Dendrochronology and dendroclimatology from bur oak trees in Birds Hill Provincial Park, Manitoba

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***Abstract*:** Living bur oak (*Quercus macrocarpa*) trees were cored at two sites in Birds Hill Provincial Park, Manitoba and used in the construction of chronologies and analysis of dendroclimatic relationships. The first site was situated on a silty calcareous substrate associated with poor water infiltration. Trees were stunted with gnarled branches, generally reaching heights not much taller than 4 to 5 m. A total of 15 trees were cored with the oldest dated tree being 93 years. At the second sampling site, trees were growing on a sandy substrate with excellent drainage. Trees sampled at this site had trunk diameters of 25 cm and larger, and were taller than 10 m. The time interval covered by 13 core samples was 117 years, 1883 to 1999. Standardized ring widths for the entire period of each chronology were correlated with monthly mean temperature and precipitation data for the months of January to December of the current growing year and for May to December of the previous growing season. While both sites produced statistically significant correlations with temperature and precipitation, the relationships did not always appear in the same months. It is hypothesized that different site physical characteristics affect ring growth response to climate variables.

Key words: dendrochronology, dendroclimatology, bur oak, Manitoba

Introduction

Annual growth rings occur in trees in the mid- and high latitudes environments where there are distinct wet and dry seasons or where there is marked seasonality in temperature (Fritts 1976). Variations in ring width are related to age and size of a tree, climate, individual tree and stand disturbance and unexplained variability unrelated to any of the above factors (Nowacki and Abrams 1997). When a tree trunk is viewed in cross-section, concentric bands or rings are visible. Every ring corresponds to a period of vegetative growth. The science of dendrochronology analyses tree rings to establish dates for these rings (Fritts 1976). Samples from a number of trees at a site are cross-dated and measured. This process provides reliable, accurate and exact dating. Dendroclimatology is an application of dendrochronology using dated tree rings to study relationships between the rings and climate and to reconstruct past climate.

Dendrochronology and Dendroclimatology in the Prairies

Commonly, in Canada, trees in mountainous or foothill areas and northern locations are sampled for dendroclimatological studies (Luckman 1993, 1998; Case and MacDonald 1995; Szeicz and MacDonald 1995; Feng and Epstein 1996; Watson and Luckman 2001). Tree growth in these locations is limited by harsh environmental conditions making them sensitive to climate changes (Bradley 1999). Tree-ring width, therefore, frequently manifests some response to the environment.

In the Prairie ecozone, tree species sampled for dendroclimatic research include white spruce in the Cypress Hills Saskatchewan (Sauchyn and Beaudoin 1998), bur oak in Manitoba (St. George, personal communication), Ponderosa pine in South Dakota (Brown and Sieg 1999) and bur oak, pine and juniper in the U.S. northern plains (Sieg *et al*. 1996).

Bur oak samples from North Dakota have provided a tree-ring record to 1676 AD (Sieg *et al*. 1996). This study correlated ring widths to total annual precipitation and spring/summer precipitation of the current growing season. Correlation coefficient (r) values ranged from 0.36 to 0.69 for total annual precipitation and from 0.31 to 0.63 for spring/summer precipitation.

In Manitoba, a flood history reconstruction for the Red River has been completed using bur oak tree ring data collected from riparian forests (St. George and Nielsen 2000). The Manitoba bur oak chronology spans 536 years, 1463 AD to 1999 AD (St. George *et al*. 1999). Living bur oaks found adjacent to the river display sensitivity to variations in river water levels. In a sample of 194 bur oaks, an anatomical ring anomaly, unusually small earlywood vessels, was associated with high magnitude floods in the 19th century. These 'flood rings' appeared in the high magnitude flood events of 1852 and 1826 (Rannie 1998). Similarly formed rings in 1747 and 1538 revealed the occurrence of previously unknown extreme floods on the Red River for those years. The relationship between bur oak ring development and flooding, however, is not simple. For the 1826 event, 24% of the samples showed flood rings and only 5.9% of the samples in 1852 had visible flood rings. Flood ring development, therefore, may depend on a tree's location in the Red River flood plain. In addition, only trees at two sites displayed flood rings. It is, therefore, difficult at this time to conclude whether any characteristics of these sites or proximity to the river played roles in flood ring development. If additional sites reveal flood ring signatures, site characteristics can be analyzed to evaluate flood impact on tree ring development. Flood rings have not yet been discovered for the 1997 flood, one with a discharge similar to 1852. This suggests that flood ring development may be dependent on time of inundation and possibly duration of inundation.

Oxygen isotope analysis of tree rings from two bur oaks sampled along the Red River in Manitoba is in progress (Buhay 2001). This research has revealed a seasonal change in oxygen isotope composition (*^{18}O) in the tree rings. Increased *^{18}O reflects increased moisture input (and potential for spring flooding) and milder temperatures. Occurrence of higher *^{18}O values in winter months, just prior to earlywood growth or in autumn months during latewood formation has been discovered in some years. It is hypothesized that the lack of a signal at one site for some high flow years in the Red River may reflect differing hydrologic regimes between the two sites. One site is at a slightly higher elevation and receives more input from groundwater recharge, especially at times of high water, while the second site may receive a more homogenous input of moisture. Further analysis is still required to investigate relationships between *^{18}O variations and different site characteristics.

