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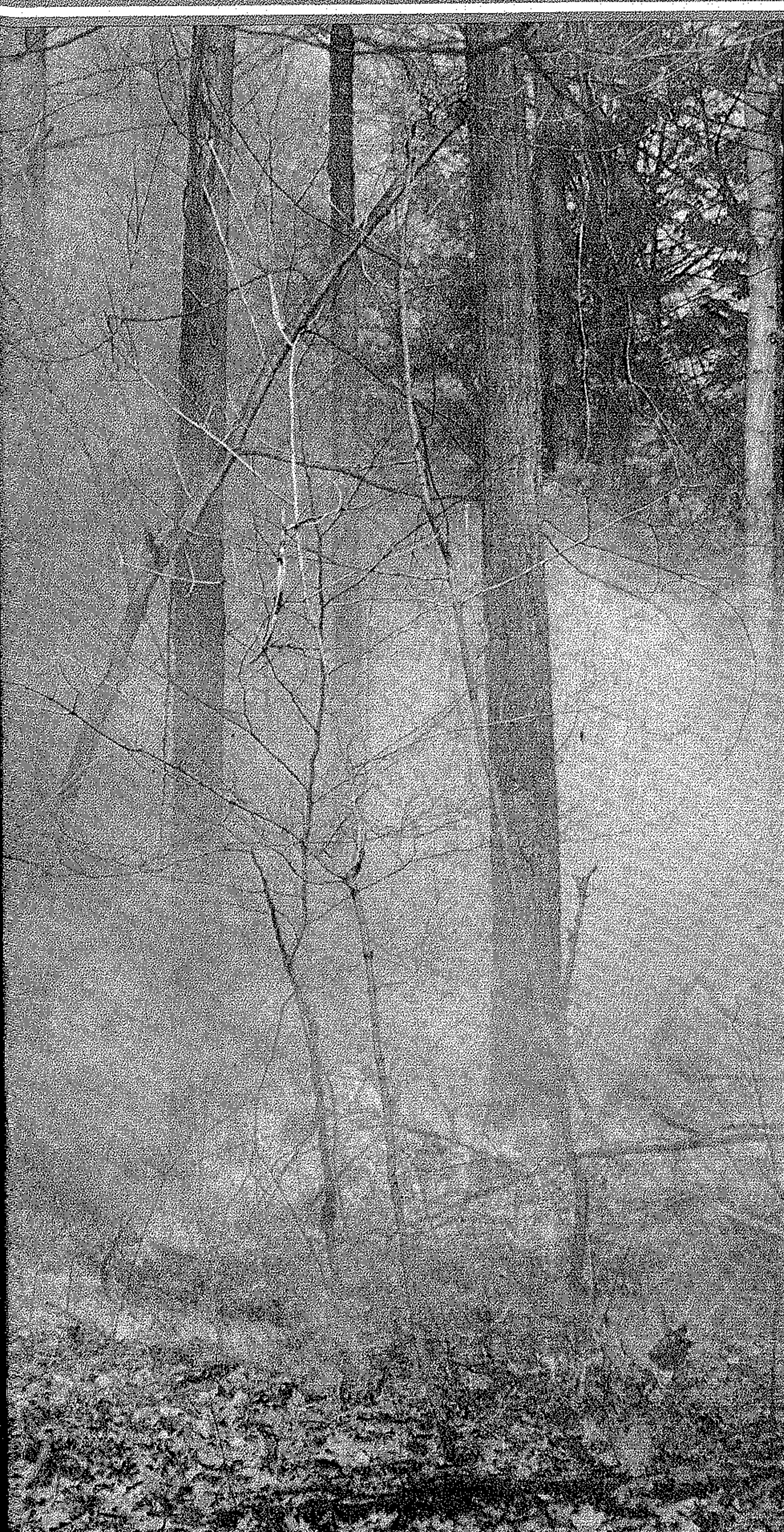

# A History of Fire, Disturbance, and Growth in a Red Oak Stand in the Bancroft District, Ontario

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R. Guyette
D. Dey

Ontario Ministry of Natural Resources

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A report prepared for the
Ontario Forest Research Institute
Silviculture Program

by
Dr. Richard Guyette
University of Missouri
1-30 Agriculture Bldg.
Columbia MO 65211 USA

and
Dr. Dan Dey
Ontario Forest Research Institute
Sault Ste. Marie, Ontario
Canada

