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Historic Disturbance Regimes and Natural Variability of Grand Portage National Monument Forest Ecosystems

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Grand Portage National Monument

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Introduction

Grand Portage National Monument (GRPO) is located in extreme northeastern Minnesota adjacent to Lake Superior and near to the Canadian border. The monument is a 9-mile by 600' strip extending from the shoreline of Lake Superior to the Pigeon River at the Fort Charlotte site (Figure 1). GRPO encompasses the portage trail used by fur trappers returning from the interior. Fur trade use of the trail extended from the early 1700s to the early 1800s. Lands of the Grand Portage Band of the Chippewa bound the monument. The Grand Portage Band manages their lands for timber production, cultural values and tourism.

GRPO occurs in the southern part of the boreal forest region of North America, a region that can be considered transitional between true boreal forests to the north and northern hardwood-conifer forests to the south (Vankat 1979). Because National Parks are mandated to manage lands within the appropriate historical context, knowledge of the natural disturbance regimes that prevailed during the fur trade era is vital. Fire (Johnson 1992), catastrophic windthrow (Frelich, 2002, White and Host 2003), and insect outbreaks (Fleming et al. 2000) have been fundamental disturbance factors shaping the composition and age structure of the southern boreal forest. The logging history of the region, coupled with settlement-era fires, fire suppression, and recent changes in land use have altered the species composition, age structure, fuel composition and distribution, natural fire regimes and other characteristics of these forests.

Our primary objectives were to 1) characterize the historic fire regime and how it influenced vegetation composition and structure along the trail during the fur trade era, 2) make inferences on natural variability of vegetation composition and structure along the trail corridor, 3) characterize current vegetation composition and age structure and examine changes in vegetation from the fur trade era to present, 4) make recommendations on future management options and research needs related to management of GRPO forest ecosystems.

Study Area: Climate, Soils, Geomorphology , and Natural Vegetation

GRPO occurs in two subsections of the Minnesota Ecological Classification, the North Shore Highlands, and the easternmost portion of the Border Lakes. The North Shore Highlands is characterized by ground and end moraine of the Superior Lobe, glacial drift is thin and exposed bedrock is common. Climate is modified by the proximity to Lake Superior, with a later start and end to the growing season, and generally cooler, moister conditions. There are two dominant Land Type Associations (LTAs) on GRPO lands. The North Shore Till Plain LTA is typified by rolling topography and predominantly clayey sediments. However, coarse textured soils (sandy loams) occur along the trail corridor. The Border Lakes is defined by scoured bedrock uplands and thin soils over bedrock. The Swamp River Till Plain LTA, composed of thick deposits of loamy till and clayey lake sediments on a nearly level to gently rolling bedrock-controlled landforms are atypical of the shallow to bedrock and coarse textured soils of the Border Lakes Subsection (Hanson 1999).

Grand Portage National Monument and Adjacent Land Type Associations

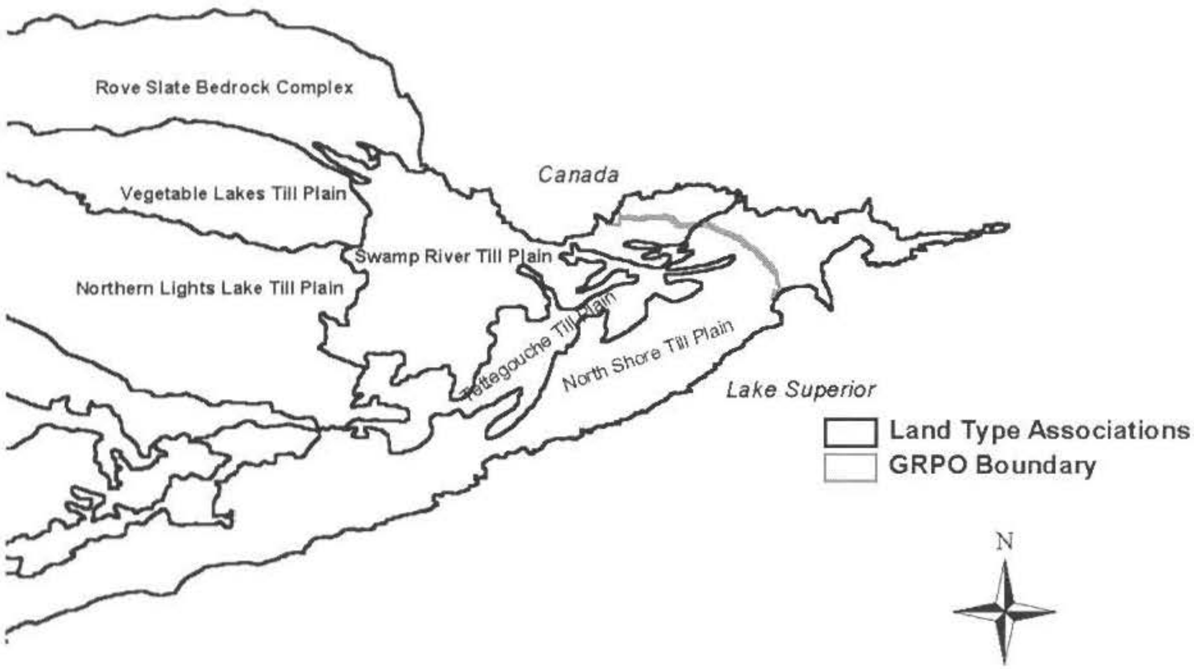


Figure 1. Map of Grant Portage National Monument and surrounding lands.

Interpolated climate data based on 30 year normals indicate that annual growing season (May-September) precipitation averages ~17", while the average for fall, winter and early spring months (Oct.-April) is approximately 11" (Figure 2) (ZedX 1995). Growing season precipitation shows a decrease beginning at the divide west from the boundary of the Swamp River Till Plain and North Shore Till Plain LTAs. Mean maximum temperatures during the growing season vary from 65 F in May and Sept. to 78 F in July. Mean maximum temperature during fall and winter range from 14 F in January to 49 F in April and 53 F in May (Figure. 3).

Presettlement (Marschner 1946, Shadis 2000) and potential natural vegetation classifications (White and Host 2000) for northeastern MN show similar forest ecosystem classes for the GRPO region. Marschner's classification based on GLO bearing trees and land survey records shows two types on the GRPO trail corridor; mixed white and red pine primarily on the Swamp River Till Plain, and aspen-birch-conifer on the North Shore Till Plain (Figure 4). Shadis (2000) classifies the Swamp River Till plain as spruce-fir and the North Shore Till Plain as North Shore Spruce-fir, a variant with relatively long intervals between stand-replacing fire events. White and Host (2000) classify most of the GRPO region as mesic birch-aspen-spruce-fir (Figure 4). This type is the 'matrix forest' for much of the northern landscape, and is broadly defined; it may contain considerable amounts of white pine, and may be dominated by white cedar and white spruce in later successional stages. Current forest cover is dominated by aspen-birch types (64%), fir-spruce types are also important covering 26% of the trail corridor. White pine occurs as scattered individuals and in small groves throughout the trail corridor. Red and jack pine occur infrequently. Upland white cedar dominates some stands in areas west of Cowboys Rd.

Fire History Models, Climate and Fuels in the Boreal Forest

Climate and Weather

Because the study area occurs in the southern part of the boreal forest region of North America, we reviewed models and concepts of fire frequency and behavior in this region.

Weather and climate patterns are the primary factors influencing fire frequency and behavior in the boreal forest region (Johnson 1992). The fire season in the boreal forest begins in the spring with the retreat of the arctic airstream and its replacement by Pacific and North Atlantic airstreams. The much warmer summer air masses lead to fuel drying and conditions favorable for lightning strikes. As the arctic airstream moves south in late summer and fall, ignitions and fire spread decrease. Synoptic weather patterns related to high-pressure ridge formation create conditions that lead to lightning ignition and fire spread. These high-pressure ridges create warm, dry weather that leads to the drying of fuels. These ridges push westerly air flow north or south of the ridge, and allow southerly air to move into the zone controlled by the slow moving or stalled ridge. The breakdown of the ridge into trough often leads to lightning and high winds; this along with the low fuel moisture levels creates high probabilities of ignition and rapid spread

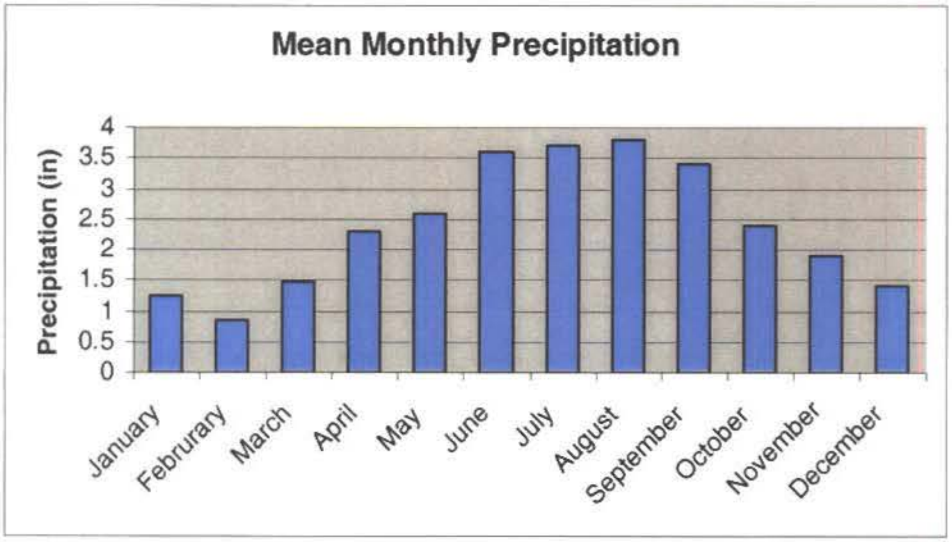


Figure 2. Mean monthly precipitation for Grand Portage National Monument based on 30 year normals (1960-1990). Precipitation values in inches. Data derived from Zedx (1995)

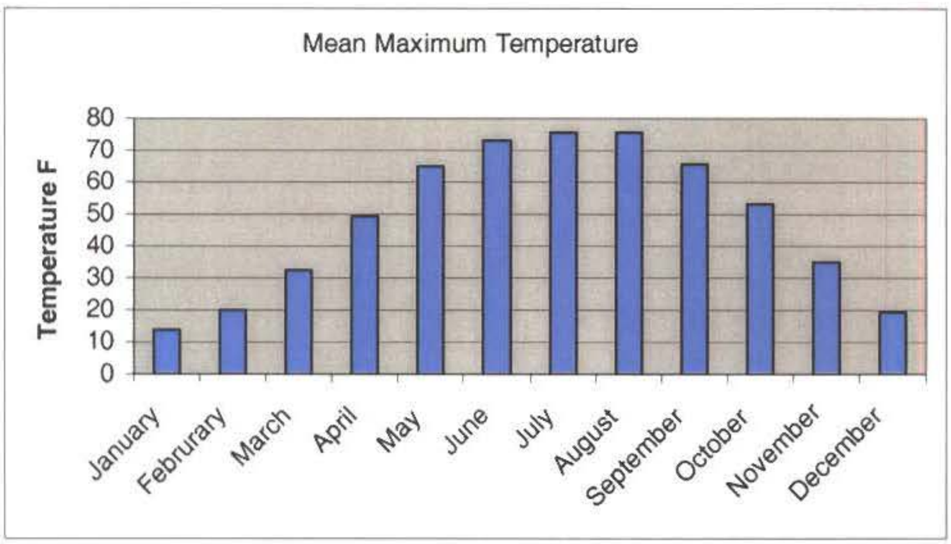
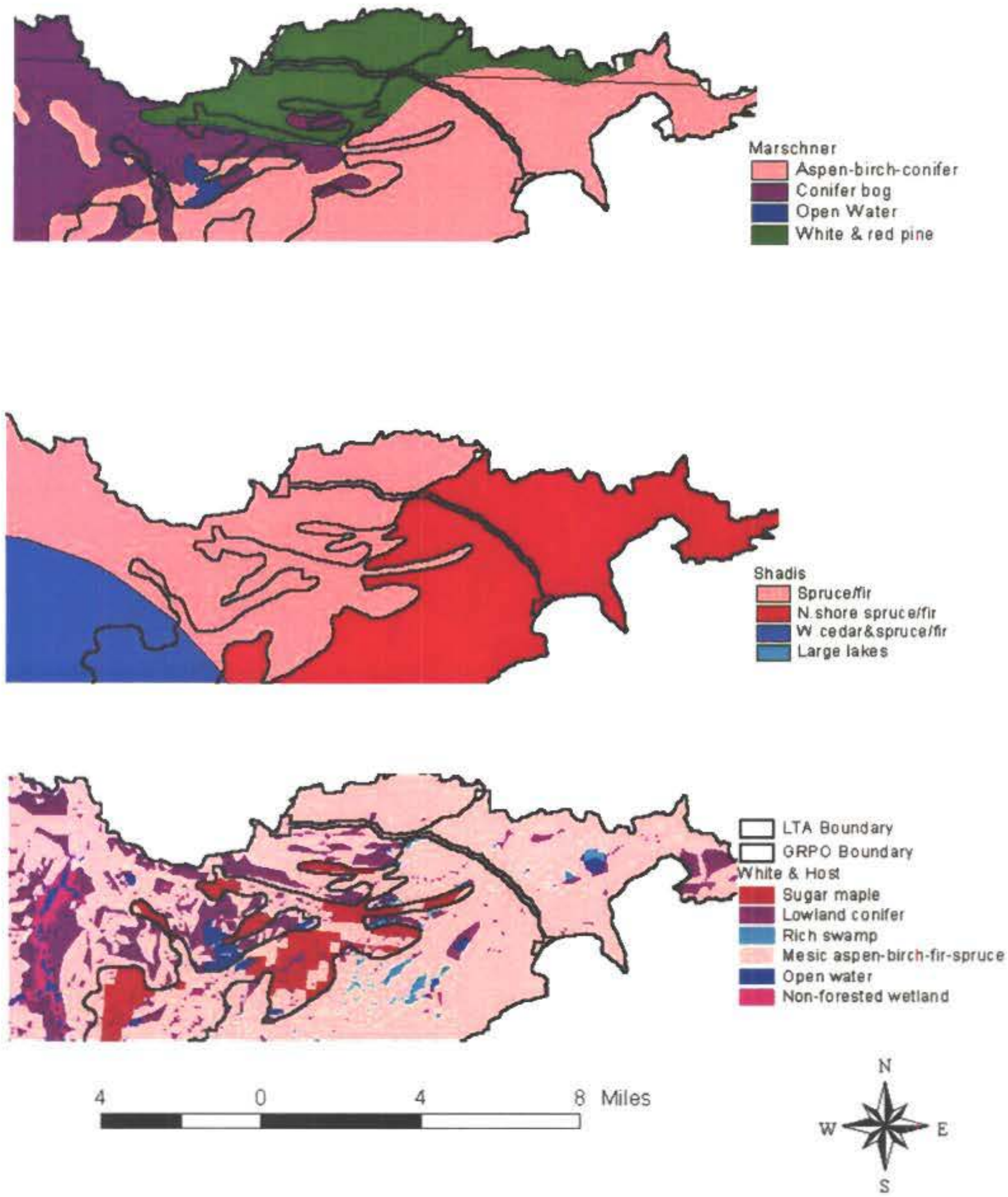


Figure 3 . Mean maximum temperatures for Grand Portage National Monument based on 30 year normals (1960-1990). Temperature values in Farenheit. Data derived from Zedx (1995)

Figure 4. Three native plant community classifications for the Grand Portage National Monument region. A. Marschner (1946), B. D. Shadis (2000), C. potential native plant communities (White and Host (2002).



rates (Johnson 1992). Large, catastrophic fire events in northern Minnesota are thought to be related to these weather patterns (Heinselman 1973).

The frequency of lightning strike ignitions varies substantially across southern Ontario. The area directly across the border into Canada from GRPO shows a lightning strike ignition frequency of 0.2-0.5 per 1000 km^2, while further west, in the area directly adjacent to the Boundary Waters Canoe Area Wilderness (BWCAW), rates are 5 to 20 times higher (Johnson 1992, Stocks and Hartley 1979).