Study Area and Site Descriptions

Birds Hill Provincial Park is located in south central Manitoba, approximately 15 km north east of the city of Winnipeg (Figure 1). This part of Manitoba is characterized by a continental-type climate with long, cold winters and short, mild to hot summers. The air temperature range is large and although highly variable, the majority of precipitation falls as rain during the summer months. Limited instrumental climate data are available for the park. Temperature, precipitation and wind were briefly recorded between August and October 1969 and again from May 1988 to November 1992. Climate normals for Winnipeg, the nearest climate station with the longest record were, therefore, used to compare ring width variations with temperature and precipitation data.

Pleistocene continental glaciation shaped the current landscape depositing glacial sediments of clay, silt, sand and gravel. Terrain is relatively flat with some rolling hills and valleys. Gently rolling till capped

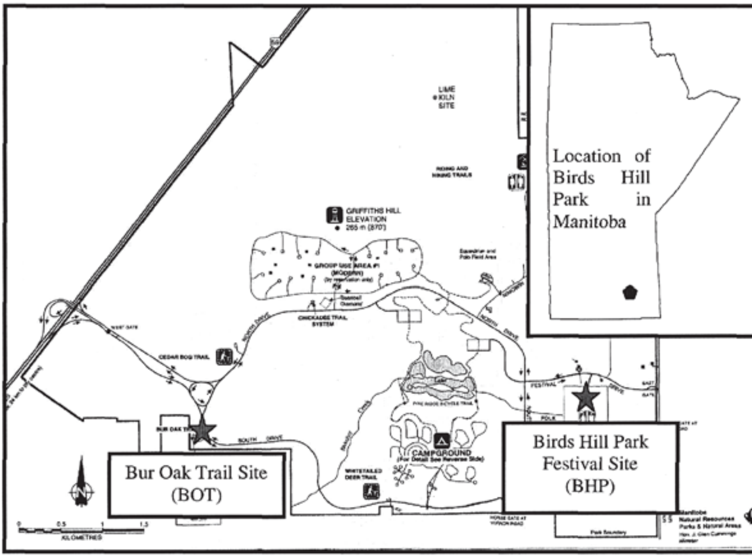

Figure 1: *Location of the Bur Oak Trail (BOT) and Birds Hill Park Festival (BHP) sites in Birds Hill Provincial Park (Source: adapted from Manitoba Natural Resources 2000).*

with prominent glaciolacustrine sediments (an esker) comprises most of the park (Matile *et al*. 2001). The soil is a black chernozem (Scott 1998).

Birds Hill Park is in a Transitional Grassland ecoclimatic region (Scott 1998). Land cover includes patches of prairie grass interspersed with Parkland vegetation dominated by aspen (*Populus tremuloides*) and bur oak (*Quercus macrocarpa*) with shrub undergrowth. Broadleaf, deciduous forests are found along streams and wetlands in areas with poor drainage. Patches of coniferous woodland are also found in the park. Tree ring sampling occurred at two separate stands of trees where bur oak dominated.

Bur oak, a deciduous, hardwood tree common to Manitoba can grow to 15 m high with a trunk diameter of 60 cm in areas of deep, rich soils (Johnson *et al*. 1995). However, in sites with a shallow soil layer, trees are shrubby when young and typically stunted as they age (Farrar 1999). Bur oak can grow for 200 years or longer. They are a drought-resistant species with deep and wide-spreading roots. Because bur oak is also fire-resistant, this tree is well adapted to the Prairie and Parkland environment where fire previously was a common occurrence.

Living bur oak trees were sampled at two sites (Figure 1). The Bur Oak Trail (BOT) site has a silty calcareous substrate with poor water infiltration (Matile *et al*. 2001). Wetland areas were in proximity to this site. Trees were stunted with gnarled branches, generally reaching heights not much taller than 4 to 5 m. There was also a dense distribution of trees at this site with heavy shrub undergrowth. The Birds Hill Park Festival (BHP) site has a sandy substrate with excellent drainage (Matile *et al*. 2001). Trees sampled at site BHP had trunk diameters of 25 cm and greater, and were taller than 10 m. Trees were more widely separated interspersed with grassy patches and only light shrub undergrowth.

Chronology Construction

A total of 13 trees were sampled at site BHP and 15 from site BOT. Trees were cored with a 16-inch or 24-inch Swedish increment borer. Coring involved inserting the boring tool into the tree at about breast height and penetrating the tree through its centre pith to ensure growth rings for the life span of the tree were acquired. The coring procedure was the same as used by St. George *et al*. (1999) to develop a bur oak chronology for the Red River Basin. Core samples were inserted into straws, labeled, and allowed to dry for approximately 10 weeks before being mounted in wooden, grooved blocks. Samples were then sanded and polished to make the rings more visible under a microscope.