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

Ministry of Natural Resources
Ontario

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

Telephone: (705) 946-2981
Fax: (705) 946-2030

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# INTRODUCTION

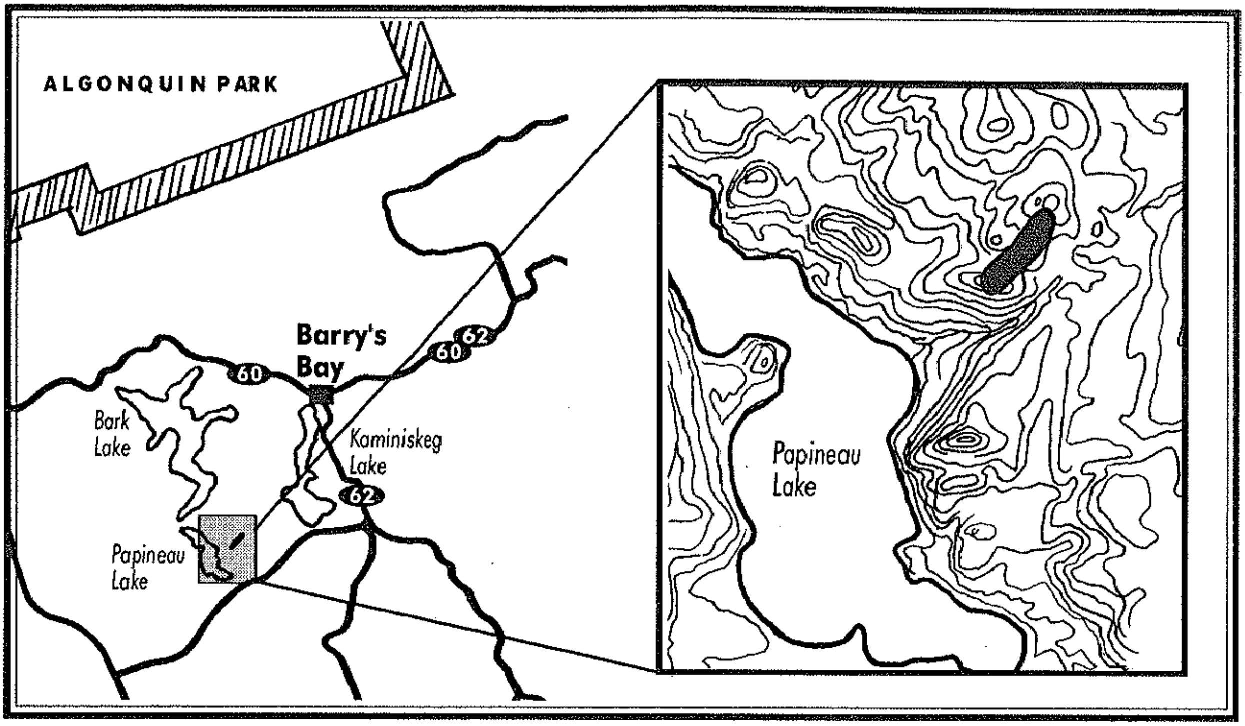
Disturbance is integral to the regeneration and growth of northern red oak (*Quercus rubra* L.) in Ontario, and historically fire has favoured red oak regeneration (Lorimer 1985, 1989, 1993; Abrams 1992; Abrams and Nowacki 1992; Johnson 1993; Van Lear and Watt 1993). In the pre-suppression era, fire was an important disturbance event that affected forest succession and regeneration in Ontario (Cwynar 1977, 1978; Lynham 1985), and many fires burned annually over large areas (Howe and White 1913; Cwynar 1977, 1978; MacKay 1978; Ward and Tithecott 1993). More recently, logging has become an important disturbance factor while fire has become less important because of suppression efforts, which began in the 1920s in Ontario (Cwynar 1977, MacKay 1978, Lynham 1985). In this report, we examine the occurrence of fire, and the effects of fire and climate on the growth and regeneration of northern red oak in central Ontario. Oak and red pine (*Pinus resinosa* Ait.) stem cross-sections taken near the ground were used to determine: 1) the dates of fire scars, 2) serial variations in growth, 3) periods of regeneration, and 4) the dates of growth release and suppression.

# METHODS

The study trees were located on a two-ha site near Barry's Bay, Ontario (Figure 1). The sample trees grew in an upland oak forest on flat to sloping terrain (0 to 35% slope). The site was somewhat pyrogenic, with fine fuels (e.g. hardwood leaf litter, grasses and forbs), a southwestern aspect, and a position at the top of a long, sloping hillside (Figure 2). The oldest oak sampled was 179 years old, and the youngest was 68. Tables 1 and 2 summarize the characteristics of the study site, the stand and the trees used in the dendrochronology analyses. Red oak comprised 39% of the stand's basal area and was present primarily in the overstorey. Sugar maple (*Acer saccharum* Marsh.) was the most numerous tree species on the site, but 88% of the maples were less than 20 cm in dbh. Sugar maple dominated the understorey with other species such as ironwood (*Ostrya virginiana* (Mill.) K. Koch). White ash (*Fraxinus americana* L.) and basswood (*Tilia americana* L.) comprised only 19% of the basal area, but a majority of these trees were greater than 20 cm in dbh. There were also minor components of black cherry (*Prunus serotina* Ehrh.), white pine (*Pinus strobus* L.), beech (*Fagus grandifolia* Ehrh.) and hemlock (*Tsuga canadensis* (L.) Carr.) in the overstorey.