Fire History Models and Fuels

Probability-based fire history models provide a useful, conceptual approach to understanding fire history data. Johnson and Van Wagner (1985) detailed the use of two fire history models, the Weibull and the negative exponential. The Weibull is an age selection model, and indicates that fire probability, or the hazard of burning rate increases with stand age, or time since fire. This has been interpreted as fuel accumulation model, indicating that ignition sources are relatively constant, and ignition and fire spread depends on sufficient fuel. The negative exponential model states that the hazard of burning rate is constant over time, and is not related to time since fire, or fuel accumulation. Studies from the boreal forest suggest that the negative exponential is the best fit for cumulative fire frequency distributions, although there are some relationships to stand age, forest structure and resulting fuel distributions (Johnson 1992). With the negative exponential distribution, mean stand age, or time since fire is equivalent to the rotation period. In boreal forest regions, this value typically ranges from 75-150 years. Crown fire potential peaks when surface fuels (needle litter, graminoids, dead woody material) and tree crowns are close together. As the crown separates from surface fuels, increasing flame length (intensity) is required to ignite crowns. As stands age beyond ~75 years, crown fire potential may decrease.

Methods and Approach

Current Forest Composition and Age Structure

We mapped current forest composition along the trail corridor using 1:15,840 color infrared photographs taken in late September, 1999. The photos were scanned and rectified to a resolution of 1 m. Digitizing was done on-screen over rectified photo images. Photos were also viewed using a Sokhisha stereoscope to aid in classification. Ground truth data was obtained during 2 field visits. Digital forest inventory data from the Grand Portage Band adjacent to the trail corridor was also used to aid in age and cover type determinations. We also used data from increment core samples to estimate stand age. The GRPO forest type polygons were digitized onto the Grand Portage Band Inventory polygons.

Tree Ring Analysis

The rectified aerial photography, in conjunction with forest inventory and topographic data were used to identify candidate areas for field sampling. The goal of this phase was to locate mature to old-growth conifer or mixed hardwood-conifer stands which might supply suitable materials for fire scar and tree ring analysis. Several candidate areas were identified and visited in conjunction with GRPO staff.

Standing large conifers and downed woody material in sample areas were systematically searched for evidence of fire scars. Increment cores were taken at dbh from several trees per area; GPS coordinates and diameters at breast height were recorded for each cored tree. Increment cores were labeled using the GRPO bird survey point numbers and stored in plastic straws. Fieldwork was conducted between October 2001 and May 2002 – additional cores were taking by GRPO staff in June 2002.

Increment cores were mounted in 0.25" grooves carved into a wooden frame and sanded with progressively finer sandpaper up to 400 grain. The mounted cores were then placed on a flatbed scanner, scanned at 800 dpi, and saved as TIFF files. The SigmaScan image analysis system was used to measure and record individual tree ring widths from the outmost ring (representing wood produced in Yr 2002) to the centermost ring. If the centermost ring did not intercept the actual center of the tree, the number of rings to the center was estimated by extrapolating widths of the earliest rings.

Relative ring widths were calculated by scaling each ring to the maximum ring width for that core. Ring width sequences were plotted over time – multiple trees per site were plotted to identify climatic and potentially fire-related changes in tree growth rates.

Tree cross-sections collected by GRPO staff were dried and sanded to 250 grain on a 52" belt sander; tree rings were then counted using a dissecting microscope.

Regional and Local Disturbance Patterns

Few detailed studies of pre-Euro-American fire regimes exist for the mixed forest province of Minnesota. Grand Portage National Monument (GRPO) is located in the North Shore Highlands Subsection in extreme northeastern Minnesota. Although relatively close to the Boundary Waters Canoe Area Wilderness (BWCAW), where detailed fire history data exists, GRPO occurs on different soils and landforms. In addition, climate is strongly influenced by the close proximity to Lake Superior. Because of logging and high severity fires that occurred after 1880, few extant trees dating from the pre-1880 period with datable fire scars exist on GRPO. In light of this limitation, we used dendrochronology along with a variety of historic and current data sources to characterize the 1600-1900 fire regime for GRPO. These include GLO bearing trees and line notes, BWCAW fire history data, regional level disturbance models, and soil, landform, and climate data.

Local and regional disturbance history was assessed from the following sources of information:

1) We utilized GLO Survey line notes transcribed by the Minnesota Institute for Archaeology (2001), and analyses done in the Northern Superior Uplands Ecological section (White 2001, White et al. 2001). Bearing tree and line note information have proven to be very useful in estimating historic vegetation composition, and disturbance frequency and severity (Zhang et al. 2000, White and Mladenoff 1994, White and Huffman 1987, Whitney 1986), and spatial patterns (White and Host 2003).

2) Written accounts derived from newspapers and historical narratives. This anecdotal information can provide useful descriptions of the dates, distribution and effects of fires, and can be used to corroborate other information (White and Huffman 1987).

3) Detailed fire history data from the BWCAW (Heinselman 1973), and fire history summaries from the Quetico region of Ontario, Isle Royale National Park, and the southern boreal forest (Johnson 1992). The BWCAW fire history provides the most detailed record of fire disturbance history in the Northern Lake States. Johnson (1992) summarizes fire regime characteristics for the southern boreal forest.

4) Regional, landscape level natural disturbance models that estimate the natural variability of forest composition and age structure under historic disturbance regimes and serve as reference conditions for comparison with current conditions (Frelich 1999, 2002, White et al. 2001, White 2001). These models are tied to native ecosystem classes that can be mapped and identified on the ground (White and Host 2000).

5) Tree ring analysis of samples along the GRPO trail corridor. Tree ring samples were used to determine stand origin dates. Ring width sequences were used to compare tree growth rates with known disturbance dates. Ring width patterns can provide valuable information on disturbance dates and tree growth response to disturbance and climate (Fule' et al. 2002, Swetnam et al. 1985).

We synthesized this information in light of the soil-climate-vegetation condition at GRPO in order to estimate historic disturbance frequencies, native plant community composition and structure, and changes since Euro-American settlement.

Results and Discussion

Cover Type and Age Class Analyses

The cover types and age classes of the GRPO are very similar to the regional structure of the Mesic birch-aspen-spruce-fir native plant community of the Northern Superior Uplands. This type is characterized by an abundance of aspen in older ages classes (75-100+ years; Figure 5). These stands originated following the large-scale harvest of pine

Figure 5. GRPO land area by age class and forest cover type. Data derived from interpreted aerial photography and Grand Portage Band inventory data.

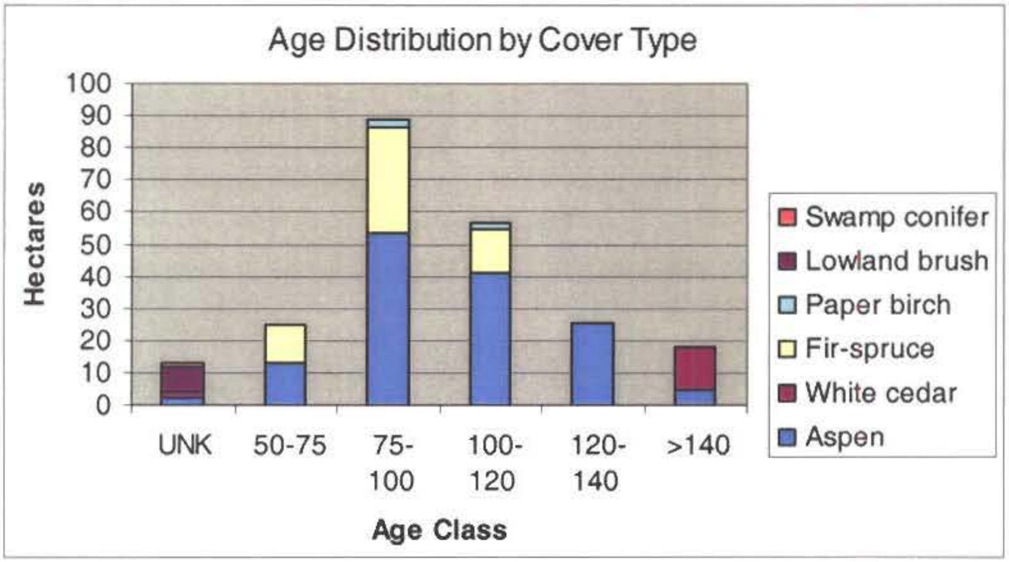
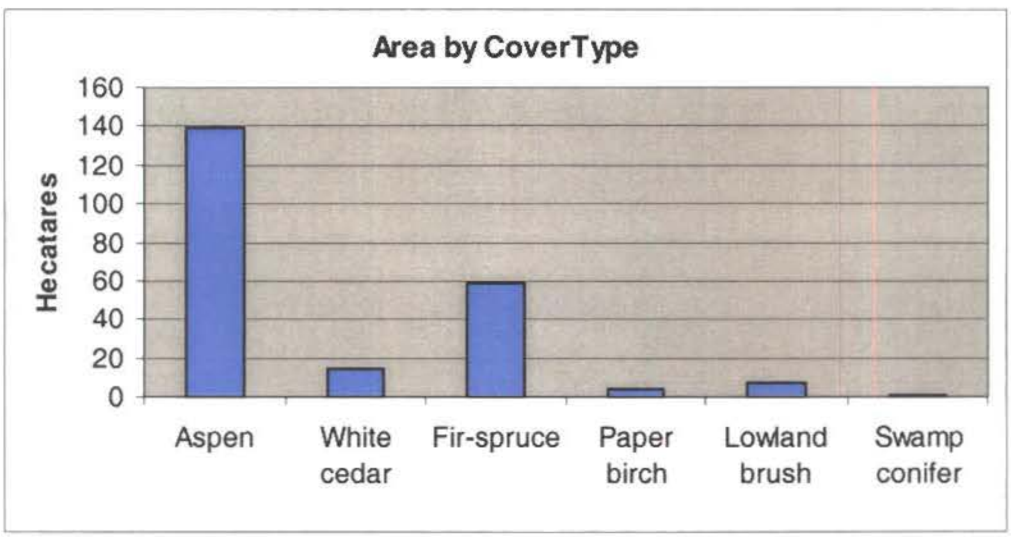


Figure 6. GRPO land area by forest cover type. Data derived from interpreted aerial photography and Grand Portage Band inventory data.



and other conifers that occurred at the turn of the century. Based on an assessment of air photos, field reconnaissance and off-trail cover type maps provided by the Grand Portage Reservation, the aspen type constitutes approximately 140 ha or 62% of the GPRO (Figure 6).

In more mesic habitats, spruce-fir is a dominant type, accounting for 26% (59 ha) of the land area (Figure 6). Most of this (56%) is in the 75-100 year age class, with approximately 22% in the 25-50 and 100-125 year age classes (Figure 5). These systems are common between Cowboys Rd. and Ft. Charlotte, and along the southernmost portion of the trail (Figures 7,8).

In certain protected upland portions of the landscape, white cedar and white pine form a late-successional/old growth community. White cedar in these stands were consistently in the 140 year or older age classes (Figures 9,10). These mature/old growth forests are an indication of relatively infrequent fire, as the thin bark of white cedar makes them highly susceptible to damage by fire (Grigal and Ohmann 1975, Burns and Honkala 1990).

Increment cores and cross sections

Most of the trees cored were white pine, white spruce, or cedar. The distribution of ages shows multiple periods of origin, with peaks in 1919, 1899, and the 1860s (Table 1). Most of these are minimum dates, as the cores of these trees were typically rotted out.

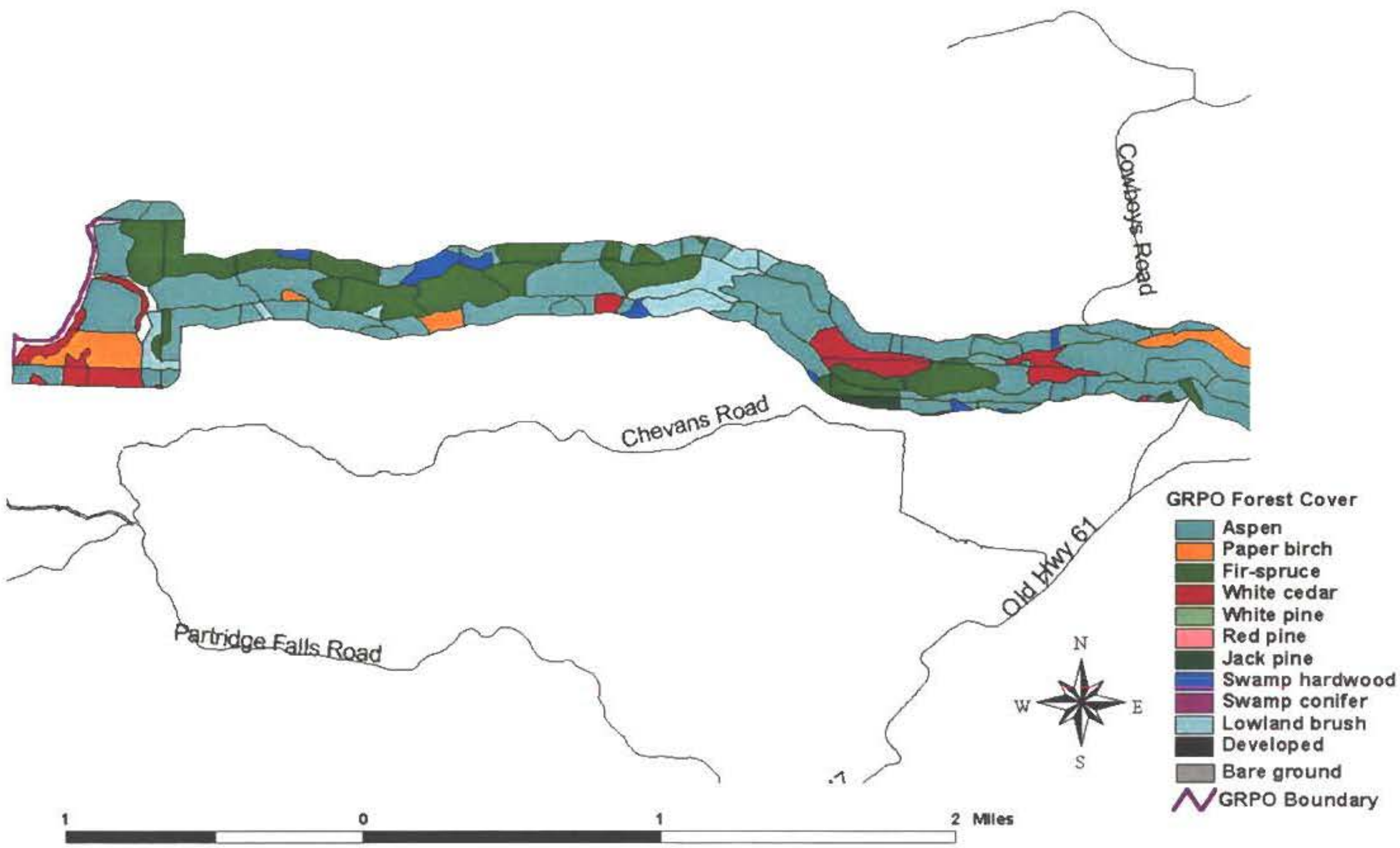
The oldest cored white pine dated to 1812, and two cored cedars dated to 1796 and 1775 (Figure 11). These oldest trees occurred in the center portion of the GRPO Trail, between Bird Points 23 and 26.

Trees in the southern portion of the trail (points 11-21) were relatively young, ranging from 73+ to 120 years old, with somewhat older trees in the Fountains area (Point 19; 95 to 120+ years old).

The grove of white pine at Ft. Charlotte (Point 37) showed a broad range of diameters (24.5 to 36.6 inches) and ages (107+ to 127+), indicating that these were established individually, rather than by a single disturbance event. White cedar at Ft. Charlotte showed a similar pattern. The oldest date over the entire study came from a cross section of a fallen white pine near Ft. Charlotte: this dated to 256+ years at 12 feet above the hollowed portion of the tree, indicating an origin of the early to mid-1700's.

Variations in ring-width patterns of multiple trees are often used to reconstruct climatic or disturbance histories of an area (Fule' et al. 2002). Drought years, for example, are often associated with a decline in growth rates, either in the drought year itself, or in following years. Similarly, climatic trends in terms of increased warm or cold periods often induce changes in photosynthetic capacity and respiration rates, which translate into changes in wood formation rates. Several of the well-known fire years were associated with pronounced changes in growth rates along the GPRO trail. At the Cascade Trail site, for example, the white pines, red pines and cedars all showed a sharp decline in relative

Figure 7. Map of GRPO forest cover types, Ft. Charlotte to Cowboy Rd. Data derived from interpreted aerial photography and Grand Portage Band inventory data.



