

THE HISTORICAL INTERACTION OF FIRE, LOGGING AND PINE:
A CASE STUDY AT CHALK RIVER, ONTARIO

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Abstract

This report describes a study of the history and present composition of two adjacent pine stands near Chalk River, Ontario. One is a three-aged jack pine (Pinus banksiana Lamb.) stand, the other a red pine (Pinus resinosa Ait.) stand with scattered white pine (Pinus strobus L.). The soil is a fine lacustrine sand.

The area was logged several times between 1837 and 1897 for both square timber and sawlogs. There were also numerous fires, including dated ones in 1914, 1882, and 1864 as well as several undated ones extending back about 300 years. The average fire interval over this time was about 37 years.

The logging and fire history has resulted in variable stocking and good growth of jack pine trees, and excellent stocking and good growth of red pine trees. The tree regeneration beneath the canopy is almost entirely white pine, most of it growing well. This suggests that in this particular habitat, white pine does not require fire for its perpetuation, and would, in the absence of fire, eventually dominate the area. The results have implications for the management of the three pines on similar sites.

Résumé

Ce rapport décrit une étude de l'histoire et de la composition actuelle de deux peuplements de Pins adjacents situés près de Chalk River, Ontario. Il s'agit d'un peuplement de Pin gris (Pinus banksiana Lamb.) à trois âges et d'un second peuplement de Pin rouge (Pinus resinosa Ait.) contenant quelques Pins blancs (Pinus strobus L.). Le sol est formé de sable fin lacustre.

La région fut exploitée plusieurs fois entre 1837 et 1897, tant pour en tirer du bois équarri que des grumes. De nombreux incendies ont eu lieu dont la dite région, y compris ceux de 1914, 1882 et 1864 et plusieurs autres non datés, remontant à 300 ans dans le passé. L'intervalle moyen au cours de cette période fut d'environ 37 ans.

Les antécédents donnèrent généralement un matériel sur pied d'une excellente qualité et une bonne croissance des Pins rouge et gris. La régénération compte presque entièrement des Pins blancs, dont la plupart sont de bonne venue. Cela porte à croire qu'en cette station particulière, le Pin blanc n'exige pas de feu pour se perpétuer et, qu'en l'absence d'incendies, il finirait par dominer la région. Il en résulte certaines implications sur la gestion des trois essences de Pin en des stations semblables.

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INTRODUCTION

With increasing acceptance of the concept of fire management on forest lands, there is need for a greater understanding and predictive ability on the part of forest land managers about the interaction of fire, logging, and forest vegetation, and its consequences in terms of forest development. One approach is to reconstruct forest history through a detailed study of live and dead plant material, and micro-topography within a forest (Henry and Swan 1974).

This paper describes one such historical study carried out to examine the interaction between fire, logging, topography, and the three pine species, jack pine (Pinus banksiana Lamb.), red pine (Pinus resinosa Ait.), and white pine (Pinus strobus L.).

THE STUDY AREA

The study area is located on the Petawawa Forest Experiment Station, Chalk River, Ontario (46°00' N lat., 77°26'W long.), within the Middle Ottawa Section (L4c) of the Great Lakes-St. Lawrence Forest Region (Rowe 1972). The climate is continental with a mean annual temperature of 4.2°C, and a mean annual precipitation of 78.8 cm of which 55.0 cm falls as rain.

The fire season runs essentially from mid-April to early November, and can be roughly characterized by stating that the maximum Initial Spread Index (ISI), Buildup Index (BUI), and Fire Weather Index of the Canadian Forest Fire Weather Index (Anon 1976) have been 21, 125, and 42 respectively since 1959, and that the maximum Monthly Severity Rating (Van Wagner 1970) for the same period has been 7.27. The FWI has exceeded the extreme value of 25 on seventy occasions since 1959.

The particular site was selected for four reasons: (1) it contained red pine, white pine, and jack pine in the same habitat type, (2) there was both living and dead fire scar evidence, (3) a well documented fire occurred in 1964, and (4) the area was included in several timber licences between 1839 and 1897.

APPROACH AND MEHTODS

A preliminary examination of the area indicated an essentially uniform habitat, part of which was occupied by single-aged red pine and white pine, and part of which was occupied by three-aged jack pine. Of primary interest was the interaction of forest development, fire, and topography, within a habitat type where all three pines were present. In other words, the basic consideration would be the habitat type, not the cover type. It was decided therefore that an informative and productive approach would be to sample intensively along a continuous strip that included all three pine species and all three age classes, and that was oriented perpendicular to the topography. The influence of topography and history on the variation in cover type possible within this single habitat type could then be clarified.

