Forest Fire History Research in Ontario: A Problem Analysis[1]

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Abstract.--This paper surveys available information on fire regimes and methodology employed in elucidating these regimes during the suppression, presuppression and post-glacial periods, principally in the boreal and Great Lakes-St. Lawrence forest regions of Ontario. The presettlement section reviews written accounts, tree-ring and fire scar dating, mapping of fire patterns, and stand age-class distribution. Research needs are suggested.

INTRODUCTION

Resource managers, recognizing that fire exclusion is often impractical and undesirable, and that total relaxation of fire protection cannot be tolerated, are faced with the formidable challenge of coming to terms with forest fires in land management. The first and most basic question that must be considered is: "What was the natural fire regime prior to the initiation of fire suppression?" An analysis of available information and data sources and a review of fire history methodology are logical steps in formulating a research program.

Heinselman[3] made the following statement about fire regimes which has served as a guiding principle in the preparation of this paper:

> ...there are a limited number of variables that determined the natural fire regimes of most regions, and of specific physiographic sites within regions. Once these variables are understood, and we have enough good fire histories to relate them to, it will become possible to estimate the probable natural fire regimes of most areas without additional fieldwork. Some of these variables include the climate of the area, the electrical storm occurrence rate, the known lightning-fire occurrence rate, the natural vegetation of the area, the productivity of the area, the natural balance between fuel accumulation and decay, the local soils and topographic situation, and any special information concerning possible unusual use of fire by man (in presettlement times).

Sharpe and Brodie (1931) remarked that "Throughout Ontario, with the exception of swampy areas, there are probably few timber stands without their fire history." The quiltwork pattern of stand age-classes in northern Ontario suggests that lethal, stand-replacing, high-intensity surface and/or crown fires are characteristic of the area. Further south the effects of sublethal, low-intensity surface fires are more pronounced. Hence, elucidation of the fire regime requires that the temporal pattern of burning be emphasized--area extent in the former area and return intervals at point locations in the latter.

The purpose of this paper is to explore the scope of our knowledge and ability to reconstruct fire history in Ontario and, finally, to identify the areas where future research efforts will be most fruitful. It is based on a review of published literature and unpublished reports, personal contacts with other workers, familiarization with available written historical sources and five seasons of direct and related field experiences in northern Ontario. This <u>problem analysis</u> is especially timely for someone who has taken on the task of "deciphering the historical nature of wildfire in the Boreal and northern Great Lakes-St. Lawrence Forest Regions of Onatrio." The paper is organized into three recognizable time periods from the standpoint of fire history--modern (since 1920), presettlement (1600-1920), and paleoecological (Holocene deglaciation). Furthermore, the presettlement

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[3]Heinselman, M.L. 1975. The history and natural role of forest fires in the lower Athabasca Valley, Jasper National Park, Alberta. Unpublished report. 63 p. [Contract Report NOR 5-980-1 on file with Canadian Forestry Service, Northern Forest Research Centre, Edmonton, Alta.].

fire record has been subdivided to cover the following topics: written accounts, tree-ring and fire scar dating, mapping of fire patterns, and stand age-class distribution.

FOREST ECOSYSTEMS OF ONTARIO

Rowe's (1972) forest regions and sections of Canada have been utilized in this paper partially as a synthesizing framework of available information (fig. 1). Where appropriate, forest section designations have been included. In addition, the latitude and longitude of place names have been included for reader convenience and reference. A forest region is a major geographical belt or zone, characterized vegetationally by a broad uniformity both in physiognomy and in the composition of the dominant tree species. Regional subdivisions, or forest sections, are geographical areas possessing an individuality which is expressed relative to other sections in a distinctive patterning of vegetation and physiography. Rowe (1972) provides a brief description of each forest section.

Three of Canada's eight major forest regions occur in Ontario. The Deciduous Forest Region, restricted to the southwestern part of the province, occurs only in Ontario and is similar to the deciduous forests of the eastern United States. The natural forest vegetation of this region has been largely eliminated by settlement and urbanization. The Great Lakes-St. Lawrence Forest Region of Canada is composed of 16 sections. Three entire forest sections and portions of eight others occur in Ontario. The most outstanding vegetational features of the region are the eastern white pines (*Pinus strobus* L.) and red pines (*P. resinosa* Ait.) although the forests contain a number of other conifers and several deciduous species, resulting in many mixed stands. Much of the area has been influenced by settlement and logging has taken its toll; only portions of the original vegetation remain intact. The vast Boreal Forest Region of Canada is composed of 45 forest sections, of which four entire sections and portions of six others are found in Ontario. The major tree species are jack pine (*P. banksiana* Lamb.), black spruce (*Picea mariana* [Mill.] B.S.P.), white spruce (*P. glauca* [Moench] Voss), balsam fir (*Abies balsamea* [L.] Mill.), trembling aspen (*Populus tremuloides* Michx.), and white birch (*Betula papyrifera* Marsh.). Unexploited forests still exist in large blocks. In reality, there is a continuum of various broadleaf deciduous forests in southern Ontario to largely coniferous forests in the north.

There are three major physiographic regions in Ontario (Rowe 1972). The Hudson Bay Lowland (B.5 and B.32) is a poorly drained region abounding in bogs and shallow lakes. The Canadian Shield, comprising the remainder of the boreal forest and most of the Great Lakes-St. Lawrence Forest Region, is characterized by Precambrian bedrock covered with a shallow layer of stony sandy till with knob/ridge topography and an extensive network of streams, rivers, lakes and bogs. Southern Ontario, chiefly D.1, is principally a gently sloping plain.

Worth noting is that mean total annual precipitation, a principal determinant of fire climate, increases on a west to east gradient and decreases from south to north (Brown et al. 1968, Chapman and Thomas 1968). Lightning fire densities in Ontario have recently been mapped for the twelve-year period 1965-1976 (Stocks and Hartley 1979). Lightning fire incidence decreases significantly as one moves eastward. The boreal (excluding B.5 and B.32) and Great Lakes-St. Lawrence forests experience between 0.5 and 3.0 lightning fires per 1,000 km^2 per year (2-12 fires/1,000,000 acres/yr).

