

# THE DENDROCLIMATOLOGICAL

## Potential of White Birch (*Betula papyrifera*) in Labrador, Canada

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### ABSTRACT

**Context:** Sites where trees are at the extreme of their climatological limits are the best suited for building climate reconstructions. White birch (*Betula papyrifera*) are often found in Canada pressing the northern extent of the boreal forest. **Aims:** This study tests the dendroclimatological potential of white birch near its northern range limit by comparing a master chronology from Labrador City, Newfoundland, Canada (N52.58 W66.55) with temperature and precipitation data from the region. **Methods:** Twenty trees were sampled twice each and crossdated to create a standardized master chronology. Temperature and precipitation data spanning 1960 – 2008 were compared to a standardized version of the master chronology. **Results:** Core samples spanned 160 years (1851-2010) with a mean age of 135. Series exhibited high intercorrelation (0.425), mean sensitivity (0.374) and autocorrelation (0.808) values. The standardized chronology exhibited strong correlations with mid-summer temperature, as well as a minor relationship with moisture availability in the previous summer. **Conclusions:** The high mean sensitivity is indicative of other regional deciduous chronologies and represents heightened sensitivity to short-term climate variance. In comparison to previous dendroclimatological studies in the area, white birch appears to have a less muted climate signal, as evidenced by its strong annual growth correlations with June and July temperature. The weak association with precipitation is indicative of other species in Labrador. This study demonstrates that high-quality dendrochronological data can be attained from white birch trees in the Labrador region and consequently, this species should be recognized as potentially a key indicator of temperature trends in the region. **Keywords:** *dendrochronology, dendroclimatology, Betula papyrifera, Labrador, temperature trends.*

### Introduction

Dendrochronology is the study of tree rings as proxy records of environmental inputs (Speer 2010). Within this discipline is the subdiscipline of dendroclimatology, which relates past and

present climate conditions such as temperature and precipitation to changes in tree growth (Kaennel and Schweingruber 1995). The use of tree-ring records has been one of the key indicators used in climate change studies on local (Elliott 2011), regional (Linderholm, Moberg and Grudd 2002) and global scales (Mann, Bradley, and Hughes 1998).

In temperate climates, local site conditions often dominate the dendrochronological signal of trees (Schweingruber, Braker, and Schar 1979). More northern climates, where trees are often under extreme climatic regimes, tend to produce chronologies that primarily reflect climatological factors (Fritts 1976; Speer 2010). As it is these same northern climates that are undergoing the most severe shifts in climate today (Solomon et al. 2007), dendroclimatological studies looking to develop strong historical proxy records of climate change would benefit from focusing on circumpolar species (Lloyd and Fastie 2002). Labrador, being the most northern portion of eastern North America is an attractive region to explore for dendroclimatological studies, and has recently been attracting specific research attention to these ends (Dumeresq 2011; D'Arrigio et al. 2003; Nishimura and Laroque 2011; Trindade et al. 2011).

Using a single species for dendroclimatological study has historically been the most commonly used approach as it simplifies sampling and analysis (Forbes, Fauria and Zetterberg 2010; Helama et al. 2005; Oberhuber, Stumb, and Kofler 1998). More recently, a multispecies approach is often prescribed as it helps to develop ecosystem level responses and corroborate results by comparing different species responses (Dumeresq 2011; Laroque 2002; Nishimura 2009; Trindade et al. 2011). Recent dendrochronological research in southern Labrador has assessed the climate signals embedded in black spruce (*Picea mariana* (Mill.) Britton, Sterns, Poggenb.), white spruce (*Picea glauca* (Moench) Voss), balsam fir (*Abies balsamea* (L.) Mill.), eastern larch (*Larix laricina* (DuRoi) K. Koch), and trembling aspen (*Populus tremuloides* Michx.) chronologies (Dumeresq 2011; Kershaw and Laroque 2012; Nishimura and Laroque 2011).

