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Fire History in Coast Redwood Forests of the Mendocino Coast, California

Abstract

We reconstructed fire history in old-growth coast redwood stands along an ocean-to-inland gradient in Jackson Demonstration State Forest on the Mendocino Coast in northern California. Fire history was reconstructed for the past two to four centuries using fire scars recorded in tree rings. Surface fires were frequent disturbances in all stands prior to the early twentieth century. Composite mean fire-free intervals aggregated within stands varied from 6 to 20 yr, and point mean fire-free intervals averaged within trees varied from 9 to 20 yr. Fires ceased in the early 20th century coincident with the advent of organized fire suppression efforts beginning in the 1930s. Fire frequency did not vary significantly along the ocean-inland gradient. Although several of the inland stands tended to record shorter intervals between fires, there was high variability among sites. These and analogous fire-scar data from other studies across the range of coast redwood forests suggest that fire frequencies have been underestimated in some past assessments. A principal reason is that fire-scar records on coast redwood trees are difficult to locate because of inadequate preservation compared to other species that experienced surface fires. Cessation of surface fires has resulted in shifts in fuel and forest structure over recent decades, and the fire history reconstructed by this study provides both guidelines and justification for ecological restoration efforts in coast redwood forests of this region.

Introduction

Fire has long been recognized as an important disturbance in coast redwood (*Sequoia sempervirens*) forests (Fritz 1931), but the exact nature of historical fire regimes in many areas is uncertain. Coast redwood grows in relatively mesic, often fog-shrouded coastal locations not usually associated with widespread or frequent fires. Past studies and reviews of coast redwood fire ecology have concluded that, over much of its range, fires were typically infrequent and that effects on forest composition and structure varied depending primarily on fire severity (Veirs 1980, 1982, 1996; Wright and Bailey 1982; Agee 1993; Sawyer et al. 2000a). However, a growing body of evidence documents that frequent, episodic surface fires were the dominant fire regime in many coast redwood forests, and that loss of surface fires has occurred over the recent century in response to loss of Native American ignition sources, active fire suppression, and other changes in land use (Finney 1990; Finney and Martin 1989, 1992; Brown and Swetnam 1994; Brown et al. 1999).

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Differences seen in fire regimes reconstructed by various studies are likely related both to site conditions that vary along ocean-to-inland gradients and with latitude (Veirs 1982, Stuart 1987, Agee 1993, Sawyer et al. 2000a) and to the differing methods used to reconstruct fire histories (Finney and Martin 1989, Brown and Swetnam 1994). Fire histories based mainly on aging of coast redwood or substory canopy trees have typically found that fires were infrequent and relatively severe, with recurrence intervals of ca. 20 to > 500 yr (Veirs 1980, 1982, 1996; Stuart 1987). Other studies examined fire scars to reconstruct relatively long intervals recorded on individual trees, with ranges from ca. 20 to > 50 yr between mixed-severity fires (Fritz 1931, Jacobs et al. 1985, Stuart 1987). Other fire-scar studies used data composited from several trees to reconstruct high surface fire frequencies in some areas, with mean recurrence intervals from 7 to 15 yr depending on site conditions and period analyzed (Finney 1990; Finney and Martin 1989, 1992; Brown and Swetnam 1994; Brown et al. 1999).

Defining the historical nature of fire has important implications for understanding ecological dynamics and guiding sustainable management in coast redwood forests (Jacobs et al. 1985, Thornburgh et al. 2000). Ecologists and managers increasingly rely on historical data to assess forest conditions over longer time scales than are available from direct observations (Morgan et al. 1994, Landres et al. 1999). Fire was an especially ubiquitous disturbance in many forests for many centuries to millennia, but historical patterns have been disrupted over the recent century by changes in land use and active fire suppression (Covington et al. 1994). Cessation of Native American burning in coastal California forests (Lewis 1973) also contributed to a general loss of historical fire regimes from this area. Changes in fire regimes in coastal forests have resulted in associated changes in vegetation patterns, such as increases in tree density and invasion of woodlands and forests into areas that were historically grass or shrub ecosystems (Brown et al. 1999). Some ecologists have suggested that coast redwood should be considered a climax species and fire-independent (Fritz 1931, Roy 1966, Wright and Bailey 1982) whereas others contend that fire is a necessary component in coast redwood ecology (Cooper 1965, Stone et al. 1972) and should be reintroduced in parks and other natural areas (Jacobs et al. 1985).

In this study, we report on an ocean-to-inland gradient of fire-scar collections from coast redwood forests in Jackson Demonstration State Forest on the Mendocino Coast in northern California. We reconstructed fire history for the past two to four centuries in seven stands to test a hypothesis that fire frequency varied from mesic coastal forests to drier inland stands (Veirs 1980, 1982). Veirs (see also Sawyer et al. 2000a) proposed that fire varied from greater than 250-yr recurrence intervals at often fog-shrouded coastal sites to ca. 50-yr intervals in inland mixed coast redwood - Douglas-fir (*Pseudotsuga menziesii*) forests. Our objectives for this study are to provide detailed fire histories from this area of the California coast and to help further define the historical role of fire in coast redwood forests throughout its range.