MODERN FIRE RECORD

Formal fire reporting by the provincial forestry service (now Ontario Ministry of Natural Resources) began in 1917 and by the 1920s most of Ontario north to approximately latitude 52° was being consistently covered. Data on B.32 and the northern portions of sections B.5 and B.22a prior to 1970 are incomplete. The first attempt to summarize the areal extent of forest fires from these reports was the inclusion of Map No. 9 (Reported Burned Areas of over 500 Acres) in the report of the 1947 Ontario Royal Commission on Forestry (Anonymous 1947b). Fire areas were color coded by two time periods (1920-1935 and 1936-1946) on a single map sheet at a scale of 1 inch to 50 miles (1 cm ≈ 31.7 km). Donnelly and Harrington (1978) have since produced an "atlas" comprising seven maps at a scale of 1:500,000 for all fires 200 hectares (500 acres) and larger covering the period 1920-1976. Individual fires have been identified by year and Rowe's (1972) forest section boundaries have been included as well. It is thought that about 95 percent of the total area burned is represented by these fires. Harrington and Donnelly (1978) subsequently compiled area burned data and computed the percentage of area burned annually by decade for several sections in northern Ontario. Their work has been updated only slightly in this paper by including fire report information for the period 1977-1979. On the basis of the average annual rate of burning, over the relatively short period during which records have been kept (i.e., the past 60 years), the present fire cycle for northern Ontario is calculated to be approximately 500 years (table 1), and this presumably reflects increasing fire control effectiveness.

PRESETTLEMENT FIRE RECORD

Written Accounts

Two of the best known historic fires in Ontario prior to 1920 are unfortunately associated with human disaster. An estimated 73 persons lost

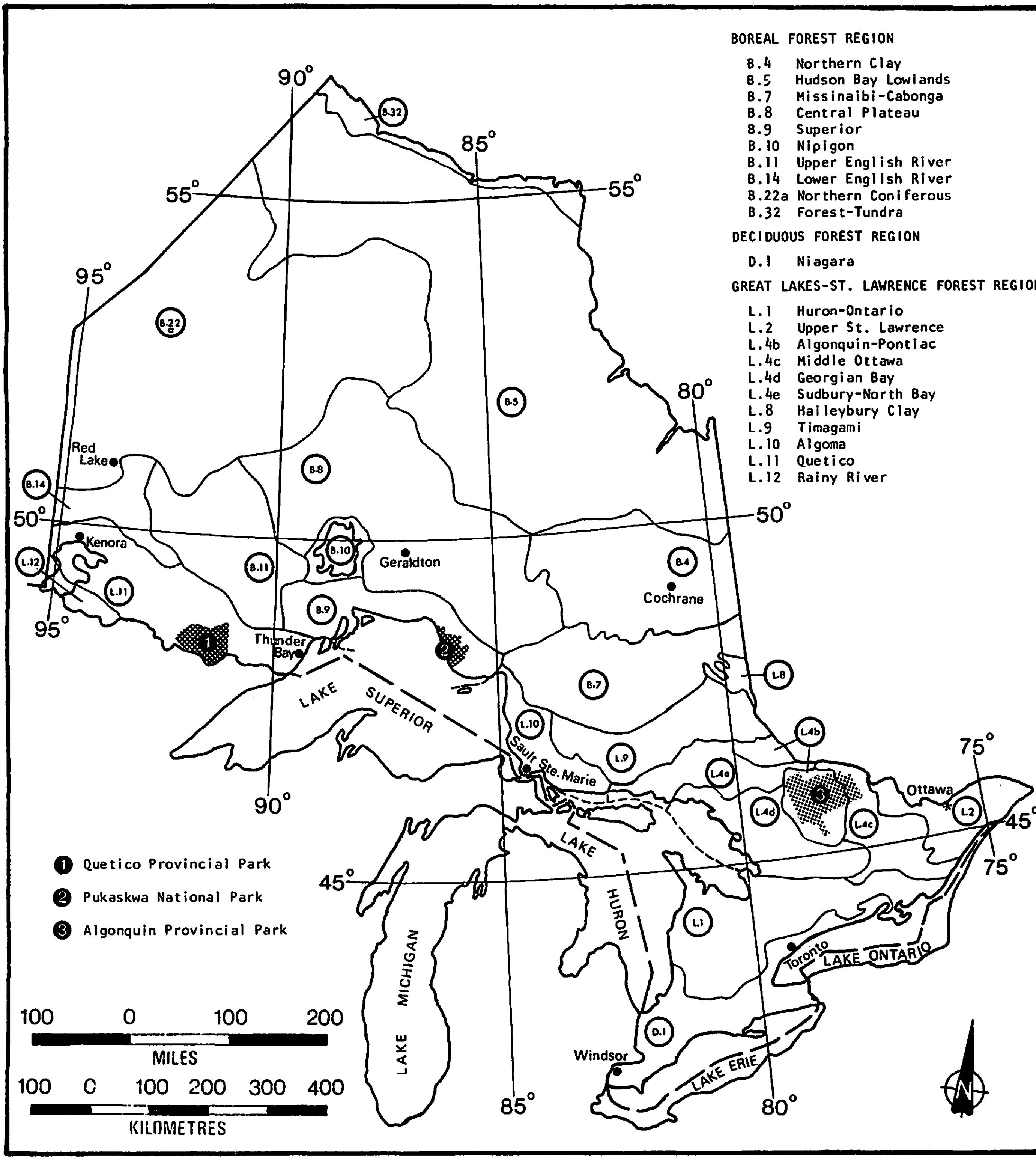

Figure 1.-- Map of forest regions and sections in Ontario according to Rowe (1972).

Table 1.--Percentage of area burned annually (by decade) and calculated fire cycle for selected geographical regions in northern Ontario based on all fires greater than 200 ha (500 acres) in size that were reported between 1920 and 1979 (adapted from Harrington and Donnelly 1978; includes data for period 1977-79).

