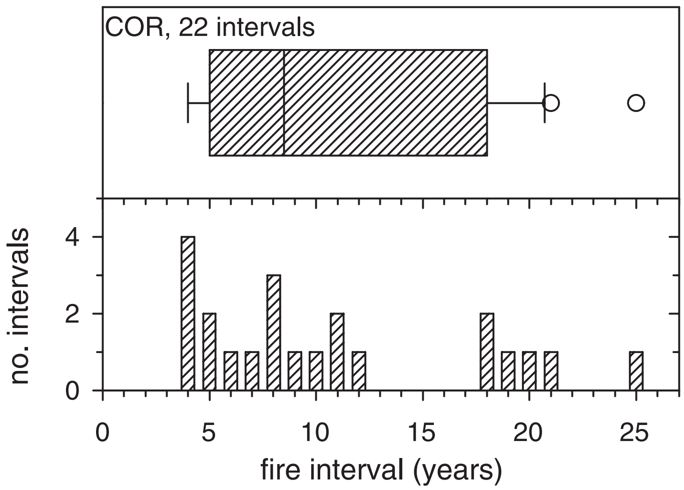


Figure 64—Composite fire intervals for COR, determined as the intervals between years with fire scars on two or more trees over the 7-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10th to 90th percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 26—Fire years with scars on two or more trees at COR.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1603	2	1	3	100	.
1629	4	1	5	100	26
1652	5	3	8	100	23
1661	11	1	13	92	9
1679	7	2	13	69	18
1687	7	2	10	90	8
1695	14	0	15	93	8
1706	14	0	15	93	11
1714	8	0	13	62	8
1719	15	1	17	94	5
1739	14	0	19	74	20
1744	9	0	16	56	5
1765	10	2	15	80	21
1771	15	0	17	100	6
1778	9	1	16	63	7
1782	7	0	15	47	4
1786	6	0	14	43	4
1790	9	0	17	59	4
1794	4	0	15	27	4
1812	23	0	23	100	18
1822	12	0	18	67	10
1834	18	1	20	95	12
1859	19	0	21	90	25
1870	7	0	17	41	11
1889	14	0	16	88	19

We were able to assign an intra-ring position to nearly ½ (44 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, nearly ½ were created by fires burning when the cambium was dormant (45 percent ring-boundary scars; fig. 65). The remaining scars were created during the growing season, and most of these were formed late in that season (11 percent in the earlywood and 44 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest (code 1045; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir (code 10451; Comer and others 2003).

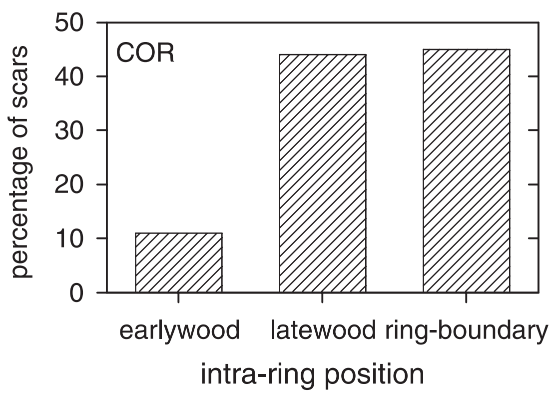


Figure 65—Intra-ring position of fire scars on ponderosa pine trees at COR during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

FLA (Flannigan Creek) Privately Owned

In 2005, we removed fire-scarred partial cross sections from 31 ponderosa pine trees over a sampling area of 69 acres (fig. 1, table 2). Most of these trees were dead when sampled (97 percent stumps). We were able to cross-date samples from 25 of these trees (81 percent), from which we identified 556 fire scars and 26 eroded fire scars (fig. 66). From the composite fire-scar record of 38 intervals over the analysis period (1650 to 1900), a fire occurred somewhere in the 69-acre sampling area every 6 years on average (range 2 to 24 years; fig. 67, table 27) and these fires scarred an average of 72 percent of the sampled trees that were recording (range 20 to 100 percent).