White birch (*Betula papyrifera* Marsh.) sparsely populates southern Labrador, where it is pushed to the edge of its climatological northern range. The species has an extensive latitudinal range to the south and following the principle of ecological amplitude, its northern most populations will be of greatest dendrochronological value (Fritts 1976). Other dendroclimatology studies in Eurasia have applied the principle of ecological amplitude when selecting birch at the limit of their climatological range, generating important insight into the climatological conditions of the region (Yu et al. 2007). To date, no known chronologies have been developed for white birch in Atlantic Canada and the dendroclimatological utility of the species in the region has yet to be assessed. Being a deciduous species, birch is likely to be more sensitive to year-to-year climate variation than the evergreens in the area (Centre et al. 2010). Trembling aspen, another potential deciduous species for analysis in the area, was not present in great enough numbers or of great enough age to be sampled and assessed effectively.

The objective of this study is to develop a crossdated white birch tree ring chronology for the forest north of Labrador City and to assess its correlation with temperature and precipitation trends in the region. In doing so, it is intended that a viable deciduous hardwood species will be identified for dendroclimatological research in Labrador. This project will guide later research in the region looking for data sets to complement and corroborate findings from dominant evergreen species traditionally assessed in dendroclimatological research.

## Materials and Methods

### *Site Description*

The site was selected approximately 3 km north of Labrador City (N52 58.726 W66 55.277) (Figure 1), situated on a hill side with a mixed white birch/white spruce canopy and a dense alder understory (Figure 2). In this region, the summers are relatively short and cool with an approximately 100-120 day growing season and winters that are long and severe with deep snow cover (Bell 2002). The Wabush climate station, which is 6.7 km from the site (Figure 1), has a mean annual temperature of  $-3.2^{\circ}\text{C}$ , a mean winter temperature of  $-20^{\circ}\text{C}$  (DJF), and a mean summer temperature of  $12^{\circ}\text{C}$  (JJA). The mean annual precipitation is 1024 mm (Environment Canada 2010).

Twenty trees were sampled at breast height (DBH) with two cores taken at  $>90^{\circ}$  separation using standard 5.1mm increment borers. For those trees on ground with a slope significant enough to affect growth, samples were taken  $180^{\circ}$  apart and perpendicular to the slope. Samples from the site were labelled and bundled and then transported to the Mount Allison Dendrochronology Laboratory for processing and analysis.

### *Laboratory Analysis*

Cores were mounted on wooden boards, and samples were

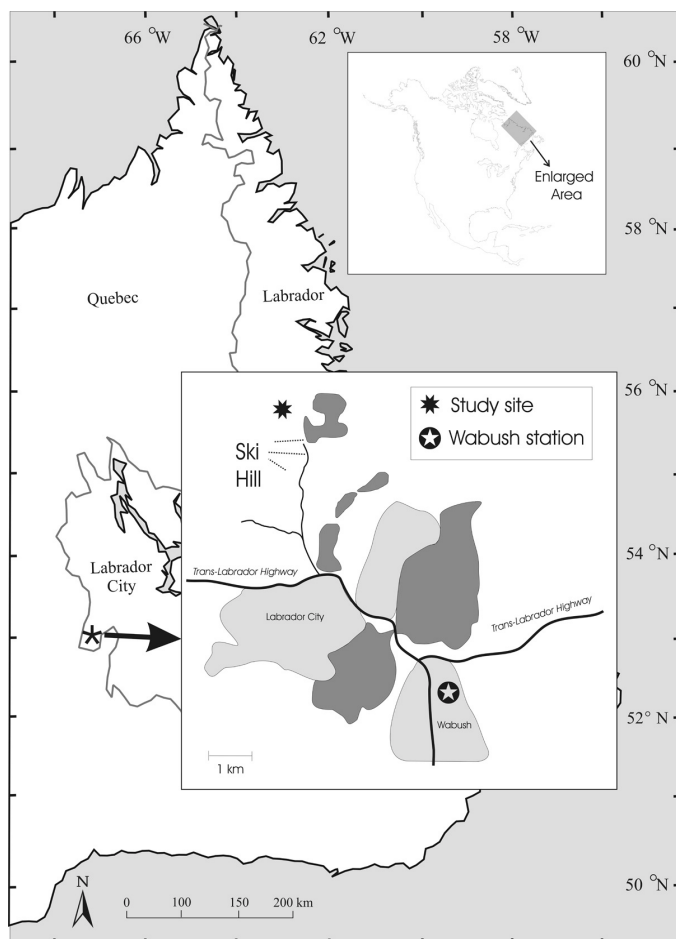


Figure 1. Map of the study site's location relative to Labrador City and the Wabush Environment Canada climate station.