Methods

Study Area

Jackson Demonstration State Forest was established in 1947 to demonstrate and research timber harvest methods and impacts in coast redwood-Douglas-fir forests of the northern California coast (Figure 1). The area that includes the 20,316 ha state forest has had a history of continuous timber production since the 1860s (Wurm 1986), and only a few areas of residual old-growth forest exist (Henry 1998). Clear-cut logging was exclusively used as a harvest method until the mid-twentieth century. Current forests typically consist of dense stands of second-growth coast redwood, Douglas-fir, western hemlock (*Tsuga heterophylla*), and grand fir (*Abies grandis*) (Henry 1998). Substory hardwood tree species include tanoak (*Lithocarpus densiflora*) and red alder (*Alnus rubra*), and

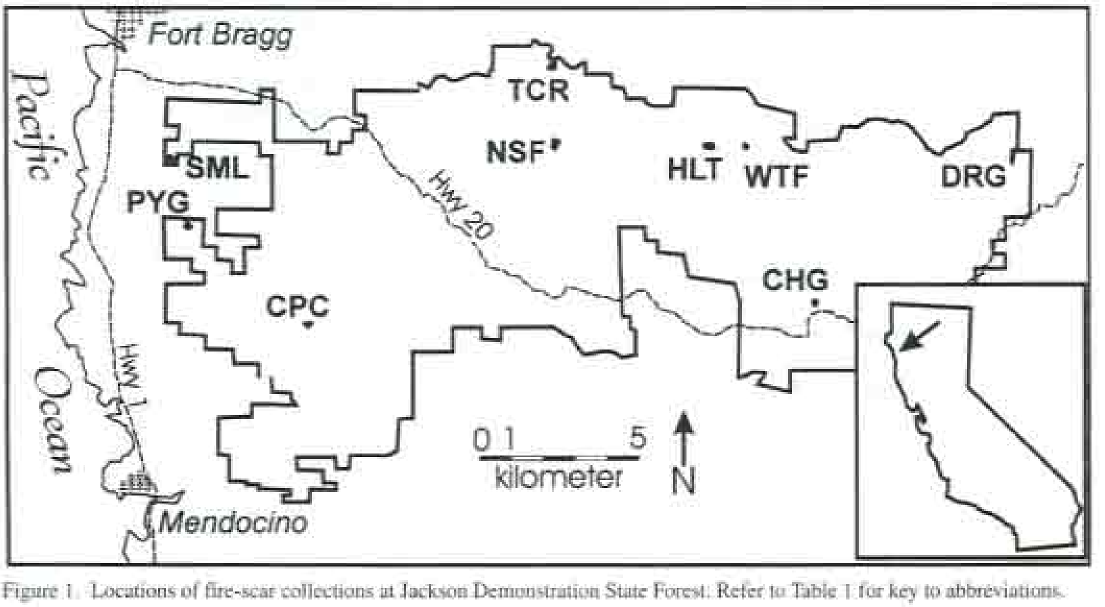

Figure 1. Locations of fire-scar collections at Jackson Demonstration State Forest. Refer to Table 1 for key to abbreviations.

understory shrub species include huckleberry (*Vaccinum* spp.), Pacific rhododendron (*Rhododendron macrophyllum*), and sword fern (*Polystichum munitim*). Overstory dominance by coast redwood generally decreases from west to east, and forests are fringed on the west by a band of coastal shrub and grasslands. Soil nutrient-poor terraces along the coast also support unique pygmy forests of stunted pines and cypress (Westman and Whittaker 1975). Coast redwood often forms pure stands in drainage bottoms or in more moist areas, but is intermixed with other species on slopes and dryer locations.

Coast redwood occurs along a relatively narrow coastal band from central California south of Monterey Bay to the extreme southwestern coast of Oregon (Roy 1966). Coast redwood forests experience a Mediterranean climate with mild, wet winters and cool, dry summers. The distribution of coast redwood in coastal mountain ranges and valleys corresponds closely to the presence of oceanic fogs that reduce evapotranspirative stress during otherwise dry summer months (Dawson 1998). Annual temperature fluctuations on the coast also are moderated by the oceanic influence relative to inland locations (Figure 2). In addition to moisture gradients that occur with distance from the ocean, three major subregions of coast redwood have been defined based on moisture regimes and forest structure (Sawyer et al. 2000b). The Mendocino Coast is in the central subregion, and coast redwood forests here are compositionally and ecologically more similar to inland Douglas-fir-tanoak forests than to coast redwood forests of the generally moister northern subregion that have affinities with northwestern coastal forests (Agee 1993, Sawyer et al. 2000b).

