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Human vs. Lightning Ignition of Presettlement Surface Fires in Coastal Pine Forests of the Upper Great Lakes

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ABSTRACT.—To recover direct evidence of surface fires before European settlement, we sectioned fire-scarred logging-era stumps and trees in 39 small, physically isolated sand patches along the Great Lakes coast of northern Michigan and northern Wisconsin. While much information was lost to postharvest fire and stump deterioration, 147 fire-free intervals revealed in cross-sections from 29 coastal sand patches document numerous close interval surface fires before 1910; only one post-1910 fire was documented. Cross-sections from the 10 patches with records spanning >150 yr suggest local fire occurrence rates before 1910 ca. 10 times the present rate of lightning-caused fire. Since fire spread between or into coastal sand patches is rare, and seasonal use of the patches by Native people before 1910 is well documented, both historically and ethnographically, ignition by humans probably accounts for more than half of the pre-1910 fires recorded in cross-sections.

INTRODUCTION

Chronologies of presettlement stand destroying fires in pine dominated portions of the Great Lakes Forest (Flader, 1983) have been derived from sediment cores containing charcoal (*e.g.,* Cole, 1995) and from General Land Office survey notes from the 1840s (Bourdo, 1956; Whitney, 1986). However, estimating periodicity of less intense but more frequent surface fires, accomplished in western North America through fire scar analysis (Arno and Sneck, 1977), has proven difficult here since massive harvest and subsequent intense slash fires destroyed most of the fire scar record near the turn of the 20th century (Cwynar, 1977; Whitney, 1986; Stearns, 1987; Karamanski, 1989; Barrett, 1995). Increased interest in the history of surface fires in eastern forests has accompanied controversies concerning the relative roles of humans and lightning as ignition sources, before major European settlement (Day, 1953; Stewart, 1963; Lewis, 1980; Pyne, 1982; Russell, 1983; Albert and Minc, 1987; Lewis and Ferguson, 1988; Patterson and Sassman, 1988; Dorney and Dorney, 1989; Guyette and Cutter, 1991; Denevan, 1992; Russell *et al.,* 1993; Campbell and McAndrews, 1995; Clark, 1995; Clark and Royall, 1995).

The only direct record of surface fire in original pine forests of northern Michigan and northern Wisconsin is contained in rare fire-scarred logging-era stumps and in fire-scarred trees that survived the cutover. Counts of annual rings between fire scars on these meager forest remnants have been used to assess preharvest and postharvest fire-free intervals (*i.e.,* periods between scarring fires; Romme, 1980) on a large, upland, sand plain in northern Lower Michigan (Simard and Blank, 1982) and in several isolated coastal sand patches in eastern Upper Michigan (Loope, 1991). Fire-scarred stumps and trees are widely scattered in similar settings in northern Michigan and Wisconsin.

The physical setting and cultural histories of small coastal sand patches along the upper Great Lakes (Fig. 1) present an opportunity to investigate further the preharvest mix of