Figure 2. A view of the site with two of the measured trees visible.

sanded with progressively finer sandpaper from 80 up to 600 grit and then polished with a buffing wheel. Ring widths were visually crossdated and then measured with a Velmex stage system, a 63x microscope, and the program J2X. Each core's growth-increment pattern was checked for signal homogeneity using the program COFECHA version 6.06p (Grissino-Mayer 2001; Holmes 1983). Where crossdating inconsistencies arose that required correction, cores were rechecked with the guidance of COFECHA outputs and pointer years (exceptionally wide or narrow rings) recognizable across multiple cores. Pointer years consistently used to crossdate the series were 1881, 1945, 1965, 1971 and 2005.

After the master ring-width chronology was developed, cores were standardized using the program ARSTAN\_41d (Cook 1985) with negative exponential regression ( $k > 0$ ), linear regression

(slope  $> 0$ ), or a line through the mean. Standardization removed any chronology trends due to decreasing ring width with age (Helama et al. 2004). Standardized cores were then reamalgamated into a standardized master chronology using ARSTAN's robust mean-averaging technique. None of the 40 series were removed from the data set in development of the final master chronology.

DENDROCLIM 2002 was used to assess which mean monthly temperature variables within an 18 month window (prior-year April to current-year October) correlated with the standardized ring-width chronology (Biondi and Waikul 2004). Results were assessed at two significance levels; correlation analysis, which derived correlation values (CV), and principle component analysis, which derived response values (RV). The use of two significant tests is due to the elevated threshold of significance for RV relative to CV, but the importance of still recognizing those CV that don't register as significant with RV analysis (Biondi and Waikul 2004). The standardized master chronology developed in ARSTAN and the homogenized mean monthly temperature and precipitation data acquired from Environment Canada's nearby Wabush climate station [Station # 8504175] (Environment Canada 2010) were used in analysis.

Results

The core samples spanned 160 years (1851-2010) with a mean-tree age of 135 (Figure 3). Growth increment chronologies exhibited significant intercorrelation (0.425) and high mean sensitivity values (0.374) (Grissino-Mayer 2001). The autocorrelation of the master, which measures the agreement between two consecutive year's growth, was (0.808) (Table 1).

Analysis of the master chronology's relationship to climate data spanned 48 years (1960-2008) and involved all 40 series (Figure 3). The radial-growth response to climate variables for white birch was strongly influenced by mid-summer temperatures (Figure 4) with a more minor relationship to moisture availability during June the previous summer (CV= 0.26) (Figure 5). Specific months of significance for temperature's effect on growth were June (CV=0.51) and July (CV=0.61,) (Figure 4).

The more statistically robust response values reported no significant relation between radial-growth and precipitation. Temperature's relationship to radial-growth exhibited strong positive

mean series length (years)	number of trees (cores)	mean series intercorrelation	average mean sensitivity	unfiltered autocorrelation
134.6	20 (40)	0.425	0.374	0.8-08

Table 1. Descriptive statistics for the white birch (*Betula papyrifera*) chronology. The 99% confidence level for series intercorrelation is 0.3281.