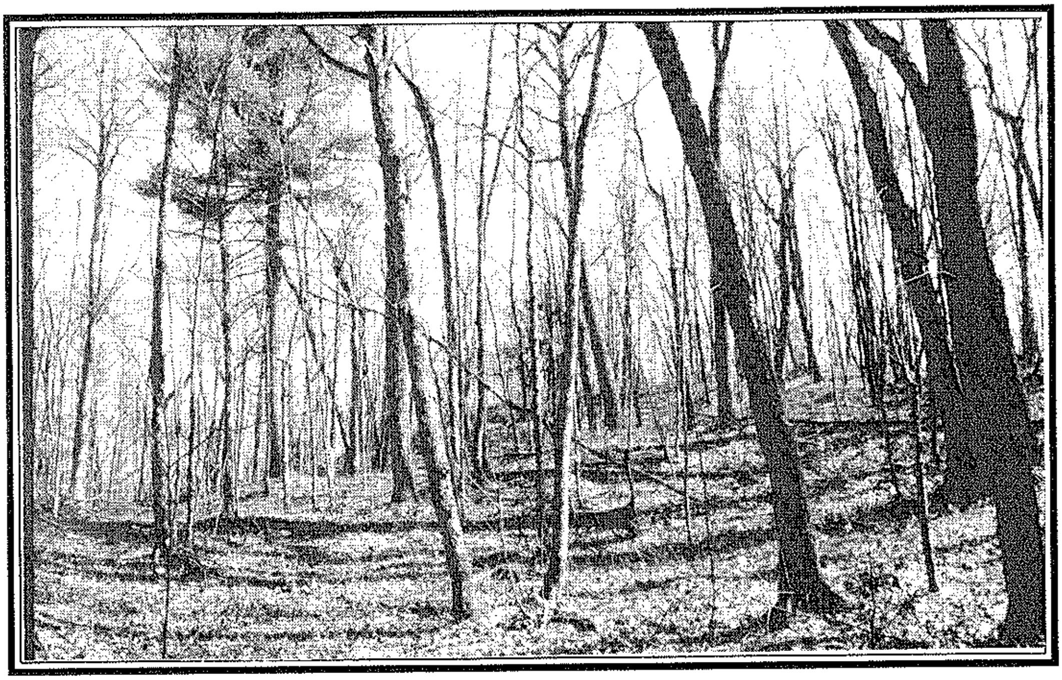
A single cross-section (taken approximately 15 to 30 cm above the ground) from each of 22 northern red oak and one red pine were used to collect growth and fire scar data. Two chronologies for red oak growth were constructed from ring-width measurements made on one growth radius (ground level) for each of the 22 trees. Series of ring-width measurements were cross-matched and checked through COFECHA, a tree-ring analysis program that

**Figure 1.** Location of the study site near Barry's Bay, Ontario.




matches ring-width series, to ensure the absolute dating of each of the 2461 annual rings (Holmes et al. 1986). Between-tree ring-width correlations ranged from 0.59 to 0.86. Curves were fitted to the raw ring-width series to minimize ring-width variance due to nonclimatic factors such as release, suppression and tree size. Two ring-width chronologies were constructed: 1) a standard chronology (Figure 3), that best reflects the growth trend of the stand due to climate and tree biology and 2) a residual chronology (Figure 4) that uses auto-regressive modelling to maximize the annual climate signal in the ring-width data. The chronologies were developed using ARSTAN, a standardization and chronology-construction program (Cook and Holmes 1984).