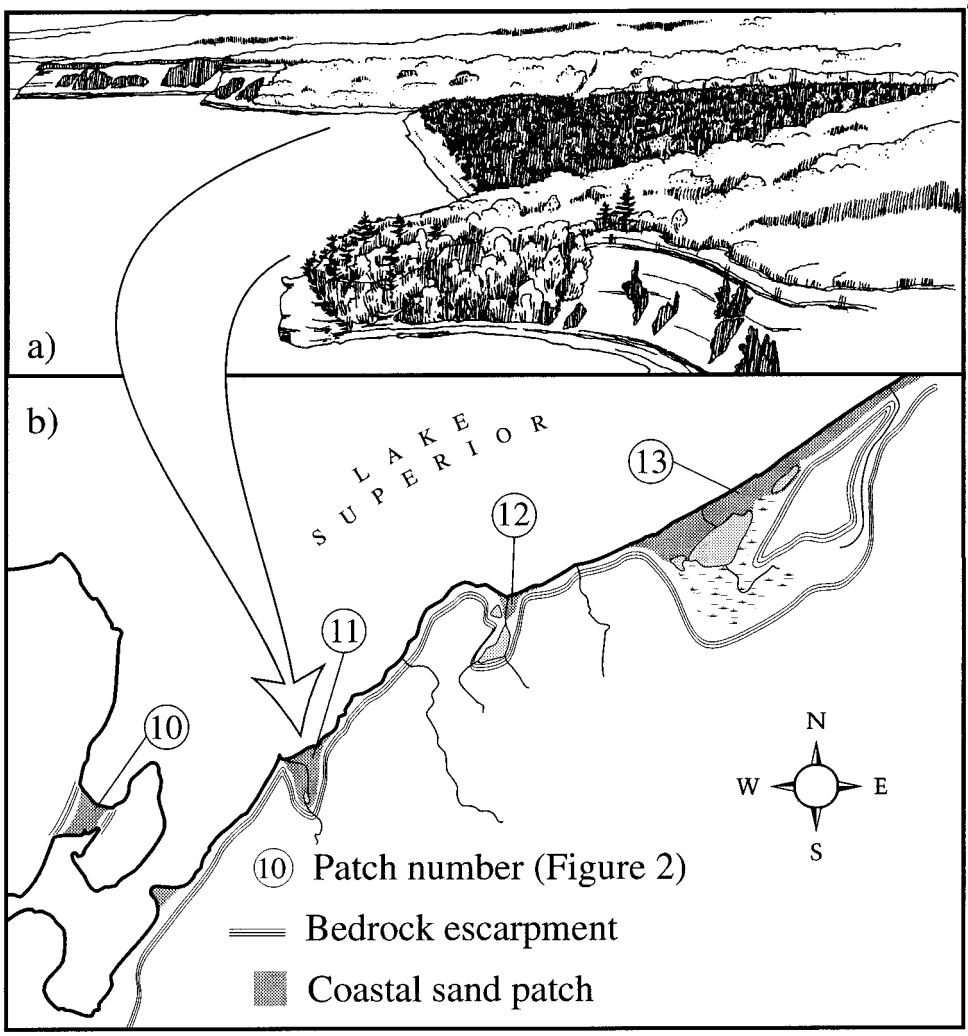

FIG. 1.—Landscape setting of several coastal sand patches along the S shore of Lake Superior: inset a) shows relationship between excessively drained sand patch soils supporting pinelands and finer textured soils on surrounding uplands supporting northern hardwood forest; inset (b) shows arrangement of coastal sand patches along the S shore of Lake Superior

human vs. lightning ignition of surface fires. Since persistent edaphic and topographic barriers to fire spread surround many of these patches (Berndt, 1977; Heinselman, 1981a; Stearns, 1987; Loope, 1991; Whitney, 1992; Carey, 1993), spread of fire into or between patches can be assumed to be rare and fires recorded within patches would have required local ignition. Native people, who used fire to dry meat and other foodstuffs for preservation (Densmore, 1979), to clear land (Albert and Minc, 1987; Cleland, 1992), and to stimulate berry production (Hagen and Rhodes, 1976) seasonally occupied camps in or near