Three parallel levelling lines were run twenty metres apart in a north-south direction, perpendicular to the sand dune orientation, and through the red pine and jack pine stands. On the centre levelling line a 10m x 200m strip was established and divided into ten 10m x 20m sectors for sampling purposes.

Within each sector all trees were numbered, mapped, aged, and their fire scar location noted, and the species, height and diameter at breast height of all trees and saplings recorded. On the basis of this information a number of trees were selected for felling to obtain more accurate information on tree ages and fire dates. Lesser vegetation was sampled on a presence-absence basis on six one-metre square plots per sector, while tree regeneration was counted and aged on a one-metre wide strip down the east side of each sector.

Soil pits were dug in each of the even-numbered sectors, the profiles described, and soil texture and pH determined.

In order to broaden and strengthen the historical input, data of three other kinds was obtained: (i) charred snags from outside but within three hundred metres of the study strip were examined for evidence of earlier fires, (ii) historical records of the Survey Records Office, the Timber Sales Branch of the Ontario Ministry of Natural Resources and the Ontario Archives were examined, and other historical sources consulted to obtain some idea of the forest cover of the study area, and the influences to which it might have been subjected within historical times.

RESULTS AND DISCUSSION

The Present Site and Vegetation

The sample strip crossed four dunes (see Fig. 1) with a maximum elevational difference of 5.8 metres, and a maximum slope of 20 percent. The soil was classified as an Orthic Humic-Ferro Podzol (Anon 1974) composed of a deep, fine lacustrine sand with a maximum silt plus clay content of 18.4 percent, a pH range of 3.9 to 6.2 with increasing depth, and with a surface organic cover of 2 to 5cm. No discernible horizontal trend was apparent in terms of texture, pH, or moisture content, all significant differences in these parameters being associated with the vertical profiles and topographic features.

A total of thirty-six species of vascular plants was noted on the sample strip, of which six were tree species, and the remainder shrubs, herbs, grasses, and sedges. The subordinate vegetation was dominated by the ericaceous shrubs black huckleberry (Gaylussacia baccata (Wang.) K. Koch), low-bush blueberry (Vaccinium angustifolium Ait.), and sour-top blueberry (Vaccinium myrtilloides Michx.). Other species of major importance in terms of frequency (Table 1) were winter-green (Gaultheria procumbens L.), sedge (Carex spp.), and bracken fern (Pteridium aquilinum (L.) Kuhn), all characteristic species of relatively dry pine sites.

The tree stratum was composed of four major species, namely jack pine, red pine, white pine, and largetooth aspen (Populus grandidentata Michx.), and four age classes of 20-40, 60, 90, and 110 years. The youngest age class was composed exclusively of white pine regeneration, a few stems of which exceeded 9.5cm at breast height and thus become included in the tree stratum. Jack pine was represented by all three older age classes, aspen by the 60-year-old age class, and red and white pine by the 90-year-old age class.

Since white pine is regenerating successfully and will eventually dominate the habitat in the absence of fire, and since the dominant understory species is black huckleberry, the area was designated as a Pinus strobus - Gaylussacia baccata habitat type.

Stocking, based on the normal yield tables for Ontario (Plonski 1974), varied from 31 percent in sector #3 to 111 percent in sector #8 (Table 2). This is not a random variation however, but a function of age class and topography or aspect. Stocking is positively correlated with the 90-year-old age class ($r = 0.83$), and negatively correlated with the 60-year-old class ($r = 0.80$), while the sectors with the highest basal areas and proportion of the 90-year-old age class were on south-facing slopes (Fig. 1).

The interface between jack pine and red pine is abrupt (Fig. 1), the former species being confined to the first seven sectors and the latter species to sectors #6, 8, 9, and 10 (Table 3). Thus sector #6 was the only sector in which the two species occurred together, and this was due only to a single red pine tree. Given the similar requirements of the two species for seedbed and light conditions, this somewhat abrupt discontinuity in cover type may be either simply an expression of limited seed dispersal, a consequence of relative growth rates and competitive exclusion, or the influence on or response to fire of the two species. From the available evidence however it is not possible to determine the responsible mechanism.

Regeneration on the other hand, which was dominated by white pine with 87 percent of the 6,200 stems per hectare, showed no correlated discontinuity with the overstory, being equally prevalent beneath both red pine and jack pine (Fig. 2). However it was not evenly distributed throughout the strip, but decreased in both directions from sector #9, which had a total of forty stems, or twenty thousand stems per hectare (Fig. 3). This was explained quite simply by the fact that the only mature, cone-bearing white pine tree on the strip was found in sector #9.

