Exploring the potential dendrochronological response of *Pinus strobus* to climate change in Minnesota

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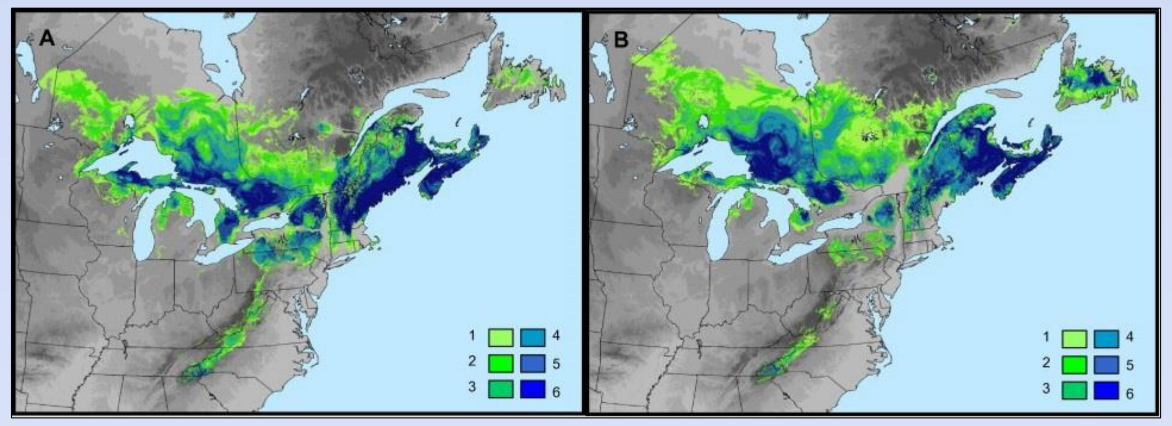
Introduction

As a species evolves in a landscape, it develops a unique range of climatic values within which it can survive. Historically, a successful species adapts to a slowly dynamic climate, but rapid shifts in climate are now influencing many species, including eastern white pine (*Pinus strobus*).

Figure 1. A picture of sample CR13. A super-dominant *P. Strobus* at Cascade River. DBH 113.3 cm. Photo credit to K. Gill

P. strobus has a large range, reaching as far west as Minnesota (Little 1971) and future climate projections indicate conditions may no longer be favorable for this species by the year 2090 (Joyce 2013). These projections also indicate that sites along the North Shore of Lake Superior may have the highest levels of resistance to change. The southwest-northeast direction of the shoreline reflects the general pattern of migration predicted of species in response to climate change. Also, if the *P.strobus* component of the North Shore ecosystem is being influenced by a changing climate even with a lake moderating effect, it may be assumed that the *P.strobus* across the rest of Minnesota is being influenced as well, and possibly at a greater rate. Given these projections and recent warmer trends in the state, we conducted a dendroclimatological analysis of *P. strobus* along the Minnesota shore of Lake Superior to determine if decreasing growth rates associated with climate were occurring. This is an attempt to actualize predictions made by climate models.

Figure 2. Projections of the range of *P. strobus* in: A (2030) and B (2060) considering 3 climate change scenarios and 2 greenhouse gas emission scenarios. Graphic (Joyce 2013)