Forest Region and Section (after Rowe 1972)	Size of Area (acres[1])	% Mean Annual Burned Area[2]							Fire Cycle[3] (yr)
		1920-29	1930-39	1940-49	1950-59	1960-69	1970-79	1920-79	
Boreal	82,319,220	0.30	0.28	0.14	0.07	0.15	0.20	0.19	526
Northern Clay (B.4)	13,327,909	.17	.03	.05	.08	.0	.03	.06	1,667
Missinaibi-Cabonga (B.7)	10,763,952	.44	.16	.49	.19	.02	.02	.22	455
Central Plateau (B.8)[4]	24,881,238	.42	.19	.03	.05	.03	.15	.15	667
Superior (B.19)	5,852,452	.08	.88	.25	.02	.0	.01	.21	476
Nipigon (B.10)	1,200,965	.17	.02	.27	.69	.0	.0	.19	526
Upper English River (B.11)	10,189,529	.19	.46	.08	.0	.12	.13	.16	625
Lower English River (B.14)	3,555,317	.58	.16	.05	.05	.04	.02	.15	667
Northern Coniferous (B.22a)[4]	12,547,857	.23	.46	.16	.03	.81	.86	.43	233
Great Lakes-St. Lawrence									
Quetico (L.11)	10,757,111	.51	.60	.03	.01	.01	.14	.22	455

[1]Acres x 0.4047 = hectares.

[2]The percentages were computed under the assumption that the portion of the surface covered by water within the boundaries of the burned areas was equal to that in the region at large (Harrington and Donnelly 1978).

[3]Based on the average rate of burning for the period 1920-1979. The reciprocal of the calculated fire cycle is the proportion of the whole region that burned annually (Van Wagner 1978).

[4]Includes that area south of latitude 52°N within the section.

their lives in a fire covering 864 mi^2 (2,238 km^2) in the newly opened mining country between Porcupine (48°30'N, 81°10'W) and Cochrane (49°4'N, 81°01'W) in 1911. In 1916, 224 people perished in a fire that covered more than 1,000 mi^2 (2,590 km^2) centered around the community of Matheson (48°32'N, 80°28'W). Numerous accounts of forest fires prior to the initiation of province-wide reporting can be found in several printed sources. The detail varies considerably, from general observations of causes and major fire years in certain locales to specific information on location and approximate areal extent of individual fires. Only a few examples can be given here to illustrate the wealth and value of fire history information available in published and unpublished forms.

Some of the earliest written accounts of forest fires were by Jesuit priests serving at various missions throughout eastern North America. Father Jean Pierre Aulneau remakred that the smoke from forest fires was so thick that it prevented him from "even once catching a glimpse of the sun" as he travelled from Lake Superior to Fort St. Charles (Minnesota) on Lake of the Woods (49°18'N, 94°52'W) in 1735 (Nute 1950). Many of the Jesuit writings are recorded in several published volumes (Thwaites 1901). However, as Leslie[4] rightly notes, "...it is difficult to tie these records to an actual area."

[4]Leslie, A.P. 1954. Large forest fires in Ontario. Unpublished report. Ontario Department of Lands and Forests, Toronto. 16 p. [copy on file with Aviation and Fire Management Centre, Ontario Ministry of Natural Resources, Sault Ste. Marie].

The chronicles of the first Europeans to traverse the country also served to document fire incidence. Alexander MacKenzie, a renowned explorer of northern Canada, mentioned that large fires occurred north of Lake Superior in 1788 and 1789 (Leslie[4]). Many diaries have been published and a considerable amount of unpublished material can be found in the Archives of Ontario in Toronto and the Public Archives of Canada in Ottawa.

Records associated with the fur trading companies contain entries of forest fires near established posts and in surrounding areas. An excellent map showing post locations and approximate length of operation is available (Anonymous 1973). The journals and reports of the Hudson's Bay Company (HBC) post traders are particularly useful and as Leslie[4] suggests "...would repay further study." J.D. Cameron, the HBC trader at Rainy Lake (48°50'N, 93°05'W), wrote that 1803 and 1804 were major fire years along the Minnesota/Ontario lakeland border country (Nute 1941, 1950). Charles McKenzie, the HBC trader at Osnaburgh House (51°08'N, 90°16'W), noted that a large part of the country between the post and the Winnipeg River in southern Manitoba was burned over in 1825 (Bishop 1974). The original HBC records are located in the Company's archives in Winnipeg, Manitoba. Microfilm copies have been filed with the Public Archives of Canada.

The field notes and maps of the Ontario provincial land surveyors (PLS) constitute an invaluable record of forest fire history (Weaver 1968). An excellent example is the published account of an extensive exploratory survey of some 60 million acres (24 million ha) in northern Ontario during 1900 (Anonymous 1901). The area was divided into ten districts and one field party was detailed to examine each district. Meridian and base line surveys which passed through miles of country afforded the opportunity to tie observations of forest fires to specific locations with a high degree of accuracy (Richardson 1929, Leslie[4]). For example, extensive portions of the country north and west of Lake Superior and as far west as Rainy Lake (48°42'N, 93°10'W) are known to have been burned over in 1845. The eastern parts of Algonquin Provincial Park were swept by fire in 1851. fires in 1855 covered an estimated 2,000 mi^2 (5,180 km^2) between the west shore of Lake Timiskaming (46°52'N, 79°15'W) and Michipicotn (47°57'N, 84°54'W) on Lake Superior. In 1864, two separate fires joined, finally covering a distance of approximately 170 miles (275 km) from the Thessalon River (46°15'N, 83°34'W) on Lake Huron to Lake Nipissing (46°17'N, 80°00'W). Fires covered more than 2,000 mi^2 (5,180 km^2) north of Lake Huron in 1871 from Lake Nipissing to the Mississagi River (46°34'N, 83°22'W). Township surveys are a very specific source of data on past fire occurrence. For example, PLS Hugh Wilson laid out the 63,630 acre (25,751 ha) Pic Township (48°41"N, 86°17'W) on Lake Superior in 1873 and determined that a large portion had been overrun by fire in 1869 (Kirkwood and Murphy 1878). Ontario is nearly covered by townships north to approximately latitude 50° and west to longitude 85° (Weaver 1968). In the remainder of the province, townships are clustered around existing population centers. The unpublished documents and maps associated with the various PLS surveys are on file with the Surveys and Mapping Branch of the Ontario Ministry of Natural Resources in Toronto.