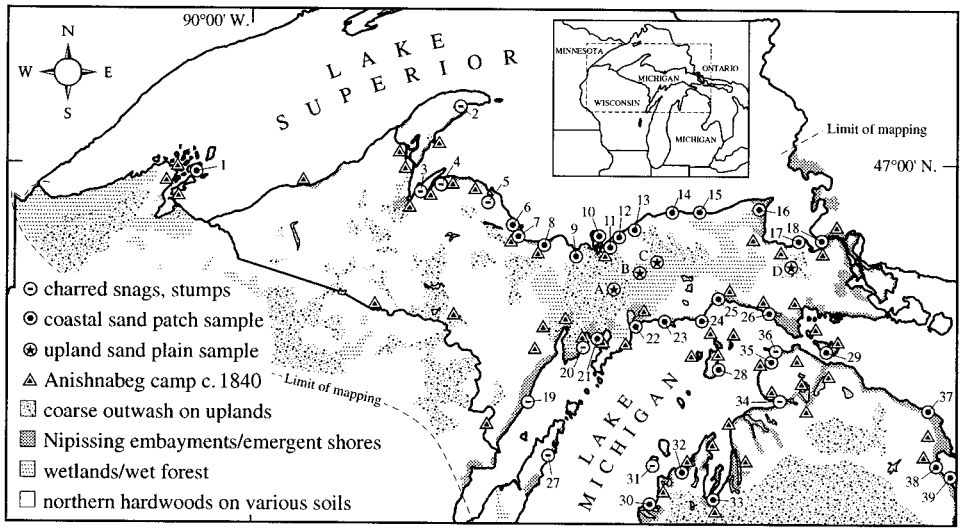

FIG. 2.—Location of coastal sand patches (1–39) and upland sand plains (A–D) selected for sampling along the upper Great Lakes

coastal sand patches during the 18th and 19th centuries, using the transportation corridors afforded by the Great Lakes (Trygg, 1964; Tanner, 1987).

The purpose of this study is to test the hypothesis that, before major European settlement, surface fires in pine forests within selected small, isolated, coastal sand patches along the upper Great Lakes occurred at rates exceeding present rates of lightning-caused fire. Analysis of fire-free intervals recorded in fire-scarred logging era stumps and fire-scarred trees that survived the cutover will be discussed in the context of modern fire incidence data available from public land management agencies, fire history literature, changes brought to the landscape by European settlement, and regional Native American history and ethnography.

METHODS

With the use of topographic and soils maps, 39 small, isolated, coastal sand patches along the upper Great Lakes were selected for sampling of stump and tree cross sections (Fig. 2; sand patches are numbered 1–39). Criteria for patch selection included: (1) lakeshore location, (2) small size, and (3) patch boundaries with high resistance to fire spread (Fig. 1). Resistance of patch boundaries to fire spread is imparted by adjacent northern hardwood or wetland vegetation (Heinselman, 1981a), abrupt soil texture changes (Berndt, 1977; Stearns, 1987; Whitney, 1992; Carey, 1993), open water, steep rock cliffs, or sand bluffs and is long standing ($\gg$1000 yr; Brubaker, 1975). Within each selected patch, charred *Pinus resinosa* stumps and large diameter fire scarred trees were sectioned to recover fire-free interval data (Fig. 3). To corroborate the logging-era origin of stumps and to estimate the period in years since the last fire at stump locations ("most recent fire free period" or MRFFP), increment core ages of nearby (<100 m) large diameter conifers with unburned lower branches were obtained and 10 yr added to account for seedling establishment and growth to breast height (Fowells, 1965, p.332). MRFFP for cross-sections from fire scarred trees was recorded as the ring count outside the most recent fire scar. An attempt was made

