Forest Research Report No. 133

Ontario

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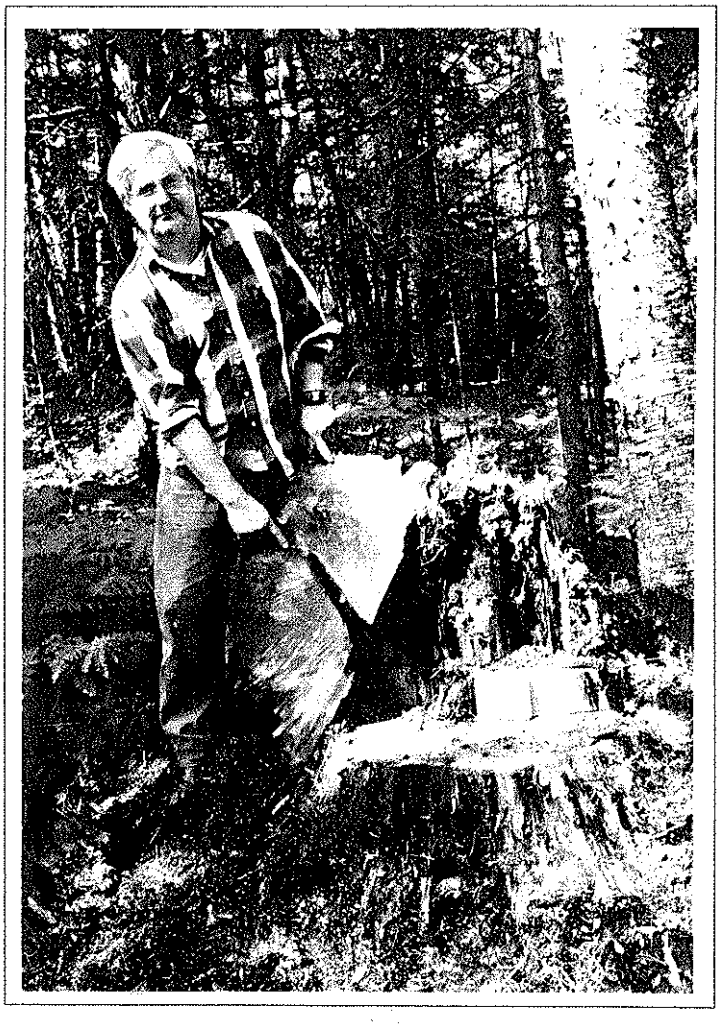

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Determining Fire History From Old White Pine Stumps in an Oak-Pine Forest in Bracebridge, Ontario

by

Richard P. Guyette
University of Missouri
Columbia, Missouri USA

Daniel C. Dey
Ontario Forest Research Institute
Sault Ste. Marie, Ontario CANADA

Chris McDonell
Ontario Ministry of Natural Resources
Bracebridge Area
Bracebridge, Ontario CANADA

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Ontario Ministry of Natural Resources
Ontario Forest Research Institute
P.O. Box 969, 1235 Queen Street East
Sault Ste. Marie, Ontario P6A 5N5
CANADA

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Ministry of Natural Resources
Ontario Forest Research Institute
P.O. Box 969
1235 Queen Street East
Sault Ste. Marie, Ontario P6A 5N5
CANADA