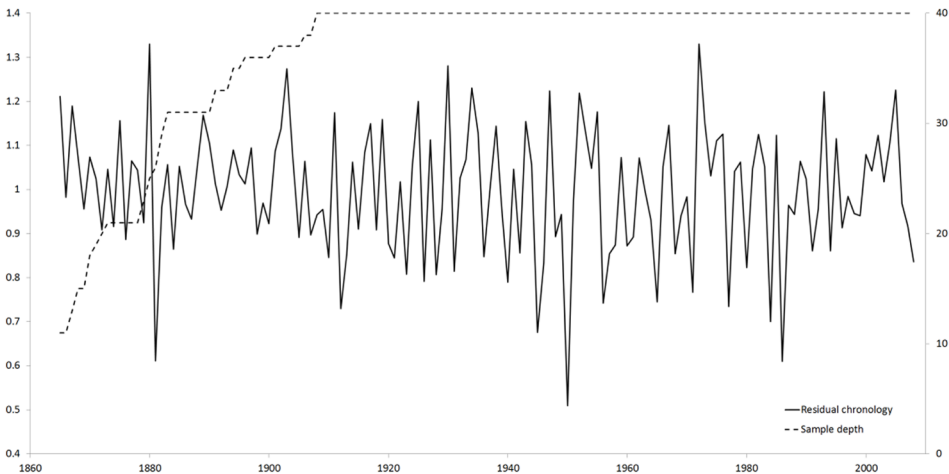


Figure 3. Master chronology's sample depth (0-40 cores) and residual values for each year's growth (deviation from chronology mean).

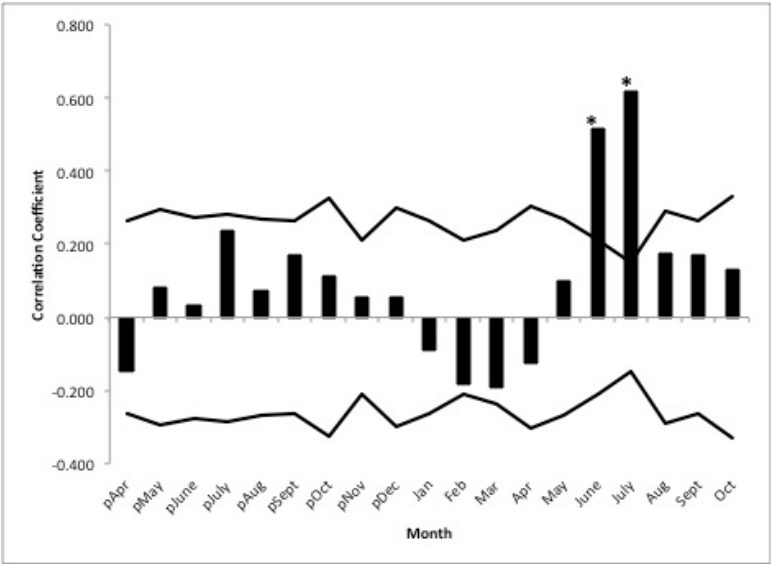


Figure 4. DENDROCLIM 2002 correlation value (CV) results for temperature's relation to growth increments organized by month (previous year April to current year October). Bootstrap correlation test requirements for 95% confidence denoted by the solid line. Starred months denote statistically significant correlations.

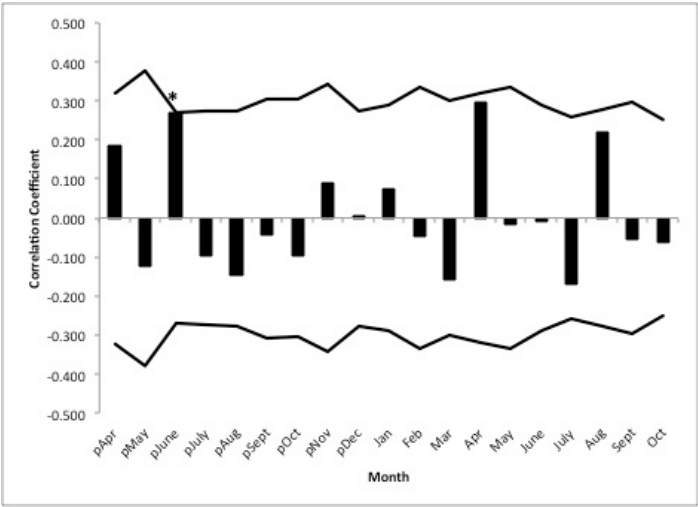


Figure 5. DENDROCLIM 2002 correlation value (CV) results for precipitation's relationship to growth increments organized by month (previous year April to current year October). Bootstrap correlation test requirements for 95% confidence denoted by the solid line. Starred months denote statistically significant correlations.