Generating a tree-ring chronology for each site and measuring ring width involved using a Velmex Tree Ring Measuring System. Each core was placed on a moveable platform under a Nikon photomicroscope connected to a television camera displaying an image of the tree rings. Dating was accomplished by counting growth rings beginning at the bark and proceeding inward. An ordinary ink pen was used to label reference dates. On a core, the outermost ring, nearest the bark was known to be 2000, the year sampling was conducted. The start of each decade (i.e., 1990, 1980, 1970, and so on) was shown by one dot on the core sample. At the 50-year age of a tree, two dots were drawn on the sample, and at 1900 and 2000, three dots indicated a new century. The time interval covered by core samples from the BHP site was 117 years, 1883 to 1999. The BOT samples spanned 93 years from 1907 to 1999. Nine of the 13 trees from the BHP site started growing early in the 20th century, prior to 1911 (Table 1). No BOT sample was dated earlier than 1901; in fact the oldest tree had a date of 1907 (Table 1). The BOT samples displayed a larger range of decades when growth began for a tree, with some samples

Table 1: *Number of trees in chronologies beginning in each decade.*

Site	Total number of trees cored	number of trees in chronology beginning						
		1900 or earlier	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950	1951 or later
BHP	13	2	7	2	1	1	0	0
BOT	15	0	2	2	3	2	4	2

starting in each decade. This may reflect a higher incidence of forest canopy openings and increased opportunities for germination.

The tree ring measuring system included a digital counter connected to a computer enabling measurement and recording of ring widths for use in cross dating. Cross dating was accomplished using the computer program COFECHA developed by Grissino-Mayer *et al.* (1996). Trees in a particular area can be expected to show similar patterns of growth since they will be influenced by similar environmental factors (Nowacki and Abrams 1997). Cross dating with the COFECHA program involved comparing ring widths of each core sample at a site to find similar patterns of growth among the trees. When similarities were identified among the samples, dates of ring formation were confirmed and a chronology established based on the synchronization of ring width patterns. Table 2 lists a selection of COFECHA program summary statistics for each sample.

For the 13 BHP samples, measured mean raw ring width was 1.75 mm with a standard deviation of 0.70 indicating moderate to fast growth (St. George, personal communication). The smallest ring width measurement was 0.32 mm in 1980; the largest was 5.21 mm in 1923. Mean raw ring width for the 15 BOT samples was 1.0 mm with a standard deviation of 0.40 mm. The lower mean signifies slower growth and less wood added annually than the BHP trees (St. George 2001, personal communication). BOT extreme measurements were smaller than BHP values, ranging from a minimum of 0.22 in 1964 and a maximum of 3.17 mm in 1955.

The sensitivity statistic (Table 2) compares width values of two successive years and expresses how reactive a tree species is to annual growth stimuli based on ring width variability (Schweingruber 1988). Values for sensitivity range from 0 to 2.0, lower values indicating less response to environmental stimuli (complacency) or fairly stable ring width sizes over the years. Larger values indicate a higher degree of annual variability (sensitivity) to environmental conditions or widely fluctuating ring widths year to year (Fritts 1976). Mean sensitivity for trees at the

Table 2: *A selection of chronology statistics for samples at the BHP and BOT sites.*

sample number	chronology	mean ring width (mm)	standard deviation	mean sensitivity	auto correlation
BHP1a	1883-1999	1.62	0.712	0.188	0.842
BHP2a	1901-1999	1.32	0.490	0.174	0.806
BHP3a	1888-1999	2.25	0.989	0.176	0.854
BHP4a	1901-1999	1.64	0.667	0.180	0.830
BHP5a	1919-1999	2.21	0.994	0.224	0.789
BHP6a	1906-1999	3.07	0.690	0.179	0.458
BHP7a	1901-1999	1.35	0.643	0.270	0.706
BHP8a	1923-1999	2.05	1.023	0.188	0.858
BHP9a	1911-1999	1.34	0.613	0.208	0.666
BHP10a	1934-1999	1.07	0.396	0.144	0.869
BHP11a	1901-1999	1.15	0.502	0.234	0.702
BHP12a	1908-1999	1.98	0.682	0.179	0.775
BHP13a	1904-1999	1.66	0.700	0.212	0.786
All samples		1.75	0.702	0.197	0.765
BOT1a	1913-1999	0.70	0.212	0.241	0.391
BOT1b*	1922-1999	0.73	0.281	0.241	0.682
BOT2a	1942-1999	0.83	0.507	0.290	0.788
BOT3a	1945-1999	1.09	0.308	0.308	0.575
BOT4a	1922-1999	0.63	0.225	0.250	0.595
BOT5a	1929-1999	0.96	0.327	0.185	0.755
BOT6a	1907-1999	1.31	0.644	0.212	0.846
BOT7a	1943-1999	1.33	0.381	0.193	0.601
BOT8a	1935-1999	1.27	0.309	0.178	0.618
BOT9a	1919-1999	1.08	0.468	0.246	0.774
BOT10a	1910-1999	0.96	0.525	0.288	0.691
BOT11a	1932-1999	0.81	0.430	0.213	0.739
BOT11aa**	1973-1999	0.68	0.263	0.180	0.788
BOT12a	1942-1999	1.49	0.501	0.219	0.702
BOT20a	1954-1999	1.12	0.472	0.217	0.838
BOT21a	1922-1999	0.99	0.452	0.233	0.755
BOT22	1964-1999	0.87	0.289	0.192	0.720
All samples		1.00	0.397	0.228	0.690