Telephone: (705) 946-2981
Fax: (705) 946-2030
E-mail: ofriin@epo.gov.on.ca

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Abstract

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Fire scars on stumps of white pine (*Pinus strobus* L.) in a red oak (*Quercus rubra* L.)-white pine forest near Bracebridge, Ontario, were dated using dendrochronological methods. A chronological record of fires that caused basal scarring is preserved in the remnant white pine stumps, which were estimated to be up to 135 years old. Large cross-sections (1.4 to 0.75 m in diameter) were cut from the solid portion of the stump. Over 100 annual rings per stump facilitated the cross-dating of 72% of the cross-sections. A tree ring chronology was developed for the site and was then dated in absolute time by comparing it with a white pine chronology derived from living trees in the same region. A composite fire scar chronology was constructed between 1664 and 1852 from 21 dated fire scars found in the 1-km^2 study area. The mean fire-return intervals ranged from more than 76 years (between 1664 and 1740) to 5 years (between 1741 and 1810). An abrupt increase in fire frequency after 1741 is attributed to increases in human population levels as Natives and Europeans reoccupied the area. The frequent fires between 1741 and 1810 are hypothesized to have advanced the regeneration and dominance of red oak over sugar maple (*Acer saccharum* Marsh.) and contributed to the present dominance of red oak in the overstory.

Keywords: Fire history, eastern white pine, northern red oak, disturbance, anthropogenic, regeneration, dendrochronology.

Acknowledgments

This study was supported by the Ontario Forest Research Institute's Great Lakes-St. Lawrence Silviculture Program, with assistance from staff at the Bracebridge Area Office, Ontario Ministry of Natural Resources. Special thanks go to Mike Walsh, who facilitated the selection of the study site. Rob McAlpine of the Petawawa National Forestry Institute gave us access to several of the Institute's white pine fire research sites, which provided invaluable information on the anatomical characteristics associated with fire injuries.

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Introduction

The regeneration and distribution of northern red oak (*Quercus rubra* L.) in Ontario are largely a result of past fire disturbance regimes (Abrams 1992, Lorimer 1993, Guyette and Dey 1995). Fires resulted from either natural occurrences (i.e., lightning), Native American land-use activities, or the logging and farming practices of early European settlers (Howe and White 1913, Day 1953, Dorney 1981, Pyne 1982, Lorimer 1993, Dorney and Dorney 1989). A historical review of fire in oak-dominated forests can provide a basis for the development of silvicultural prescriptions that use prescribed burning to regenerate northern red oak.

In the central region of Ontario, fire histories developed from living trees are usually limited to the last 100 to 150 years because most of the forests are second growth. In much of the former white pine (*Pinus strobus* L.) country in Ontario, partially decayed pine stumps occur in the forest understory. These trees were harvested during the early pine logging era (circa 1850 to 1930). Although the exteriors of these stumps are badly decayed, on some sites they contain sound wood internally near the ground line (Figure 1). If these old pine stumps could be used to date the occurrence of fires, it should be possible to reconstruct fire histories that span 200 to 300 years or more.

One objective of this study was to develop a dendrochronological methodology for determining pre-European fire history in the white pine region in Ontario. In addition, the study was intended to document the fire regime in an oak-dominated forest near Bracebridge.

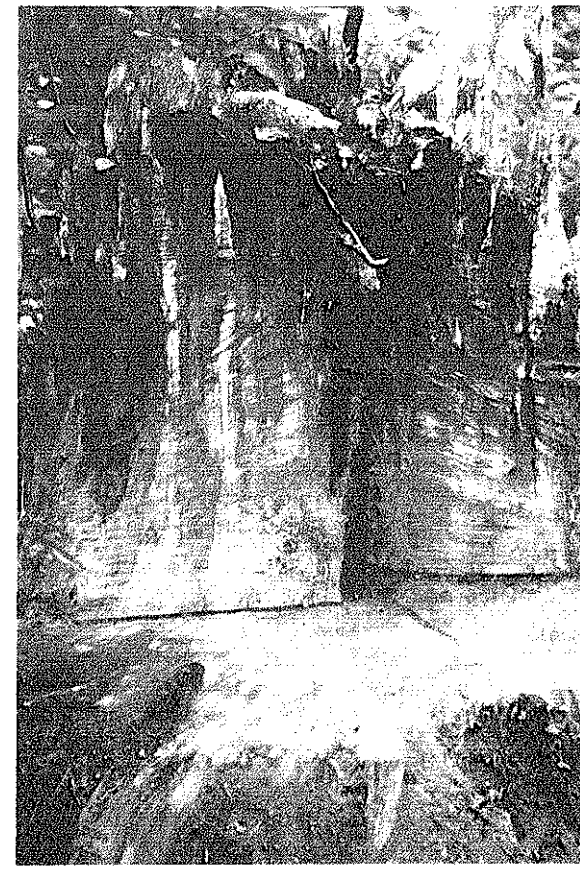

Figure 1. *A vertical section through an old white pine stump in the Bracebridge study area. Note the sound wood in the interior of the stump.*