White pine regeneration has been establishing successfully since 1939, with peak years of establishment occurring in 1958 and 1965, probably as a result of good seed production combined with favourable weather in these years. From the shape of the frequency curve (Fig. 4), the height and vigour of the stems (Fig. 2), the greatly increased competition afforded by the regeneration itself, and the fact that it was established during the optimum seed production period for white pine (Anon 1948), it is felt that the regeneration forms a single, relatively stable population, and not one that is being continually replaced through attrition at one end and addition at the other. This being the case, establishment of the successional stand has taken place over the thirty-five year period between approximately the fifty-fifth and ninetieth years of the parent trees, but 35 percent of the total became established in the two years of 1958 and 1965, and 94 percent over the twenty-two year span between 1951 and 1973.

The Written Historical Record

In a map drawn by Hawkins (1837) red pine is shown on the sandy plains south and west of Chalk Bay and only three miles from the study site, while Bell (1847), Hamilton (1857), and Lyons (1855) all noted the presence of red and white pine north of the Chalk River and close to the study site.

The importance of red and white pine on the area is supported by the fact that it was under license in the years 1839, 1860-1880, and 1893-1897. In 1907 the land was expropriated by the Dominion Government for the Petawawa Military Reserve, thereby putting an end to any further exploitation of the forest. The precise extent of the logging carried out under the licences is unknown, but certainly only red and white pine were taken (Lambert 1967, Saunders 1963), and of these only the largest trees since a regulation stated that timber must square eight inches (Anon 1957), while the practice in the Ottawa Valley was that only timber that squared at least twelve inches was taken. Furthermore trees with any crook or significant sweep were ignored, so it can be presumed that sufficient red and white pine were left to constitute a quantitatively adequate seed source. However towards the end of the century the sawn timber market became a dominant force and many stands were logged over for the second and third times, removing material left behind by the highly selective practices of the square timber trade. On the area included in the future Petawawa Military Reserve this did not occur until the timber sales of 1887, which resulted in removal of all the accessible red and white pine (Anon 1952).

The lumbering industry was closely followed by settlement, first as a support system to the industry and subsequently in its own right. This activity was stimulated by the Public Lands Act of 1853 which set up a Colonisation Fund for colonisation roads and land grants in the Ottawa-Huron Tract (Lambert 1967). Although the study site itself was never settled, adjacent areas were. The Pembroke to Mattawa colonisation road built between 1867 and 1876 passed within one-half mile to the west (Anon 1963), and was closely followed by the construction of the Pembroke to Callander section of the Canada Central Railway (sold to CPR in 1881) between 1876 and 1882, which also passed within one-half mile of the study site. Thus the area was subjected to increasing and fairly intensive human activity from the 1830's down to the present.

One might expect that forest fires would be associated with this human activity and in fact this was the case. However the first record of fire in the region dates back from 1616 when Champlain made his second voyage up the Ottawa River, and used the word "brulé" several times in his notes (Anon 1952). It is unknown whether the source of ignition during this period before European exploitation and settlement was due to lightning alone, or whether the indigenous peoples such as the Algonquins were also responsible, such as was the case in the New England States (Bromley 1935, Day 1953).

The Ottawa Valley region has recorded major fires in 1833, 1851, 1868, 1870-71, and 1875 (Cwynar 1975, Lambert 1967, Whitton 1974), while a study of fire history in Barron Township, Algonquin Park, only thirty-five kilometres west of the study site, has dated fires back to 1696 (Cwynar 1975). On the Petawawa Military Reserve in particular, a detailed study by Crealock in 1938 (Bickerstaff 1942) reported that the area had been burned over repeatedly since at least 1647, with dated fires occurring in 1716, 1748, 1832, 1862, and 1875. It has been stated further that six major fires occurred on the area between 1860 and 1919 (Anon 1952), while a more recent study found fire scar evidence for fires in 1854, 1871, 1892, 1927, and 1936 (Brace 1972).

The historical record therefore is one of considerable disturbance associated with lumbering, road construction, railway construction and fire.

The Forest Record

The presence of three age classes on the study site is explained by the occurrence of three fires, evidence for which is contained in the basal fire scars present on the two oldest age classes (Figs. 5 and 6). These fire scars date the two most recent fires at 1914 and 1882, while the date of origin of the oldest age class of jack pine can be set at 1864, which has been recorded as a major fire year in Colorado (Clements 1910), Minnesota (Frissel 1973, Heinzelman 1973, Spurr 1954, Swain 1973, Verrall 1938), Manitoba (Heinzelman 1973) and Algonquin Park, Ontario (Cwynar 1975).