* A second core from the same tree

** A partial core broken from BOT11a

BHP site was 0.20 and slightly higher, 0.23, at the BOT site. Trees at both sites were generally complacent not showing dramatic changes in ring width related to environmental conditions although site BOT is slightly more sensitive to some growth forcing factor.

The first-order autocorrelation statistic (Table 2) quantifies the extent to which growth in one year was influenced by the previous year(s) (Fritts 1976). Higher values mean radial growth in one year was influenced by conditions the previous year. For both sites, autocorrelation values were fairly high, exhibiting a mean of 0.765 for the BHP samples and 0.690 for the BOT samples.

Tree ring widths are typically influenced by a variety of non-climatic factors and, therefore, show trends or patterns of growth related to such things as tree aging, trunk diameter increase, competition and even micro-scale site characteristics. The most common growth trend is a pattern of decreasing ring width with age (Fritts 1976). As a tree gets older, it loses vigour because increasing trunk diameter presents more surface area for a ring to form (Foster and LeBlanc 1993). The computer program ARSTAN (Grissino-Mayer *et al*. 1996) was applied to statistically standardize or remove growth trends. Figure 2 illustrates the removal of this growth trend from sample BHP9a. The growth of trees at the BHP site is influenced more by aging and decreasing ring width trends. This is probably related to the more open site conditions allowing BHP trees to grow with less competition for light and nutrients. BOT trees were all densely packed with heavy shrub undergrowth.

Figure 3 shows the completed, compiled chronologies for site BHP and site BOT. Generally, the BHP and BOT chronologies exhibited common variability at both sites although some asynchronous trends were visible.

While peaks and valleys were similar in each chronology, the BOT trees showed a stronger response in ring width variation confirming the slightly higher sensitivity value shown in Table 2. An extended period of below average ring widths appeared at both sites in the 1960s. Smaller widths also prevailed between 1910 and 1920 and in the 1930s. In the 1930s, however, BOT trees appeared to show greater sensitivity than BHP trees. Ring widths for BOT trees remained below average values for a longer period of time. Larger ring widths were visible in the 1940s, 1950s and 1970s.

For all the standardized widths, measurements were ranked listing smallest to largest rings and the year they occurred for each sample. Then, years of occurrence of the three smallest and three largest detrended ring widths were identified. The 1960s had the most trees, 28, with extremely

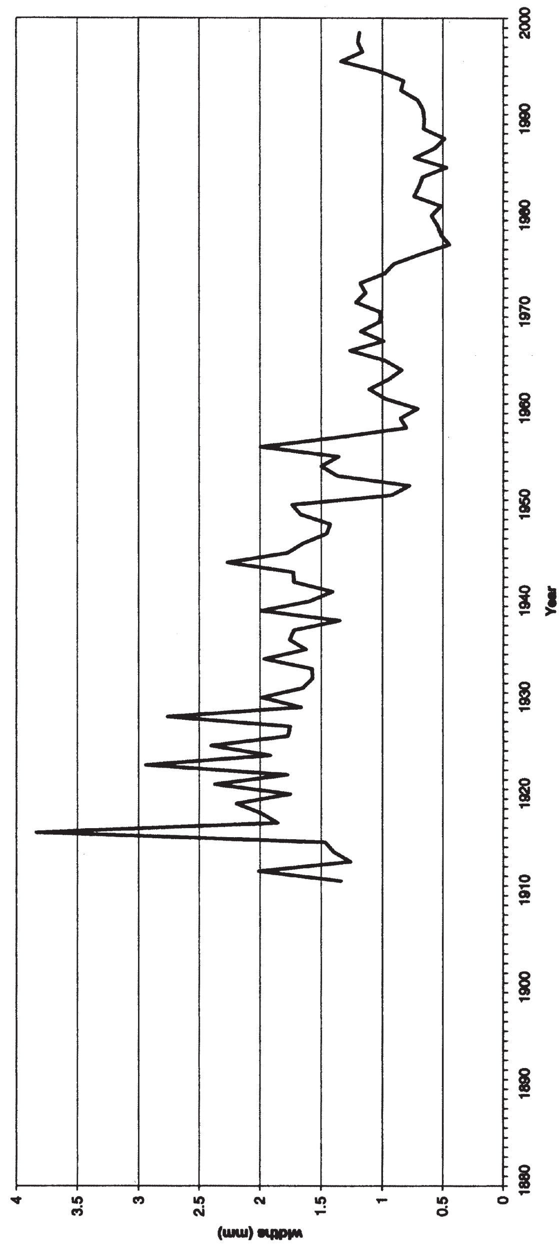

Figure 2: *Raw measured tree ring widths (top) and ring widths detrended with ARSTAN (bottom) from sample BHP9A at Birds Hill Park Festival site.*