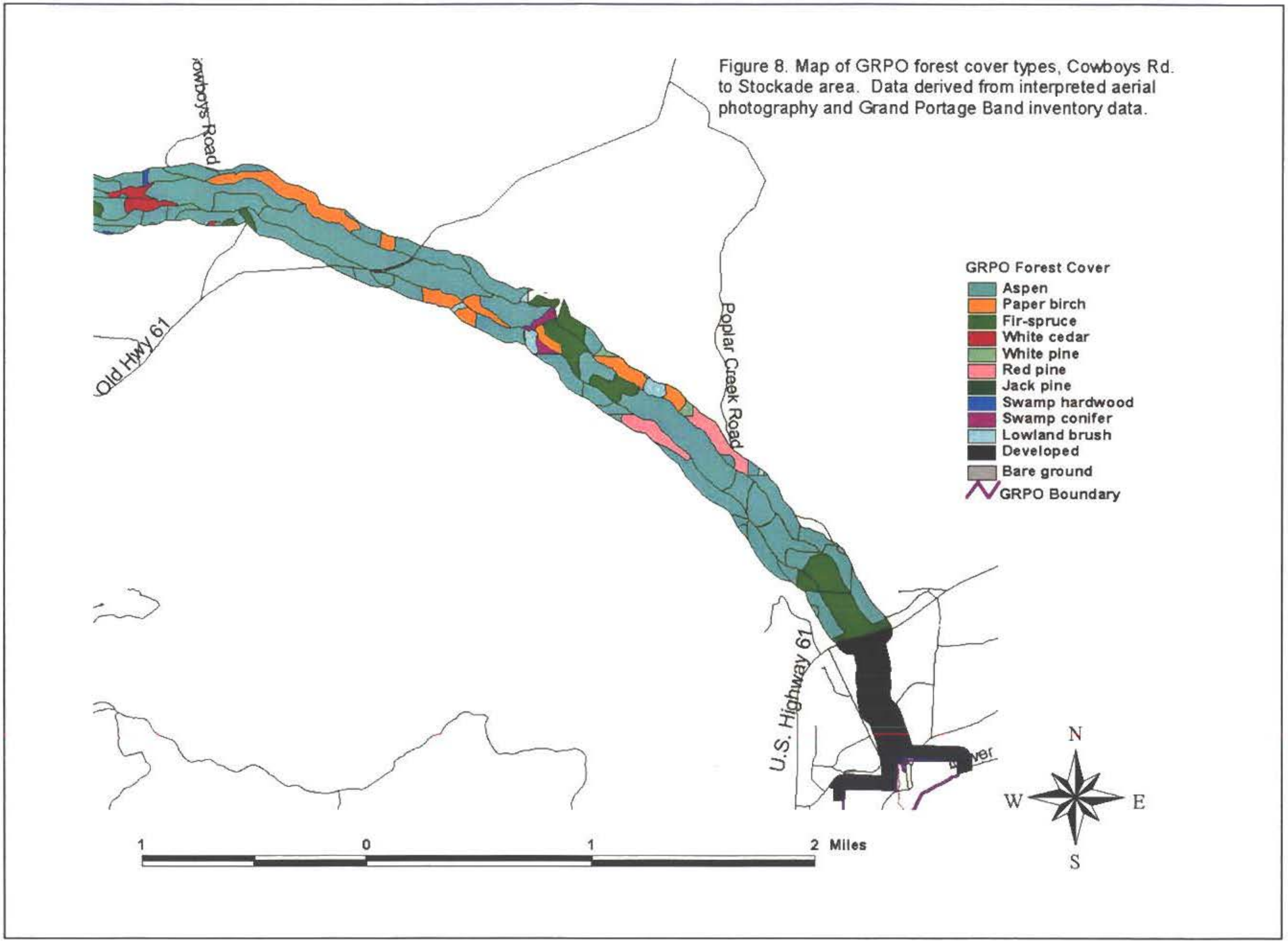


Figure 8. Map of GRPO forest cover types, Cowboys Rd. to Stockade area. Data derived from interpreted aerial photography and Grand Portage Band inventory data.

Figure 9. Map of GRPO age class structure, Ft. Charlotte to Cowboy Rd. Data derived from interpreted aerial photography, tree-ring samples and Grand Portage Band inventory data.

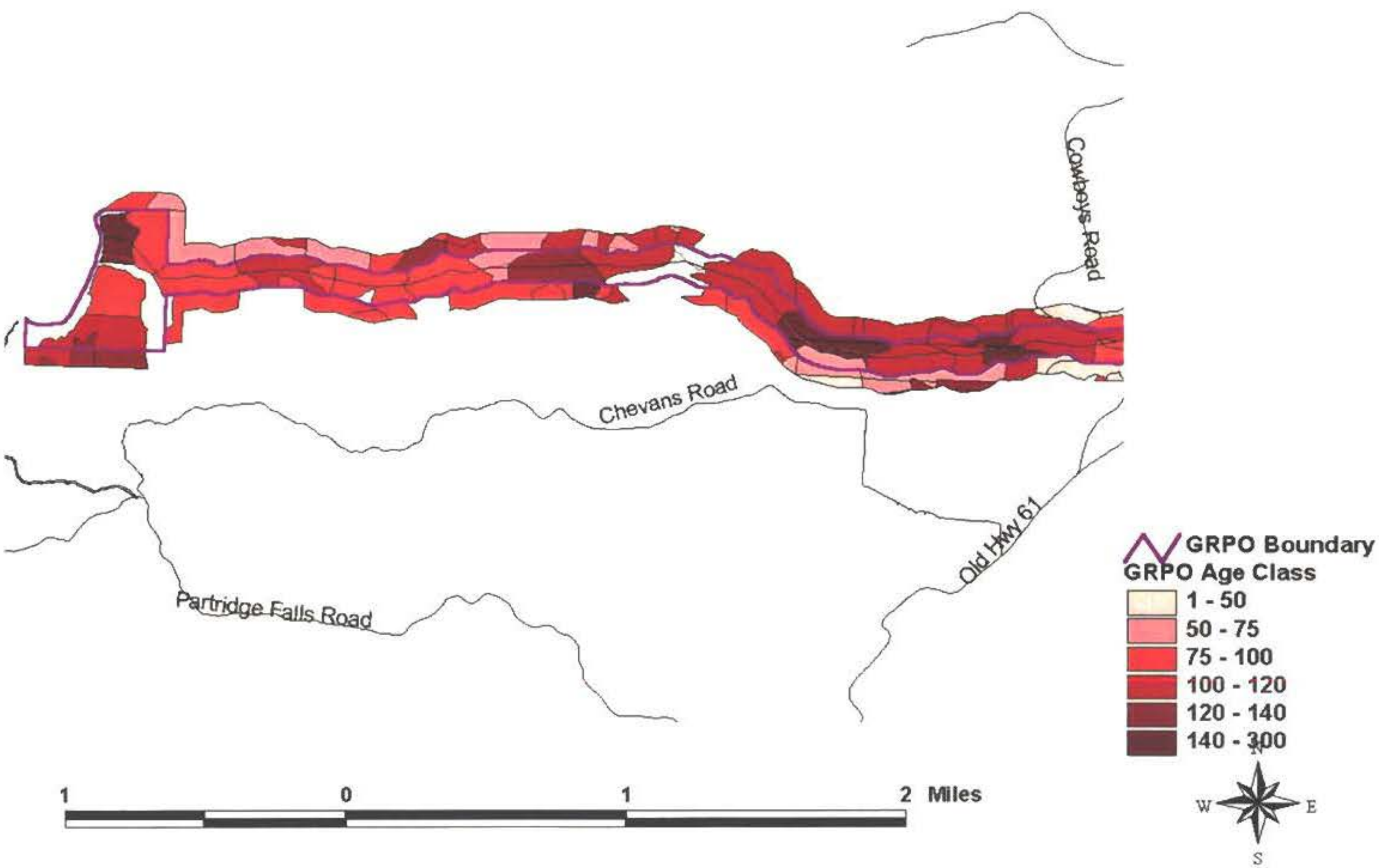


Figure 10. Map of GRPO age class structure, Cowboy Rd. to Stockade area. Data derived from interpreted aerial photography, tree-ring samples and Grand Portage Band inventory data.

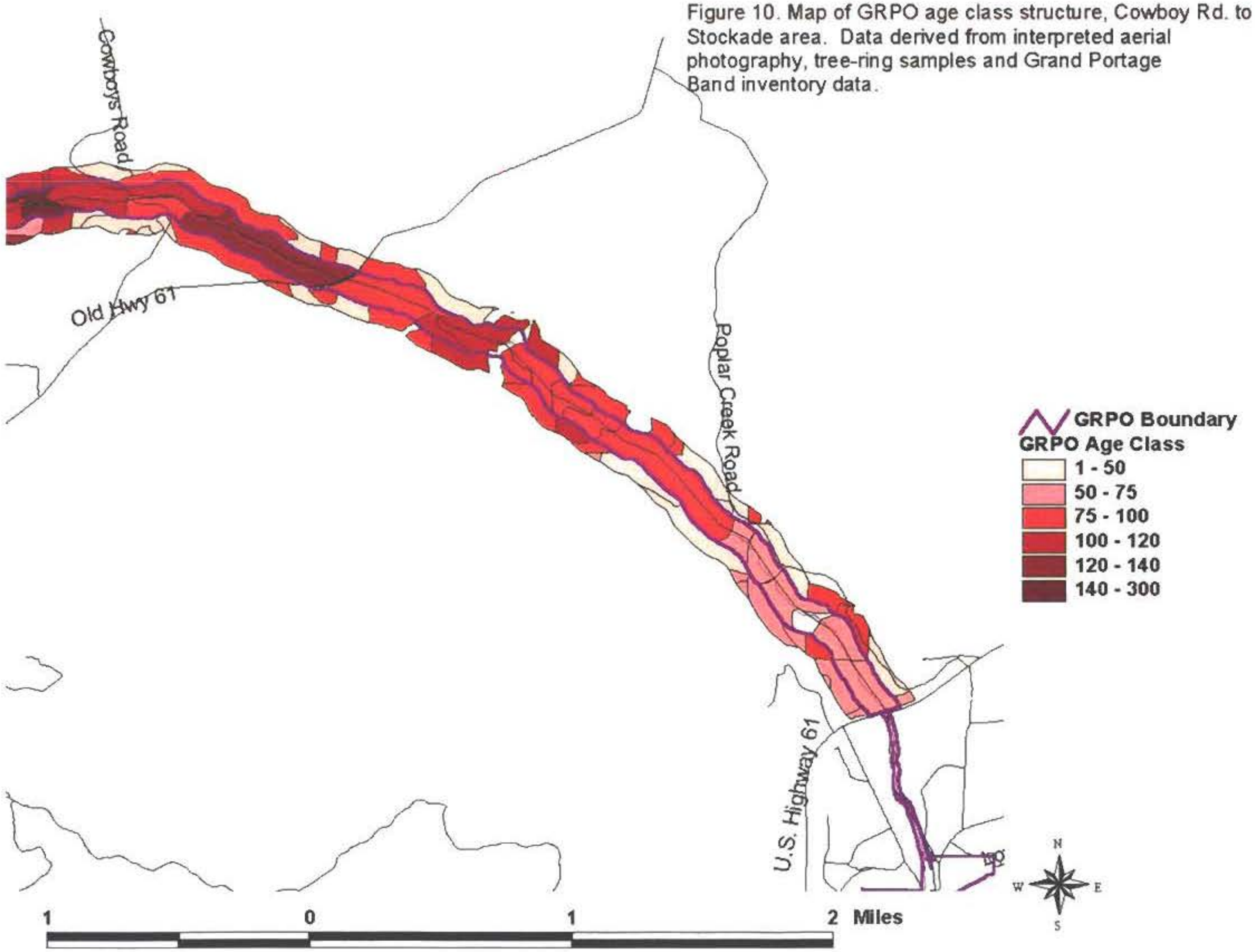


Table 1. Increment core samples for Grand Portage National Monument.

Core#	Slope	Aspect	Date	Species	Dbh inches	Age	X-coord	Y-coord
11.1	40+	NW	5/29/02	White Pine	22.3	73+	297687	5318631
11.2	40+	NW	5/29/02	White Pine	23.62	98	297684	5318600
11.3	40+	NW	5/29/02	W Spruce	18.5	84	297657	5318594
11.4	40+	NW	5/29/02	White Pine	21	88+	297657	5318594
12.1			6/28/02	White Spruce	16.5	104+	297208	5319074
13.1		40°	5/28/02	White Pine	19.6	83+	297192	5319095
13.2		40°	5/28/02	White Spruce	16.1	104	297188	5319044
13.3		40°	5/28/02	White Pine	28	83+	297234	5318919
13.4		40°	5/28/02	White Pine	25.79	99+	297226	5318879
19.1	5%	SE	5/28/02	White Pine	25.98	112	295396	5319777
19.2	5%	SE	5/28/02	Red Pine	18.4	95	295374	5319761
19.3	5%	SE	5/28/02	Red Pine	24.61	116	295388	5319750
19.4	5%	SE	5/28/02	White Spruce	18.7	97	295401	5319728
19.5	5%	SE	5/28/02	White Pine	24.1	115	295469	5319688
25.1			5/30/02	White Cedar	18.1	138+	292993	5319995
25.2			5/30/02	White Cedar	21.97	206+	293069	5320023
30.1	5%	20°	5/30/02	White Pine	72	84+	291936	5320506
30.12	5%	20°	5/30/02	White Pine	72	81+	291936	5320506
30.2			5/30/02	Jack Pine	16.77	115	291514	5320520
32.1	5%	20°	5/30/02	White Cedar	12.5	48+	290995	5320408
32.2	5%	20°	5/30/02	White Cedar	13.1	72+	290985	5320403
32.3	5%	20°	5/30/02	White Cedar	17.13	57+	290978	5320406
32.4	5%	20°	5/30/02	White Cedar	7.9	75	290978	5320398
33.1	5%	20°	5/30/02	Red Pine	20.63	107	290392	5320357
33.2	5%	20°	5/30/02	White Pine	19.17	92+	290392	5320357
34.1	5%	20°	5/30/02	Red Pine	25	102	290088	5320444
34.12	5%	20°	5/30/02	Red Pine	25	108+	290088	5320444
34.2	5%	20°	5/30/02	White Pine	22.64	87+	290131	5320396
37.1	8/14	250°	5/30/02	White Pine	36.61	117+	289051	5320624
37.2	8/14	250°	5/30/02	White Cedar	14.6	151+	289036	5320675
37.3	8/14	250°	5/30/02	White Pine	27.36	124+	289043	5320647
37.4	8/14	250°	5/30/02	White Cedar	13.4	100+	289047	5320640
37.5	8/14	250°	5/30/02	White Pine	31.5	127+	289069	5320706
37.6	8/14	250	5/30/02	White Spruce	15.7	114	289081	5320679
37.7	8/14	250°	5/30/02	White Pine	62.3	107+	289095	5320717
21.1p			6/28/02	White Pine	22.32	103	294524	5320039
24.1s			6/28/02	White Spruce	20.2	107+	293780	5319943
25.1p			6/28/02	White Pine	37.3	137+	293292	5319915
26.1t			6/28/02	White Pine	47.8	190+	293054	5320059
2-wc			10/1/03	White Cedar	18	104+	294125	5319954
32.1A	5%	20°	5/30/02	Red Pine	22.83	117	290806	5320385
3-wc			10/1/03	White Cedar	15.39	135+	294139	5320019
4-wc			10/1/03	White Cedar	14.64	227+	294135	5320018
5-wc			10/1/03	White Cedar	17.15	147+	294150	5319948
6-wc			10/1/03	White Cedar	21.25	133+	294151	5319949
7wc			10/1/03	White Cedar	20.6	58+	294222	5319953
8-wc			10/1/03	White Cedar	28	163	294228	5319940
F26			7/25/02	White Pine		256+	292958	5320110
F30			7/25/02	Jack Pine		120+	291510	5320522
F37			7/25/02	White Spruce		101+	289043	5320511
rp-1			10/1/03	Red Pine	30	119+	295414	5319739