Any attempt to describe a fire in terms of behaviour and intensity from a limited areal study must be approached with caution, since these characteristics can be highly variable for any particular fire over time and space. Little can be said about the 1864 fire from the ground evidence, which is very limited. However as pointed out above, this was a major fire year of subcontinental drought, and it was also a year following very heavy lumbering activity (Whitton 1974), with its accumulation of logging debris providing abundant and concentrated fuel patterns.

The 1882 fire, which came out of the southwest based on fire scar evidence, resulted in a combination of generally excellent red pine regeneration, highly local survival of 17-year-old jack pine, and excellent regeneration of jack pine on north-facing slopes, indicating a fire of highly variable, low to moderate intensity.

One problem associated with this fire is that the only sign of parent red pine was a number of charred snags, mostly around 30cm in height but a few attaining 3m or so, varying in basal diameter from 7.5 to 26.4cm, and varying in age (on the basis of remaining rings) from 52 to 176 years. Since red pine requires a living seed source, and since a fire of such moderate intensity as described above will not kill mature red pine, then some living parent trees should be present given the longevity of the species, or at least some sign of the fallen stems beneath the duff if the trees had died subsequent to the 1882 fire. However natural death is also precluded since the snags were generally sound and no evidence of fallen stems could be found. The only remaining conclusion therefore is that the parent red pine were logged out some time after the 1882 fire, possibly in the period 1893-97 while the area was under license. The stumps would then have become charred in the 1914 fire.

The bulk of the 30-year-old red pine survived the 1914 fire regardless of location, while jack pine survived only on north-facing slopes since the wind was once again from the southwest with an average direction of S 22°W. Furthermore, while the red pine remained sound and generally unaffected by the scarring, even though over 50 percent of the cambium was killed, the jack pine became infected and developed butt rot, demonstrating the greater resistance to fire and disease of the former species, probably as a result of the sealing action of resin (Verrall 1938), a response mechanism that jack pine appears to lack.

Jack pine regeneration after the 1914 fire was generally poor. On the north-facing slopes this was due to insufficient removal of forest cover, while on the south-facing slopes it was probably due to a combination of insolation exposure and insufficient removal of duff. In the area north and west of the study strip however, where the topography was more level, little survival of the 1882 trees occurred and regeneration was generally excellent indicating a fire of moderate to high intensity. The high survival rate of the 1882 trees on the strip, and the influence of topography on jack pine survival, indicates a fire of relatively low intensity. The consistent scarring of all trees on the northeast regardless of slope indicates a wind of fairly constant direction and therefore of moderate speed, perhaps in excess of 15km/h. This would suggest a situation of low ground fuel availability but good burning conditions such as occurs in the early spring.

In 1964 a fourth fire passed within 50 metres of the study strip, and it was only prevented from reburning by an existing bush road and fire control efforts. This was an early spring crown fire that attained a frontal intensity of approximately 18000 kW/m (Van Wagner 1965), and resulted in excellent regeneration of up to 50 thousand jack pine seedlings per hectare.

On the basis of living evidence and including the fire of 1964, it can be said that in the one hundred year span between 1864 and 1964, four fires occurred with intervals of 18, 32, and 50 years, yielding an average interval of 33 years.

Examination of ten charred snags resulted in the identification of a number of fire scars, but the evidence was somewhat complex and confusing since none of the snags was complete, being mostly burned out on the one side where fire scars were to be expected, and having an unknown number of outer rings burned off. The ages, based on remaining rings, ranged from 52 to 176 years, and of the ten snags two had no fire scars, five had one fire scar, two had two fire scars, and one had four fire scars. This yielded a total of thirteen fire intervals with an average length of $23 \frac{1}{2}$ - 1 years, excluding the above 50+ interval.

The oldest snag, which like the others was red pine, was three metres in height, sound, and well charred. The only conclusion therefore is that it was killed by fire and not logged. Since both the 1882 and 1914 fires were of too low an intensity to kill a mature red pine, and since the charring must have resulted from at least one if not two fires, then this snag must have been killed in the 1864 fire, or at least no later. Adding a conservative ten years to the total age for outer ring loss due to burning, the origin of the snag would be placed in 1678. Thus it can be stated that red pine has occupied the site for at least three hundred years, that frequent fire has been a feature of the area for the same period, and that with a minimum of eight fires, the average fire interval over this period was 37 years.