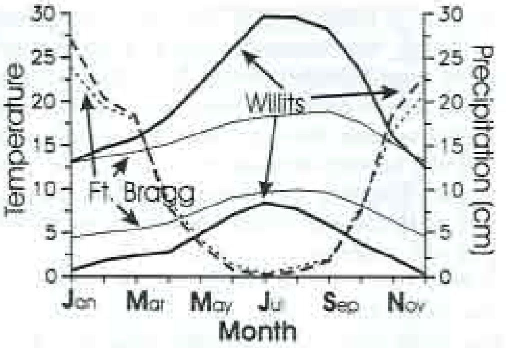

Figure 2 Climate summaries for Ft. Bragg on the coast (light lines), and Willits, 39 km inland (heavy lines). Mean monthly maximum and minimum temperatures (solid lines) and total precipitation (dashed lines) are from Western Regional Climate Center (2002).

Prior to Euro-American settlement that began in this area in the mid-nineteenth century, many (if not most) historical fires were likely set by humans. Lightning during the historic period has been rare on the California coast, especially compared to other regions in California (Program for Climate, Ecosystems, and Fire Applications 2002). References to Native American burning practices are extensive (Lewis 1973, Boyd 1999), and coastal tribes were known to have set fires for clearing brush, hunting, or accidentally.

Selection of Sites and Trees for Reconstruction of Fire History

We selected stands for reconstruction of fire history based on the presence of living old-growth coast redwood trees (Figure 1, Table 1). All stands had predominantly or exclusively coast redwood overstory. We surveyed known patches of residual

TABLE 1. Fire history sites at Jackson Demonstration State Forest.

Site	Site code	Elev. (m)	Dist. from ocean (km)	Slope (deg)	Aspect	Site area (ha)	No. of trees collected/aged
Simpson Lane	SML	82 - 98	2.8	<5	W	18.6	15/0
Pygmy Forest	PYG	94 - 110	3.2	<5	NW	6.2	9/6
Caspar Creek	CPC	195 - 213	8.0	5-10	W	12.8	8/0
N. Fork of the S. Fork	NSF	350 - 398	14.7	20-25	N	10.0	8/4
Three-Chop Ridge	TCR	350 - 384	14.7	20-25	S	10.8	6/3
High-Low Trestle	HLT	366 - 421	19.3	35-45	S	22.0	32/14
Waterfall Grove	WTF	280 - 338	20.3	0-40	S	16.9	18/8
Chamberlain Grove	CHG	219 - 244	22.1	10-30	SE	5.6	15/8
Dresser Grove	DRG	314 - 366	27.8	10–15	N	14.5	15/5
Total trees collected/aged							126/48

old-growth forest at JDSF for either living trees or stumps with sequences of fire scars that resulted from repeated surface fires. We also surveyed several harvested areas but were not able to find suitable fire-scar records. Stumps were typically heavily decayed and charred from past broadcast burning that took place during logging operations (Wurm 1986). Random selection of sites was, therefore, not possible because of the extreme rarity of preservation of appropriate fire-scar data both across the JDSF landscape and on individual trees. As with other paleoecological data (e.g., pollen sequences, fossil assemblages), adequately preserved paleo-fire records are patchily distributed and directed sampling had to be employed to derive a useful data set. However, because of the arbitrary nature of preservation of the residual old-growth stands where we reconstructed fire histories, we consider the distribution of our sites to be randomly placed across the landscape and, thus, likely representative of landscape patterns of fire occurrence over the past few centuries.

Once trees with fire-scar records were found, we used a chainsaw to cut partial transverse cross sections from a location with the most visible fire scars. On several trees, more than one cross section was cut in an effort to obtain more complete sequences. Our goal during sampling was to compile inventories of fire events from fire scars recorded on 8 to 30+ trees in stands 4-20 ha in size for as far back in time as fire-scar records could be found (Swetnam and Baisan 1996, Brown et al. 2001). Our population of interest for fire frequency analysis consists of fire events that occurred prior to extensive logging that began in this area in the 1860s.

Development of Fire Chronologies

All wood samples were prepared and surfaced such that cellular structure was visible in tree rings. We attempted to crossdate tree-ring series using skeleton plots (Stokes and Smiley 1968) and cross-correlations of measured ring widths (Brown and Swetnam 1994). Unusually narrow and wide rings and locations of fire scars were marked on skeleton plots made for each cross section (also see methods in Finney and Martin 1989 and Brown and Swetnam 1994). We also recorded positions of fire scars within ring series, which is an indication of seasonal timing of past fires. Ring widths on selected radii of some cross sections were measured using a moveable stage connected to a linear encoder. Cross correlations of measurements between radii were calculated using program COFECHA (Holmes 1983). Skeleton plots and measured ring widths were compared to each other, to those made from living unscarred Douglas-fir in the same stands, and to existing tree ring-width chronologies and reconstructions of Palmer drought severity indices (PDSI) for this area of northern California (National Geophysical Data Center 2002).