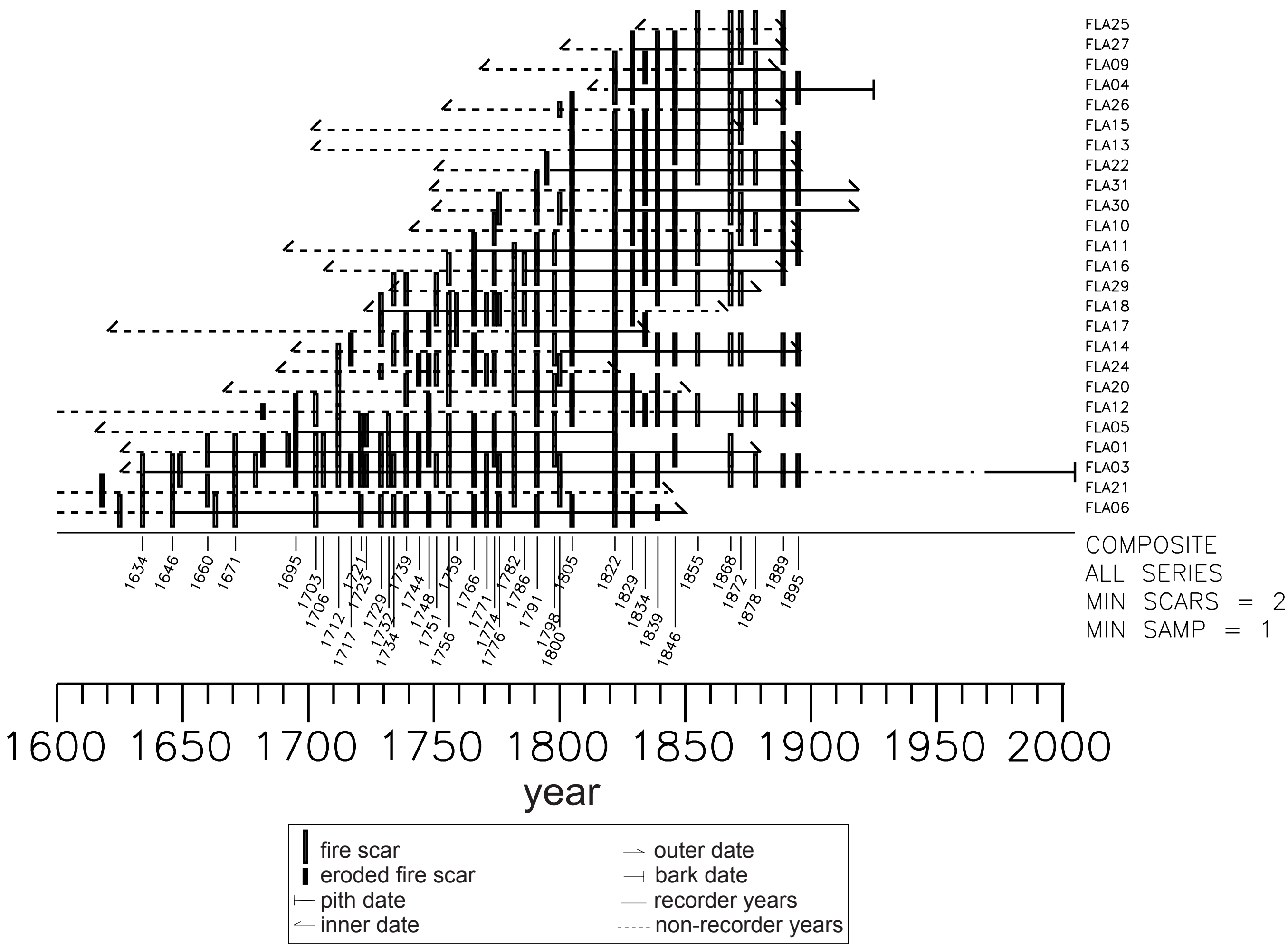


Figure 66—Fire chart for FLA. Each horizontal line indicates the length of record for a single tree (Grissino-Mayer 2001). The short vertical lines indicate years when that tree had evidence of fire (a fire scar or eroded fire scar). The dates at the bottom of the chart are the composite fire record that includes years when two or more trees at the site had evidence of fire. Recorder years (solid lines) generally follow the first scar on each tree. Non-recorder years (dashed lines) precede the formation of the first scar on each tree, but also occur when a period of the fire record was consumed by subsequent fires or decay. Inner and outer dates are the dates of the earliest or latest rings sampled for trees where pith or bark was not sampled.