Methods

Site location and characteristics

The white pine samples were obtained from an oak-pine forest 7 km northeast of Bracebridge, Ontario. The sample area (about 1 km^2) is within Lot 10, Concession VIII, Macaulay Township, Town of Bracebridge, District Municipality of Muskoka. The coordinates of the area's center are 45°47′90″N, 77°47′47″W.

The site is level to gently sloping, with elevations ranging from 275 m to 320 m above sea level. It is underlain by the granitic bedrock that is characteristic of the Precambrian Canadian Shield landform type. Exposed bedrock and glacial tills of variable depths occur in the study area. The soils are generally sandy in texture. Low, wet areas within the site may have provided fire breaks during low-intensity fires.

The study site is part of the Great Lakes-St. Lawrence Forest Region of Canada and is completely forested.

The dominant tree species are northern red oak, sugar maple (*Acer saccharum* Marsh.), white pine, and red maple (*Acer rubrum* L.). The mature, mixed hardwood-pine stand is about 90 to 100 years old.

Sampling

The old white pine stumps in the study were all located within 100 m of a road because the large stem sections (some >50 kg) were very heavy. The sound wood of the stump was cleared of decayed wood and organic debris down to ground level. Factors that may have favoured the preservation of pine stump wood are anaerobic conditions, high resin content, high water content in the wood, low soil pH and low soil temperature. Cross-sections of 25 white pine stumps were cut with a chain saw between ground level and 20 cm. Felling wedges were used to prevent the weight of the stump from pinching the saw bar and chain. The stumps were selected for sampling based on their soundness, size, number of rings, completeness of the tree ring series, and the presence or possibility of fire scars. Five of the samples had no evidence of fire scarring after cutting and were left at the site, leaving 20 samples for analysis.

Only one of the pines in the sample had died of natural causes. The remainder had been felled in timber harvesting operations. Although the actual dates of early logging in the study area are unavailable, it is known that 12 families established farms on the 597-ha property (today known as the Bracebridge Resource Management Centre) between 1868 and 1872. The first sawmill in the Muskoka area was built in 1861, and within 5 to 10 years, several mills were operating in the Bracebridge area. No commercial timber harvest occurred in the study area from 1955 until the past few years. It therefore appears that the white pine used in this study were cut anywhere from 40 to 130 years ago.

Historical records indicate that logging occurred in the 1860s along the Opeongo River, Algonquin Park, Ontario. Decaying white pine stumps along this river were studied to characterize a relationship between stump condition and the time elapsed since cutting. The conditions of old white pine stumps at the Opeongo and Bracebridge sites were comparable, indicating that the stumps at the Bracebridge site were from white pine harvested more than 100 years ago.

Fire scars

Although the pine stumps in the sample had charcoal present in the surrounding soil and organic debris, charcoal was only rarely found in the cross-section itself. To differentiate between fire scars and injuries caused by mechanical damage, *fire scar* was defined as the death of a cambial section that occurred near ground level on the tree's bole. Fire scars were identified by callus tissue, local disruption of cambial growth, trauma-tic resin canals, and, occasionally, overall growth response. Many injuries were not counted as fire scars. For example, scars that showed evidence of mechanical damage (e.g., wood indentations) or small point injuries were noted but not considered to be of fire origin. Injuries that may have been fire scars were not included if callus tissue was absent. Fire scars ranged from large, open injuries (Figure 2) to smaller injuries on lower stem buttresses.