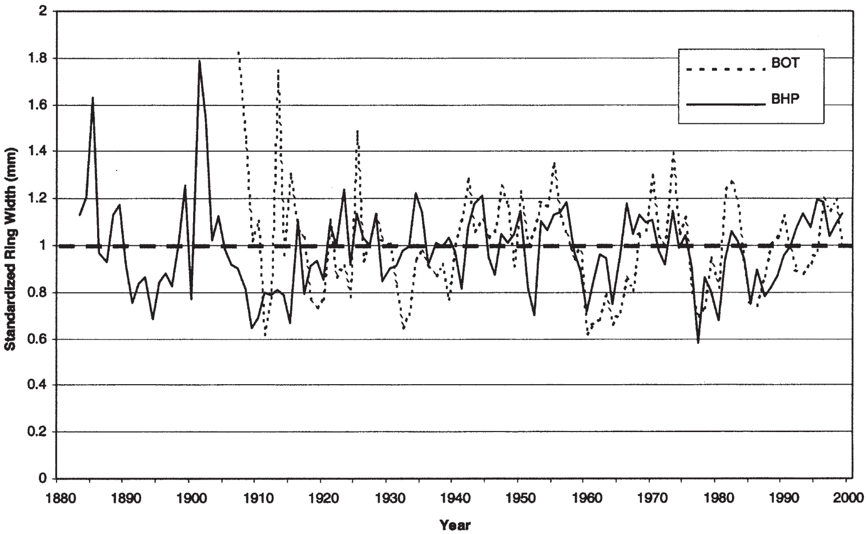

Figure 3: *Bur Oak Trail (BOT) and Birds Hill Park Festival (BHP) site chronologies.*

low widths followed by the 1930s with 13 (Figure 4). Drought in the Prairies during the 1930s and 1960s is well documented (e.g., Dey 1982; Bonsai *et al*. 1993). Environment Canada (2001) ranked 1960 and 1961 as the two driest years in the Canadian Prairies in the 20th century and annual precipitation records at Winnipeg identify 1961 as the driest year on record since 1872. The 1970s and 1980s both had 11 trees with some of their lowest widths and the decade of 1910 to 1919 had 10 trees. The 1970s also recorded some of the largest ring widths (14 trees). With a combination of some of the smallest and largest ring width chronologies, the 1970s decade showed the most variability. Large ring widths were found in the 1950s (13 trees) and 1940s (12 trees). Additional analysis is required to compare dry and wet conditions with the ring width variability shown in Figures 3 and 4.

Tree Ring Width and Climate Correlations

Correlation analysis was employed to compare ring widths at each site with temperature and precipitation parameters. Statistically significant values of *r* suggest some control by the climate variable. Correlations were tested using the one-tailed t-test. Significance levels ranged between