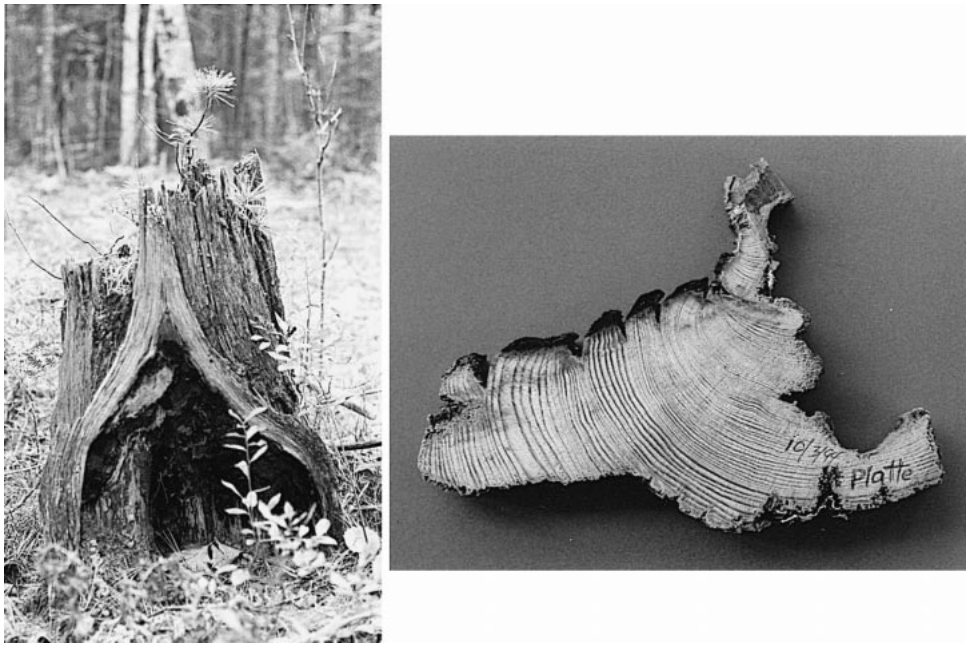

FIG. 3.—Logging-era *Pinus resinosa* stump and cross-section

to use additional species prone to fire-scarring but these proved not long-lived enough to provide an adequate record (*Pinus banksiana*) or were prone to rot (*Pinus strobus*).

To provide an additional comparison of fire-free intervals from nearby large upland sand plains (Simard and Blank, 1982) with those in small coastal sand patches, fire-scarred trees >150 yr old were located and sectioned in three large upland sand plains in eastern Upper Michigan (Albert *et al.*, 1986). A record of surface fire-free intervals from a *Pinus resinosa* cross-section at a fourth upland sand plain near Raco, Michigan was provided by Dr. Bryce Smith of Lake Superior State University (Fig. 2; sand plains are lettered A–D) .

RESULTS

All 39 coastal sand patches, as well as all four upland sand plains, currently support second growth and younger pine stands containing abundant evidence of logging and fire. Retrieval of fire-free interval data associated with presettlement forests, however, was rare and uneven. Ten of the chosen coastal sand patches contained charred snags and stumps whose cross-sections revealed no fire-free intervals (Fig. 2: ''charred snags/stumps''). This finding indicates either that no scarring fires occurred before harvest or, perhaps more likely, that fire-scar evidence of earlier fires was destroyed by later intense slash fires that commonly followed logging (Pyne, 1982; Karamanski, 1989; Barrett, 1995). Nevertheless, stump and tree cross-sections (all *Pinus resinosa*) clearly revealed fire-free intervals, bracketed by scars, within the remaining 29 coastal sand patches (Table 1, Fig. 2) and in all four upland sand plains (Table 2, Fig. 2). Interval numbers recovered and record duration were uneven, ranging from single fire-free intervals, each bracketed by two scars (Fig. 2: patches #7, 37, 39, Table 1) to a sequence of 10 scar-bracketed fire-free intervals spanning 144 yr (Fig. 2: patch #30, Fig. 3, Table 1). Cross-sections documenting four or more fires were

TABLE 1.—Characteristics of fire-scarred cross-sections and "most recent fire free periods" (MRFFPs) recovered from 29 coastal sand patches. Several MRFFPs were initiated before 1910 and thus exceed 85 years in duration. Fire years are derived from tree cross-sections. * = data from Alexander *et al.*, 1979. + = composite fire record spans more than 150 years. Note that the one fire interval spanning 1910 (patch #17) is not included as either before or after 1910

Patch location (Fig. 2)	# of x-secs. (s = stump t = tree)	Sand patch size (ha)	$\bar{x}$/SD(n) of fire-free intervals [yr] ending at/ before 1910	$\bar{x}$/SD(n) MRFFPs [yr] (no bracketed fire-free intervals initiated after 1910 were recorded)	Fire years (available from tree x-sections but not stump x-sections)
1+	1s	10	32.0/11.3(3)	75(1)	
6	1s	50	12.3/4.0(3)	100(1)	
7	1s	120	17(1)	95(1)	
8	1s	1300	11.0/3.1(6)	85(1)	
9	1s	260	13.3/2.9(3)	75(1)	
10+	1t	35	31.3/19.0(3)	138(1)	1763, 1795, 1845, 1857
11+	2s, 1t	70	28.0/14.1(12)	98.0/19.9(3)	1768, 1814, 1856, 1880, 1885, 1908
12	3s	30	27.9/13.7(7)	89.7/12.6(3)	
13+	6s	275	18.1/11.7(28)	87.0/9.7(6)	
14	1s	300	11.3/6.7(3)	88(1)	
15	1s	175	24.0/22.6(2)	85(1)	
16+	1s	200	29.7/6.0(3)	73(1)	
17+	1s, 1t	130	16.8/12(8)	73.0/4.2(2)	1842, 1850, 1857, 1892, 1909, 1919
18*+	1t	20	29.5/13.3(4)	118(1)	1759, 1791, 1805, 1831, 1877
21	1s	70	19.0/2.6(3)	85(1)	
22	1s	250	10.7/3.8(4)	80(1)	
23	1s	30	28.0/18.4(2)	84(1)	
24	1s	70	18.7/9.2(4)	80(1)	