References to forest fires are also found in the published reports and maps of the Ontario Bureau of Mines and Geological Survey of Canada (e.g., Ferrier 1920, Nicolas 1921). For instance, during his travels in 1888 through the Hunter's Island area in what is now Quetico Provincial Park, Smith (1892) stated that there had been three recent periods of fire: in 1870, 1879 and 1885-1886. He gives a long list of lakes whose shores showed evidence of those fire episodes. Bell (1904) describes an area of over 3,000 mi^2 (7,770 km^2) that burned in 1901 south and west of Lake Kesagami (50°23'N, 80°15'W). Collins (1909) remarked that much of the country between the east and west branches of the Montreal River (47°08'N, 79°27'W) was swept by several fires in September, 1908.

The relative roles of lightning and man as ignition sources during the presettlement era are known only qualitatively. As Wright and Heinselman (1973) point out, though, "The key question is whether lightning alone is an adequate source of ignition to account for the observed extent of burning in given ecosystems." Lutz (1959), in his review of the various historical causes of fire in the boreal forest, was of the opinion that lightning was certainly responsible for starting fires but that man had been a more important cause. There is little doubt that man has been a factor in the proportion of area burned (Richardson 1929, Sharpe and Brodie 1931, Leslie[4]), particularly through his carelessness with campfires. The white man's intentional use of fire in those activities associated with prospecting and the railroad in the late 1800s and early 1900s is a case in point. For example, there were two large fires in 1891 and 1896 along the Canadian Pacific Railroad line (Richardson 1929) between Pogamasing (46°55'N, 81°46'W) and Woman River (47°31'N, 82°38'W), a distance of some 80 miles (129 km).

The extent to which natives used "prescribed" fire in their culture is difficult to assess. Harnden[5] related an interesting account of the use of fire by Indians for wildlife habitat improvement. In 1948, during a canoe trip on Poshokagan Lake (49°22'N, 90°20'W), 80 miles northwest of Thunder Bay, he met a French immigrant who had lived most of his life with the native Indians of northwestern Ontario. At the time, the man was approximately 75 years of age, having arrived in northwestern Ontario when he was about 17. The Indians were apparently well aware that young vigorous forests were usually the most suitable habitat for a large variety of animal and plant species. In order to maintain sufficient areas suitable to their needs, Indian bands set fire to selected areas at appropriate times and thus manipulated the forests. Consequently, over the long term, perhaps a generation or more, most of northwestern Ontario was burned by the Indians.

Assessing the influence of man-caused fires on the regime may be immaterial, for man probably served merely as an alternative ignition source in most areas. Fuels and weather determined whether ecologically significant fires occurred (Heinselman 1973). Any detrimental effects associated with a short-interval fire regime were probably localized and in most cases not of great significance on a regional scale except for those situations where repeated fires followed logging and land clearing (Howe 1915, Sharpe and Brodie 1931).

Tree-Ring And Fire Scar Dating

Some 50 years ago Richardson (1929) in his booklet on Ontario forestry wrote "...strange as it may seem, the magnificent pineries composed as they were of trees nearly all of the same age, were the result of forest fires which occurred some time in the distant past." Richardson was undoubtedly referring to red and white pine stands which are reasonably reliable as a source of fire dates, but there is a period between the time fire occurs and the time natural regeneration begins, and this period must be taken into

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[5]Harnden, A.A. 1978. Personal correspondence. Canadian Forestry Service, Great Lakes Forest Research Centre, Sault Ste. Marie, Ont.

account when one tries to determine exact fire dates. Jack pine, and to some extent black spruce, are especially good colonizers following fire. Ring counts of aspen and birch are especially difficult. White spruce can be used to obtain "minimum" fire origin dates.

Red and white pine each have a maximum life-span of 400 years, although the latter is more prone to decay. White and black spruce may live for up to 250-300 years, but for the latter such ages are encountered only in rather large lowland areas. Jack pine stands seldom exceed 200 years. The preceding estimates are based on values found in the literature for Ontario and on personal experience. For instance, one of the oldest known intact jack pine stands in Ontario (*ca.* 1772 fire origin) is found along the Aubinadong River (46°52'N, 82°24'W; L.9). No standard correction factors for increment boring height (in order to arrive at total age) are available although these could be developed from stem analysis data available for large trees, by progressive measurement of seedling heights on recent wildfire sites, and/or by aging seedlings. Factors no doubt vary according to site conditions.

Jack and red pine constitute the most abundant source of live basal fire scar material in the north and south, respectively. Double fire scars are reasonably common on jack pine (fig. 2). For example, we were able to document the origin, 1899, and previous fires, 1831 and *ca.* 1780 (corrected pith year), for an experimental fire study area in a mature jack pine stand near Kenshoe Lake (48°56'N, 85°16'W; B.8). Triple scars are exceedingly uncommon. In only one case during a survey of over a hundred fire origin stands in northwestern Ontario was a triple encountered. Approximately 12.5 miles (20 km) northeast of the town of Pickle Lake (51°35'N, 90°00'; B.22a) a triple fire scar cross-section collected in 1978 revealed fires in 1929, 1863, 1835 and *ca.* 1799 (corrected pith year). Red pine has a great resistance to decay resulting from fire scars, as is readily apparent in a cross-section taken in 1980 from a specimen (*ca.* 1671 origin) on Kwinkwaga Lake (48°49'N, 85°20'W; B.8) exhibiting evidence of fires in 1829 and 1818.

Dead fire scar material has been found to be an invaluable means of extending fire chronologies back in time. As part of the survey referred to earlier, a double fire-scarred jack pine killed in a known fire (1932) area on Tackaberry Lake (51°23'N, 93°05'W; B.22a) was collected in 1976 and showed evidence of fires in 1845, 1807 and *ca.* 1792 (corrected pith year). Fire scars on recent wildfire sites have proven useful in documenting stand history associated with permanent regeneration plots on these areas. Near the Allan Water train stop on the Canadian Pacific Railroad line (50°14'N, 90°12'W; B.11) a 1976 fire-killed jack pine revealed previous fires on the site in 1910, 1843, and *ca.* 1797 (corrected pith year).