CONCLUSION

The main points of interest concerning the study area and its forest cover are as follows:

1. In this habitat, periodic fire of varying intensity would maintain the present pyric climax of mixed jack, red, and occasional white pine, but the indefinite exclusion of fire would eventually result in the edaphic climax of white pine alone; hence the name Pinus strobus - Gaylussacia baccata habitat type.
2. The fine, well-stocked, even-aged red pine stand on the study area resulted from a combination of selective logging and fire of moderate intensity. Similar well-stocked jack pine stands on relatively level ground near the study site followed fires of constant high intensity that killed the existing stand, while the patchy, multi-aged jack pine on the study area itself resulted from fires of variable low to moderate intensity on uneven topography.
3. In 1914, the thirty-year-old red pine was able to survive fire of variable low to moderate intensity with little loss apart from basal scarring, and the seventeen-year-old jack pine was able to both survive and provide adequate regeneration for a partial new age class. However, the survival of the jack pine was limited and highly localised, and butt rot developed from the scarring; by contrast, the survival of the red pine was general, and the trees remained sound after scarring.
4. The present pyric climax of red pine and jack pine makes optimum use of the habitat and would, under management, provide the highest possible timber yields from it.

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TABLE 1. Percent frequency of subordinate vegetation.

SPECIES	PERCENT FREQUENCY
<i>Gaultheria procumbens</i> L.	78.2
<i>Carex</i> spp. L.	73.3
<i>Pteridium aquilinum</i> (L.) Kuhn	66.7
<i>Gaylussacia baccata</i> (Wang.) K. Koch	58.3
<i>Maianthemum canadense</i> Desf.	56.7
<i>Vaccinium angustifolium</i> Ait.	48.3
<i>Vaccinium myrtilloides</i> Michx.	48.3
<i>Oryzopsis asperifolia</i> Michx.	36.7
<i>Linnaea borealis</i> L.	18.3
<i>Lycopodium complanatum</i> L.	15.0
<i>Kalmia angustifolia</i> L.	13.3
<i>Lysimachia terrestris</i> (L.) BSP.	8.3
<i>Chimaphila umbellata</i> (L.) Bart.	8.3
<i>Epigaea repens</i> L.	6.7
<i>Amelanchier</i> spp. Medic.	6.7
<i>Comptonia peregrina</i> (L.) Coult.	6.7
<i>Corylus cornuta</i> Marsh.	6.7
<i>Polygala paucifolia</i> Willd.	6.7
<i>Acer rubrum</i> L.	6.7
<i>Melampyrum lineare</i> Desr.	5.0
<i>Apocynum androsaemifolium</i> L.	5.0
<i>Cypripedium acaule</i> Ait.	3.3
<i>Prunus pumila</i> L.	3.3
<i>Pyrola rotundifolia</i> L.	3.3
<i>Rubus allegheniensis</i> Porter	3.3
<i>Arctostaphylos Uva-ursi</i> (L.) Spreng.	3.3
<i>Chamaedaphne calyculata</i> (L.) Moench	1.7
<i>Cornus canadensis</i> L.	1.7
<i>Diervilla lonicera</i> Mill.	1.7
<i>Goodyera repens</i> (L.) R. Br.	1.7
<i>Trientalis borealis</i> Raf.	1.7

TABLE 2.-- Characteristics of the tree stratum by sectors

Sector		Age Class Distribution by Stems %			Basal Area m ² /h	Percent Stocking
No.	Number of Stems/Hect.	60 years	90 years	110 years		
1	550	100	-	-	15.4	61
2	350	90	-	10	12.1	47
3	350	72	14	14	7.9	31
4	500	8	84	8	25.0	99
5	300	-	75	25	16.5	65
6	500	7	93	-	23.1	91
7	350	100	-	-	14.7	58
8	650	13	87	-	48.8	111
9	500	10	90	-	41.4	94
10	500	45	55	-	30.9	70

TABLE 3.-- Number of stems per hectare and basal area of major tree species in tree stratum by species and by sector.

Sector No.	Jack Pine		Red Pine		White Pine		Aspen	
	Stems/ Hect.	BA m ² /h	Stems/ Hect.	BA m ² /h	Stems/ Hect.	BA m ² /h	Stems/ Hect.	BA m ² /h
1	550	15.4	-	-	-	-	-	-
2	350	12.0	-	-	-	-	-	-
3	250	7.1	-	-	50	0.5	-	-
4	400	23.8	-	-	100	1.2	-	-
5	300	16.1	-	-	-	-	-	-
6	400	19.8	100	3.4	-	-	-	-
7	300	14.1	-	-	50	0.6	-	-
8	-	-	650	48.8	-	-	-	-
9	-	-	400	36.8	50	4.3	50	0.4
10	-	-	250	24.4	-	-	250	6.5