TABLE 1.—Continued

Patch location (Fig. 2)	# of x-secs. (s = stump t = tree)	Sand patch size (ha)	$\bar{x}$/SD(n) of fire-free intervals [yr] ending at/ before 1910	$\bar{x}$/SD(n) MRFFPs [yr] (no bracketed fire-free intervals initiated after 1910 were recorded)	Fire years (available from tree x-sections but not stump x-sections)
25+	1s, 1t	250	11.8/4.0(12)	96.0/1.4(2)	1827, 1839, 1849, 1864, 1874, 1892, 1898
26	1s	130	10.0/1.4(2)	66(1)	
28	1s	35	7.7/2.9(3)	99(1)	
29+	1s	10	12.0/6.5(7)	105(1)	
30+	1s	520	14.4/6.4(10)	94(1)	
32	1s	780	32.0/19.8(2)	70(1)	
33	1s	500	14.0/2.0(3)	85(1)	
35	1s	70	13.0/1.4(2)	95(1)	
37	1s	50	32(1)	70(1)	
38	1s	85	13.6/4.3(5)	79(1)	
39	1s	40	14(1)	91(1)	
Overall $\bar{x}$/SD(n)		198.2/278.9(29)	18.4/11.5(147)	88.4/14.8(40)	

found in 17 patches. Multiple cross-sections were retrieved from only five patches; of these, cross-sections <100 m apart in two patches (Fig. 2: patch #s 17, 25, Table 1) appear to record the same fires. Multiple cross-sections, >100 m apart, recorded noncorresponding fire-free intervals in three patches (Fig. 2: patch #11, 12, 13, Table 1). A composite record of 148 scar-bracketed, fire-free intervals and 40 MRFFPs was recovered from 29 coastal sand patches. A record of 28 scar-bracketed fire-free intervals and four MRFFPs from four upland sand plains was recovered (Table 1).

Preharvest fire-free intervals derived from stump cross-sections from coastal sand patches average 17.5 yr (SD = 12.0, n = 125) and MRFFPs at stump collection sites average 86.3 yr (SD = 11.9, n = 35). The latter figure, in concert with historical accounts (Carter, 1977; Simard and Blank, 1982; Karamanski, 1989; Rydholm, 1989; Barrett, 1995), approximates 1910 (1995, the year of data collection, minus ca. 85) as a rough regional point of reference for the late stages of timber harvest just before "major European settlement." In comparing the lengths of fire-free intervals before and after this point of reference, data derived from both stumps and live trees are useful, but differences in their application must be noted. Tree cross-sections provide a dependable calendar year chronology of scarring ground fires at the site of the cross-section. Records from fire-scarred stumps differ from tree-derived records in that: (1) calendar year fire dates cannot be determined since specific harvest dates within patches are unknown and (2) the record of pre-harvest fire chronology is commonly truncated at the outer surface of the stump by burned or rotted surfaces (Fig. 3). As a result, an unknown "time gap" exists between the end of the fire chronology recorded on each stump and the beginning of its associated MRFFP (Table 1). Stump cross-sections and increment core derived MRFFPs thus provide qualitative fire chronologies; scarring fires at the site before harvest are documented and a minimum estimate of time elapsed since the last fire is obtained. If data from both stumps and trees are combined, scar-bracketed, fire-free intervals ending at or before 1910 average 18.4 years (SD = 11.4, n = 147). Although tree cross-sections from coastal sand patches revealed no fire-scar bracketed fire-free intervals initiated after 1910 (one interval recorded in patch #17 spans 1910), MRFFPs, (Table 1, column 5), provide an estimate of 88.4 yr (SD = 14.8, n = 40) for time elapsed since the last scarring fire at sample sites. Fire-scarred trees >150 yr old provide absolute dates for 28 fires (Table 1, column 6). Only one post-1910 fire is recorded in tree cross-sections from coastal sand patches and 18 of 24 MRFFPs document the absence of fire after 1910 at stump collection sites.