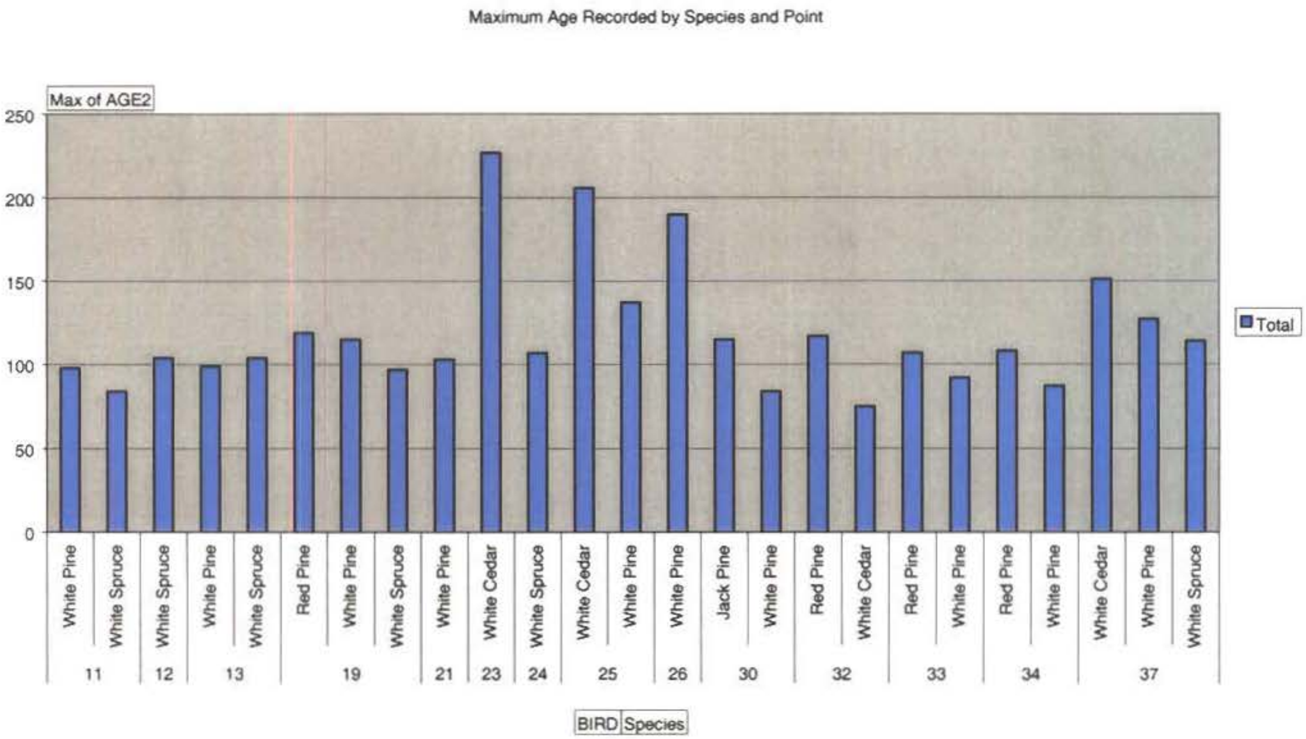


Figure 11. Maximum recorded ages based on increment cores, bird count point and tree species

growth rate after 1936, a well-known fire year (Figures 12a-c). This effect was also evident at the Cowboy Rd. site (Figures 13a-d), but to a lesser degree at other locations. The fact that there is spatial variability in ring width patterns indicated that the landscape does not respond uniformly to these major climatic events. Subtle differences in local hydrology, as well as topographic effects, can ameliorate or exacerbate climatic effects, resulting in short term changes in productivity, and possibly long-term changes in forest cover types, as competitive relationships among species are altered.

The old-growth cedars at the Cowboys Rd. site show strong positive increases in relative ring widths associated with the major fire years 1801, 1822, 1854, 1864, 1874, 1910, 1921 and 1936 (Figures 13a-d). Obviously, this site could not have experienced anything more intense than a light maintenance fire during any of these years, providing evidence for long fire intervals at certain points along the trail. The increased growth rates observed during high fire years may be due to the interaction of locally mesic site conditions in conjunction with temperatures favorable for growth.

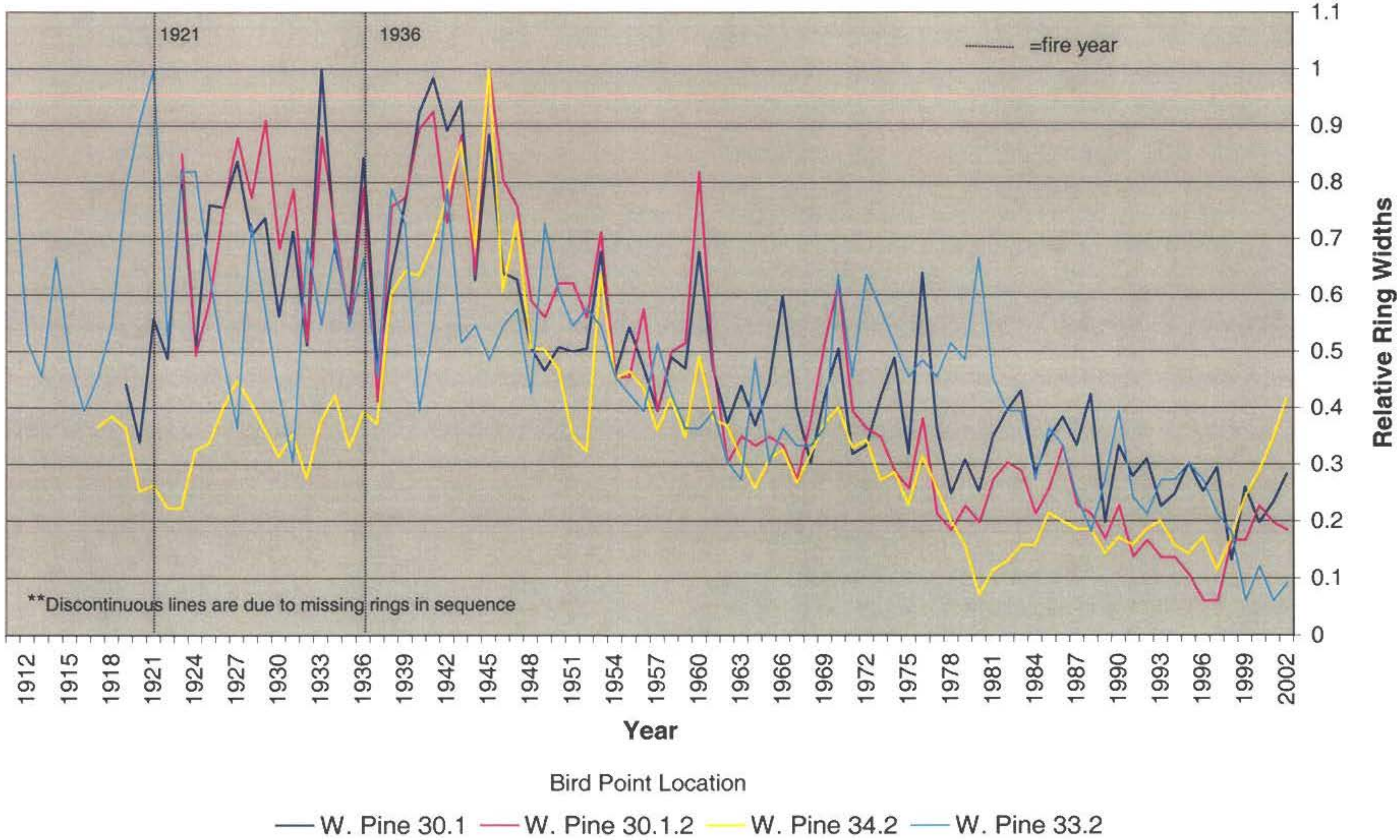
There was a tight correlation in relative growth rates between the white cedar (37.4) and white spruce (37.6) cored at Ft. Charlotte (Figure 14b). There is a growth rate spike associated with the 1920 and1936 fire years; the 1910 fire year marked the end of a 10 year period of decline in growth rates (Figures 14a,b). Similar patterns were observed at the Poplar Creek and Fountains sites (Figures 15,16). Tree-ring widths have been relativized and represent and index of annual radial growth (Swetnam et al. 1985).

Regional and Local Disturbance Patterns

The BWCAW has the most complete record of fire history in the region. The BWCAW is located to the west of GRPO, covers approximately 1,030,000 acres and extends for 110 miles along the U.S.-Canadian border. Thin, coarse textured soils over bedrock are characteristic of the region, however lacustrine clay sediments are also present. Dry-mesic jack pine-black spruce covered much of the bedrock-controlled uplands. Dry-mesic white pine-red pine types were also abundant. Mesic birch-aspen-spruce-fir was more abundant on till-plains in the eastern portion of the BWCAW. The fire chronology ranges from 1577 to 1972 (Heinselman 1973). Heinselman estimated a 100 year rotation period for stand replacing fires in the BWCAW as a whole but noted substantial variability related to fuel distributions, vegetation type, physiographic factors, lightning and human ignition, and climatic variation. White and red pine types occurred in areas protected from severe fire by lakes and topographic features, and where fire occurred more frequently in the understory removing ladder fuels and maintaining pine dominance. Stands of mature-old white cedar, an extremely fire-sensitive species were confined to areas protected from fire such as lakeshores. The Quetico Provincial Park adjacent to the BWCAW was subject to very similar disturbance patterns and frequencies (Wood and Day 1977).

Figure 12a: Cascade Trail

Normalized tree ring widths and major fire years in NE Minnesota



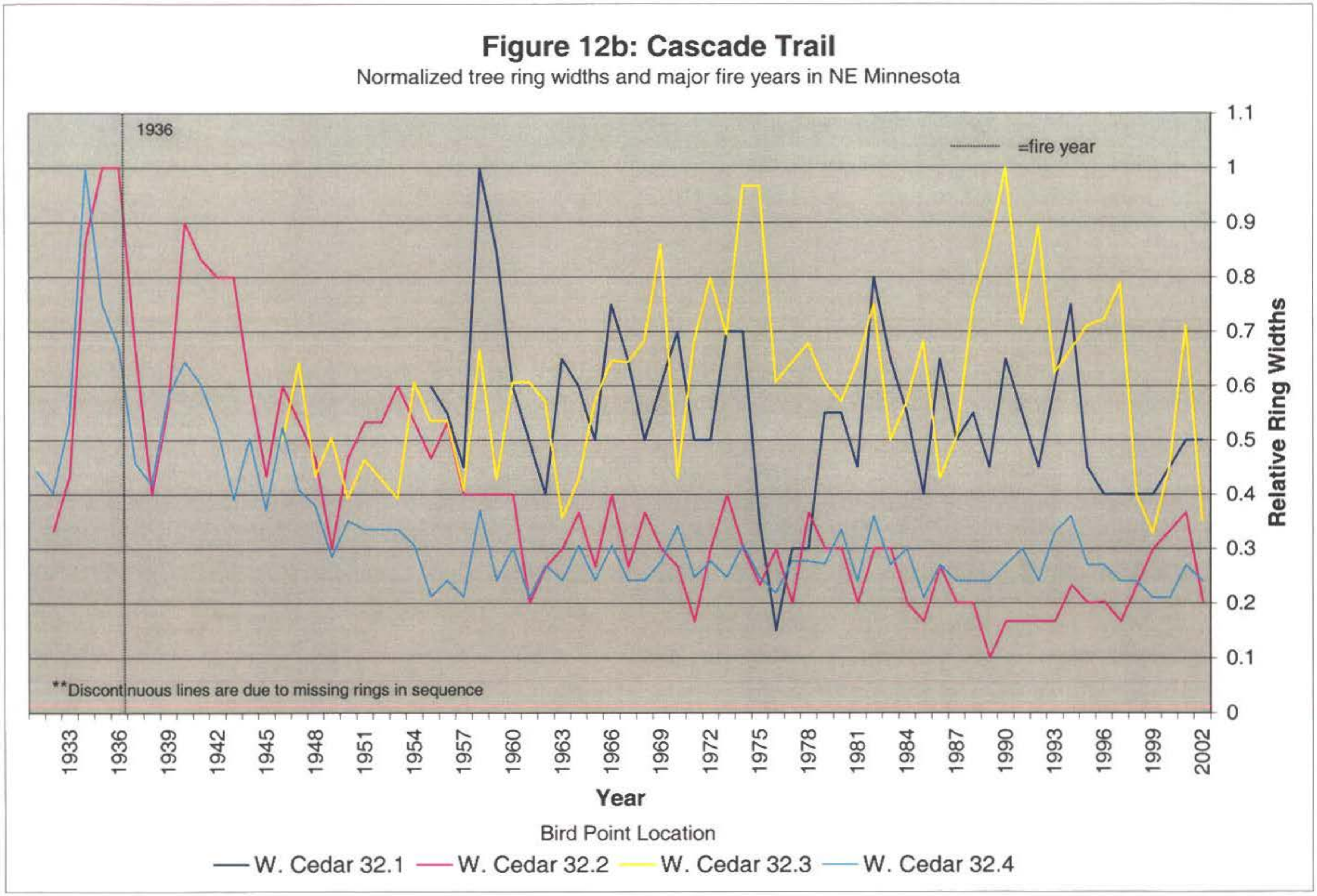


Figure 12b: Cascade Trail
Normalized tree ring widths and major fire years in NE Minnesota
1936
=fire year
**Discontinuous lines are due to missing rings in sequence
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Relative Ring Widths
1933
1936
1939
1942
1945
1948
1951
1954
1957
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
Year
Bird Point Location
W. Cedar 32.1
W. Cedar 32.2
W. Cedar 32.3
W. Cedar 32.4

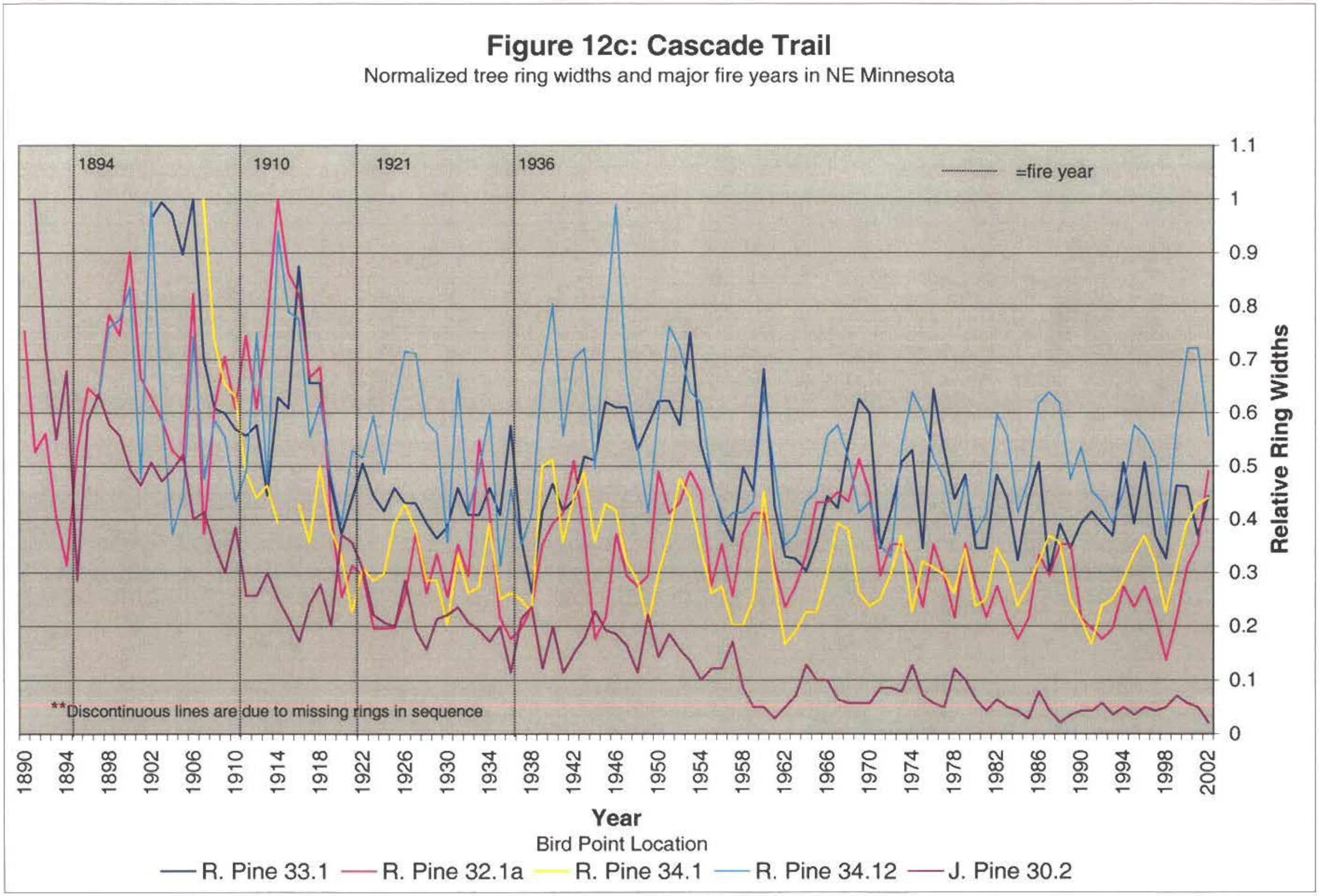


Figure 12c: Cascade Trail
Normalized tree ring widths and major fire years in NE Minnesota
1894
1910
1921
1936
=fire year
**Discontinuous lines are due to missing rings in sequence
Relative Ring Widths
Year
Bird Point Location
R. Pine 33.1
R. Pine 32.1a
R. Pine 34.1
R. Pine 34.12
J. Pine 30.2