We compiled approximate fire dates for all fire-scarred trees in each stand into fire chronologies using program FHX2 (Grissino-Mayer 2001). FHX2 is an integrated package for graphing and statistical analyses of fire-scar data. Fire frequencies for different periods of the fire chronologies were estimated using mean fire intervals (MFI) and Weibull median probability intervals (WMPI) (Grissino-Mayer 1999). Variability in fire intervals is reported as the first standard deviation and range of intervals. We also calculated mean point fire intervals based on fire intervals recorded within individual trees. We used regression analysis to assess whether there were significant differences in composite and point MFIs along the ocean-inland gradient.

Results

Fire Chronologies

We determined approximate fire-scar dates on 48 trees from 7 stands out of a total of 126 trees sampled from 9 stands (Table 1, Figure 3). We were unable to determine fire-scar dates on many trees because of the often extreme tightness of ring series that made ring counts unreliable. On other trees, fire-scar sequences were too eroded by decay or past burning of the scarred surfaces (Figure 4), and fire dates were available back to only the late 19th century at the earliest. Two of the sites (SML and CPC) lacked fire dates to calculate pre-harvest fire frequency.

Certainty in crossdating was not possible in any coast redwood samples, generally because tree rings tended to be complacent with little variability in ring widths or other climatically-controlled morphological characteristics with which to cross-match with other trees in a stand or area (Fritz and Averill 1924, Fritz 1940, Schulman 1940, Brown and Swetnam 1994). Tree rings in coast redwood trees also often end abruptly for no