Ground-level sections of live white pine were taken from stands with recent and known fire histories (i.e., Chalk River and Temagami sites) to aid in the anatomical identification and verification of fire scars (Figure 3). Cross-sections were also cut from a site along the Opeongo River in Algonquin Park, Ontario, that was believed to have experienced few fires. The Opeongo pine were used as a control to verify the identity of fire scars, stump condition and age in the study samples.

Cross-dating

The detailed observations of annual rings that are necessary for cross-dating require that cross-sections be surfaced to reveal the structure of the rings. Cross-sections were surfaced using an electric hand planer with a sharp carbide blade. If rings were narrow or indistinct, the ring structure and cellular detail were revealed using sandpaper (220 to 600 grit).

Visual cross-dating was used to identify signature years in which climate limited the growth of all trees (Stokes and Smiley 1968, Guyette and Cutter 1991). Ring-width plots with anatomical notes on ring structure (e.g., false

Figure 2. Some fires cause large scars at the base of mature white pine.

rings and latewood characteristics) were used for visual cross-dating and comparison.

The COFECHA computer program (Holmes et al. 1986) was used to ensure the accuracy of both relative and absolute dating among the samples. Each sample had from 1 to 3 ring-width series measured either from pie wedges taken from the cross-section or from traced acetate overlays of ring-width radii. The least disturbed ring-width series on the cross-section was chosen as the radius of measurement. The traced acetate overlays were necessary when the diameters (0.75 to 1.4 m) of the cross-sections were too large for the measuring equipment or when intact cross-sections were needed for fire scar analysis. Using these overlays caused no loss in accuracy because the rings tended to be quite large (i.e., more than 1 to 8 mm in width) in the white pine cross-sections taken at ground level.

A floating chronology (undated in absolute time) was established from the samples. Absolute dating of the pine stumps was then accomplished through comparisons with white pine ring-width chronologies from Dividing Lake (67 km northeast of the study site) and Hobbs Lake (228 km northwest of the study site) (Guyette and Dey, unpublished). Both chronologies fully overlapped all of the sample ring-width series from the Bracebridge site.

Results and Discussion

Cross-dating

Most (72%) of the white pine samples were successfully cross-dated, and no missing rings were found in these samples. False rings were readily identifiable and were usually confined to injury sites and juvenile wood. All dated samples had at least 100 rings, and the average cross-section had 132 rings. The pith dates from 10 of the sample trees ranged from 1664 to 1710. The average between-tree correlation for the ring-width series from the Bracebridge site (detrended and auto-regressively modelled to remove auto-correlation) was 0.48. Thus, even correlations for short (e.g., 50-year) sections of ring-width series were significant ($p < 0.01$).

The chronology for the study area dated from 1664 to 1852 (Figure 4) and was significantly correlated with the white pine chronologies from Dividing Lake (r=0.55, n=175 years), Hobbs Lake (r=0.46, n=125 years) and Swan Lake (r=0.45, n=100 years). An early (1664 to 1713) section of the Bracebridge ring-width chronology was not significantly correlated with these chronologies, indicating that ring width in the juvenile or crown-formed wood of this species is only weakly influenced by annual fluctuations in climate.

Human influences on fire frequency

A composite fire scar chronology was constructed between 1664 and 1852 from 21 dated fire scars found in the 1-km^2 study area. Evidence exists that 15 fires (Figure 5) occurred