Cross-sections from fire-scarred trees in four upland sand plains (Fig. 2: A–D, Table 2) provide absolute fire chronologies within their immediate vicinities. On upland sand plains, fire-free intervals ending at or before 1910 average 23.0 yr (SD = 13.8, n = 18); fire-free intervals initiated after 1910 and MRFFPs, average 29.3 yr (SD = 26.7, n = 10). Fire yr, as determined from ring counts, are noted in Table 2, column 6.

DISCUSSION

While data from 29 cross-sections from coastal sand patches are consistent in suggesting relatively short fire-free intervals before about 1910 and an abrupt lengthening of fire-free intervals after that date, interpreting pre- and post-1910 rates of fire occurrence requires caution. Specific harvest dates for patches are generally unavailable and the pre-1910 record of fire-free intervals was obscured by stump deterioration and postharvest fires. Since it is unknown whether shorter records (*e.g.,* Fig. 2: patch #s 7, 37, 39; Table 1) represent fewer fires, differential stump preservation, or destruction of the record of earlier fires by later fires, data from these cross-sections cannot be assumed to typify long term histories of surface fire. However, mean fire-free interval calculated from records >150 yr long (as

TABLE 2.—Characteristics of fire-scarred tree cross-sections recovered from four upland sand plains. The "most recent fire free period" (MRFFP) at the site of each cross-section, although not bracketed, is included with "fire-free intervals initiated after 1910." Note that fire-free intervals spanning 1910 are not included as either before or after 1910

Plain location (Fig. 2)	# of x-secs. (all are trees)	Sand plain size (ha)	$\bar{x}$/SD(n) of fire-free intervals [yr] ending at/ before 1910	$\bar{x}$/SD(n) of fire-free intervals [yr] initiated after 1910 + MRFFPs	Fire years
A	1	3900	13.0/5.0(3)	64(1)	1871, 1893, 1901, 1910, 1931
B	1	2600	29.0/12.5(6)	25.3/28.0(3)	1721, 1758, 1793, 1834, 1866, 1873, 1895, 1919, 1920, 1976
C	1	2800	25.2/18.6(6)	19.2/16.8(4)	1754, 1793, 1844, 1854, 1865, 1899, 1905, 1918, 1920, 1934, 1976
D	1	7800	16.7/2.3(3)	38.0/46.7(2)	1854, 1868, 1886, 1904, 1919, 1924
Overall $\bar{x}$/SD(n)		4275/2418(4)	23.0/13.8(18)	29.3/26.7(10)	

determined by total ring count for fire scarred trees or total ring count + MRFFP for fire scarred stumps) can be combined with corresponding mean patch sizes (Table 1) to derive a reliable estimate of pre-1910 fire occurrence rates within those patches (fires/time/area). A comparison with present day estimates of lightning-caused fire can then be made.

For the 10 coastal sand patches where records of fire-free intervals span more than 150 yr (Table 1), fire-free intervals ending at or before 1910 average 19.4 yr (SD = 12.2, n = 90), while the mean of MRFFPs is 92.5 yr (SD = 18.2, n = 19; no scar-bracketed fire-free intervals were initiated after 1910). The relatively short pre-1910 fire-free intervals from 10 coastal sand patches appear similar to earlier portions of the fire-free interval record from four upland sand plains (23.0 yr; Fig. 2, A–D, Table 2) and to that reported from low relief uplands elsewhere within the upper Great Lakes region (Heinselman, 1981a, 1981a,b, Simard and Blank, 1982). Short fire-free intervals within extensive, low relief uplands, however, are usually the result of overlap of multiple large fires ignited at widely separated points, rather than the result of multiple ignitions near the scarred stump or tree (Heinselman, 1973, 1981b). In contrast, the short fire-free intervals reported here in 10 coastal sand patches were recorded in small (ca. 200 ha), isolated flammable forest patches embedded in a generally nonflammable landscape of upland hardwoods or wetlands. Since fire occurrence rate represents the inverse of fire-free interval (fires/ year/area vs. years/ fire/area; Romme, 1980), data from 10 coastal sand patches (1 fire/20 yr/200 ha; Table 1) suggest a pre-1910 fire occurrence rate of ca. 25 fires/year/100,000 ha.