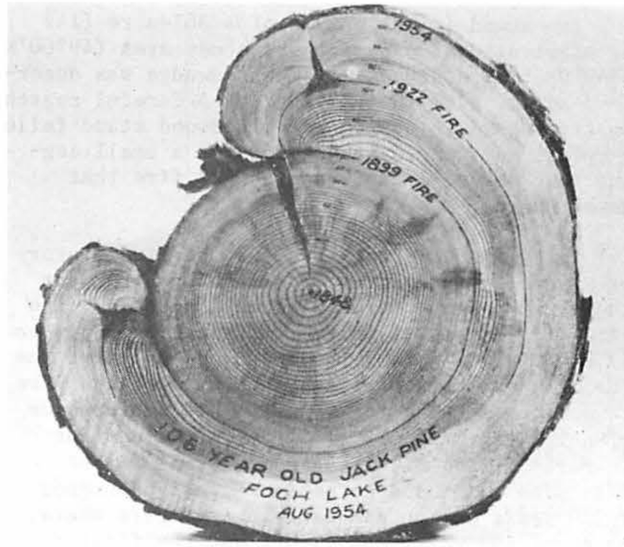

Figure 2.--Cross-section of a double fire-scarred jack pine collected near Foch Lake (49°15'N, 85°20'W; B.8) in August, 1954 for stand aging purposes during a timber cruising operation. The second scar date was inadvertently mislabelled 1922 instead of 1923. The spceimen measures 10 inches (25 cm) in width. (Photo courtesy of The Ontario Paper Company Limited, Manitouwadge, Ont.).

Rondeau Provincial Park, located on the north shore of Lake Erie (42°17'N, 81°51'W; D.1), is a 4,450 acre (1800 ha) remnant of the deciduous forest that once covered most of the southwestern peninsula of Ontario before the days of the early settlers. Bartlett (1956) obtained the ages of 610 trees from increment cores at DBH and freshly cut stumps during an extensive examination of age-class composition in 1954. Sixty saplings were subjected to stem analysis and average correction factors were computed in order to arrive at total age (6 yr for DBH height and 2 yr for stump height). Bartlett concluded that fires were "common" in the white pine-oak (*Quercus* sp.) forest type between 1664 and 1839. The oldest, even-aged groups of white pine were regarded as having originated following fire between *ca.* 1749 and 1758. The broad distribution of ages obtained in the hardwood forest type suggested that the community had been relatively undisturbed by fires since at least 1664. Heinselman[6] was forced to rely almost soley on increment cores from white spruce in estimating fire origin dates for the Slate Islands located along the north shore of Lake Superior (48°40'N, 87°00'W; B.9). During a brief 3-day field trip he was able to reconstruct a major portion of the area's fire history which was required for an evaluation of woodland caribou habitat characteristics.

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[6]Heinselman, M.L. 1978. Personal conversation. Department of Ecology and Behavioral Biology, University of Minnesota, Minneapolis, Minn.

The stand (fire) origin of a 367-acre (149 ha) silvicultural experimental study area (49°00'N, 85°49'W; B.8) southeast of Manitouwadge was determined as *ca.* 1761 (Hughes 1967). A careful search for fire scars in the upland mixedwood stand failed to reveal any fire scars except for a small segment that burned in 1850 and a 1922 fire that passed nearby.

Turner (1950) reconstructed the fire history for several of his spruce budworm-forest impact study areas using tee-ring counts and basal fire scars. For example, in the Mississagi River area (47°00'N, 83°00'W; L.9) he found in 1946 that the ages of most white, red and jack pine stands were all between 160 and 165 years. This corresponds to Sharpe and Brodie's (1931) observation that "In parts of the Mississagi Provincial Forest white pine was found to be in the neighbourhood of 350 years of age and carrying two fire scars, one about 150 years ago [1780] and the first one about 250 years ago [1680]." At his Manitowik Lake-Michipoten River location (48°00'N, 84°30'W; B.7) he found scar evidence for fires in 1790, 1828, 1845, 1875, 1878, 1891 and 1901.

Howe (1915) undertook a detailed survey of forest conditions in areas that had burned once, twice, three and several times within Methuen Township, and a portion of Burleigh Township (44°40'N, 78°03'W; L.1). The total area involved amounted to 86,333 acres (34,939 ha). From tree-ring counts of aspen and fire scar dating of red and white pine he documented fires in 1880, 1890, 1895, 1897, 1899, 1905, 1907 and 1910. (I am assuming that "years" date from a reference year of 1915). A cross-section from a single fire-scarred red pine snag disclosed that it has been scarred when it was 25, 43, 55, 64, 82, 88, 96 and 100 years old. This corresponds to a return interval of 12.5 years. The photo of a *ca.* 1678 origin triple fire-scarred red pine cross-section showing fires in 1744, 1756, and 1766 from his report was reprinted in a short popularized article (Anonymous 1923).

Bickerstaff (1942) reported that much of the Petawawa Forest Experiment Station (now Petawawa National Forestry Institute) which shares Algonquin Park's northeast boundary (46°00'N, 72°26'W; L.4c) has been repeatedly swept by fire since at least 1647, with dated fires occurring in 1716, 1748, 1832, 1862 and 1875. Six major fires were reported to have occurred between 1860 and 1919 (Anonymous 1947a). Brace (1972) found fire scar evidence for fires prior to 1920 in 1854, 1871, and 1892. From written and forest records Burgess (1976) was able to document eight separate fire events during the last 300 years for a mixed jack-red-white pine area on the Station. The average fire interval over this time was approximately 37 years (Burgess and Methven 1977).

A red pine fire-scarred cross-section taken from a mixed pine stand in the Parke Township (46°30'N, 84°30'W; L.10) near Sault Ste. Marie revealed an average return interval of 30 years with a range of 14-46 years on the basis of five fire events for the period 1727-1877 (Alexander et al. 1979). The cross-section and entire "cat face" have been developed into a display located in the Great Lakes Forest Research Centre's (GLFRC) main entrance area. Approximately 900 people visit the Centre during the summer months. Further fire scar and tre-ring dating in the 5,300-acre (2,145 ha) township was completed in 1979 and 1980. This work is being done by Stephen W.J. Dominy, a forestry student at Lakehead University in Thunder Bay who is supported in part by GLFRC. The results form the basis of a Bachelor of Science thesis due to be completed in May 1981.