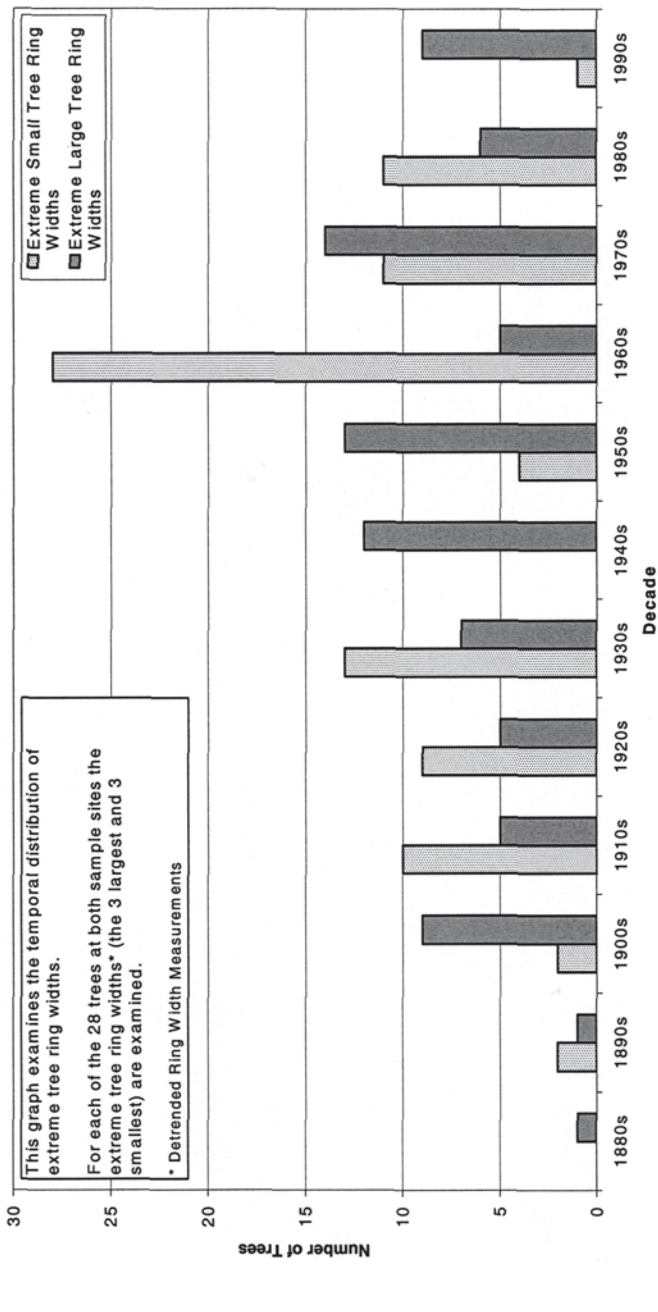

Figure 4: *Distribution of extreme ring widths by decade.*

0.0005 and 0.1 for temperature correlations and between 0.005 and 0.1 for precipitation correlations. Because *r* values were relatively small, ranging from approximately 0.1 to 0.4, other environmental factors, such as substrate composition, competition or biological agents also influenced growth response and may play a more important role in determining ring width size for bur oak at the BOT and BHP sites. These correlations with climate are, however, still relevant because they show if relationships exist and the strength of those relationships.

Standardized ring widths for the entire period of each chronology were correlated with monthly mean Winnipeg temperature data for the current growing year and for May to December of the previous year. Various studies have shown significant relationships between tree growth and climate of both the current growing season and previous years (e.g., Stockton and Meko 1983; Larsen and MacDonald 1995; Sieg *et al*. 1996; Watson and Luckman 2001).

A total of five significant negative correlations with temperature and one positive correlation were derived for the BOT site (Figure 5). One-tailed t-test significance levels for the correlations ranged between $p<0.0005$ to $p<0.1$. Perhaps the positive correlation in December is related to a combination of temperature and precipitation input, such that a warm December is a wetter December. Six significant negative correlations with temperature appeared at the BHP site (Figure 6). T-test significance levels ranged between $p<0.01$ to $p<0.1$

Both sites showed relationships with temperatures of the previous year, the BOT site with three months, May, June and July with negative correlations and the BHP site with only one significant negative correlation (July). Negative correlations with the months of May and June in the current growing year were also demonstrated at both sites. Most significant negative temperature correlations were found in May of the current growing season at the BOT site and in the previous July at the BHP site. Negative correlations signify higher temperatures produced smaller ring widths and lower temperatures resulted in larger rings. Balling *et al*. (1992) proposed significant correlations with climate variables in the previous growth year resulted because of a ‘feedforward effect’. That is, the preceding year’s weather had an impact on growth during that year and in the following year. Temperature and/or moisture stress during the previous season may, therefore, weaken a tree’s developmental response in the following growth year(s). With warm summer temperatures increasing evapotranspiration, moisture stress in the previous year may have more impact on BHP trees as shown by the higher correlation value (Figure 6). In the current growing

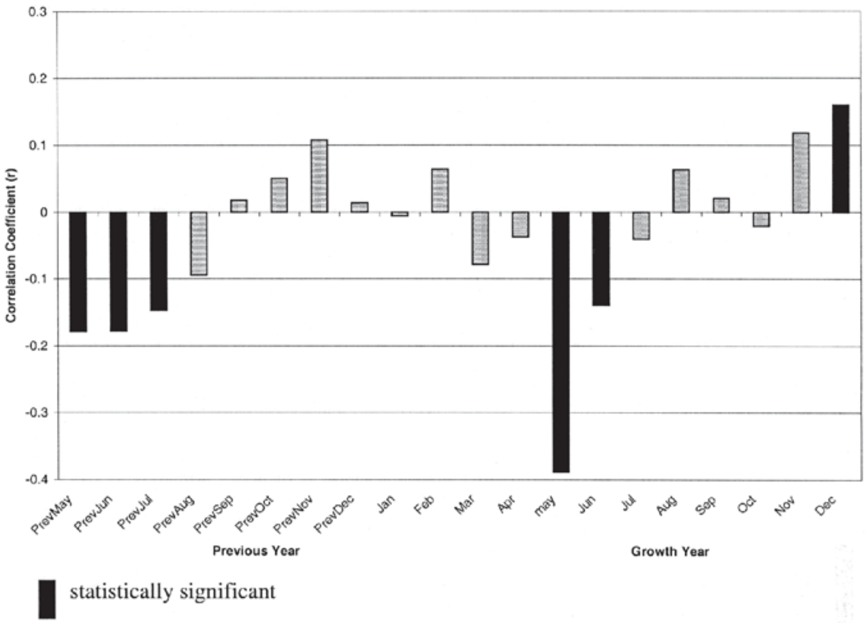

Figure 5: *Correlation coefficients between standardized ring widths and monthly mean temperature for BOT trees.*