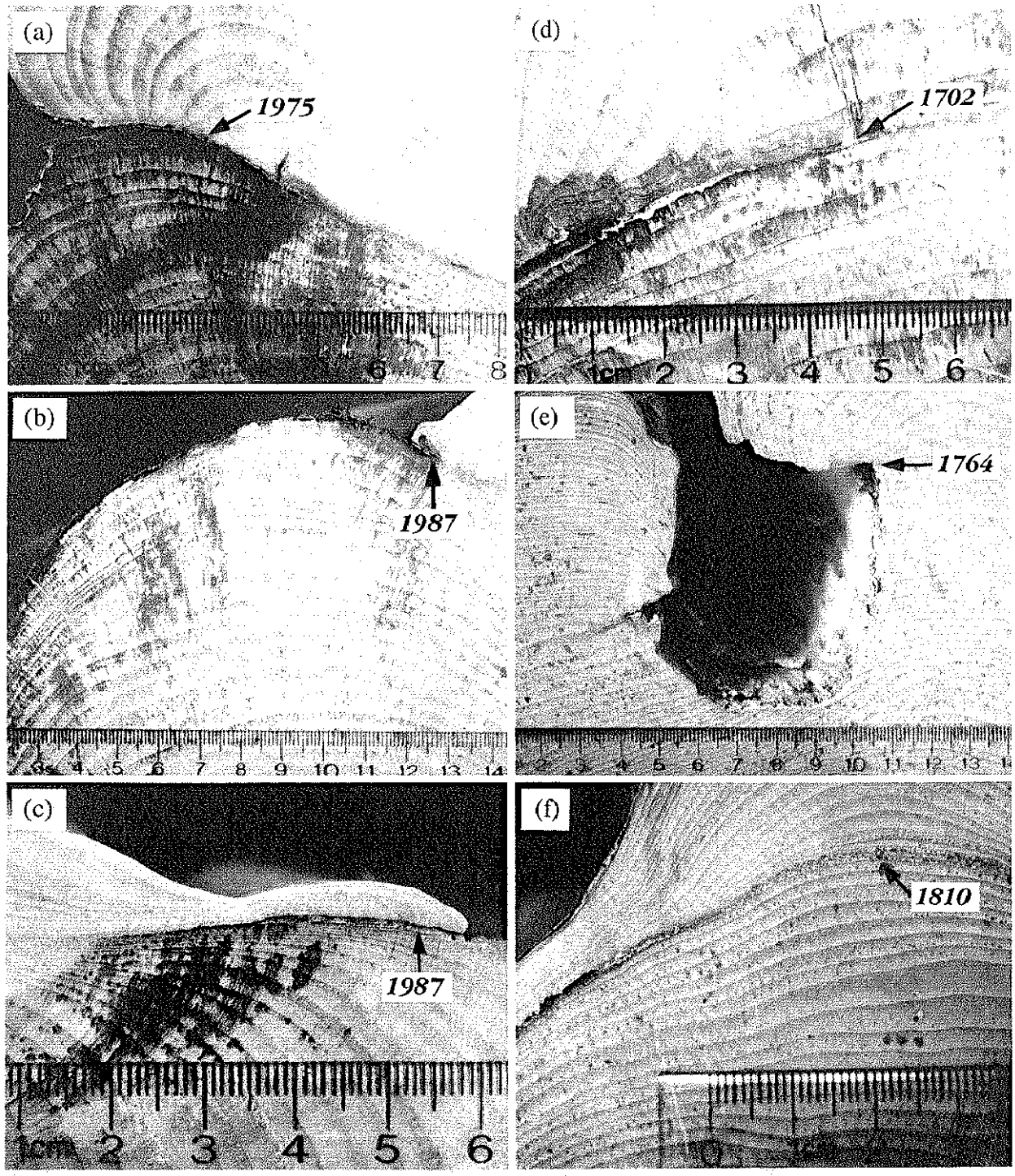

Figure 3. *A comparison of white pine fire scars from live trees (a,b,c) that were wounded during prescribed burns of known dates and dated fire scars on remnant stumps (d,e,f) sampled in the Bracebridge study area. The prescribed burns were conducted by Petawawa National Forestry Institute researchers in 1975 (a) and 1987 (b,c). Three types of fire-related injuries are shown: (1) large (>100 cm²) cambial wounds (a,d) at the base of the bole, (2) medium-sized (<100 cm²) cambial wounds (b,e), and (3) small fire-related growth anomalies and traumatic resin canals that occurred during fire years (c,f). Large cambial wounds, such as the 1702 fire scar illustrated in (d), are rare.*