Cwynar (1975, 1977) developed a presettlement fire chronolgy, principally from wedges of red pine fire scars, for the 45,960-acre (18,600 ha) Barron Township which lies in the east half of Algonquin Provincial Park (45°53'N, 77°54'W; L.4b). Sampling was carried out by foot and canoe during the summer of 1974. Sixteen fire years were identified as having occurred between 1696 and 1920. Accuracy of the fire scar dating was judged to be ± 2 or 3 years. Increment cores were also taken from dominant trees at most fire scar sites.

Woods and Day (1976, 1977) reconstructed the presettlement fire history of a 230,000 acre (93,080 ha) portion of Quetico Provincial Park, known as Hunter Island, by aging wedges of basal fire scars and increment cores of fire-initiated stand age-classes. Because of possible inaccuracies in age determinations, fire origin dates were placed in 10-year periods going back to 1770. The sampling was carried out during the 1975 and 1976 field seasons and was confined to areas along major waterways which afforded access by canoe.

A current study in the 460,000-acre (186,000 ha) Pukaskwa National Park involves the use of increment cores from fire-initiated stands and basal fire scar cross-sections of live residuals and snags to construct a chronology of major fire years (Alexander 1978). Access and the shear size of the area posed a formidable challenge. The shoreline area and adjacent islands in Lake Superior were intensively sampled by motorboat. Over 125 sample sites were selectively located in the interior of the park on the basis of a careful review of existing forest inventory maps. Most of these areas were reached with a Hughes 500D helicopter. Sampling was carried out during portions of the 1977-79 field seasons. The field data are being supplemented by stand aging information collected as part of a biophysical resource inventory of the park. Where possible, fire origin dates are bieng confirmed by written accounts. The climatic history of the park and its relation to fire occurrence are also being investigated in a cooperative study with dendroclimatologists M.L. Parker and L.A. Jozsa of the Forintek Canada Corp.'s Western Forest Products Laboratory in Vancouver, British Columbia. Red pine (the eastern cousin of ponderosa pine) stands were sampled at four locations and the increment cores were subjected to X-ray densitometry techniques. Analysis and interpretation of the data are still in progress.

Mapping Fire Patterns

Fry[7] notes that "...an age-class distribution map for a management unit in northern Ontario is little more than a mosaic that visually tells us where fires burned, when they burned and what they looked like in terms of area covered." Recent burns were mapped (chiefly by aerial sketching) during province-wide forest surveys in the 1920s (Sharpe and Brodie 1931). This represents the earliest mapping of fire patterns at such a large scale with reasonably accurate detail. Reconstructing historic fire patterns is no doubt more readily accomplished in northern Ontario than further south.

Howe (1915) was able to produce a "fire incidence" map for Methuen and Burleigh Townships at a scale of 1 inch to 2 miles (1 cm ≈ 1.27 km) from the fire scar and tree-ring data gathered along cruise lines. Recent burn areas comprised 51,334 acres (20,775 ha) of the total 84,333 acres (34,130 ha) of forested area under investigation. Areas burned once, twice, three and many times (since the present stand establishment) comprised 33.8, 34.6, 13.6, and 18.0 percent of the study area, respectively. Cwynar (1975, 1977) was not able to develop true fire history or stand origin maps (Heinselman 1973). Instead he reproduced maps in which fire scar locations and fire-initiated forest stands, presented separately, were used to show the approximate areal extent of eight major fire years between 1763 and 1914, five of which covered more than half the township (1763, 1780, 1854, 1864, 1875).

Lynn and Zoltai (1965) developed a stand origin map at a scale of 0.75 inch to 1 mile (1 cm ≈ 1.18 km) for a 21.0 mi^2 (54.4 km^2) area (49°56'N, 87°07'W; B.8) northwest of Geraldton from forest inventory maps and stand aging data. An area of approximately 12 mi^2 (31 km^2) was delineated as having burned in 1880. An area of about 5 mi^2 (13 km^2) was swept by fire in 1920, 1922 and 1923 while the remaining area was burned in 1830, 1852, 1860, and 1870.

Woods and Day (1976) initially produced a "burn period" map at a scale of 1 inch to 1 mile (1 cm ≈ 1.58 km) for approximately 100,000 acres (40,500 ha) of their Hunter Island study are from data collected in 1975, existing forest inventory maps, and interpretation of 1948 and 1965 aerial photos. This was subsequently combined with further information collected in 1976 and with photo interpretation, and a final map was printed at a scale of 2 inches to 2.65 miles (1 cm ≈ 1.19 km) with areas delineated by decade intervals back to 1770 (Woods and Day 1977). Over 75 percent of the study area was burned over between 1860 and 1919.

Stand origin and fire history maps for Pukaskwa National Park are being produced from the tree-ring/fire scar data tied to forest inventory maps from stereoscopially interpreted aerial photographs taken in 1949, 1963, and 1973. The northern half of the park also has 1937 photo coverage. The 1949 maps constitute the most compelte and reliable inforamtion on forest stand mosaics. Stands were delineated by 20-year age-class groups up to 140+ yr. The entire project was supervised by S.T.B. Losee, a pioneer of forest aerial photo interpretation in eastern Canada. Extrapolations of field data to adjacent areas are being made out of necessity.

Harrington[8] has illustrated the potential of satellite imagery in mapping fire patterns for a pilot study area near Trout Lake in northwestern Ontario (51°12'N, 93°07'; B.22a) that has a history of large fires between 1932 and 1976. Recent fire mosaics were readily identifiable and appeared as bright to progressively darker colors. Older age-classes (1915 and 1856) were very dark blue. Remote sensing is a rapidly advancing technology in northern Canada. It will very likely paly a major role in future fire history investigations.