**Figure 2.** Representative photographs of the upland oak study site, showing typical stand and site characteristics.



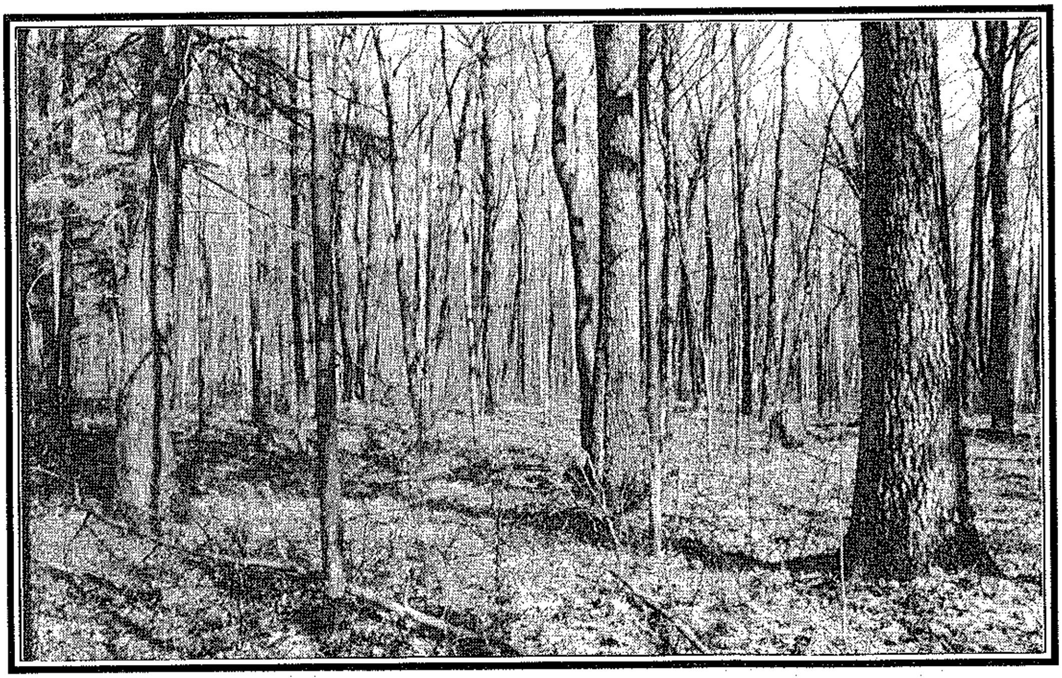


**Table 1.** Site and tree characteristics for northern red oak sampled in this study.

| Variable | N | Minimum | Maximum | Mean | Std Dev |
|---|---|---|---|---|---|
| Slope (%) | 22 | 0 | 35 | 18 | 12.0 |
| Aspect (degrees) | 22 | 0 | 340 | 226 | 87.9 |
| Pith Date (years) | 22 | 1814 | 1925 | 1887 | 29.7 |
| Diameter (cm) | 21 | 18.5 | 66.7 | 37.4 | 12.23 |
| Age (years) | 22 | 68 | 179 | 105 | 29.7 |
| Growth (mm/dia/year) | 21 | 2.3 | 5.4 | 3.6 | 0.7 |

**Table 2.** Characteristics of the study stand.

| Species | Basal Area [1] ($m^2$/ha) | Trees Per Ha [1] | Average Dbh (cm) |
|---|---|---|---|
| Red Oak | 12.15 | 144.2 | $30.5 \pm 11.8$ |
| Sugar Maple | 10.22 | 675.4 | $10.6 \pm 8.9$ |
| Basswood | 3.64 | 57.7 | $25.4 \pm 13.2$ |
| White Ash | 2.35 | 48.1 | $22.6 \pm 10.5$ |
| Ironwood | 1.69 | 122.2 | $11.0 \pm 4.6$ |
| White Pine | 0.49 | 1.2 | 67.5 |
| Hemlock | 0.47 | 2.5 | $42.8 \pm 25.7$ |
| Beech | 0.40 | 20.6 | $12.4 \pm 10.1$ |
| Black Cherry | 0.10 | 3.7 | $21.8 \pm 0.5$ |
| Total | 31.51 | 1095.9 | 22.3 |

[1] For trees $\geq$ 2.5 cm in dbh.

**Figure 3.** A standard ring-width index derived from 22 red oak trees, which maximizes the biological response of the stand, including short-term autocorrelated growth trends. An index value of 1.0 represents the average ring-width growth for red oak in this study.