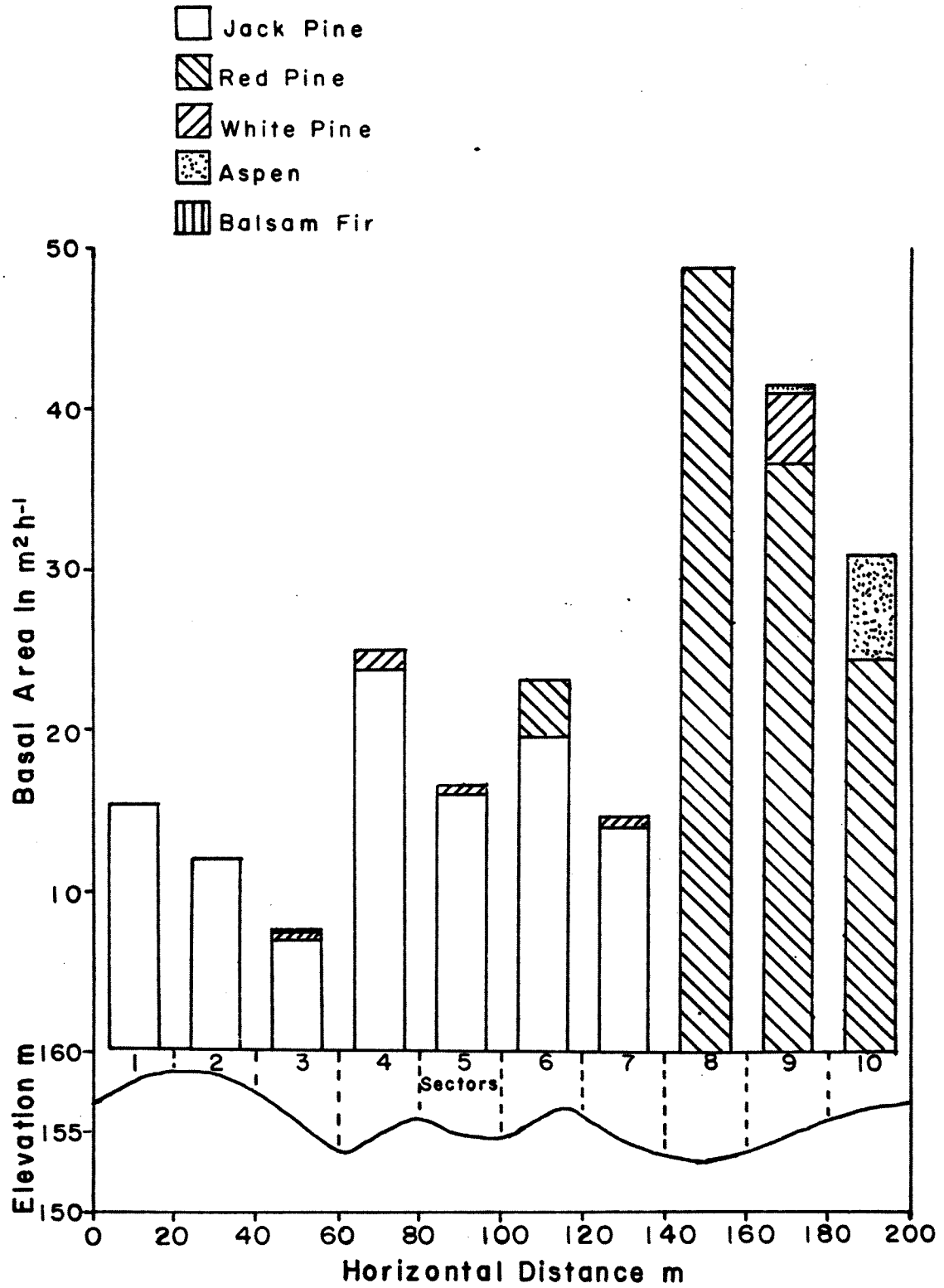


Figure 1. Basal area of tree stratum by species, over topographic profile.



Figure 2. View of understory showing white pine regeneration beneath jack pine (sector #7) and red pine (sector #9).