Stand Age-Class Distribution

Brodie and Sharpe (1931), in their publication on Ontario's forest resources stated that "...fires have occurred periodically up to the present time, giving rise to series of age-classes, thus providing an opportunity for seeing the development of stands from youth to maturity." Germane to this section of the paper are some additional statements and observations from various surveys conducted in northern Ontario during the 1950s and 1960s. MacLean and Bedell (1955) noted that most parts of the Northern Clay belt (B.4) had:

> ...burned at least once during the past 130 or 140 years, and even-aged stands predominate The age-class distribution indicates that widespread fires took place about 1820, between 1850 and 1865, about 1895, and in 1923. It appears that dry condi-

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[7]Fry, R.D. 1976. Prescribed fire in the forest. Paper presented at the Ontario Ministry of Natural Resources Prescribed Burning Seminars (November 23-25, Quetico Centre and November 30 - December 2, L.M. Frost Natural Resources Centre). 22 p.

[8]Harrington, J.B. 1976. LANDSAT imagery applied to the ecology of the Canadian boreal forest. Paper presented at the Fourth National Conference on Fire and Forest Meteorology (St. Louis, Missouri, November 16-18). 4 p.

tions accompanied by high fire frequency, occur at about 30-year intervals. This conclusion is substantiated by similar findings to the south and east in Forest Section B.7. Owing to the flat nature of the topography, the fires burned over the whole landscape, from the driest sand plains to the wettest swamps. In this respect Forest Section B.4 differs from Forest Section B.9 where the topogrpahy is much rougher, fires are usually confined to the higher ground, and great difficulty is encountered in finding swamps which have been burned in the past 120 years...[Bedell and MacLean 1952 were not able to find any stands > 200 years in more than 600 examined in B.9].

MacLean (1960) stated that most mixedwood stands in sections B.4, B.8, and B.9 had:

> ...originated from fires which took place since the year 1800. Stands from earlier fires are infrequent and rarely extensive. However, a few of these very old stands were found in each of three sections under consideration.

Zoltai (1965) made the following comment about northwestern Ontario (principally sections L.11, B.11 and B.14):

> The fire disturbance is so widespread throughout the region that areas not burned within the last 100-150 years are exceedingly rare.

These statements indicate that the frequency or distribution of stand age-class is a major feature of northern Ontario's forest landscape strongly associated with the area's fire history and that differences in the geographical pattern of burning do exist.

Heinselman (1973) referred to the average time required for fire to burn over an area equivalent to the total area under consideration prior to fire suppression as the natural fire rotation. Van Wagner (1978) used the term fire cycle to mean the same thing. The definition is worded in this way to allow for the likelihood that some portions of the area will experience shorter return intervals while others will be missed by fire for fairly long periods. The fire rotation or cycle is the appropriate yardstick of forest renewal in natural fire-dependent ecosystems. Cwynar (1975, 1977) deduced a presettlement fire rotation of 70 years for Barron Township on the basis of the conservative assumption that fires during the five major fire years covered at least half of the area and tha small fires in 1844, 1889, and 1914 each burned a quarter of the township. Wodds and Day (1977) calculated a natural fire rotation, founded on the best period of record prior to 1920 (i.e., 1860-1919), of 78 years. An inherent problem in using a percent annual burn figure derived from reconstructed fire year maps in calculating fire rotations or cycles is the loss of record of the exact area burned by past fires because of succeeding fire events.

Van Wagner (1978) has illustrated that the distribution of stand age-classes in natural fire-dependent forest ecosystems experiencing a stand renewing fire regime should, if we assume a random ignition pattern and uniform flammability regardless of age, match a negative exponential (NX) function. The assumptions used in the model require clarification. Lightning fire ignitions occur in a more or less random fashion and any non-uniformity in flammability throughout the fire cycle is not likely to affect the age-class distribution (ACD) adversely. The NX model of ACD predicts that about one-third of the forest is older and that two-thirds is younger than the fire cycle which is equal to the mean stand age. The average interval between fires at a given point is theoretically the same quantity as the fire cycle. Van Wagner (1978) has shown that Heinselman's (1973) stand origin map data for the remaining 415,000 acres (168,000 ha) of virgin forest in the Boundary Waters Canoe Area, which borders Quetico Provincial Park on the north, to fit a NX distribution approximating a presettlement fire cycle of 50 years. This differs considerably from the natural fire rotation of 100 years derived earlier by Heinselman (1973) for his entire 1,000,000 acre (404,700 ha) study area. Van Wagner's (1978) concept of fire cycle is also appropriate to a particular forest vetetation type that is intermingled on a regional scale with other types that have different cycles.[9] Upland forest types no doubt have variable fire cycles and are certainly shorter than those for lowland communities.

The NX model of ACD can be used to determine fire cycles for forests such as those found in northern Ontario. Its main advantage over other model forms is its simplicity.[9] The mathematics is easy, the resulting graphic model is easily visualized, and a less than perfect fit may be interpreted as mere roughness in the natural fire process. One might suspect that fire cycles could be estimated from stand data generated by Ontario's forest inventory program (Anonymous 1978) but it is doubtful that the classification of stand age groups delineated almost wholly from interpretation of aerial photographs is sufficiently precise to permit accurate determinations. Calculations must therefore depend on the distribution of stand ages obtained by random sampling. A large body of data is needed, both on the area sampled and on the age of stands, to obtain a good statistical fit.[9] A forest section might be regarded as a sufficiently large area. An alternative to sampling would be stand origin

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[9]Van Wagner, C.E. 1980. Personal correspondence. Canadian Forestry Service, Petawawa National Forestry Institute, Chalk River, Ont.

map data such as Heinselman's (1973). The old age tail is an important aspect of the NX model and must be carefully accounted for in the study area.[9]

Some mention should be made here of computer modelling of stand age-class distributions and related interactions. The simulations of ACD influenced by random fire and timber harvesting such as those presented by Van Wagner (1978) can provide considerable information that will be useful in planning fire and land management strategies. A further example of fire history-ecology modelling is offered by Suffling et al. (1980) who developed scenarios for projections in stand ACD, species composition and furbearer population changes over time, until the year 2017, as influenced by fire control, fire control and logging, and a completely natural regime of fire and no logging.