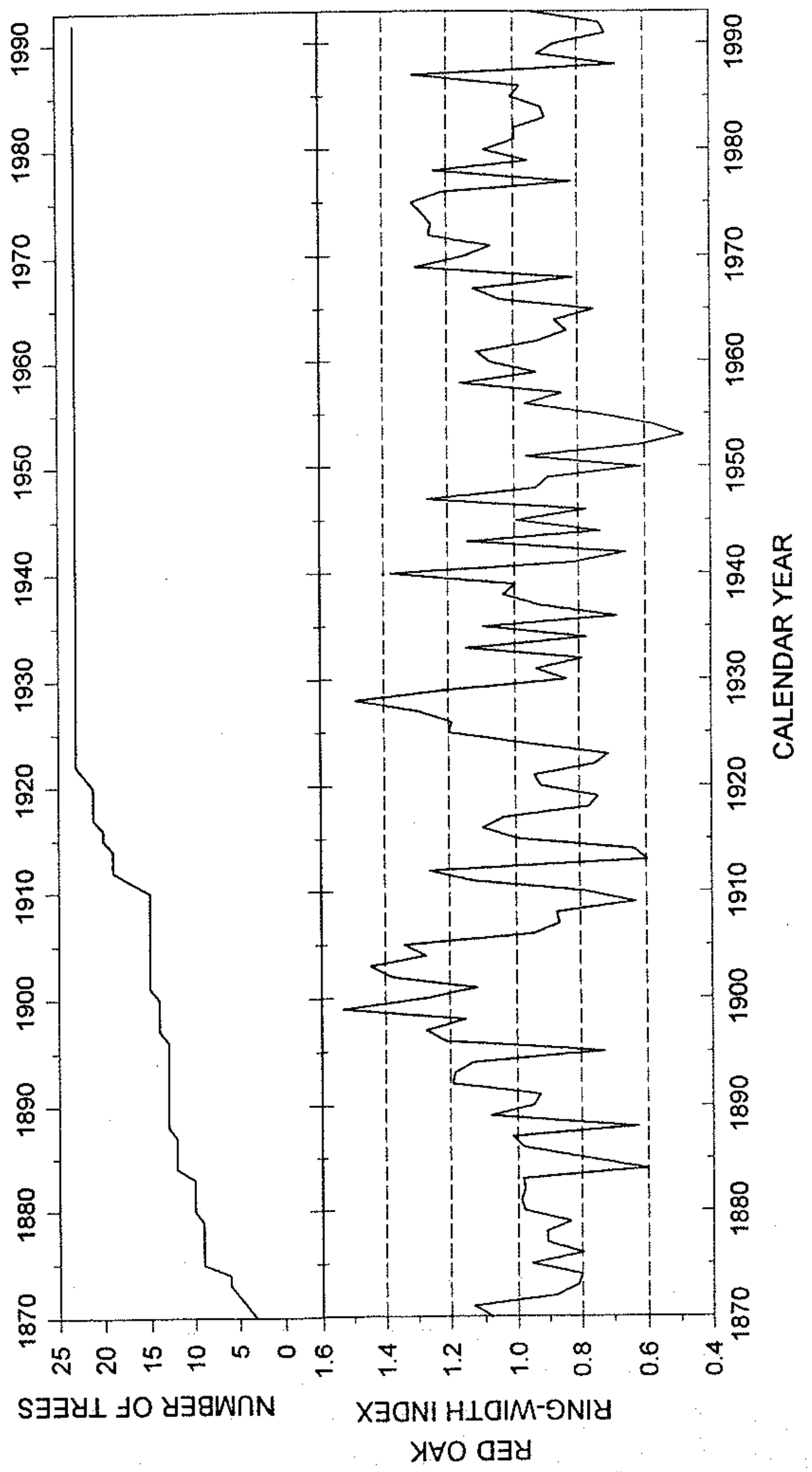
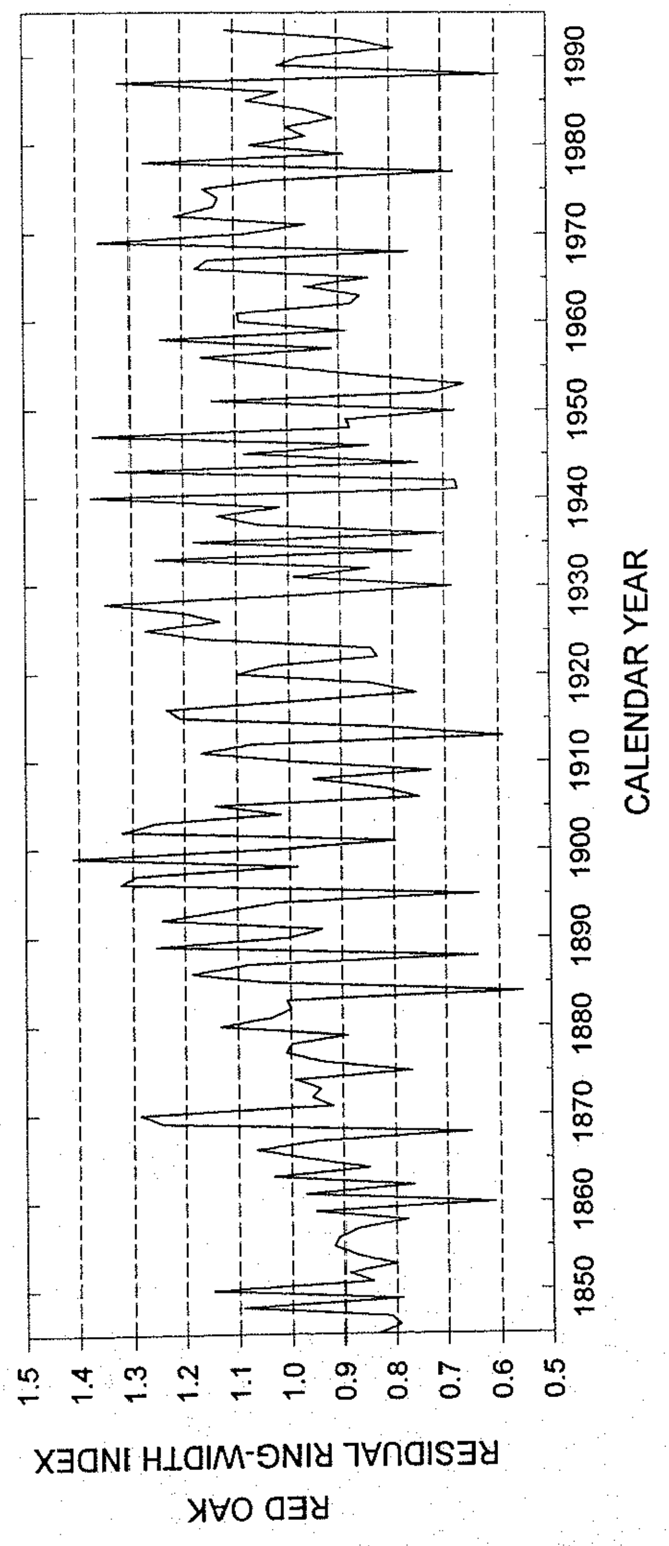