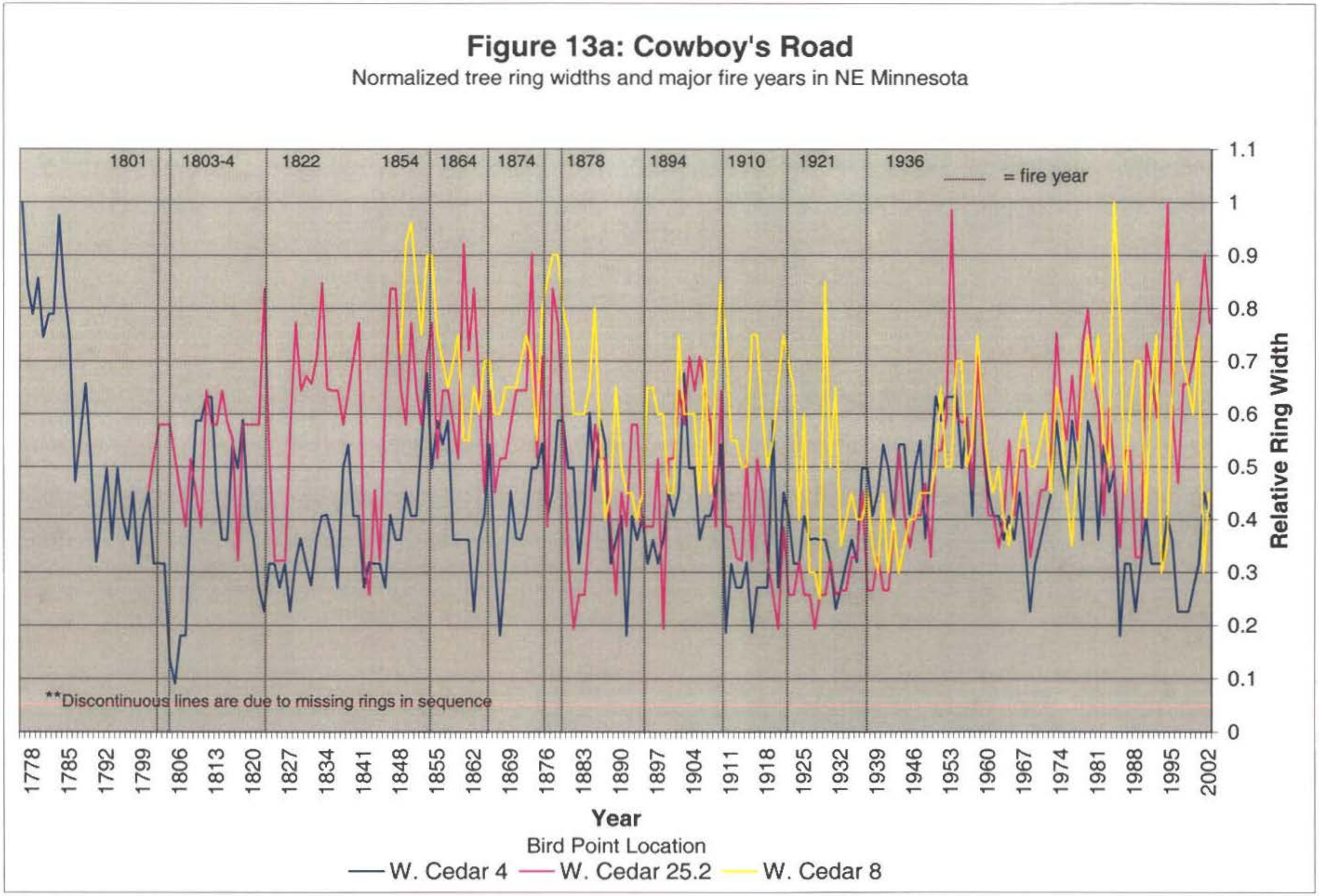


Figure 13a: Cowboy's Road
Normalized tree ring widths and major fire years in NE Minnesota
1801
1803-4
1822
1854
1864
1874
1878
1894
1910
1921
1936
= fire year
**Discontinuous lines are due to missing rings in sequence
Relative Ring Width
Year
Bird Point Location
W. Cedar 4
W. Cedar 25.2
W. Cedar 8

Figure 13b: Cowboy's Road

Normalized tree ring widths and major fire years in NE Minnesota

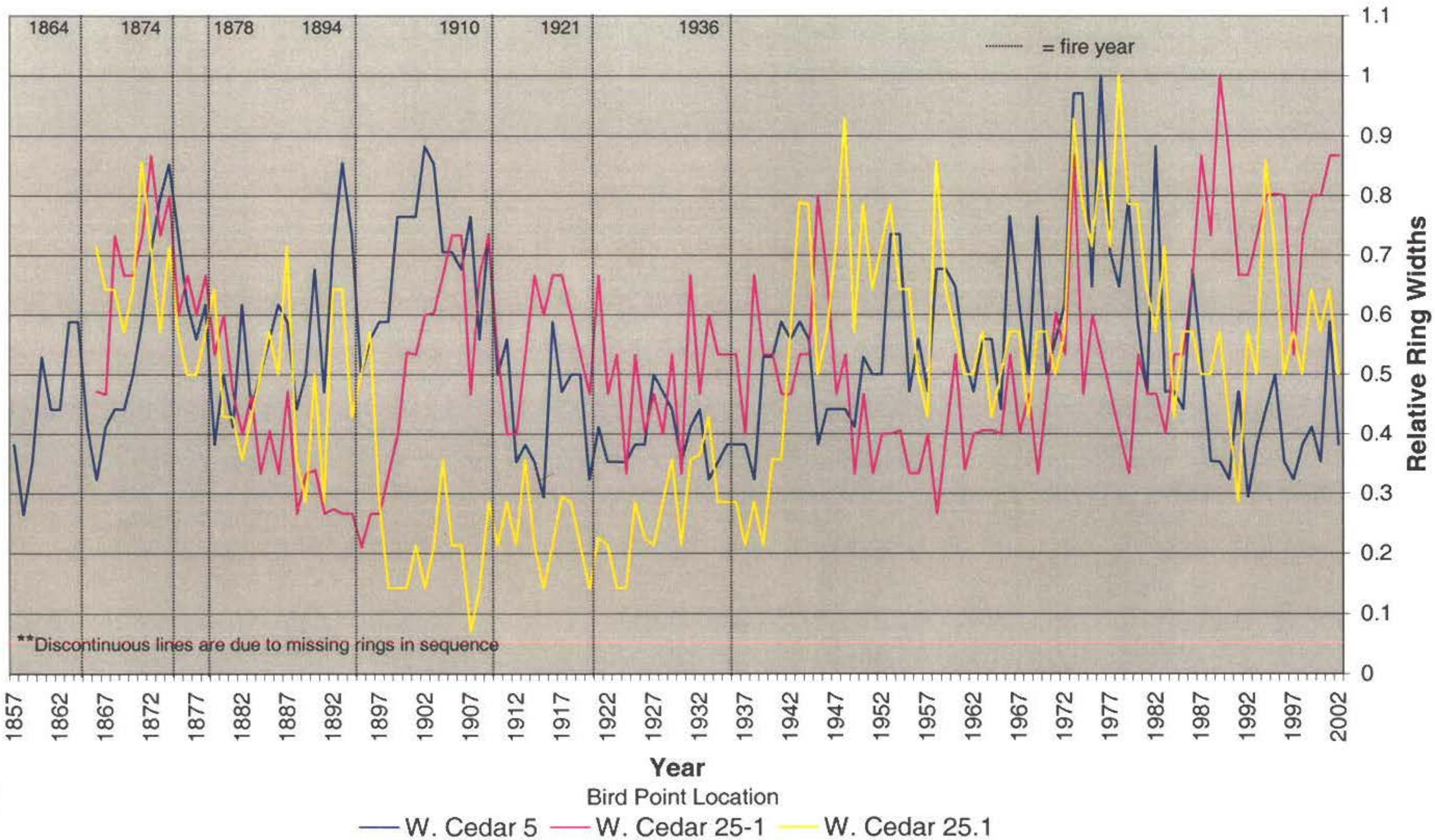
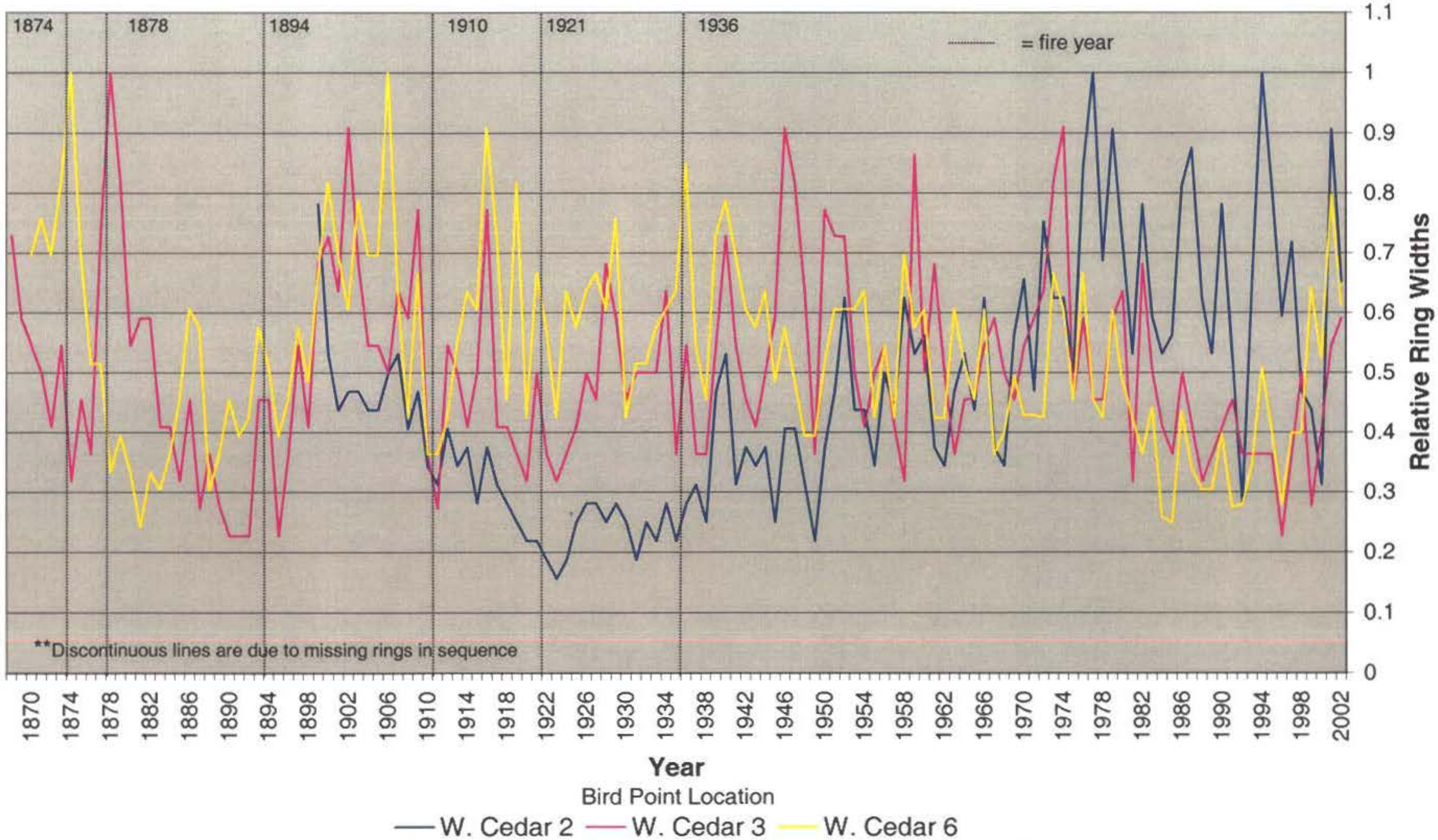


Figure 13c: Cowboy's Road

Normalized tree ring widths and major fire years in NE Minnesota



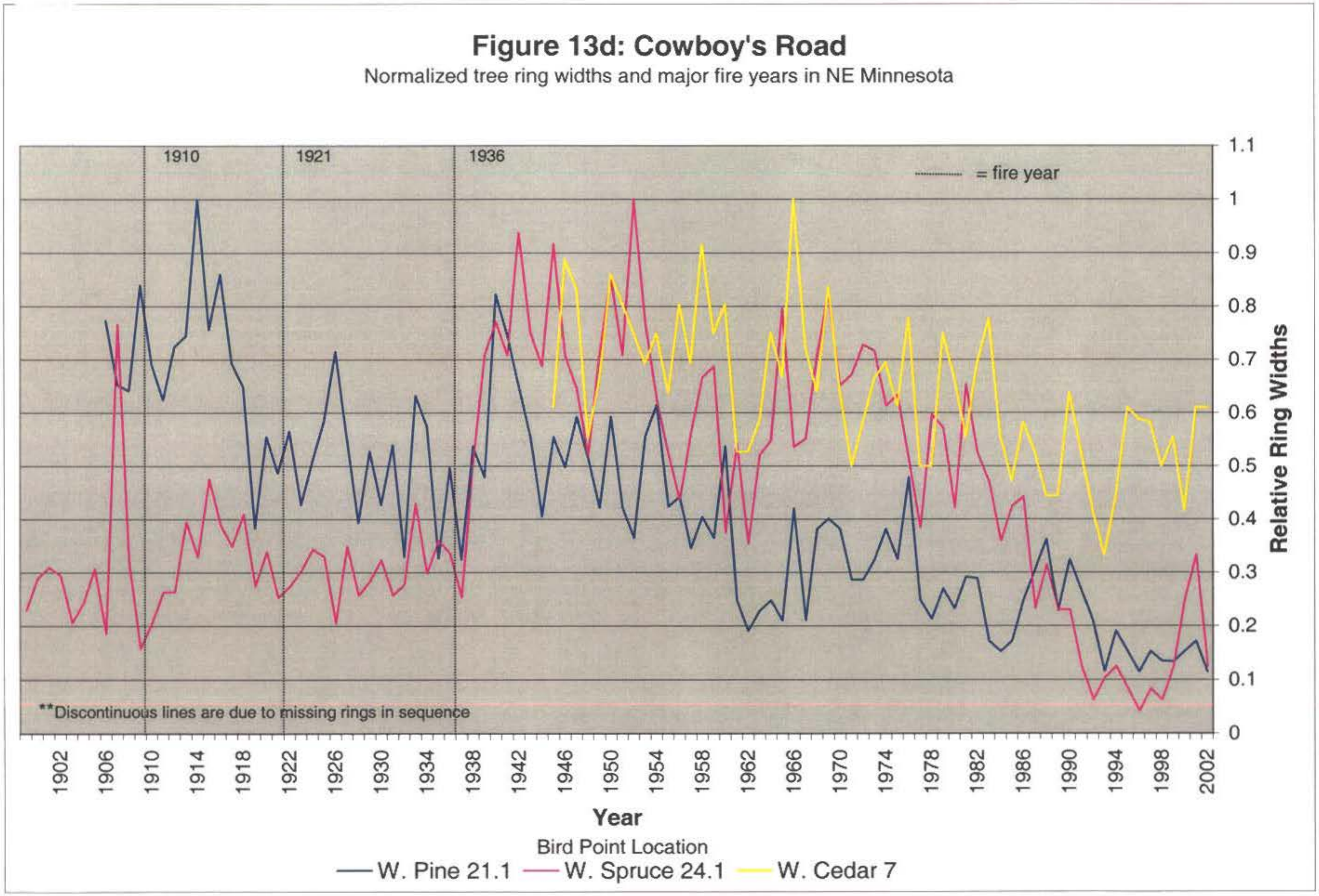


Figure 13d: Cowboy's Road
Normalized tree ring widths and major fire years in NE Minnesota
1910
1921
1936
= fire year
**Discontinuous lines are due to missing rings in sequence
Relative Ring Widths
Year
Bird Point Location
W. Pine 21.1
W. Spruce 24.1
W. Cedar 7