PALEOECOLOGICAL FIRE RECORD

The oldest positive evidence of fire in Ontario comes from charred wood remains, found 200-300 feet (60-90 m) below the surface at Scarborough Heights near Toronto (Penhallow 1904), which dated back to the Early Wisconsin glacial period (60,000-70,000 years ago). Terasmae (1967) attributed the consistently high percentages of jack pine and white birch pollen found in core sediments from Nungesser Lake in northwestern Ontario (51°28'N, 93° 30'W; B.22a) to frequent forest fires in the region throughout postglacial (Holocene) time--more than 9,000 years. Charcoal fragments/depsoits have also been casually noted in core samples of lake and peat bog sediments taken for palynological studies. For example, "charcoal bookmarks" at varying depths, dating back to deglaciation (8,000-11,000 years ago) have been documented at Harrowsmith Bog (44°25'N, 76°42'W; L.1) in southern Ontario (Terasmae 1969) and in Thane Lake (48°20'N, 84° 59'W; B.8) in northern Ontario (Terasmae 1967).

The only charcoal stratigraphy studies of lake sediments (combined with pollen analysis) undertaken in Ontario are confined to Algonquin Provincial Park and nearby areas. Cwynar (1975, 1978) analyzed a 500-year section of laminated sediment for charcoal influx from Greenleaf Lake (46°63'N, 77°57'W; L.4c) on the east side of the park. Six distinct peaks documented between 770 and 1270 A.D. resulted in a fire return interval of approximately 80 years for the lake's drainage basin. Terasmae and Weeks (1979) examined the extent of charcoal abundance and frequency of occurrence at Found Lake (45°31'N, 78°31'W; L.4b) in the southwestern portion of the park, and at Perch Lake (46°02'N, 72°21'W; L.4c) and Boulter Lake (46°09'N, 79°02'W; L.4b) east and northwest of the park, respectively. An additional site, Lac Louis (47°15'N, 79°07'W), approximately 16 miles (26 km) east of the Ontario/Quebec border and within section B.8, was also sampled. The Found Lake sediment revealed a sparseness of charcoal whereas the limited core sample from Boulter Lake exhibited both a high frequency and an abundance of charcoal. For Perch Lake, the fire frequency was judged to be 140-150 years. The mean fire frequency in the Lac Louis area was calculated to be 95-100 years for the past 9,000 years but increased to 48-56 years approximately 4,000-7,000 years ago. In support of this work (1976) developed a slide preparation technique for determining the presence of charcoal particles that could be used for continuous sampling of lake sediment cores. All the data reported in Terasmae and Weeks (1979) can be found in Weeks' (1976) undergraduate thesis.

Site selection remains a major consideration in charcoal stratigraphy studies. Meromictic lakes (overturning does not extend to the bottom) are preferred sample locations, but they are exceedingly rare. The Experimental Lakes Area in northwestern Ontario (49°30'-45'N, 93°30'-94°00'W) is known to contain a number of meromictic lakes (Schindler 1971). Schindler[10] has indicated that probably less than one percent of the lakes on the Canadian Precambrian Shield are meromicitc in nature. The exact mechanisms of charcoal dispersal from source to deposition in lakes requires further investigation.

CONCLUSIONS AND RESEARCH NEEDS

Area burned maps on a provincewide scale have been prepared from fire report information for the period since approximately 1920. Fire cycles for the recent past, based on percent annual burn, have been calculated. Written accounts are a potentially useful data source on fire incidence between *ca.* 1700 and 1920. Tree-ring and fire scar dating has been widely used. Reconstructing fire patterns for presettlement times is limited to a few study areas. The mosaic of even-aged forest stands in northern Ontario lends itself well to mathematical deduction and modelling of natural fire cycles. Extension of fire history back to the end of pleistocene glaciation has been at least partially successful but is confined to a small number of concentrated sites.

A question that must be addressed here is: "How much do we need to know about the historical role of fire?" Management concerns and contributions to ecological knowledge must be considered jointly. Fire history information may also have site specific and area specific uses, e.g., for fuel complex assessment, ecological surveys and investigations, insect and disease susceptibility, wildlife habitat evaluation, research study area

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[10]Schindler, D.W. 1980. Personal conversation. Department of Fisheries and Ocenas, Western Region, Freshwater Institute, Winnipeg, Man.

description, and natural history interpretation. Man has so greatly altered the natural fire regimes of southern Ontario that elucidation would be virtually impossible if not academic in many areas. From a fire and land management perspective, the needs in northern Ontario are great and the information currently available is limited. The complexity of the area coupled with its vastness dictates the neef for a comprehensive study of a single forest section initially. The following research needs represent a compromise between these two interest groups. They should be the focus of a forest fire history research program in Ontario over a 2-to-5-year period. In selecting these research needs I have considered the likelihood of problem solution, the applicability of research results, available resources, and financial limitations.

1. The written accounts of fire history should be systematically assembled and catalogued, carefully synthesized, and made readily available in the form of a single published compendium or a series of publications. Cooperation with historical geographers would be beneficial.

2. A handbook similar to Arno and Sneck's (1977) should be developed for forest situations found in the boreal and Great Lakes-St. Lawrence regions of Ontario. It should be based on previous local experience and written to cover the perceived uses of fire history information.

3. The Northern Coniferous forest section (B.22a) is a likely candidate area for an integrated study of fire hisotry. It is largely unmodified by logging and fire protection although expansion of these activities is imminent. Fire periodicity is extraordinarily high and so it should serve as a reference by which to gauge the fire regimes of other forest sections. Such a study should involve an integrated team of scientists and consist of random age-class/fire scar sampling, stand origin mapping at representative locations, and charcoal/pollen analysis of selected lakes and bogs. Forest section B.22a is sufficiently large for the application and further testing of Van Wagner's (1978) NX model. Charcoal fragments are known to be rather abundant in postglacial lake and peat sediments in the area.[11]

4. The relationship between past climatic characteristics and fire history utilizing dendroclimatological techniques needs further investigation but such work should await the results of the pilot effort in Pukaskwa National Park. If red pine tree rings are indeed a sufficiently sensitive barometer of climatic fluctuations then a network of sample sites would be necessary. A number of small red pine stands are found across northern Ontario (Haddow 1948); the northernmost stand is located at Nungesser Lake.

[11]Terasmae, J. 1978. Personal correspondence. Department of Geological Sciences, Brock University, St. Catharines, Ont.

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