Several estimates of lighting fire frequency in upland forests of northern Michigan are available from the literature (Schroeder and Buck, 1970; Stocks and Hartley, 1977). In addition, aircraft detection and improved record-keeping over the past 30 yr have produced solid empirical data bases for lightning-caused fires which are maintained by the U.S. Forest Service, the Michigan Department of Natural Resources and the Ontario Ministry of Natural Resources. Based on these data sources, lightning fires in pine forests of the upper Great Lakes are represented by the upper limit of a lightning-fire frequency ranging from 0.5 to 2 fires/yr/100,000 ha., a range that is less than 10% of the 1750–1910 AD rate estimated above from 10 isolated coastal sand patches. This comparison assumes: (1) that coastal sand patches are well insulated from fire ignited outside each patch and (2) that rates of lightning fire occurrence, 1750–1910 AD, were similar to those of the last 30 yr. The latter assumption above is consistent with regional paleoclimatic studies which suggest that the period spanned by our data was no warmer and probably cooler than the present (Swain, 1978; Gajewski *et al.,* 1985; Winkler, 1988).

While surface fire in pine forests does not require severe drought, lightning fires are more common during drought (Lorimer and Gough, 1988; Pyne *et al.,* 1996). Our small data set gives no indication that fires in coastal sand patches peak during drought years (Table 1). While fires recorded in upland sand plains in 1871, 1895, 1910, 1918, 1931, 1934, 1976 (Table 2) appear to reflect historically prominent fire/drought years (Haines and Sando, 1969; Heinselman, 1973; Karl *et al.,* 1983), these years are unrepresented in the few absolute fire chronologies from coastal sand patches. In contrast with the pattern from samples in coastal sand patches, wherein only one fire is documented after 1910, several post-1910 fires are recorded in upland sand plains (Table 2).

Changes in fire-free interval that correspond in time with European settlement have been reported in other studies in the region. In an upland sand plain in northern Lower Michigan, Simard and Blank (1982) report relatively long fire-free intervals before settlement, a decrease in interval length with slash and clearing fires of settlement and a return to longer fire-free intervals with the onset of modern fire suppression. In contrast, data from coastal sand patches portray a pattern of frequent fire (short fire-free interval) before timber har-

vest and abrupt truncation of fire incidence correspondent with timber harvest and sparse European settlement.

Overall, cross-section and increment core data suggest that, if present rates of lighting-caused fires are assumed, the pre-1910 rates of surface fire occurrence in 10 coastal sand patches with >150 yr of record exceeded, by an order of magnitude, that expected from lightning-ignition alone. The hypothesis that Native people were the primary supplemental source of ignition for "surplus" surface fires is consistent with available site specific archaeological, ethnographic and historical data from the region (McKenney, 1959; Quimby, 1960; Trygg, 1964; Dobson, 1978; Conway, 1979; Densmore, 1979; Mason, 1981; Warren, 1984; Tanner, 1987; Benchley *et al.,* 1988; Cleland, 1992; Conway, 1992; Clark, 1993; Anderton, 1995). While there are many possible sources for the high variability evident among samples of pre-1910 fire free-interval in all coastal sand patches sampled, the observed patterns are consistent with periodic human ignition under varying conditions, needs and opportunities. Since institutional fire suppression by Europeans was largely ineffective until the early 1930s (Mitchell and Robson, 1950; Pyne, 1982), changes in Native land use practices after about 1910 (Cleland, 1992) is a possible explanation for the early (prior to effective fire control by Europeans) cessation of fires at the locations of cross-sections.

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