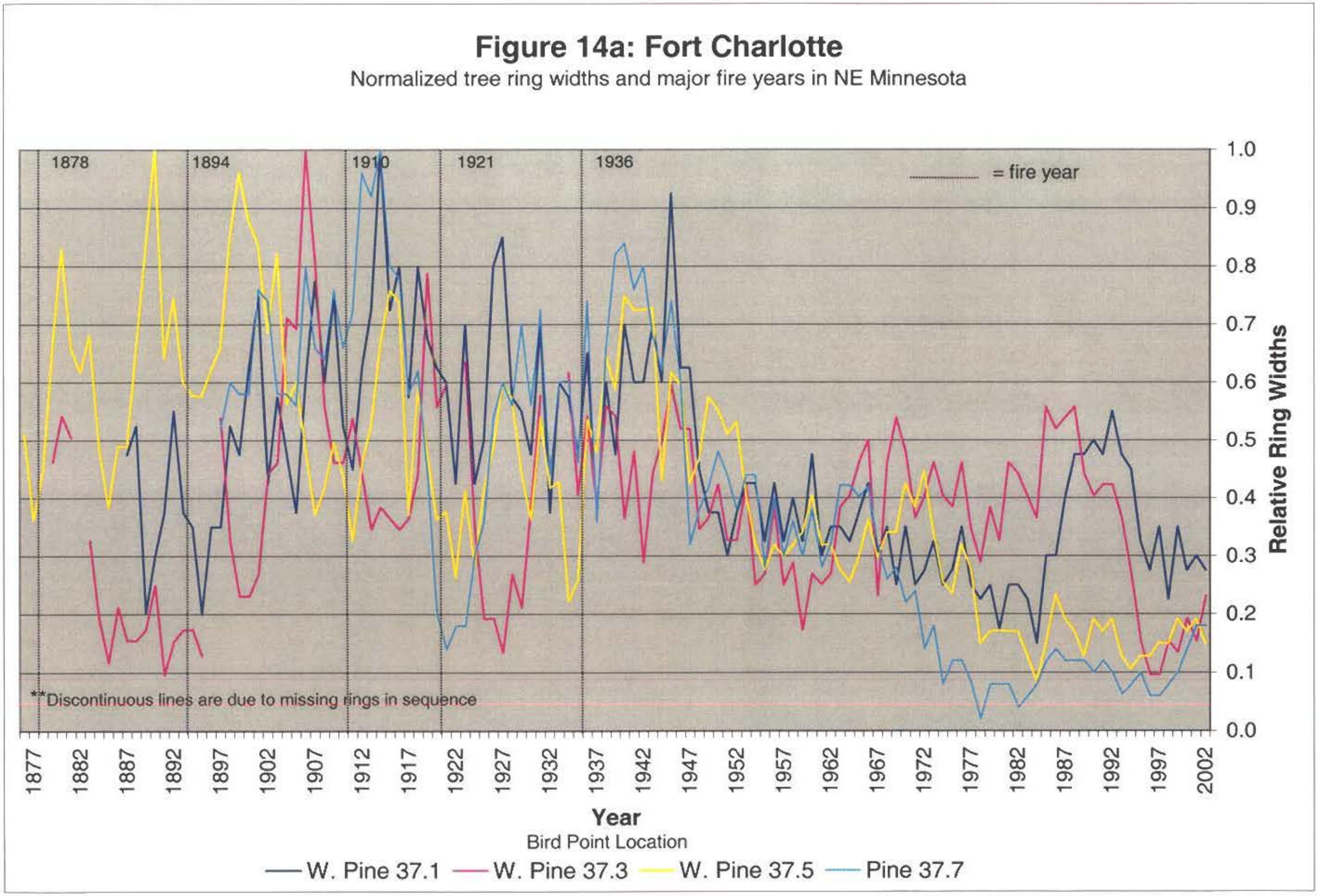


Figure 14a: Fort Charlotte
Normalized tree ring widths and major fire years in NE Minnesota
1878
1894
1910
1921
1936
= fire year
**Discontinuous lines are due to missing rings in sequence
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Relative Ring Widths
1877
1882
1887
1892
1897
1902
1907
1912
1917
1922
1927
1932
1937
1942
1947
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997
2002
Year
Bird Point Location
W. Pine 37.1
W. Pine 37.3
W. Pine 37.5
Pine 37.7

Figure 14b: Fort Charlotte

Normalized tree ring widths and major fire years in NE Minnesota

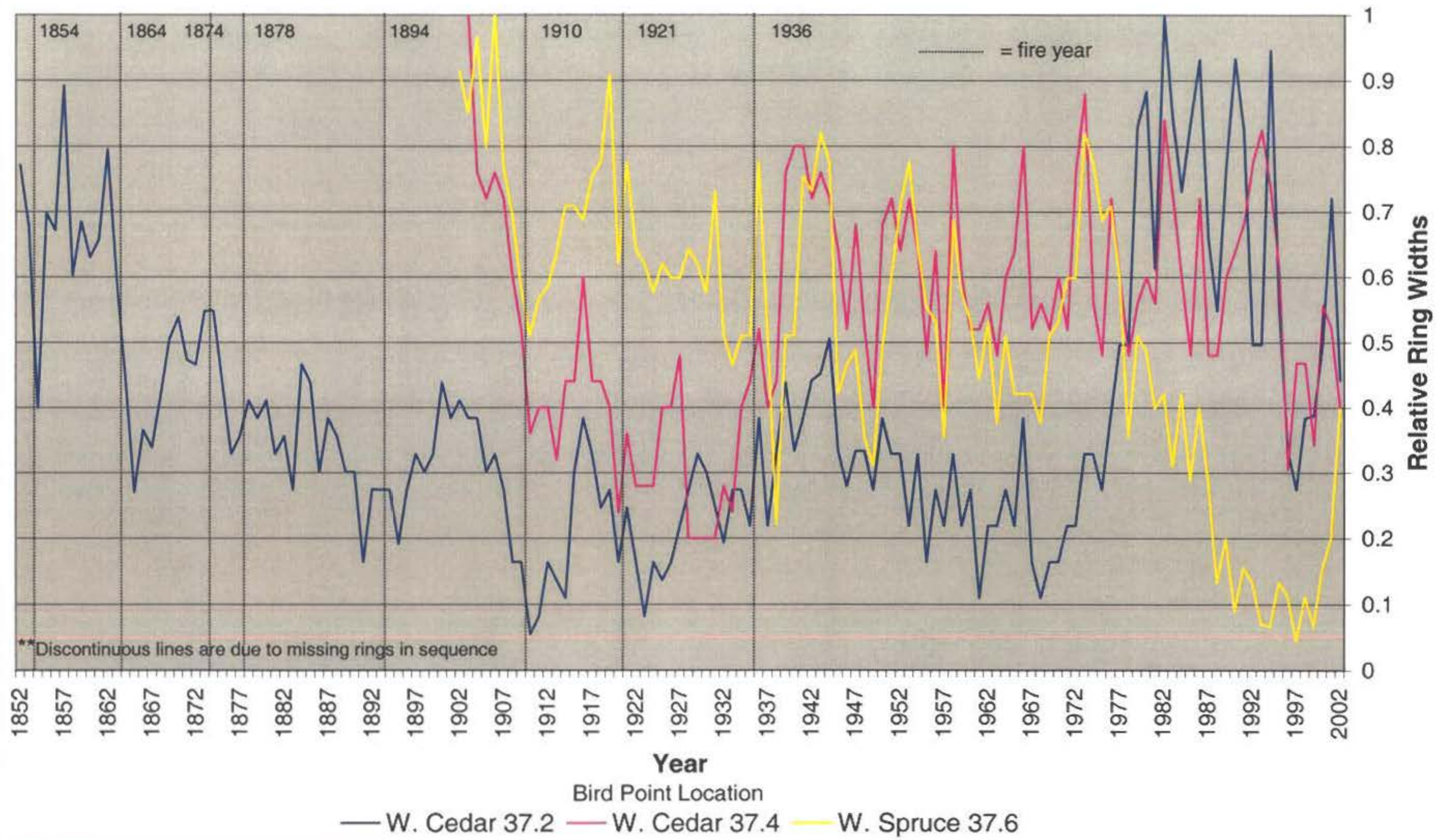
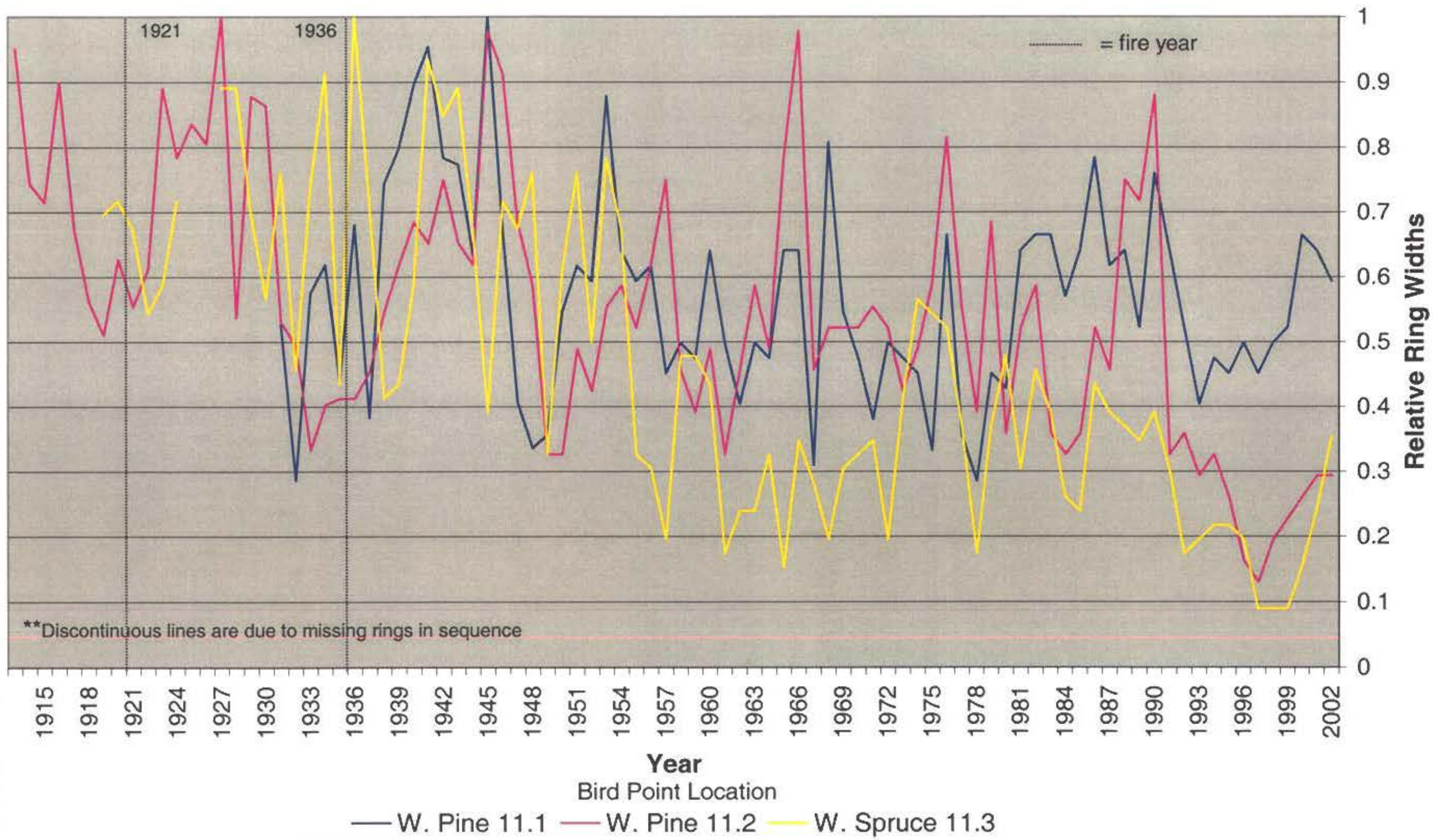


Figure 15a: Poplar Creek

Normalized tree ring widths and major fire years in NE Minnesota



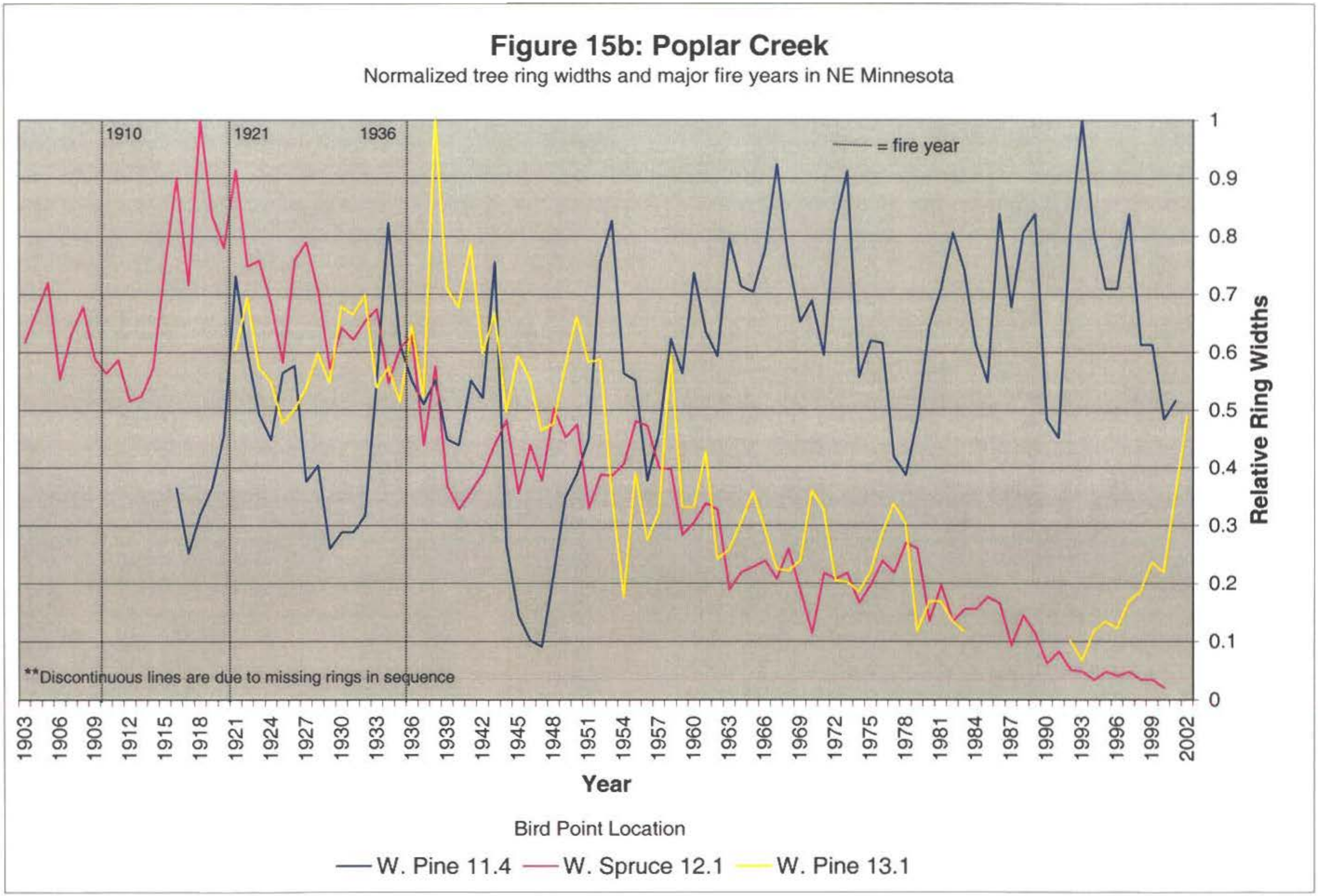


Figure 15b: Poplar Creek
Normalized tree ring widths and major fire years in NE Minnesota
1910
1921
1936
= fire year
**Discontinuous lines are due to missing rings in sequence
Relative Ring Widths
Year
Bird Point Location
W. Pine 11.4
W. Spruce 12.1
W. Pine 13.1