We were able to assign an intra-ring position to over ½ (58 percent) of the scars that were formed during the analysis period (1650 to 1900). Of the scars to which we could assign an intra-ring position, over ½ were created by fires burning when the cambium was dormant (59 percent ring-boundary scars; fig. 68). The remaining scars were created during the growing season, and most of these were formed late in that season (2 percent in the earlywood versus 39 percent in the latewood). The LANDFIRE database indicates that the dominant EsP within 50 m of the center of this site is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest (code 1045; Comer and others 2003). The dominant BpS is Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest-Ponderosa Pine-Douglas-fir (code 10451; Comer and others 2003).

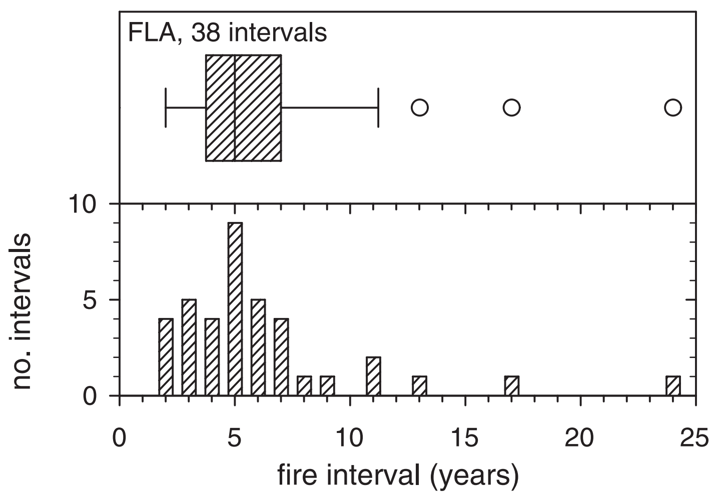


Figure 67—Composite fire intervals for FLA, determined as the intervals between years with fire scars on two or more trees over the 69-acre sampling area during the period from 1650 to 1900. In the box plot (top), the box encloses the 25th to 75th percentiles and the whiskers enclose the 10th to 90th percentiles of the distribution of intervals. The vertical line across the box indicates the median fire interval, and all values falling outside the 10th to 90th percentiles are shown as circles. In the histogram (bottom), the same intervals are plotted in 1-year bins.

Table 27—Fire years with scars on two or more trees at FLA.

Year	No. fire-scarred trees	No. trees with eroded fire scars	No. recorder trees	Percentage of trees scarred	Fire interval (years)
1599	2	0	2	100	.
1634	3	0	3	100	35
1646	2	1	2	100	12
1660	2	0	4	50	14
1671	4	0	4	100	11
1695	4	0	5	80	24
1703	4	0	5	80	8
1706	2	0	4	50	3
1712	5	2	6	100	6
1717	2	0	5	40	5
1721	4	0	4	100	4
1723	2	0	4	50	2
1729	5	1	6	100	6
1732	3	0	5	60	3
1734	4	0	7	57	2
1739	8	0	9	89	5
1744	3	0	6	50	5
1748	6	0	8	75	4
1751	4	0	7	57	3
1756	10	0	10	100	5
1759	2	0	6	33	3
1766	9	1	9	100	7
1771	5	0	8	63	5
1774	6	0	9	67	3
1776	4	0	7	57	2
1782	10	2	13	92	6
1786	2	0	10	20	4
1791	12	0	14	86	5
1798	7	0	12	58	7
1800	4	1	14	36	2
1805	16	0	19	84	5
1822	22	0	22	100	17
1829	16	0	20	80	7
1834	10	0	18	56	5
1839	17	1	19	95	5
1846	14	0	18	78	7
1855	13	0	18	72	9
1868	16	0	17	94	13
1872	10	0	18	56	4
1878	8	0	17	47	6
1889	14	0	14	100	11
1895	9	0	10	90	6