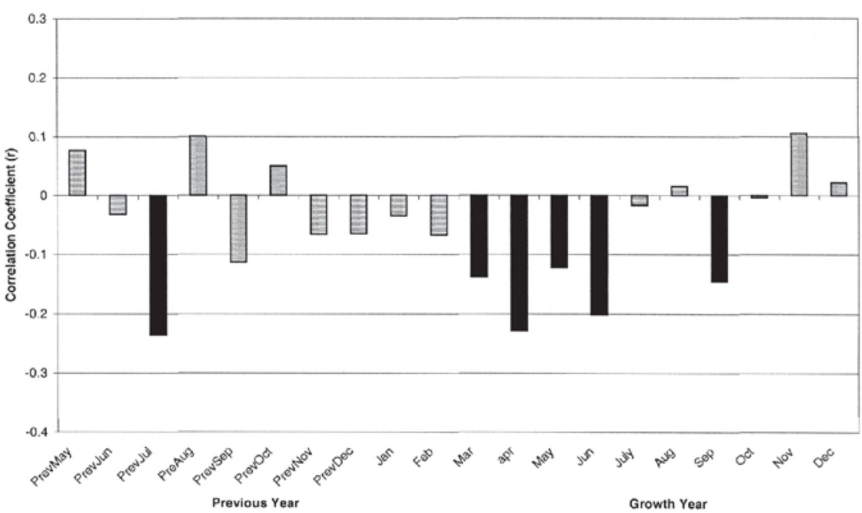

Figure 6: *Correlation coefficients between standardized ring widths and monthly mean temperature for BHP trees.*

season, trees at the BHP site became sensitive to temperature sooner and over a longer period than trees at the BOT site. Warmer temperatures in spring may melt snow more quickly but also increase evapotranspiration. Evapotranspiration rates may be more important to BHP trees because moisture from snowmelt or precipitation percolates more efficiently through the sand and gravel substrate. For BOT trees, moisture remains available to roots because infiltration is slower in silty substrate so evapotranspiration does not become important until later in the spring.

Correlations of standardized ring widths to Winnipeg monthly precipitation totals resulted in three significant positive correlations and one negative correlation at the BOT site. T-test significance levels ranged between $t<0.005$ to $p<0.1$. Three significant positive and one negative correlation also occurred at the BHP site. Significance levels ranged between $p<0.01$ to $p<0.1$. The highest significant (positive) correlation was found in January at the BOT site (Figure 7) and in June at the BHP site (Figure 8). Positive correlation values indicate higher precipitation resulted in larger ring width formation and lower precipitation resulted in smaller ring widths. Common positive correlations at each site occurred for the previous September and current growing season January. Both sites likely depend on stored moisture from months of the previous growing year and from winter snowmelt. The BOT site was slightly more respondent to winter precipitation accumulation as a moisture source for its growing season. Occurrence of positive correlations in the previous July at the BOT site could also indicate more reliance of BOT trees on stored moisture in the next year. Since the BOT site had no significant correlations during the current year, trees may be adapted to having less moisture available through direct precipitation input during the growing year. Therefore, moisture from the previous year and winter moisture are sufficient for growth requirements of BOT trees. Sand and gravel substrate at the BHP site allows better drainage so trees do not only depend on stored subsurface water but also require additional moisture from rain during the growth season (positive June correlation).

Summary

Of the 11 significant correlations between monthly mean temperature and standardized tree ring widths, 10 were negative indicating warmer temperatures were related to smaller rings. A total of six positive and two negative significant correlations were found between monthly precipitation and ring widths. Positive correlations suggest higher precipitation

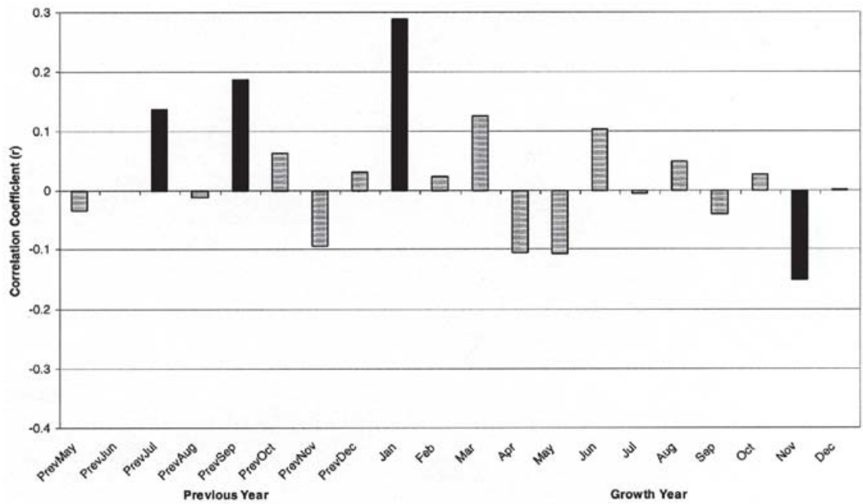

Figure 7: *Correlation coefficients between standardized ring widths and monthly mean precipitation for BOT trees.*