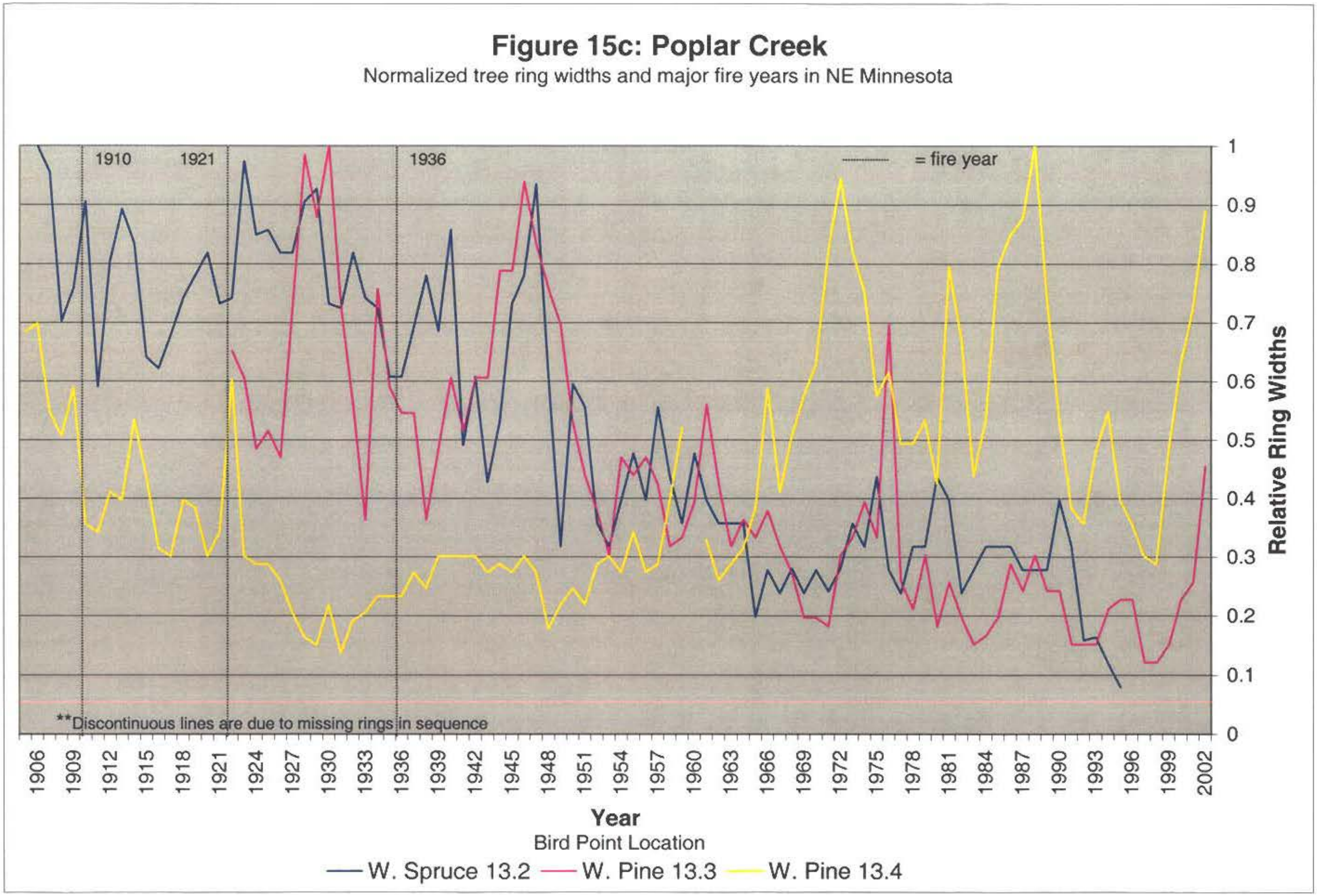


Figure 15c: Poplar Creek
Normalized tree ring widths and major fire years in NE Minnesota
1910
1921
1936
= fire year
**Discontinuous lines are due to missing rings in sequence
Relative Ring Widths
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1906
1909
1912
1915
1918
1921
1924
1927
1930
1933
1936
1939
1942
1945
1948
1951
1954
1957
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
Year
Bird Point Location
W. Spruce 13.2
W. Pine 13.3
W. Pine 13.4

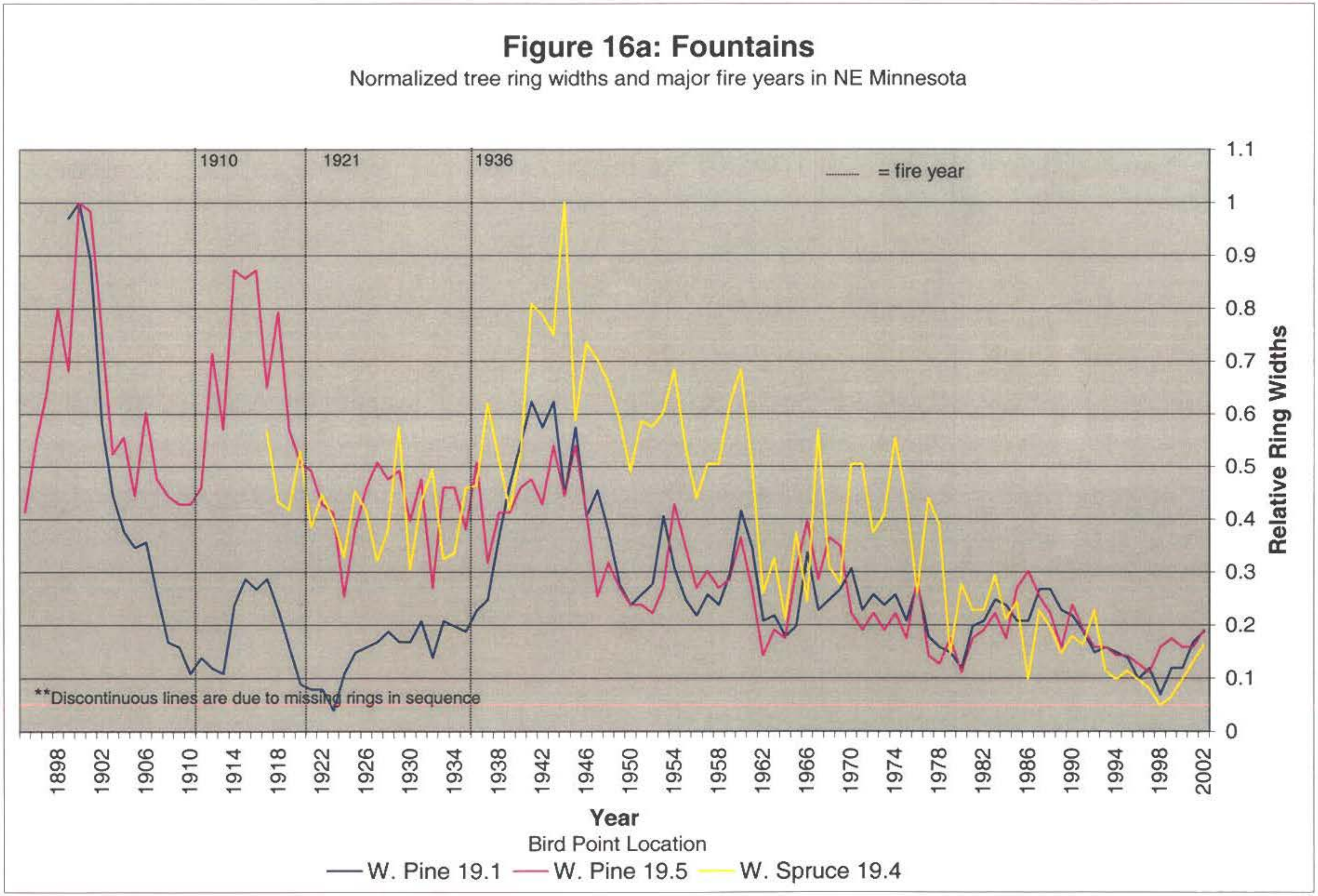


Figure 16a: Fountains
Normalized tree ring widths and major fire years in NE Minnesota
1910
1921
1936
= fire year
**Discontinuous lines are due to missing rings in sequence
1898
1902
1906
1910
1914
1918
1922
1926
1930
1934
1938
1942
1946
1950
1954
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
1998
2002
Year
Bird Point Location
W. Pine 19.1
W. Pine 19.5
W. Spruce 19.4
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Relative Ring Widths

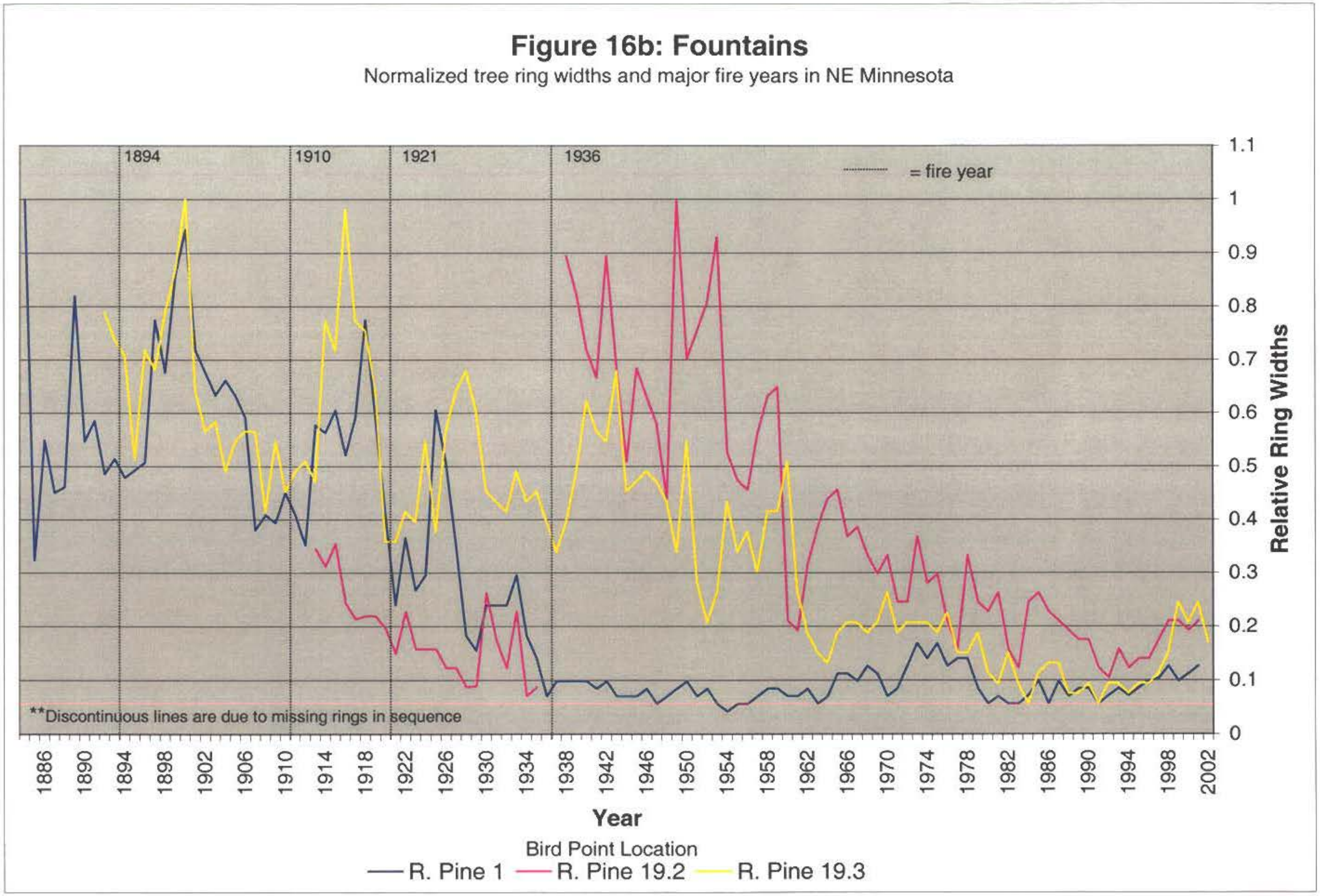


Figure 16b: Fountains
Normalized tree ring widths and major fire years in NE Minnesota
1894
1910
1921
1936
= fire year
**Discontinuous lines are due to missing rings in sequence
Relative Ring Widths
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1886
1890
1894
1898
1902
1906
1910
1914
1918
1922
1926
1930
1934
1938
1942
1946
1950
1954
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
1998
2002
Year
Bird Point Location
R. Pine 1
R. Pine 19.2
R. Pine 19.3

Frelich (1999) summarized the disturbance rotation period estimates for the Northern Superior Uplands ecological section. Fire rotation estimates were based primarily on BWCAW fire history data.

Table 2. Disturbance rotation period estimates used for Northern Superior Uplands Range of Natural Variability models (Frelich 1999, White et al. 2001).

Ecosystem	Rotation period range		
	Stand-leveling wind	Stand-replacing fire	Maintenance fire
Mesic and dry-mesic white and red pine	1000-2000	150-300	40
Northern hardwood	1000-2000	2000-4000	
Lowland conifer	1000-2000	150-300	
Mesic birch-aspen-spruce-fir	1000-2000	100-200	
Jack pine-black spruce-oak	1000-2000	50-100	

An analysis of GLO bearing tree data (White and Host unpublished data) and GLO line note descriptions (White and Host 2003) indicate similar disturbance frequency values for the Border Lakes subsection, but also shows considerable variability across the Northern Superior Uplands ecological section. White and Host (2003) conducted a spatial analysis of GLO line note descriptions of forest disturbances to estimate rotation periods at the subsection level. This work showed that there is significant variability in fire regime at the subsection level, with the Border Lakes showing the shortest rotation period for fire whereas the North Shore Highlands and the Toimi/Laurentian subsections showed much longer intervals (Table 3). An analysis by ecosystem type across the NSU shows similarities to BWCAW based estimates, but also indicates that fire frequencies were quite variable for ecosystems at the section level (Table 4). BWCAW data (Frelich 1999, Heinselman 1973) show a 100-200 year rotation period for Mesic birch-aspen-spruce-fir (Table 2), while the section-wide analysis shows a 500-year period. Section level analysis of mesic pine systems shows a similar overall fire rotation period to the BWCAW, although data suggest that a majority of these fires were maintenance rather than stand-replacing fires.

Paleoecological analysis of charcoal and pollen indicates that the northeastern portion of Isle Royale National Park was subject to periodic severe fire events over the last 1000 years (Cole 1995). Southern boreal forest genera *(Picea, Pinus, Abies, Betula)* dominated the pollen flora over the 1000 year time period. White and red pine forests were maintained on coarse textured soils at Pictured Rocks National Lakeshore by relatively frequent surface fires (1/21.8 years) (Loope 1991). These studies demonstrate that both stand replacing and surface-maintenance fire occurred on areas influenced by Lake Superior. Soil texture, as it influences vegetation and fuel moisture levels has been shown to be an important component in the feed back loop in fire adapted ecosystems (Heinselman 1973, Wright and Bailey 1982, Whitney 1986, Loope 1991).

Table 3. Disturbance rotation period estimates (yrs) for NSU subsections based on analysis of GLO line note descriptions using a 15-year recognition window.

Disturbance Type	Border Lakes	North Shore Highlands	Nashwauk Uplands	Toimi/Laurentian Highlands
Fire	177	612	319	1,113
Wind	1,363	3,040	561	6,365
Dead	0	0	24,913	320
All wind and fire	148	507	178	862
All disturbances	145	500	176	233

Table 4. Fire rotation periods for ecosystem classes in the Northern Superior Uplands based on analysis of GLO section corner disturbance using a 15-year recognition window. Includes maintenance and stand replacing fire.