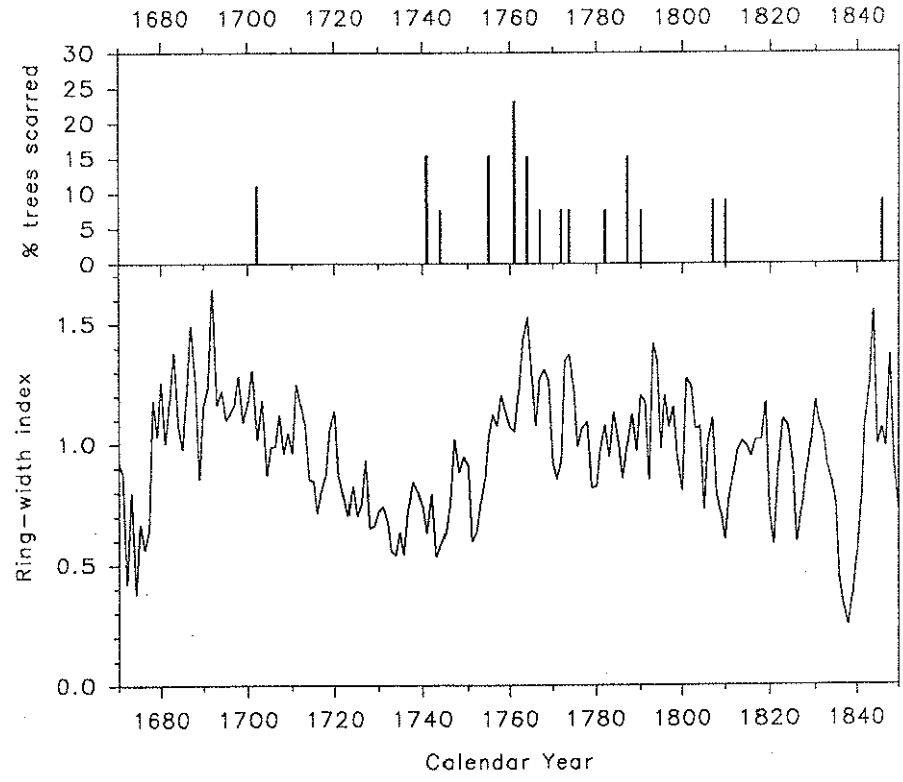

Figure 4. (a) Fire dates and the percentage of the sample of white pine that was scarred by each fire.

(b) A ring-width chronology for white pine in the Bracebridge study area.