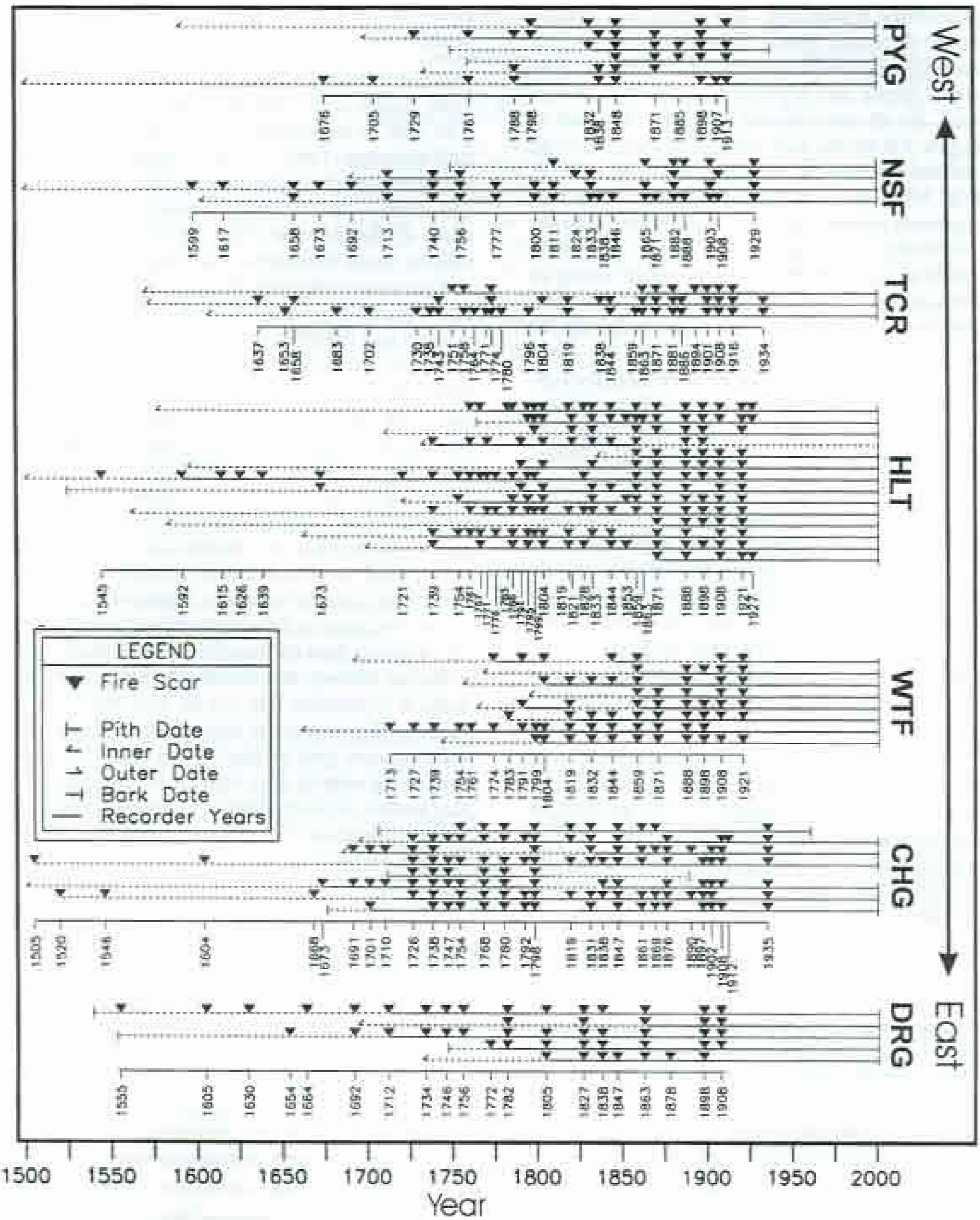

Figure 3. Fire chronologies for Jackson Demonstration State Forest sites. All samples are from coast redwood. Time spans of individual trees are represented by horizontal lines with inverted triangles marking dates of fire scars. Pith or bark dates refer to pith or bark present on cross sections while inside or outside rings refer to cross sections with unknown numbers of rings to pith or bark. Inside dates on several trees extend earlier than 1500. Dashed segments on trees are decayed segments where fire scars are likely missing from the fire-scar record. These segments were not used to calculate point fire frequencies in Table 3.

predictable reason (i.e., not driven by climatic stress) (Fritz and Averill 1924, Fritz 1940) which further complicated compilation of complete ring series within and between trees. For these reasons, we do not consider fire dates reported in Figure 3 to be absolute dates. However, tree-ring and fire-scar dates on most trees in four sites (WTF, NSF, HLT, and CHG) were consistent back to a regionally narrow ring at 1829, and we have greater confidence in dating of fires for this period. In addition, we were able to cross-match timing of fire scars back to the early 1700s in all sites, and fire dates reported in Figure 3 are likely not far off from true dates, if at all. Several fire dates (e.g., 1754, 1819, 1871, 1908) were recorded synchronously across multiple stands (Figure 3), and we have some confidence that these represent larger-scale fires that burned across the JDSF landscape.

No fire scars were recorded in any stand after the middle 1930s (Figure 3). Fire frequency through time appears to have been relatively uniform in most stands, with no major changes in fire frequency through periods of adequate sample depth (i.e., numbers of trees per year) in each chronology. The longest intervals in most chronologies were recorded during the early nineteenth century (Figure 3).

Where fire-scar position within ring series could be determined, fire scars occurred almost exclusively late in the growing season or as dormant season scars between two rings (Table 2). The majority of fires likely occurred during the period from late August to late fall (October to November).

Fire Frequency Along the Ocean-Inland Gradient

Pre-20th century fire frequency was generally high in all stands, with composite MFIs ranging from 6 to ~ 20 yr depending on site location and period analyzed (Table 3). The longest mean intervals were recorded in the westernmost stand (PYG) and several of the centrally located sites recorded some of the shortest (TCR, HLT). WMPIs are slightly lower than MFIs reflecting positive skew in interval distributions (Grissino-Mayer 1999). Fire-interval distributions tend to be positively skewed and WMPI is argued to be a more robust estimator of central tendency in interval data (Grissino-Mayer 1999). Composite fire frequencies were not significantly related to the ocean-inland gradient in regression analysis. Although there was a tendency for composite frequencies to decrease from west to east (Table 3), this decrease is likely related to the number of trees included in composite fire chronologies which tended to be greater in the more eastern stands (Table 1). Greater number of trees in a composite chronology will tend to include more fires if average fire size was less than the area from which trees were collected (Brown and Swetnam 1994). Furthermore, it is possible that not all fires that burn at the base of an individual tree are recorded as scars and fire scars may be lost from a record by erosion or burning in later fires. Censoring of fire-scar records on individual trees also will result in higher composite fire frequencies with greater number of trees used to calculate composite fire intervals.

TABLE 2. Fire-scar positions in annual rings and probable season of occurrence (fire-scar positions after Dieterich and Swetnam 1984), based on 544 total fire scars.

Fire-scar position	No. of scars	% of total scars[1]	Probable season of occurrence
Dormant	217	52	After growth ended: September to late fall
Latewood	164	39	In the latewood band: mid-August to September
Late-earlywood	20	5	Latter third of the earlywood; July to August
Middle-earlywood	15	4	Middle third of the earlywood; June to July
Early-earlywood	0	0	Early-third of earlywood; April to May
Unknown	128	—	Fire-scar position within ring could not be assessed

[1] Excluding unknown scars

TABLE 3. Fire frequencies in coast redwood stands at Jackson Demonstration State Forest.