**Figure 4.** A residual ring-width index, which maximizes the annual growth response of the oak stand to climate. An index value of 1.0 represents the average ring-width growth for red oak in this study.



# FIRE FREQUENCY

Based on the trees in the study, the mean fire-free interval (MFI) was calculated at six years for the period between 1875 and 1954 based on 17 dated fire scars (Figure 5). Fire-free intervals varied in length from two to more than 18 years. The most recent evidence of fire was in 1954 and the earliest fire was in 1884. The lack of fires before 1870 may be due to the small sample of oaks that were greater than 120 years old. Cwynar (1977) found that the mean fire frequency from 1696 to 1974 was 11.2 years in Barron Township, Algonquin Park. Many of the fires on the study site occurred in the same years as other extensive fires in Ontario (Howe and White 1913, MacKay 1978, Lynham 1985). For example, fires in 1911 and 1916 on the study site occurred at the same time as the great Porcupine (1911) and Matheson (1916) fires (MacKay 1978).

Fire years may be related to years of low precipitation, as documented by the presence of narrow annual growth rings. Eight of the 13 fires occurred in years with narrow rings. Several of the fire years (1884, 1936, 1941, 1952) coincided with years ranked by their extreme growth reductions (Table 3). The probability of fires that produce scars on trees may be greater during years of low precipitation. Cwynar (1977) reported that most major fires in Barron Township, Algonquin Park from 1696 to 1974 probably occurred during periods of drought of sub-continental extent, and that major fire years (e.g. 1875) coincided with periods of drought in southern Ontario.

**Figure 5.** A chronology of red oak pith dates, which identifies periods of stem initiation, and a fire chronology derived from oak and pine fire scars. The mean fire-free interval between 1875 and 1954 is six years. The lack of fires before 1870 may be due to the small sample (three trees) of oaks with pith dates before 1870. One oak with a pith date of 1814 is not shown in the upper graph.