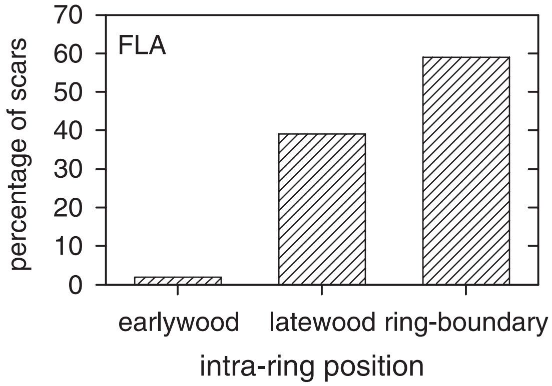


Figure 68—Intra-ring position of fire scars on ponderosa pine trees at FLA during the period from 1650 to 1900, as a percentage of scars for which it could be determined. Ring-boundary scars were formed by fires that burned between cambial growing seasons when the cambium was dormant, whereas earlywood and latewood scars were formed by fires that burned during the cambial growing season.

Discussion

Accurate Fire Histories From Stumps, Logs, and Snags

Samples from dead trees can be crossdated to yield accurate fire histories. Although removing small partial cross sections from living ponderosa pine trees does not often lead to their death (Heyerdahl and McKay 2001, 2008), removing samples from trees that are already dead can provide long, annually accurate histories of fire without any damage to living trees. Indeed, some fire histories are reconstructed entirely from dead trees, including those in national parks where removing samples from living trees is generally not permitted (for example, Swetnam 1993). Fire scars often persist even after a dead tree begins to decay (Van Pelt and Swetnam 1990), especially if the tree is from a resinous species like ponderosa pine. For example, we sampled 45 ponderosa pine stumps and one log at VIZ (fig. 1, table 2) from which we accurately dated tree rings between 1579 and 1902, including 1,463 fire scars dating as far back as 1611. One substantially eroded stump alone yielded scars from 32 different fires (fig. 2b). Dead trees, especially stumps, can also be easier and safer to sample than living trees and multiple samples can be taken from the same tree to ensure that the complete record of fire is captured. Unfortunately, fire scars are generally lost forever when modern prescribed or wildfires consume all or part of the dead trees on which they were preserved (Van Pelt and Swetnam 1990).

Climate Drivers of Regional-Fire Years

Most of the sites we report here (all but BAN, NFS, and TTM) were sampled for our broader study to infer the climate drivers of regional-fire years in the Northern Rockies (Heyerdahl and others 2008). The accurate dating techniques we used also allowed us to discover that prior to 1900, fires were remarkably widespread during some years, including one year (1748) in which fires were recorded at 10 of the sites we report here (across what are today seven different national forests). We also discovered years during which fires were not recorded at any of our sites. For example, there was a gap in fire at all sites around 1700 during a period of consistently cool spring-summer temperatures (fig. 69; Heyerdahl and others 2008). In a related study, we inferred the climate drivers of 20th century regional-fire years from digital fire atlases and found they were similar to those we reconstructed from tree rings for prior centuries (Morgan and others 2008). Since 1650, years of widespread fire in Idaho and western Montana generally had warm springs followed by warm, dry summers. Warm springs likely lengthened the fire season due to early melting of snowpack (Westerling and others 2006). In addition, during the 20th century, years of widespread fire were generally years when the Pacific Decadal Oscillation (PDO) was positive (Morgan and others 2008). Variation in PDO accounts for roughly 1/3 of the variance in modern spring snowpack in this region (Gershunov and Barnett 1998; Harshberger and others 2002; McCabe and Dettinger 2002). However, PDO was not a strong driver of fire in past centuries, consistent with a decrease in the strength of the PDO during this time (D'Arrigo and others 2001; Gedalof and others 2002; Hidalgo 2004). With the projections of more warm springs for the future under human-induced climate change, this region is likely to continue experiencing years of widespread synchronous fires in the future (Kittel and others 2002; McCabe and Wolock 1999; Mote 2006).