Site	Period analyzed	Intervals per stand MFI ± 1 SD (yr)	WMPI (yr)	Range (yr)	Intervals per tree No. of trees	MFI ± 1 SD (yr)
PYG	1700s	–	–	–	–	–
	1750 - 1850	17.4 ± 12.3	15.8	6 - 34	5	24.5 ± 5.9
	1800s	13.2 ± 6.3	12.9	6 - 23	6	18.8 ± 7.7
NSF	1700s	21.8 ± 4.6	22.1	16 - 27	3	21.6 ± 0.1
	1750 - 1850	12.9 ± 6.7	12.4	5 - 23	3	14.4 ± 5.1
	1800s	9.8 ± 4.4	9.6	5 - 19	4	13.0 ± 5.1
TCR	1700s	9.4 ± 7.4	8.3	3 - 28	2	9.9 ± 2.3
	1750 - 1850	9.3 ± 5.3	8.8	3 - 19	3	12.4 ± 0.9
	1800s	10.0 ± 5.2	9.6	4 - 19	3	11.1 ± 0.7
HLT	1700s	7.1 ± 4.9	6.5	3 - 18	8	11.6 ± 6.2
	1750 - 1850	6.0 ± 3.3	5.7	2 - 15	10	13.0 ± 4.9
	1800s	8.6 ± 4.6	8.1	2 - 17	14	14.5 ± 2.6
WTF	1700s	–	–	–	2	14.7 ± 3.3
	1750 - 1850	10.0 ± 3.4	10.1	5 - 15	5	12.7 ± 1.5
	1800s	13.4 ± 2.4	13.6	10 - 17	8	14.9 ± 2.3
CHG	1700s	10.8 ± 3.3	10.9	6 - 16	8	12.2 ± 2.0
	1750 -1850	11.6 ± 4.7	11.5	6 - 21	8	13.7 ± 2.0
	1800s	9.8 ± 3.1	9.8	7 - 14	7	14.1 ± 3.7
DRG	1700s	14.0 ± 5.1	14.0	10 - 22	3	15.0 ± 4.3
	1750 - 1850	15.2 ± 6.2	15.1	9 - 23	4	17.9 ± 3.2
	1800s	15.5 ± 5.0	15.6	9 - 22	5	24.1 ± 7.0

Point fire frequencies averaged within individual trees before averaging within sites confirm that fire frequency did not vary significantly across the ocean to inland gradient (Table 3). There is consistency in fire frequencies recorded on individual trees, with most trees recording interval ranges from around 10 to 20 yr depending on site and period analyzed. Although, again, there was a tendency for the western stands to have recorded slightly longer intervals than those in the east, this trend was not significant in regression analysis.

Discussion

Fire History on the Mendocino Coast

Surface fires were frequent disturbances in coast redwood forests of the Mendocino Coast prior to the early 20th century (Figure 3). Long sequences of fire scars recorded on individual trees were rare but present in all old-growth stands we examined. As stated in the methods, because of the random nature of preservation and locations of these stands, we believe that reconstructed patterns of episodic surface fires represent the typical fire regime in this area. Although we did not collect tree-origin data from the stands we sampled, we do not believe that large portions of this area burned in past catastrophic fires over the period covered by fire-scar records, although mixed-severity burning (i.e., containing some component of overstory mortality) likely occurred during some fires across limited areas. Frequent surface fires, by themselves, imply that fuel buildup and formation of ladder fuels needed for fire to burn catastrophically were less likely to have occurred than if intervals between fires were longer (Keane et al. 1990). We were unable to reconstruct fire history in any of the cut-over areas because of a lack of adequate preservation of fire-scar records. Our experience is that processes of decay and erosion have removed fire-scar records from these areas, rather than that the records were never there originally. Coast redwood trees appear to be more susceptible to burning or decay of scarred surfaces, likely as a result of less woundwood formation on fire scar margins as part of the compartmentilization process in the wound area (Figure 4; Smith and Sutherland 2001), in contrast to pines or other