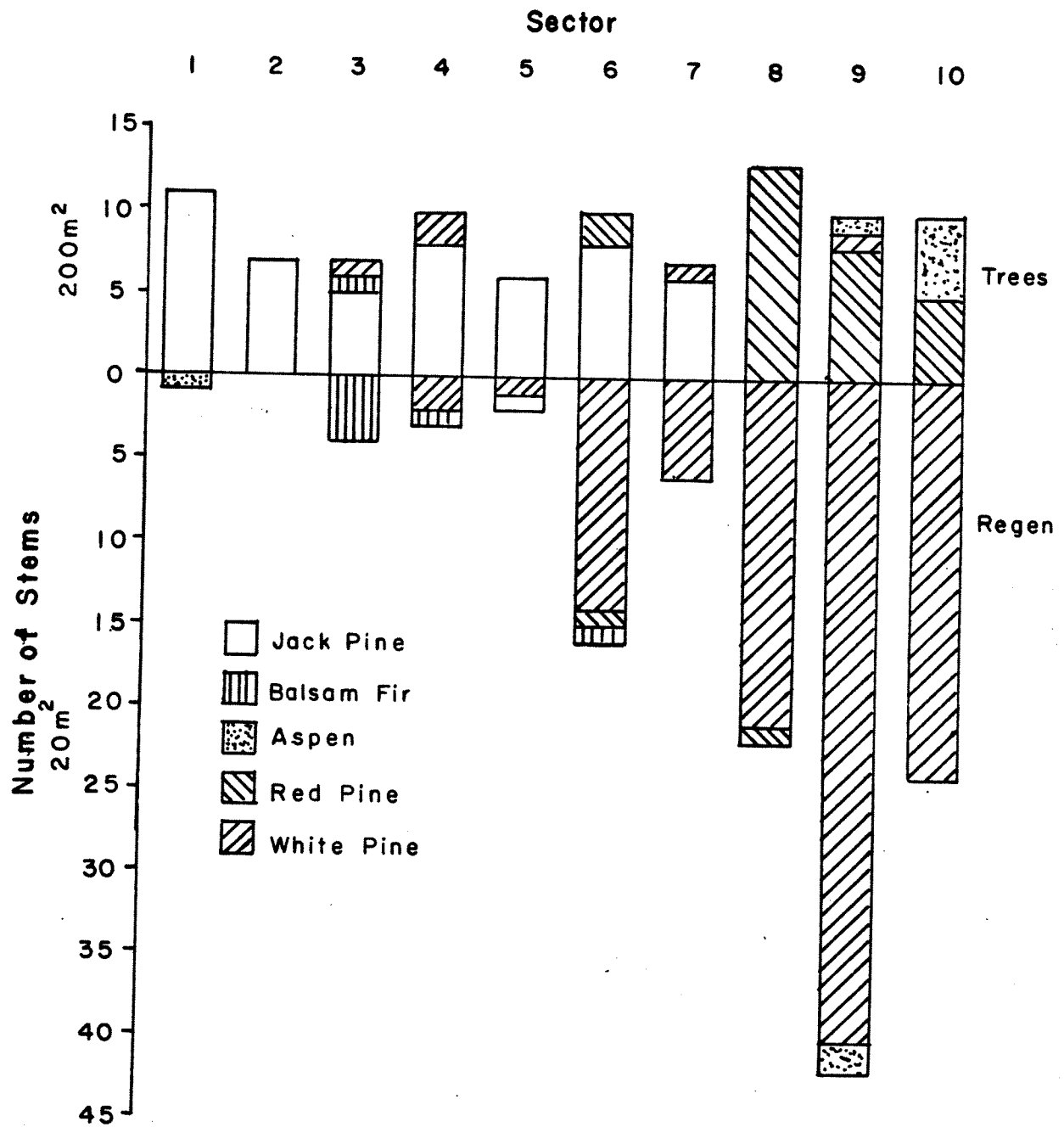


Figure 3. Bar graph of tree and regeneration stem number by species and by sector. Tree number based on full 200m² sector, regeneration number based on 20m² strip per sector.