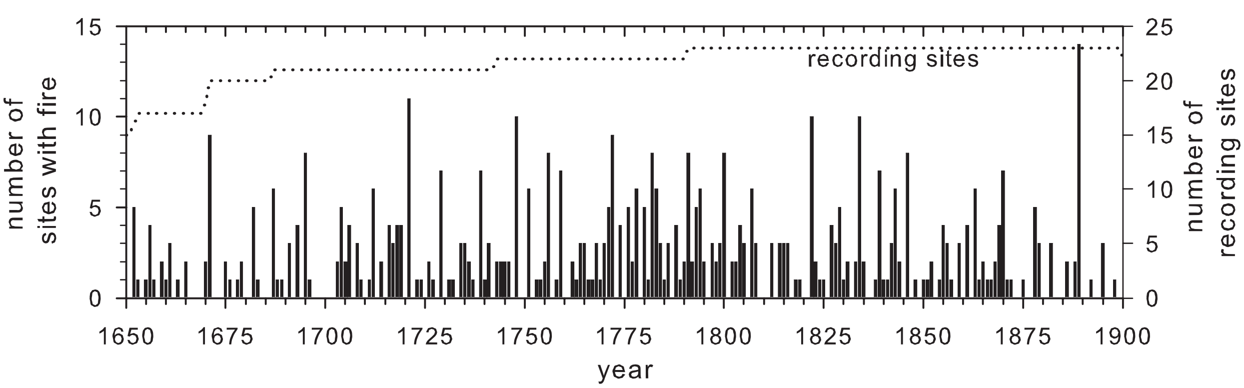


Figure 69—Annual synchrony in fire across our 23 dry-forest sampling sites in the Northern Rockies (vertical bars) and the number of fire-scar sampling sites with ≥2 trees recording (dotted line).

Management Implications

We used our fire chronologies to identify the occurrence and infer the causes of years of widespread, synchronous fires, but these chronologies can also be used to understand site-specific ecosystem conditions, such as forest composition and structure, that result from historical contingencies of climate, fire, and other factors at those sites. For example, although all of our sites share a climate-driven gap in fire around 1700 (fig. 69), there are other site-specific gaps in fire such as 1716 to 1746 at SHE (fig. 3), 1804 to 1824 at WSR (fig. 18), and 1852 to 1882 at HOL (fig. 24). These gaps, and the variation in fire intervals that they generate, can be obscured by time-averaged mean fire intervals (Swetnam and Baisan 2003). For example, FLA has a clear central tendency in mean fire interval of 6 years with 18 intervals falling between 5 and 7 years (fig. 67). In contrast, the distribution of fire intervals at SML is notable for its variation, with a mean interval of 15 years but only two intervals falling between 14 and 16 years (fig. 7).

The historical surface-fire intervals we reconstructed at our sites can be used to determine the Fire Regime Condition Class of those sites (Hann and others 2003). These intervals can serve as reference conditions, which are used to estimate the degree of departure of the modern fire regime at a site from the regime historically sustained there (Hann and others 2003). Historical fire intervals at our sites are consistent with those inferred for similar forests in the region. Mean fire intervals at our sites ranged from 6 to 29 years compared to published Fire Regime Condition Class reference conditions of 17- and 30-year mean fire intervals for dry forest BpS categories in this region ("Ponderosa pine-northern and central Rockies" and "Douglas-fir-interior Rocky Mountains", respectively ; Hann and others 2003). Our site-specific fire histories provide additional information about variation in fire intervals through time, information that is lacking in the published reference conditions. Such variations were likely important to forest structure as regeneration in ponderosa pine forests is episodic and the young trees that are vulnerable to fire are more likely to survive if there are occasional long fire intervals (Agee 1993). Our fire histories contain little data about modern fire regimes that could be used to determine Fire Regime Condition Class because most of the tree-rings we sampled were formed before 1900. However, modern fire intervals could be estimated from digital fire atlases (Gibson 2006; Morgan and others 2008).

As is true for any sample from a population, mean fire intervals that are computed from a large number of fire intervals are likely more accurate than those computed from only a few intervals (Parsons and others 2007). For example, the mean fire interval we estimated from 39 intervals at BMT is likely to be more accurate than the one we estimated from only 8 intervals at LOW.