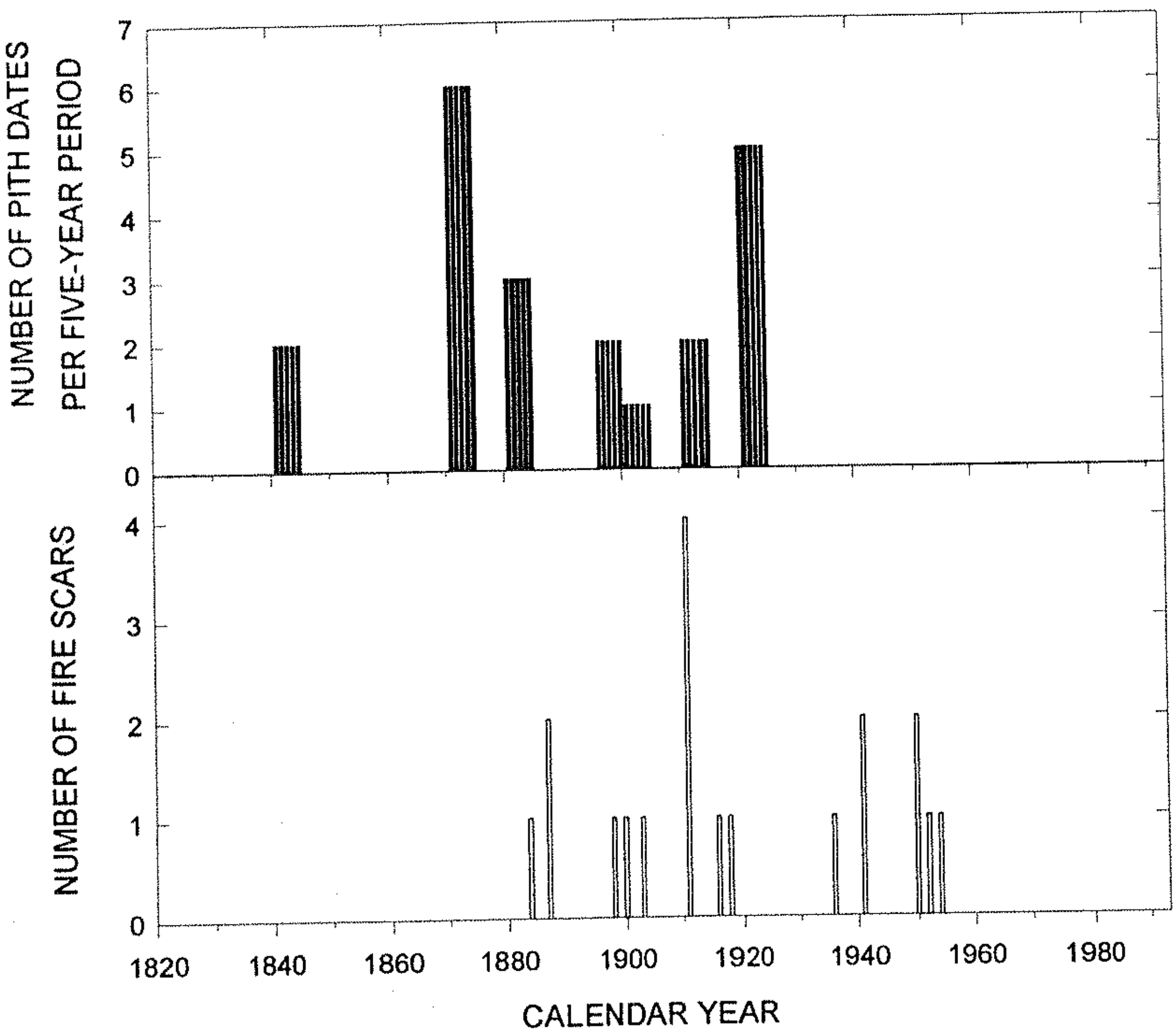


**Table 3.** The ten largest annual growth reductions over the last 120 years. Years are ranked in order of decreasing annual growth reductions. Annual growth reduction is calculated by dividing the diameter growth of a specified year by the previous years growth.

| Rank | Calendar Year | Percentage of Previous Year's Growth |
|---|---|---|
| 1 | 1988 | 45 |
| 2 | 1941 | 49 |
| 3 | 1913 | 55 |
| 4 | 1944 | 56 |
| 5 | 1884 | 56 |
| 6 | 1888 | 60 |
| 7 | 1934 | 60 |
| 8 | 1936 | 60 |
| 9 | 1952 | 63 |
| 10 | 1948 | 64 |

About 38% of the trees that were analyzed were established during a period (1880 to 1919) of high fire frequency (MFI = five years). Another 22% became established in the early 1920s at the beginning of a period of lower fire frequency (MFI= 15 years, 1920 to 1949) (Figure 5). These data indicate that regeneration of the current forest was disturbance-based on this site. Frequent disturbances (e.g. fire, logging, settler activity) have led to an extended oak regeneration period (1840s-1920s) on this site. Fire has been a significant disturbance factor that has favoured oak regeneration and development on this site. Multi-aged oaks now comprise a significant portion of the dominant overstorey trees (Table 2).

Several of the sample trees (six of 22 trees) had very slow initial stem growth for periods ranging from 13 to 56 years. Each tree eventually showed a sudden growth increase presumably due to release from competition. Diameter growth the year after "release" was from 182% to 680% of the previous year's growth. These oaks were sapling-sized (three to ten cm in diameter at ground level) and ranged in ages from 13 to 56 years when they were released.