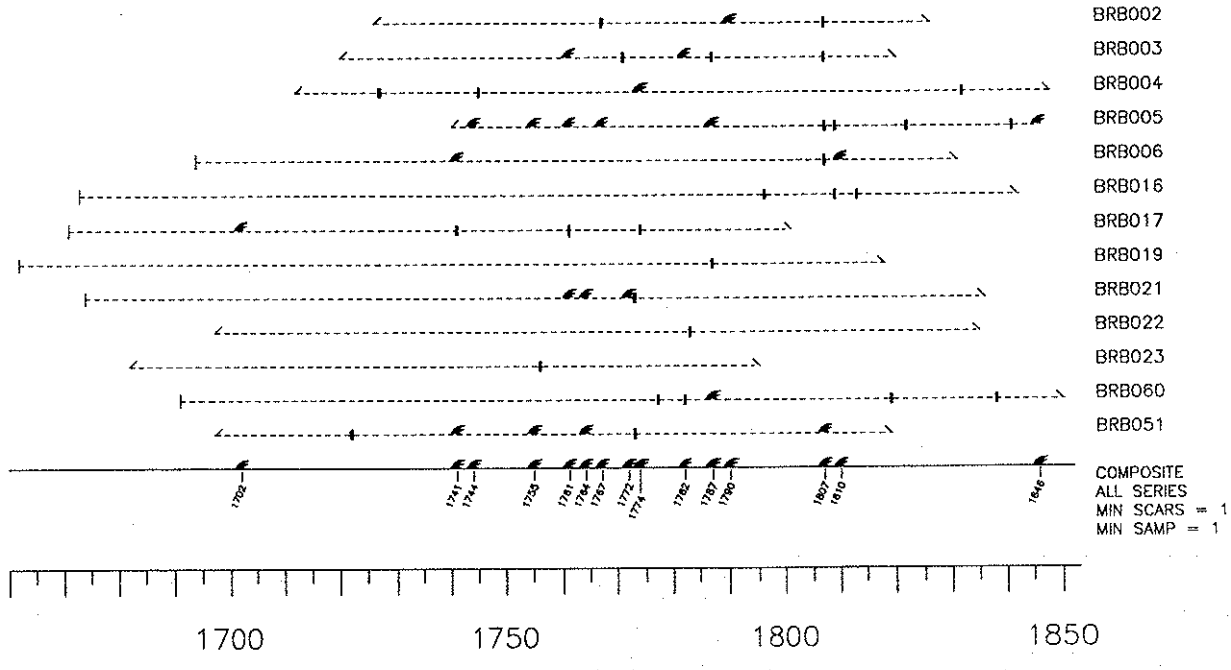

***Figure 5.** A plot of dated samples and their associated fire scars, injuries, pith dates, and outside rings, as well as a composite fire chronology. Solid flames indicate fire scars. Short vertical bars indicate injuries that may or may not have resulted from fires. Thin vertical bars indicate pith dates, and slanted thin bars indicate inside and outside rings of the sample.*

during the 188-year period of record (1664-1852). Table 1 gives the fire intervals for various periods within the study's chronology. The mean fire-return intervals ranged from more than 76 years (1664-1740) to as few as 5 years (1741-1810). The abrupt increase in fire frequency after 1741 is attributed to a human population change.

The study site is located on the north branch of the Muskoka River, which was a major travel route for Natives and European explorers. Native occupation of sites within a few kilometers of the study site has been documented (Murray 1963). Natives used fire to manipulate the environment to their benefit. Fire was used for hunting animals, increasing browse and forage for game animals, improving the production of berry-producing plants, and conducting warfare, as well as for agricultural purposes (Pyne 1982, Dickason 1992, Kidwell 1992).

During the 17th century, Native use of the area had been affected by inter-tribal relations, the fur trade, disease epidemics, changes in the subsistence economies of Native peoples, and major displacements of their nations (Rousseau and Brown 1990, Trigger 1990, Dickason 1992, Surtees 1994, Trigger and Day 1994). The drastic fluctuations in populations and changes in their lifestyles altered the occurrence of anthropogenic fires in the surrounding forests.

The area was initially inhabited by the Hurons, but by the mid-17th century, epidemics and invasions by the Iroquois produced a largely transient population, whose activities were based on the fur trade and warfare. The Ojibwa replaced the Iroquois in the beginning of the 18th century. The change from traditional Huron occupation of the study area to a transient use coincides with a period of relatively low fire frequency (i.e., 1664 to 1740). From 1740 onward, reoccupation of the study area by Natives and European fur traders may account for the observed increase in the frequency of fire between 1741 and 1810.

Scarring of white pine

Many tree species are very resistant to scarring from low-intensity fires because of their thick bark, landscape position, diameter or mass. This study provides an interesting example of white pine's resistance to scarring on level to gently sloping sites. Three of the sample trees were scarred in the 1761 fire, and another tree had a possible fire injury. The fire of 1761 was

Table 1. *Fire intervals in the Bracebridge oak-pine forest from 1664 to 1852. "Years of record" are the total number of years for all trees on the site for a given period. The fire-free interval is the mean number of years between fires.*

	Period			
Calendar year	1664-1740	1741-1810	1811-1852	1664-1852
Years of record	583	873	260	1,716
No. of fire scars	1	19	1	21
Years per scar	583	46	260	82
No. of fire years	1	13	1	15
Mean fire-free interval	>76	5	>42	13

severe enough to release many of the dominant white pine from competition, as suggested by sudden increases in tree ring widths (Figure 6).