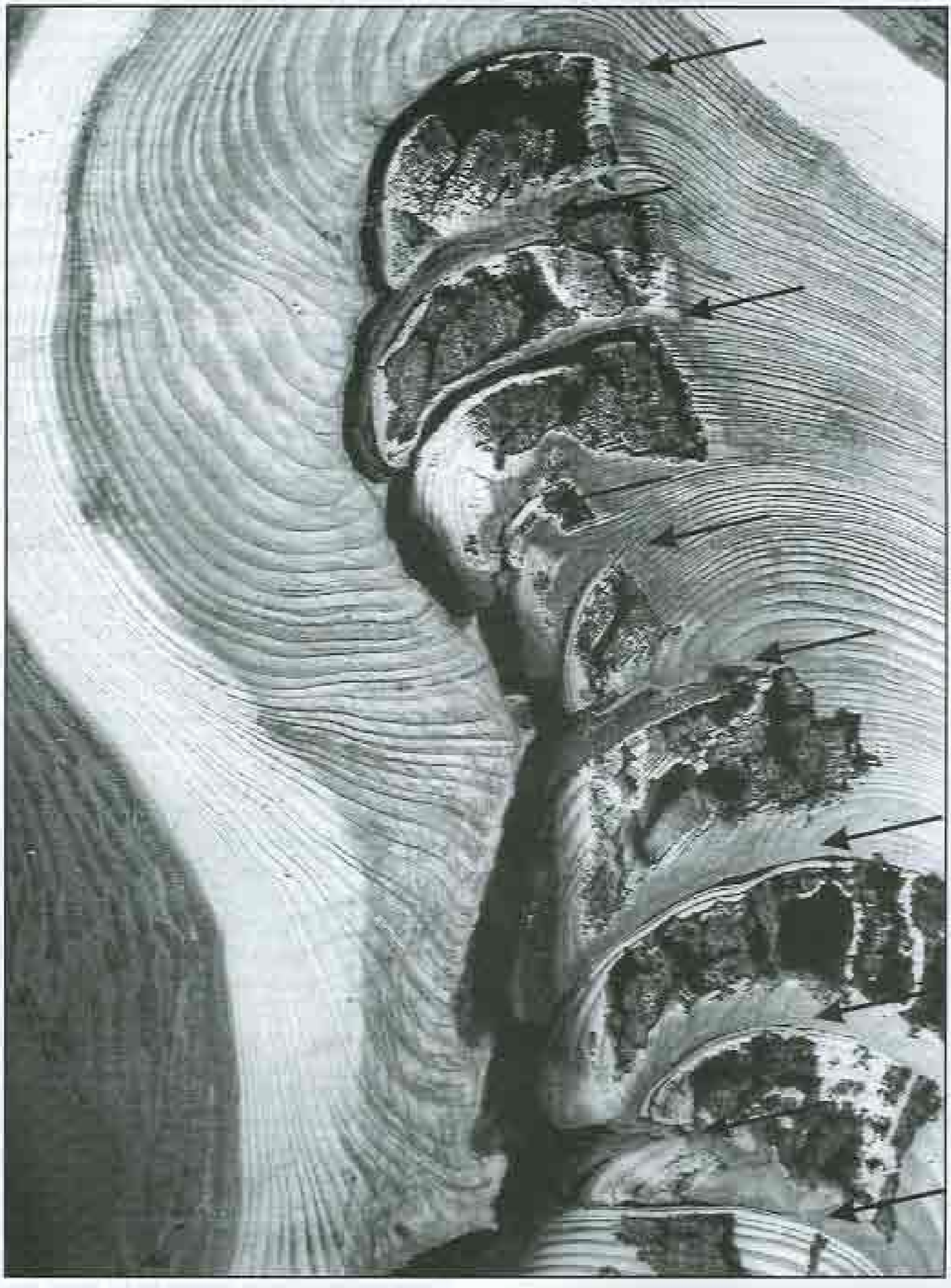

Figure 4. Image of fire-scar sequence on tree TCR-6. Fire scars are marked by black arrows. Note wood decay on outside margins of fire-scar sequences. In coast redwood, compartmentilization through woundwood formation in the injury areas (Smith and Sutherland 2001) tends to stop where fire scars end in the ring series, whereas in other species (e.g., pines, giant sequoia) woundwood formation occurs continuously to the outside of wood growth. More continuous woundwood formation in pines and other species results in less decay of scarred surfaces and thus better preservation of fire-scar sequences through time.

species in which well-preserved fire-scar sequences are commonly used to reconstruct fire history.

Fire frequencies that we reconstructed in stands and on individual trees (Table 3) are similar to fire frequencies recorded in many lower-elevation forests of the western United States, including ponderosa pine (*Pinus ponderosa*) and mixed-conifer forests of the Southwest (Swetnam and Baisan 1996, Brown et al. 2001) and giant sequoia (*Sequoiadendron giganteum*) and mixed-conifer forests of the Sierra Nevada (Swetnam 1993, Beaty and Taylor 2001). Fire frequencies in Table 3 also are comparable to those found in mesic coastal Douglas-fir forests at Olympic National Park well to the north of the Mendocino Coast (Wetzel and Fonda 2000) and strengthen our argument that surface fires are not only restricted to dryer inland forests. As in virtually all fire histories reconstructed from forests throughout western North America, fires ceased entirely during recent decades as a result of land use changes and fire suppression (Figure 3). On the Mendocino Coast, active fire suppression began after the Comptche Fire in September 1931, burned ~12,150 ha of forest southeast of JDSF. Before this date, wildfires were rarely suppressed unless they threatened homes. During the early Euro-American settlement era (after ca. 1850), ranchers and loggers routinely set fires to increase grazing area and to reduce slash before harvesting of logs. After the Comptche Fire, the California Department of Forestry and Fire Protection (CDF) established fire stations that initiated the period of total fire exclusion that continues to the present (Figure 3).