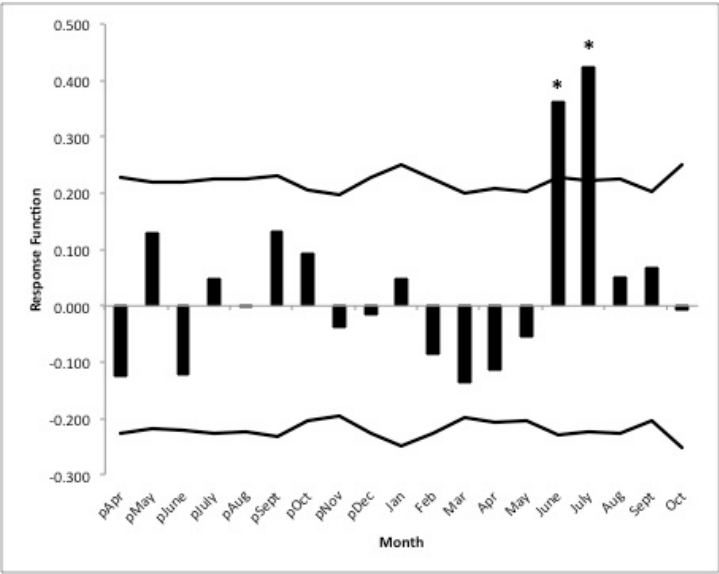


Figure 6. DENDROCLIM 2002 response value (RV) results for temperature's relationship to growth increment organized by month (previous year April to current year October). Bootstrap correlation test requirements for 95% confidence denoted by the solid line. Starred months denote statistically significant correlations.

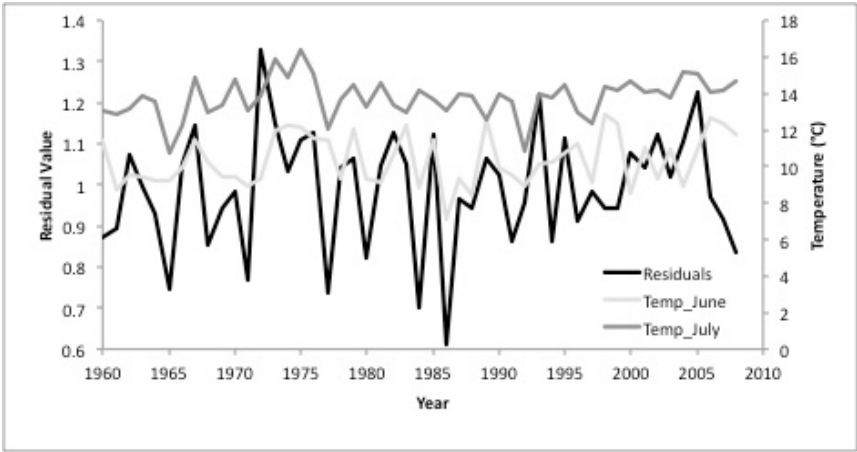


Figure 7. June and July monthly average temperatures from Environment Canada Wabush Station (8504175) (Canada 2010) plotted alongside the standardized master chronology residuals.



associations during June ( $RV=0.36$ ) and July ( $RV=0.42$ ) (Figure 6). Annual fluctuations in growth corresponded especially well to June and July temperatures in 1965, 1967, 1986, and 1993 (Figure 7).

## Discussion

The autocorrelation values for this site are consistent with those measured for other species sampled in Labrador (Dumeresq 2011; Kennedy 2010; Kershaw and Laroque 2012; Nishimura and Laroque 2011). The intercorrelation value for this site is well in excess of the 0.3218 value needed to attain the 99% confidence interval threshold, meaning that the master chronology is a good representative of the series sampled. The relatively elevated mean sensitivity value for this birch site is consistent with deciduous aspen (Dumeresq 2011) and eastern larch (Dumeresq 2011; Nishimura and Laroque 2011) tree chronologies previously assessed from Labrador. This heightened mean sensitivity represents greater sensitivity to short-term climate variance (Oberhuber, Stumb, and Kofler 1998), and is likely associated with the higher susceptibility of deciduous trees to the extreme northern climate (Dunwiddie and Edwards 1985). Crown loss due to late spring snowstorms and early abscission caused by early fall frost events likely contribute to this heightened deciduous species sensitivity to climate relative to needle bearing species.