Ecosystem Class	Rotation period (yrs)
Mesic northern hardwood	4,400
Mesic white pine-red pine	375
Mesic birch-aspen-spruce-fir	500
Dry-mesic white pine-red pine	190
Dry-mesic jack pine-black spruce	140

The BWCAW data provides the most reliable record of pre-Euro-American disturbance frequencies. However other regional level analysis shows that disturbance frequencies varied significantly by subsection and ecosystem type, and thus underscores the problems with extrapolating disturbance frequencies for the BWCAW beyond the Border Lakes subsection where different soil, climate and topographic conditions may prevail.

Climate and Soil Conditions on GRPO and the Border Lakes

An analysis of regional climate (Zedx 1995) and soil patterns (LMIC 2000) suggests that the GRPO region differs substantially from Border Lakes region encompassing the BWCAW. In general, soils in the Border Lakes tend to be thinner, have coarser texture and higher drainage rates than soils along the GRPO corridor. Climate data shows growing season temperatures increase and precipitation decreases from GRPO westward. Lightning strike ignitions may occur from 5 to 20 times more frequently in the BWCAW region (Johnson 1992). In general, this information suggests that conditions tend to be more mesic along the GRPO trail than those prevailing in the Border Lakes region. Low fuel moisture conditions and lightning strikes occur less frequently in the GRPO region than in the more fire prone landscape of the Border Lakes.

Along the GRPO trail corridor, significant variability in soils and topography does occur. The western portion of the trail in the Swamp River Till Plain occurs on clay soils with level to rolling topography. The section on the North Shore Till Plain occurs on clay, sandy loams and scoured bedrock and has greater topographic variation. This variation in soil moisture influences vegetation composition, fuel characteristics and fire probability(Wright and Bailey 1982, Whitney 1986).

Historical Accounts of Vegetation and Fire in the GRPO Region

Although GRPO may be relatively mesic and have low lightning ignition frequency, analysis of tree ring data, GLO line notes for the GRPO area, and historical accounts indicate that much of the GRPO burned over during the late 19th and early 20th centuries. It is likely that many of these ignitions were human caused, but fuel moisture and climate allowed significant fire spread and tree mortality.

GLO survey line note data indicate that a majority of the area was burned over and in an early successional state at the time of survey (1892-93) (Institute of Minnesota Archeology 2001). Line descriptions indicate dense brush and young aspen-birch were the predominant vegetation types at this time. General vegetation descriptions from the 1859 survey for township 64R6E indicate spruce, pine, fir, white and yellow birch and aspen were important on upland near river bottom and on land between steep ridges. A description of township 63N6E notes (1892-3 survey) that the land from 1 to 1.5 miles from the lakeshore was burned over and formerly was a dense growth of spruce and fir. The descriptions for townships 64N5E and 63N5E indicate relatively recent fire disturbance, with brush and early successional forests covering most of the land (Institute of Minnesota Archeology 2001). A human caused fire occurred in 1873, which likely burned most the Portage area with the exception of a 2-mile wide strip that began 4 ¾ miles north of the village and extended to the end of the Portage (Winchell 1893, from Woolworth 1993). Stand origin data from tree ring analysis and Grand Portage Band inventory data indicate pre-1880 stand replacing disturbances. Two accounts describe 1878 as a major fire year in the region, and one specifically mentions the Grand Portage area (St. Paul Pioneer Press, White 1967).

Numerous fires occurred in northeastern Minnesota during the settlement (1870-1910) and post-settlement periods (1910-1940) (Appendix A). It is likely that many of these were of human origin, were fueled by logging slash and growing season drought conditions. Heinselman (1973) documented an increase in fire frequency from 1868-1911, with the average fire return interval changing from 4.3 years in the pre-settlement period to 2.1 during the settlement period. Rotation period estimates changed from 122 years in the pre-settlement to 87 years during the settlement period. Although this difference may be due to an artifact of fire scar sampling in which subsequent fires remove evidence of earlier fires. It is notable that 80% of the BWCAW area burned during the settlement period can be accounted for in 2 fire years, 1875 and 1894. It is likely that ignitions increased during the settlement period because of increased human activity (Heinselman 1973, White and Host 2003, however, fire spread was still regulated by weather and fuel moisture levels (Johnson 1992).

Natural Variability in Forest Composition and Structure

Based on regional assessments of historical fire frequency, and local and meso-scale soil and climate conditions in the GRPO area, we suggest that the more moderate climate and mesic soil moisture conditions, coupled with the relatively low frequency of lightning strike ignitions created a fire regime different from that in the BWCAW. Because of the environment at GRPO, conditions favorable for fire ignition and spread occurred less frequently at GRPO than in more drought prone areas such as the BWCAW (Johnson 1992). Analysis of historic growth stage composition and disturbance in Northern hardwood and conifer forests of the North Shore Highlands indicates that mesic hardwood and conifer sites burned infrequently (1000-2000 year rotation) while mesic conifer dominated systems were subject to a 200-400 year fire cycle (White et al. 2002) (Fig. 17). We believe that the forests of GRPO are similar to the mesic conifer pathway shown with a 200-400 year fire cycle. Loope's (1989) assessment of GRPO suggests a similar fire regime to the BWCAW, but likely with longer intervals between fire (stand replacing and surface). Surface fire may have been a component in GRPO forest as well. Some dry-mesic pine stands do occur on sites that would be more fire prone. Surface fire would maintain pine dominance by producing favorable seed bed conditions, reducing ladder fuels by killing understory vegetation, and by maintaining pine needle litter which drys out more readily and ignites more easily than the compact litter of short needled conifers Sackett (1980). Mature white and red pine stands have a lower risk of crown fire because of the long flame lengths required to reach crown height (Johnson 1992).

GRPO forests fall primarily into the mature-multi-aged vegetation growth stages (> 120 years, mature white pine, multi-aged conifer) with substantial areas in multi-aged white pine-spruce-fir (Fig. 17). When viewed at the regional level, GRPO has a greater proportion of land in mature and later successional stages, and less in the younger growth stages. Estimated composition by age class based on GLO bearing tree data (White 2001) shows that conifer species (white pine, white spruce, white cedar, tamarack and balsam fir) comprised 70-80% of stem densities in the mature and late successional growth stages during the pre-Euro-American settlement period. Our observations of GRPO forests suggest that with some notable exceptions, conifers are under represented in the mature and later successional growth stages. Aspen likely is significantly more abundant in current forests than in the pre-Euro-American settlement period (White 2001). This may be the result of fires in the late 19th and early 20th centuries that removed conifer seed sources and regeneration from the area. This suggests the need to re-introduce disturbances in the GRPO forest.

The landscape level changes in forest composition and structure from later successional conifer dominated forests to early successional and mature hardwood dominated forests has also changed the fuel characteristics. Rate of fire spread in the boreal forest is directly correlated with the amount of deciduous ground fuel. As the amount of deciduous material increases, rate of spread decreases. Conifers produce more fine fuels

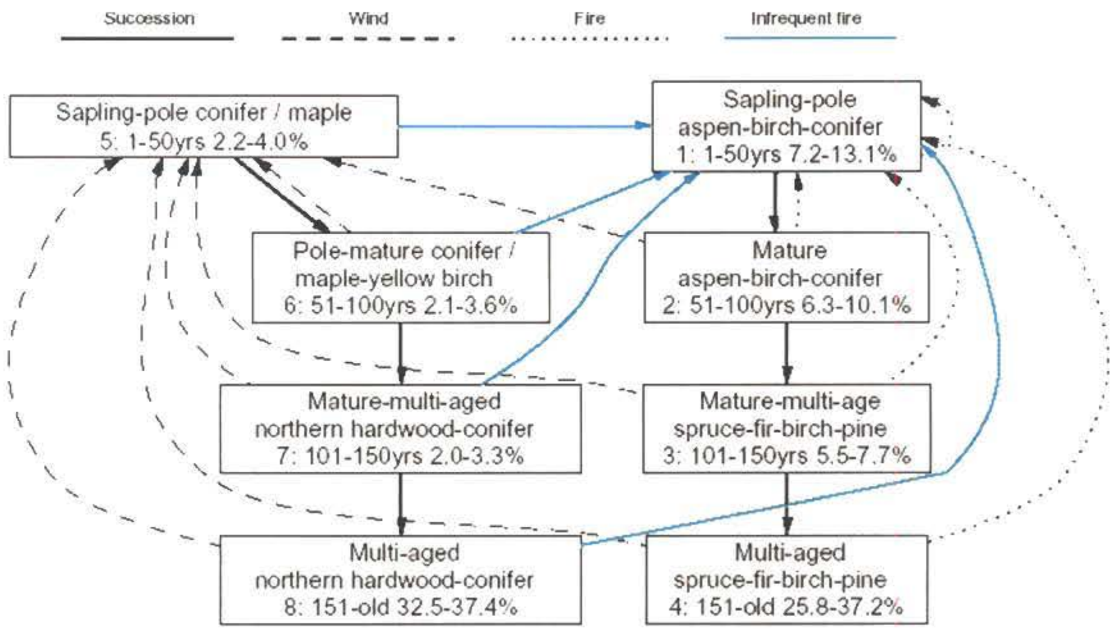


Figure 17. Vegetation growth stages and successional pathways for the northern hardwood-conifer system. Disturbance intervals: Wind = 1000-2000, Fire = 200-400, Infrequent fire = 1000-2000. Source: White et. al. 2002

in the form of needle litter, bark and twigs than deciduous forest. Conifers also retain higher amounts of dead branches (Johnson 1992). While fire suppression likely has had impacts, the changes in fuel quality and quantity may have had a greater effect on fire probability in the southern boreal forest (Johnson and Miyanishi 2001).

Current management in the region (winter logging, even aged management) tends to favor the regeneration of sprouting species (aspen) over conifers. Because of the later successional character of the GRPO forest, there is a good opportunity to restore and maintain compositional characteristics of the pre-settlement forest. The relatively abundant pine, spruce and cedar may provide good opportunities for maintenance and regeneration of these species.

Summary and Conclusions

1) Much of the current forest at GRPO originated after fires that occurred post 1870. Compositionally, forests are similar to those in the region with high abundance of quaking aspen, although there are localized areas of higher conifer abundance. In terms of age structure, GRPO forests have a greater representation of mature and late successional growth stages than is present in managed forestlands in the area. The old, multi-age cedar white pine stands are relatively rare in region.

2) The analysis of increment cores and cross sections shows that there are a number of trees that pre-date settlement era forest disturbances. Some tree samples indicate stand origin dates in the early 1700s.

3) Comparisons of ring-width patterns with major fire years showed varying tree growth responses. Many of the samples showed declines in growth rates in 1936, a well documented year of fire and drought. The old-growth cedars at the Cowboys Rd site show strong positive increases in ring-widths associated with a number of fire years.

4) While the BWCAW data provides the most reliable record of pre-Euro-American disturbance frequencies, other analysis shows that disturbance frequencies varied significantly by subsection and ecosystem type. This underscores the problems with extrapolating disturbance frequencies for the BWCAW beyond the Border Lakes subsection where different soil, climate and topographic conditions may differ.

5) Human caused fires burned over much of the trail corridor from 1870 to 1911.

6) The more moderate climate and mesic soil moisture conditions, coupled with the relatively low frequency of lightning strike ignitions created a fire regime different from that in the BWCAW. Because of the environment at GRPO, conditions favorable for fire ignition and spread occurred less frequently at GRPO than in more drought prone areas such as the BWCAW

7) The mesic conifer dominated forest systems of the GRPO area were subject to a 200-400 year fire cycle for stand replacing fires. Windthrow (1000-2000 year cycle) and insect infestations also influenced forest dynamics. Maintenance fire (20-40 year interval) may have been important for pine dominated stands on dry-mesic sites.

Recommendations

While the evidence indicates that fire return intervals are longer on the GRPO compared with other forests of the region, fire was still the dominant stand-initiating disturbance for these forests. It also was an important maintenance disturbance, reducing competition from and fire-intolerant tree species and shrubs, releasing nutrients, and providing a suitable seedbed for a number of species. Consequently, fire, or at least management practices that emulate fire, does have a role in these ecosystems. However, the spatial extent of the GRPO is much smaller than the scales of fire that have historically occurred in this region. Given the relatively narrow corridor of GRPO, it follows that any sort of prescribed fire treatments should be done cooperatively with the adjacent land owners.

There are management prescriptions that emulate the effects of maintenance fires, including manual removal of brush and understory trees, scarification to expose a mineral seedbed, and creation of canopy gaps. The GRPO, like most areas of northern Minnesota, has an abundance of the mature-to-old aspen cover type. Many of these stands are currently succeeding to balsam fir. An alternate successional pathway that occurs in more dry-mesic landscape conditions leads to the development of a mixed pine overstory; this type is generally underrepresented, as the lack of maintenance fire and subsequent competition from balsam fir have precluded establishment of understory white and red pine. One possible technique to encourage reestablishment of pine would be to remove some of the balsam fir understory and use scarification to expose mineral soil. This would be most effective in drier sites where existing canopy gaps to allow greater penetration of light to the forest floor.

There is a transition along the trail from the lake-influenced systems in the southern part of the trail to the more boreal forests along the upper trail. Various researchers have drawn lines that bisect the trail, corresponding to subsection boundaries (MN DNR), native plant communities (Shadis 2000, White and Host 2000), or soils (MN Soil Atlas). However, these lines were drawn to delineate large landscape features, and are quite imprecise at the scale of the GRPO. Obviously the proximity to Lake Superior is a key factor in moderating local weather patterns along the GRPO, but the degree to which this effect extends inland, and its consequent effect on plant community composition, productivity, and probably fire history remain unknown. We suggest that a fairly simple study based on a set of data-logging temperature-humidity sensors along the trail could provide relevant information on the extent of the lake effect. This information would be useful for more accurately defining the ecological transition that occurs along the trail, which in turn relates not only to historic fire patterns, but also factors such as plant diversity and productivity, as well as risk from fungal pathogens (c.f. White, Brown and Host, 2002).

Acknowledgements

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Appendix A. Dates and information sources of major fire years in northeastern Minnesota. (See figure 13-16).

Date	Source
1727	Heinselman (1973)
1735	White, J.W. 1967. Historical Sketches of the Quetico-Superior. USDA Forest Service.
1755	Heinselman (1973)
1759	Heinselman (1973)
1801	Heinselman (1973)
1803	White, J.W. 1967. Historical Sketches of the Quetico-Superior. USDA Forest Service.
1804	White, J.W. 1967. Historical Sketches of the Quetico-Superior. USDA Forest Service.
1822	Heinselman (1973)
1854	Heinselman (1973)
1860	White, J.W. 1967. Historical Sketches of the Quetico-Superior. USDA Forest Service.
1864	Heinselman (1973)
1871	White, J.W. 1967. Historical Sketches of the Quetico-Superior. USDA Forest Service.
1872	White, J.W. 1967. Historical Sketches of the Quetico-Superior. USDA Forest Service.
1873	Woolworth, A. R. 1993.
1874	White, J.W. 1967. Historical Sketches of the Quetico-Superior. USDA Forest Service.
1875	Heinselman (1973)
1878	St. Paul Pioneer Press, Sept. 1 1878
1878	White, J.W. 1967. Historical Sketches of the Quetico-Superior. USDA Forest Service.
1894	Heinselman (1973)
1894	White, J.W. 1967. Historical Sketches of the Quetico-Superior. USDA Forest Service.
1908	Woolworth, A. R. 1993.
1910	White, J.W. 1967. Historical Sketches of the Quetico-Superior. USDA Forest Service.
1917	Grand Marais Pioneer/Cook County Herald
1921	Grand Marais Pioneer/Cook County Herald
1923	White, J.W. 1967. Historical Sketches of the Quetico-Superior. USDA Forest Service.
1925	Grand Marais Pioneer/Cook County Herald
1926	White, J.W. 1967. Historical Sketches of the Quetico-Superior. USDA Forest Service.
1929	White, J.W. 1967. Historical Sketches of the Quetico-Superior. USDA Forest Service.
1929	Grand Marais Pioneer/Cook County Herald
1933	Grand Marais Pioneer/Cook County Herald
1936	White, J.W. 1967. Historical Sketches of the Quetico-Superior. USDA Forest Service.
1936	Cook County Herald, Aug. 6, 1936
1936	Cook County Herald, July 23, 1936