Red oak growth was autocorrelated (1st order $r=0.31$) from year to year indicating that the present year's growth was highly dependent on the previous 3 or 4 years of growth. Tree size and age were highly correlated ($r=0.69$, $p=0.05$) among the sample trees. Growth of the red oaks decreased during major dry periods in central North America such as 1913-1914, 1930-1936 and 1952-1954 (Cook et al. 1992). Analysis of long-term weather data collected at Bancroft, Ontario (40 km from the study site) revealed that: 1) mean precipitation during May-July, 2) precipitation during May-July in the previous two years, 3) extreme maximum temperature during June-August and 4) extreme maximum temperature in the previous September were significantly correlated to red oak ring-width growth ($r=0.63$, $p=0.0001$). Ring-widths of the Bancroft red oak chronology also were correlated with the year to year ring-width variations of oak species (e.g. $r = 0.38$, $p=0.001$, $n=100$) growing as far to the southwest as the American states of Missouri, Arkansas, and Texas (Stahle et al. 1985).

In 1988, red oak diameter increment was only 45% of the previous year's growth (Table 3). This was the greatest annual growth reduction in more than 120 years. Severe growth reductions such as these in the red oak group may lead to a subsequent long-term decrease in growth potential and ultimately to oak decline (Wetteroff 1993). During the five years since 1988, growth has been both below average and has shown reduced ring-width variance over time. These are two signs of a growth decline (Wetteroff 1993). Further climatic analysis and monitoring of these stands may be warranted.

To identify years of sudden, "long-term" growth changes, a comparison between the future seven years diameter growth and the previous 7 years growth was used for each year of the chronology (Table 4). For example, diameter growth from 1956 to 1963 was 144% of the growth from 1949 to 1956. Thus, there was a sudden growth increase beginning in 1956. Similar comparisons were made using a four year growth period. Table 4 lists specific years of sudden growth increases (percentages > 100) and growth reductions (percentages < 100). The largest "long-term" growth reduction began in 1906 while the largest sudden growth increase began in 1956. These changes are probably related to climate, climate-reduced biological potential, or disturbance (e.g. fire).

**Table 4.** Sudden "long-term" growth changes in red oak between 1880 and 1986 based on seven- and four-year comparisons. Percentages are weighted averages of seven, or four years of growth divided by the preceding seven, or four years of growth, respectively. Calendar years indicate the first year of the sudden growth change. The data have been ranked by percentage.

| Rank | Year | 7-Year Average (%) | 4-Year Average (%) |
|---|---|---|---|
| Largest Growth Increase | 1956 | 144 | 155 |
| | 1924 | 141 | 141 |
| | 1969 | 135 | 130 |
| | 1896 | 127 | 126 |
| | 1934 | 84 | 84 |
| | 1913 | 81 | 75 |
| | 1941 | 84 | 74 |
| | 1977 | 81 | 80 |
| | 1950 | 74 | 71 |
| Largest Growth Reduction | 1906 | 69 | 63 |

# CONCLUSIONS

The occurrence of fire, and the effects of fire and climate on the regeneration and growth of red oak were studied in an upland red oak forest in central Ontario. Red oak comprises a major portion of the overstorey in this mature, mixed-species forest. Regeneration of red oak occurred over an extended period (i.e., the early 1800s to the 1920s), which was characterized by frequent fire disturbances. The ages of dominant, overstorey oaks ranged from 68 to 179 years. Frequent fire disturbances favoured the development of sapling-sized red oak advance reproduction. With the advent of fire suppression and a reduction in fire frequency, these oak were able to grow into the overstorey. Red oak diameter growth was affected by: 1) low precipitation in the spring and early summer during the current and previous two growing seasons, 2) high summer temperatures and 3) high fall temperatures in the previous growing season. Annual diameter growth was reduced by about 50% in years with hot, dry summers such as 1988.

Fires occurred every 2 to 18 years at this site before 1955. The pre-1950s fire regime, with its short fire-free intervals, favoured the development of oak advanced reproduction by limiting the development of less fire-resistant, shade-tolerant species in the understorey (e.g. sugar maple, beech and ironwood). There was no evidence of fire after 1955. The absence of fire has led to the dominance of shade-tolerant species over red oak in the understorey. Consequently, future removal of the overstorey may result in a reduction in the number of red oak and other less shade-tolerant tree species, especially where shade-tolerant species dominate the understorey. Fire suppression and the consequent loss of oak may result in the reduction of both economic and biodiversity values on these sites.

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