Birch's positive association with June and July temperature in this study is consistent with other research findings which have identified that temperature's most important months of influence on tree growth generally fall in the summer (May-August) in Labrador (Nishimura and Laroque 2011) and specifically June in inland Quebec (Lapointe-Garant et al. 2010). A recent study on birch in Iceland reported strong associations between both June and July temperatures with tree growth as well (Levanic and Eggertsson 2008). This reinforces the results of this study on a regional, as well as circumpolar scale.

While the dominant force limiting growth according to our results is temperature, there remains a weak association with the precipitation component of the climate signal encoded in annual growth (Figure 5). Other dendrochronology studies in Labrador illustrate that the dominant growth suppression factor on trees in the region is temperature, with precipitation, when discernible, being of minor secondary importance (Kennedy 2010; Lapointe-Garant et al. 2010; Nishimura 2009; Trindade 2009). Considering this research context, it is difficult to trust the precipitation results of this study as they barely manage to cross the threshold of statistical significance, and only do so for the weaker CV parameter and not the more robust RV significance test. This study does not support the use of birch in Labrador as a proxy of precipitation trends in the region.

If we limit our assessment of white birch's dendroclimatological research potential to the more stringent response value (RV) results, the efficacy of the species is quite apparent. Previous dendroclimatological studies conducted near Labrador City report statistical significance in temperature's relationship with growth in July for eastern larch (*Larix laricina*) ( $RV=0.28$ ) and May for black spruce (*Picea mariana*) ( $RV=0.22$ ,  $0.31$ ) (Nishimura and Laroque, 2011). In comparison, the birch chronology of this study is more strongly temperature limited as evidenced by the heightened RV values associated with June ( $RV=0.36$ ) and July ( $RV=0.42$ )



temperature (Figure 6). The birch chronology developed in this study has the second highest RV value for a growth relationship with monthly mean temperatures in all of Labrador on record (Dumeresq 2011; Kennedy 2010; Nishimura and Laroque 2011; Trindade et al. 2011). Therefore, birch should be considered one of the more sensitive indicator species for temperature fluctuations in Labrador and further research projects should accommodate it in their study design framework where possible.

Other hardwood species in the area are too sparse and too young for effective dendrochronological assessment, further emphasizing the importance of white birch in the area. A similar opportunity for birch chronologies filling deciduous hardwood gaps likely exists elsewhere in Labrador, particularly in the more inland and northern parts of the province, but due to the lack of attention white birch distributions receive (Payette 1993), the fulfillment of such potential is likely to be opportunistic in nature with sampling of birch stands done secondarily while focusing on the dominant conifer species in the region.

We recommend further study of birch in Labrador to assess its response to all the bioclimatic zones it is present in, as identified through dendrochronological modeling with other species (Dumeresq 2011; Kennedy 2010; Kershaw and Laroque 2012; Nishimura and Laroque 2011).

## Conclusions

This study establishes that high-quality dendrochronological data can be attained using white birch trees near their range limit in southern Labrador. Birch at this site produced exceptionally strong correlations with temperature. The statistical relationship between growth and precipitation was weak and this corroborates earlier study results in the region. The absence of aspen in the area leaves birch as the only deciduous hardwood species in inland Labrador for supplementing the previously developed conifer chronologies. Given the strength of association with summer temperature, birch may be a better species to select where its range overlaps with other deciduous species such as aspen and larch. Given the confirmation between white birch and other species exhibiting a relationship with summer temperature and tree growth, and the heightened sensitivity of white birch's response, it can be concluded that this species could potentially be of vital importance in subsequent dendroclimatological studies in Labrador. Birch should be considered in all future dendrochronology studies in Labrador, and other northern boreal to sub-arctic transition zones where it is present.

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