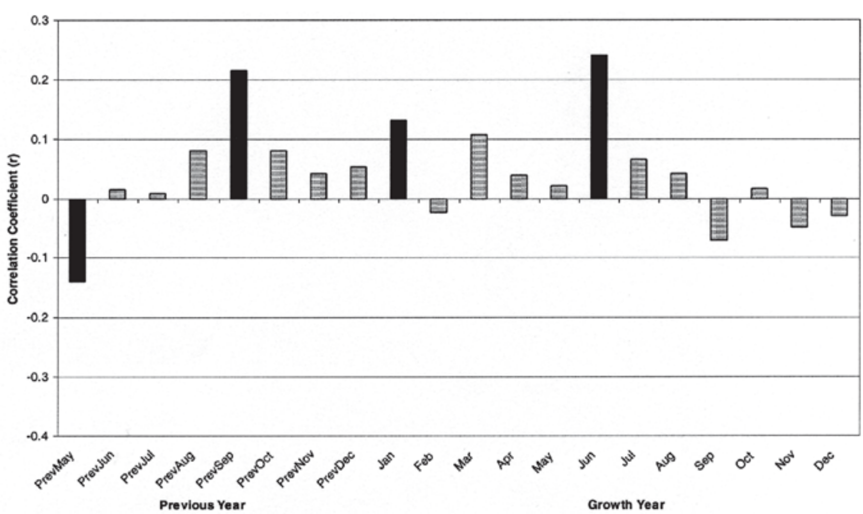

Figure 8: *Correlation coefficients between standardized ring widths and monthly mean precipitation for BHP trees.*

generated larger rings, lower precipitation smaller rings. At the BHP site, there were positive correlations with precipitation in the previous autumn and winter and during the current growing season. With the BOT trees, positive correlations with precipitation were found only in autumn or winter of the previous year. Timing of the correlations suggests that both sites relied upon soil moisture storage from any autumn precipitation and from snowmelt. With bur oaks at Birds Hill, a store of subsurface water appears to supply sufficient moisture for trees at the less permeable BOT site during the growing season since significant positive relationships with precipitation did not manifest during the current year growing season. The BHP site, however, required additional water from rain during the growing season because permeable substrate allowed moisture to percolate deeper through the ground. In fact, the most significant relationship between ring growth and precipitation at the BHP site occurred in June of the current growing season, when most earlywood development occurs.

No study has yet definitively substantiated a relationship between Manitoba bur oak growth and different surface conditions. St. George and Nielsen (2000) have hypothesized that flood ring development in Manitoba bur oak growing along the Red River may be dependent on a tree's location in the Red River flood plain and local site characteristics. After analyzing oxygen isotope concentrations in annual tree rings from two trees at two sites along the Red River, Buhay (2001) has also speculated on the response of Manitoba bur oak trees to varying moisture supplies. Because oxygen isotope concentrations measured in the rings were not synchronized at the two sites, it was hypothesized that different hydrologic regimes influenced moisture conditions at the two sites. Trees at one site sit at a slightly higher elevation and receive more moisture from groundwater recharge when precipitation input is increased. These trees appear to have a greater dependence on direct precipitation input. Trees at the second site may receive a more homogenous input of moisture. In Europe, Cufar and Levanic (1999) found oaks growing in dry sites were more reliant on direct precipitation input as a water supply. Trees growing in lowland sites with swampy conditions and sufficient soil water were not as dependent on direct precipitation input during their growing season. Foster and Brooks (2001) produced chronologies for slash pine (*Pinus elliottii*) sampled from dry and wet sites in Florida. After correlating growth rings with climate variables, they reported variations in growth response at the different sites. Pines growing on sites with shallow water tables displayed negative correlations with increased water input and pines growing on sites with deeper water tables displayed positive correlations with increased water input. Future analysis of the Birds Hill bur oak samples will involve selecting case study years with small and large ring widths to verify the correlation patterns at both sites and further investigation of site characteristics.

Bur oak tree ring width variability in the Manitoba Prairie environment is sensitive to moisture input and must be dependent on the inter-relationships of temperature and precipitation input during the growing season and in previous years. Other variables (e.g., competition for light and moisture and biological influences) also influence radial growth of tree rings. Substrate composition especially appears significant in how bur oaks respond to precipitation input at different seasons. This study has described climate-ring width relationships derived from bur oak trees at Birds Hill Park. Initial results indicate that the same tree species does not experience the same responses to the same climate forces. Bur oak trees growing in different substrate environments may be showing evidence of adaptability to the differing physiographic conditions by their water requirements. This preliminary research suggests that substrate character may have to be considered when bur oak tree ring chronologies are developed in the Canadian Prairies and U.S. northern Plains. Additional research at other sites and more detailed analysis of site characteristics is required to confirm the responses of bur oak to their environment.

Acknowledgements

Thanks to Scott St. George, Geological Survey of Canada and Erik Nielson, Manitoba Geological Survey for helping me to learn about the process of tree ring analysis and for the use of their tree ring laboratory.

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