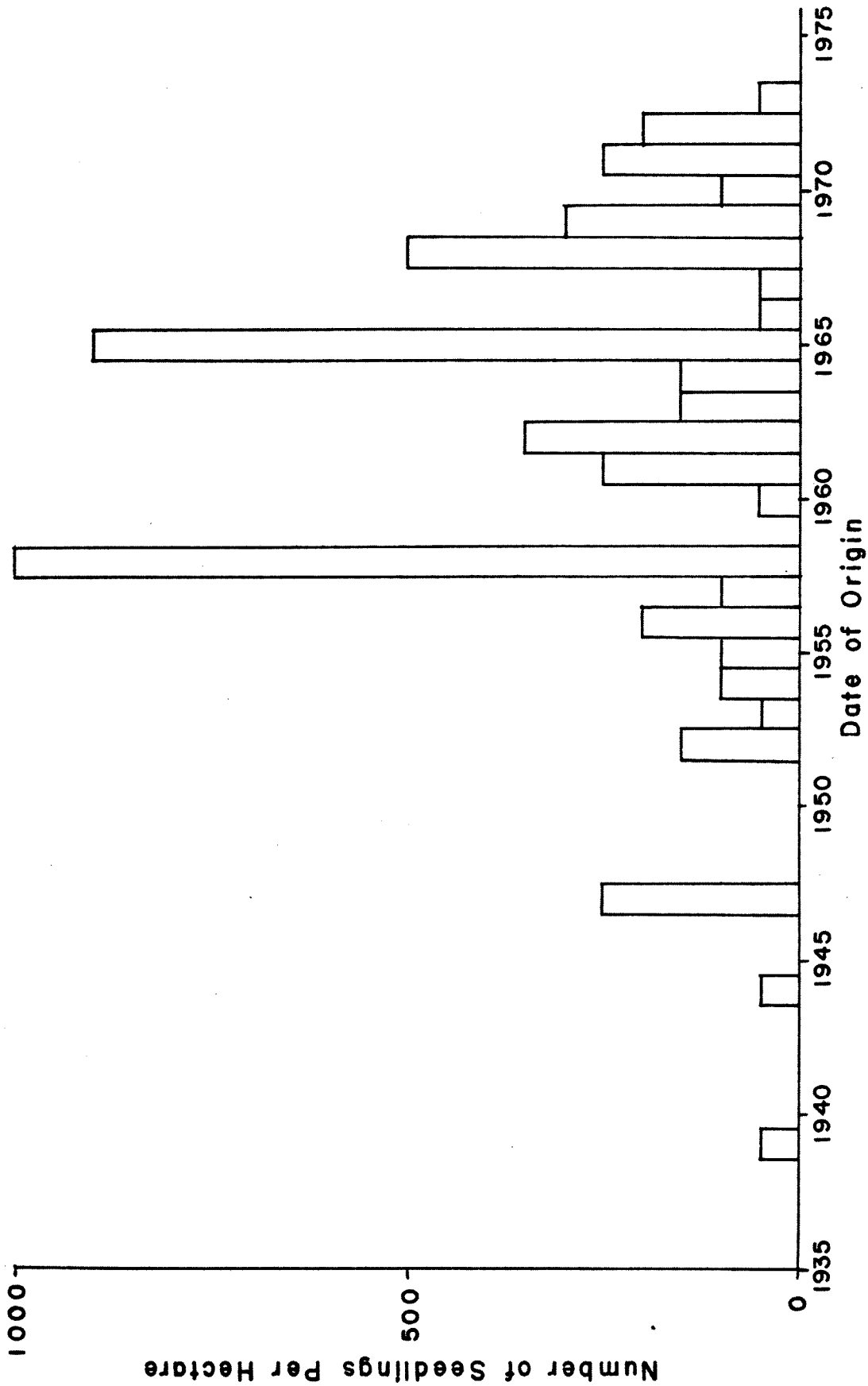


Figure 4. Distribution of date of origin of white pine regeneration. Parent trees became established in the decade after the 1882 fire.



Figure 5. Standing stem and basal disc of 110-year-old jack pine showing a double fire scar dating fires in 1882 and 1914.

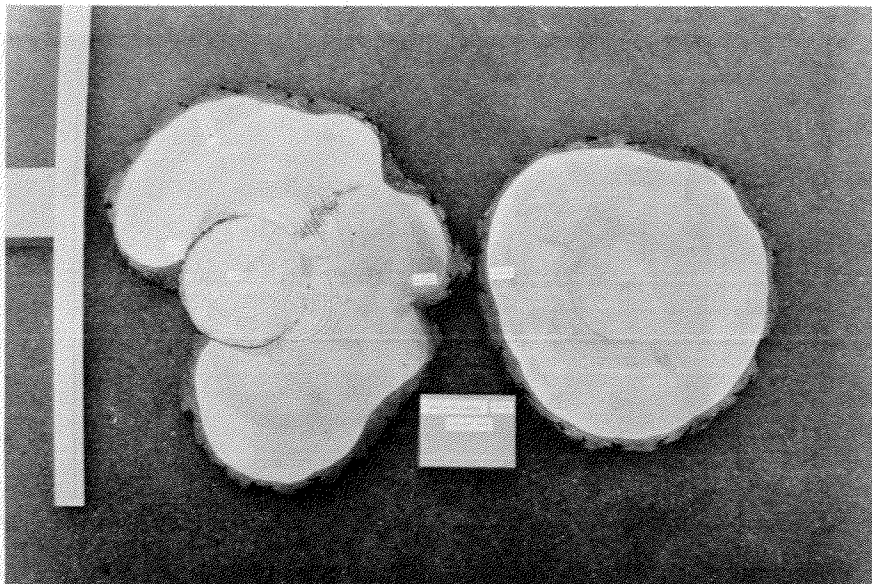


Figure 6. Standing stem and discs from 87-year-old red pine tree showing fire scar from 1914 fire.