Coast redwood occurs in coastal mountain ranges that receive moisture inputs from cool summer fog during otherwise dry summer months (Roy 1966, Dawson 1998). Fog-shrouded coastal sites would not, at first glance, appear to be areas able to support frequent or widespread surface fires. However, understory fuels typically cure after summer fogs dissipate during the later summer or fall and before winter rains begin (Arno and Alison-Bunnell 2002), which is the period during which most fires occurred in the historical record (Table 2). Although inland stands are warmer with a greater range of temperature variations (Figure 2), fire frequency did not vary significantly along the ocean-inland gradient (Table 3), undoubtedly as a result of other site factors not accounted for by the gradient we tested. Fire occurrence and spatial patterning are highly variable processes, driven by multiple spatial and temporal factors that cannot always be accounted for or predicted. We found fewer well-preserved pre-settlement fire-scar records in stands close to the coast, and most of our data are from what should be considered as intermediate to dry inland stands (Veirs 1982). Forests along the coast were harvested earliest during the early settlement period (Wurm 1986) and presumably experienced more burning - and, thus, greater loss of fire-scar evidence - after trees were cut in the early logging era. The one coastal stand in which we were able to reconstruct pre-settlement fires, PYG, tended to have longer intervals than more inland sites (Table 3). However, all stands, regardless of their location, recorded higher fire frequencies than those hypothesized by Veirs (1980, 1982).

Implications of the Fire History for Management of Old-Growth Coast Redwood Forests

Loss of surface fires from coast redwood forests has led to changes in associated ecosystem patterns and processes that are analogous to those in ponderosa pine and other low-elevation forests of the western North America (Covington et al. 1994). Frequent surface fires promote open, low-density stand structure by killing a majority of tree regeneration before it has a chance to reach canopy status. Fire-intolerant species, such as grand fir, western hemlock, and hardwoods, would have had less opportunity to establish between fires and likely were not as abundant in pre-fire exclusion forests as they are today. Biomass of shrubs also would have been reduced because of recurrent mortality during episodic burns. Duff and woody litter would have been reduced, and diversity and biomass of grass and herbaceous vegetation likely were correspondingly greater (Covington et al. 1994). Increases in fuel loads, tree density, canopy coverage, and formation of ladder fuels result in feedbacks to the fire regime, with the result that crown fires replace surface fires as the dominant fire behavior when fires occur. Although fire exclusion on the Mendocino Coast occurred later in the 20th century than many other low elevation forests in North America, coast redwood forests are often nearly twice as productive as pine or mixed-conifer forests of the central mountains or Sierra Nevada in California. Because of higher productivity in these relatively warm, wet coastal forests, changes in community composition and fuels structure may be as pronounced as in other forests that experienced earlier loss of surface fire regimes.

The probable role of Native-Americans in fire ignitions leads to questions concerning the appropriate approach to management of coast redwood ecosystems in this area. In the absence of human ignitions, it is likely that fires would not have been as common, and historical forest composition and structure may have been quite different under such altered fire regimes. Historical variability in fire regimes reconstructed by this study does not imply that we are documenting a natural range of variability (i.e., driven by primarily natural processes). Rather, we document the fire regime that was dominant for the few centuries before fire suppression and other ubiquitous land use impacts brought by rapid human population increases that accompanied Euro-American settlement. Historical data are meant to provide restoration ecologists and land managers with descriptions of ecosystem conditions over long time scales, regardless of whether they were influenced by human or natural factors (Landres et al. 1999). How these data are used in management decisions is as much a societal as it is an ecological question. Do we attempt to restore these forests to historical conditions, or let them return naturally to a fire regime that would have likely been present in the absence of Native American influence?

What is clear from this study is that recent assessments of historical fire regimes in coast redwood forests (Sawyer et al. 2000a) have, for the most part, underestimated the frequency and probable role of surface fires in at least some coast redwood forests over the past several centuries. In our experience, we found fire-scar records to be rare because of poor preservation. Where fire-scar records have been compiled, fire histories have documented that many coast redwood forests are not burning today nearly as often as they did in the past (Finney 1990; Finney and Martin 1989, 1992; Brown and Swetnam 1994; Brown et al. 1999). Recognition of changes caused by loss of surface fires has resulted in efforts to restore historical processes in many low-elevation forests throughout western North America (Landres et al. 1999). The fire history reconstructed by this study provides both guidelines and justification for ecological restoration efforts in coast redwood forests of this region.

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