If most fires do not burn the entire sampling site, composite fire intervals decrease as the area over which trees are composited increases (Arno and Petersen 1983; Falk and others 2007). For each of our sites, we report the intervals between fires that scarred at least two trees somewhere at that site.

However, the sites from which we report intervals vary in area from 5 to 367 acres. The locations of trees we sampled could be mapped and intervals recomputed by re-compositing the fire-scar record at each site over a similarly sized area. However, if every fire is recorded on every tree at a site, then reducing the compositing area within that site will not change the fire intervals. Pooling the data across all sites, ½ the fires we reconstructed scarred most (77 percent) of the recording trees at a site.

It is challenging to map fire regimes across landscapes based on fire histories reconstructed over small areas like ours (Keane and others 2003; Morgan and others 2001). Our site-specific fire regimes can probably be extrapolated to similarly sized areas with similar topography and forest vegetation that are adjacent to but not separated from our sites by barriers to fire (for example, a wide river). However, extrapolating them beyond these areas should be based on an understanding of the biophysical factors that drive spatial variation in historical fire regimes (Keane and others 2003; Morgan and others 2001). These factors can operate over a wide range of spatial scales – from regional gradients in climate to local gradients in topography (for example, Heyerdahl and others 2001). We specifically targeted dry forest sites that historically sustained frequent fire. While these data are appropriate for some analyses, such as identifying years of regional synchrony in fire (Heyerdahl and others 2008), they do not capture the full range of variation in fire intervals or fire severity that forests across the region sustained in the past.

The season during which a fire burns can have ecological consequences for such things as forest structure or understory composition (Harrington 1993; Kerns and others 2006). We report the intra-ring position of fire scars that could be used to infer the seasonal timing of past fires, but such inferences require data on the phenology of cambial growth, in other words, the seasonal timing of radial growth. Unfortunately, very little is known about cambial phenology in this region. The Forest Service documented tree phenology in the Northern Rockies in the early 20th century (Schmidt and Lotan 1980). However, they recorded only an inaccurate measure of cambial activity—the ease with which bark slipped from the xylem of an increment core (Wilcox and others 1956)—so their data cannot be used to infer the seasonal timing of past fires. In the future, we may be able to estimate the seasonal timing of past fires using the results of studies now underway in this region to measure modern cambial phenology and to determine the intra-ring position of 20th century fires with known burning dates.

For More Information

Our fire-scar dates and associated metadata (including the species and location of each tree) are available from the International Multiproxy Paleofire Database (IMPD), a permanent, public archive maintained by the Paleoclimatology Program of the National Oceanic and Atmospheric Administration in Boulder, Colorado (http://www.ncdc.noaa.gov/paleo/impd/paleofire.html;

IMPD site codes are given in table 2). Additional metadata is available from the Rocky Mountain Research Station Archive (http://www.fs.fed.us/rm/data-archive/access/contents_location.shtml; follow links to "Crossdated fire-scar fire histories from ponderosa pine-dominated forests of Idaho and western Montana"). More information about the results of our broader study is available in the peer-reviewed literature (Heyerdahl and others 2008; Morgan and others 2008; Shapiro-Miller and others 2007, all available from TreeSearch: http://www.treesearch.fs.fed.us/). We and others report elsewhere on two additional crossdated surface fire histories from the Northern Rockies that we did not report on here: POW (Shapiro 2006; Shapiro-Miller and others 2007) and LUB (Jones 2005). These data are also available from the International Multiproxy Paleofire Database (sites uspow001 and uslub001, respectively). For the broader study, we also assembled and error-checked a digital polygon fire atlas of 20th century fires (1900 to 2003) from records maintained at 12 national forests and two national parks in Idaho and Montana west of the Continental Divide (Gibson 2006; Morgan and others 2008). This atlas is available from the Fire Research and Management Exchange System (FRAMES, http://frames.nbii.gov). The wood samples we collected are permanently archived and currently reside at the USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, 5775 US W Highway 10, Missoula, MT 59808.

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