Despite the death of other less-resistant trees, only about 25% of the white pine were scarred (Figure 4). The white pine averaged about 74 years old at the time of the fire (1761 fire date minus 1687, the mean pith date at ground level). Thus, it is likely that lower-intensity fires would scar a much smaller percentage of trees, as seems to have been the case during many of the other fire years in the study area. Low-intensity fire years are represented by single scars and no growth release following the burn.

Summary

Remnant white pine stumps in the understory of an oak-dominated forest were used to construct a fire history for a site in the Bracebridge region of Ontario. These white pine stumps were estimated to have been cut more than 100 years ago. Although the exterior wood is in an advanced stage of decay, the interior wood remains sound. Anaerobic conditions inside the stump likely inhibited decay. These stumps were cross-dated and used to reconstruct histories of tree growth and fire regimes.

A fire chronology was constructed for the period from 1664 to 1852. During that time, the frequency of fire varied considerably. The fire-free interval from 1664 to 1740 was greater than 76 years, but thereafter it suddenly decreased to as little as 5 years. The longer fire-free interval before 1741 is associated with a drastic decline in Native populations resulting from measle and smallpox epidemics, disruption of traditional Native subsistence economies, and displacement of local peoples from the area by the Five Nations of the Iroquois. Reoccupation of the area by Natives and Europeans led to a dramatic increase in fire frequency. The short (5 year) fire-free interval from 1741 to 1810 probably favoured oak regeneration and set the stage for the development of the present oak-dominated forest.

Remnant white pine stumps provide valuable information on long-term trends in growth of individual trees and stand disturbance regimes. However, each year the decay process continues, leaving us fewer stumps and fewer rings per stump to study. As this information is irretrievable, further study should occur soon.

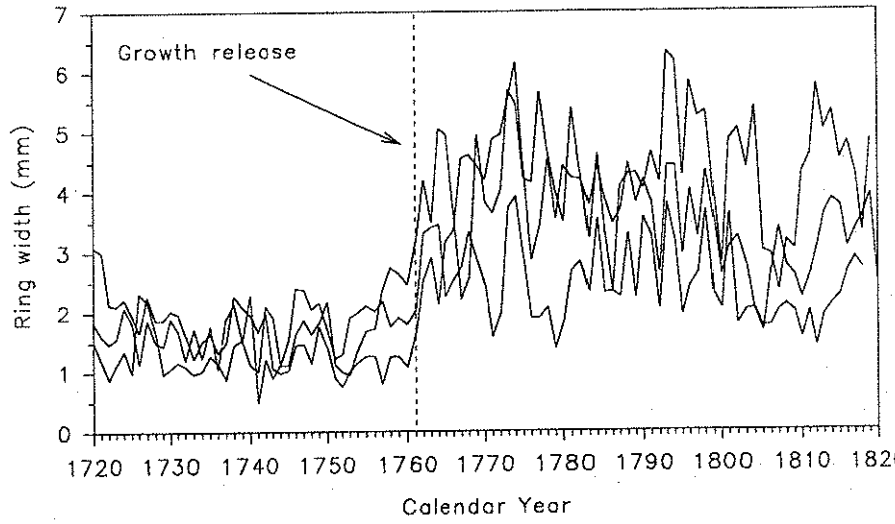

Figure 6. *The growth release of 3 white pine beginning after the 1761 fire. This abrupt growth increase was probably due to the release of the trees from competition for light, water or nutrients. These 3 dated pine stumps had no fire injuries or scars in 1761. The 1761 fire, however, did scar the highest percentage of trees of any fire in the record.*

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