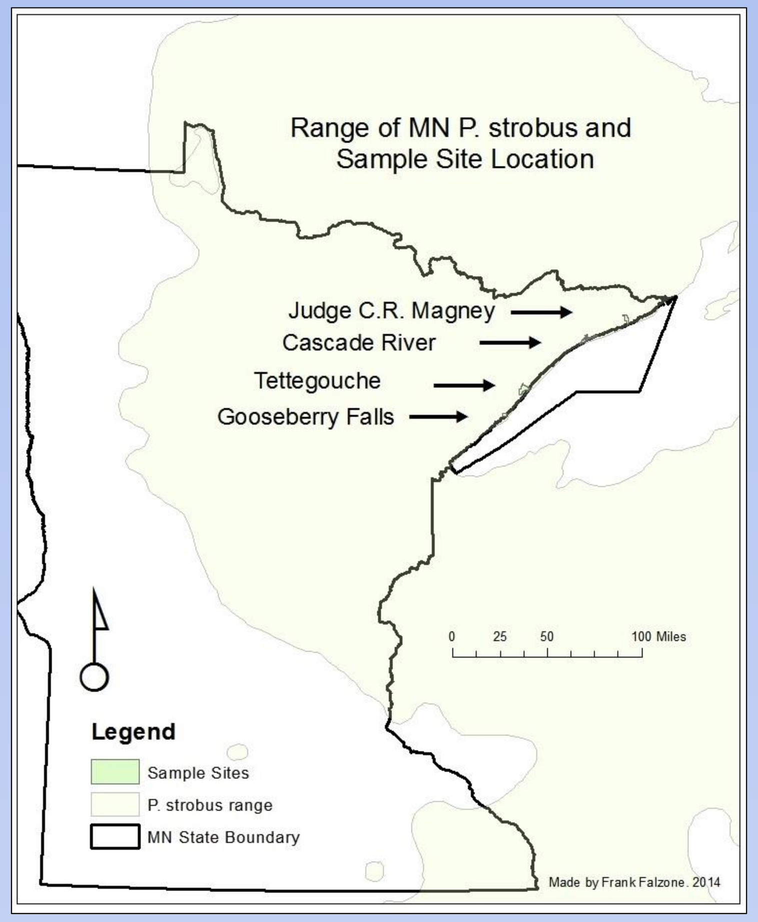
Methods

Sample Sites

The North Shore of Lake Superior was chosen as a location for study sites due to the predicted resistance to climate change.

Public land near the North Shore was used as sample locations. These sites include Gooseberry Falls, Tettegouche, Cascade River, and Judge C.R. Magney State Parks.

Figure 3. A map highlighting sample site locations along North Shore of Lake Superior. Boundary of Minnesota and Minnesota range of *P. strobus* identified.



Sampling Trees

To maximize climate sensitivity, increment core samples were taken at 0.30 m from trees that were super-dominant canopy trees, and also grew on soil that may be susceptible to water stress. Discretion was used when selecting sample trees.

Photo 4: Site at Cascade River. Example of super-dominant and likely climate sensitive trees. Photo credit to K. Gill.

Weather Information

Maximum temperature and precipitation data was collected from Prism Data Explorer (PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, created 3 April 2014). Measurements were available on a monthly basis since 1895 for each site location. A single GPS point was used at each site to represent the weather that each tree experienced at that specific site.

Analysis/Results

Measuring Annual Growth

Using a Velmex Micrometer, the radial increment was measured on increment cores to the nearest five nanometers. Once a value is measured for each ring on each core, they were cross-dated using COFECHA. This program uses a statistical algorithm to ensure the quality of a chronology. Before de-trending, COFECHA output gives an average of mean sensitivity, which represents the year-to-year variability in ring width (Table 1).

Table 1. The number of samples, the average sample age, and average mean sensitivity at each site.

	Gooseberry Falls	Tettegouche	Cascade River	Judge C.R. Magney
Number of Samples	16	21	18	24
Average Sample Age	101.3	105	185.1	115.9
Average Mean Sensitivity	0.229	0.241	0.218	0.258

Standardization

As a tree grows and becomes taller and wider, gross annual ring width becomes smaller due to the increasing surface area that the new wood has to cover. ARSTAN is a program that de-trends annual growth measurements by taking an increasing surface area into account, as well as other factors such as competition or disturbance (Cook 1985). Removing trends that are not climate related allows for a clear and accurate relationship between tree growth and climate to be distinguished.

Correlation and Response between Tree Growth and Climate

The significant correlation and response relationships of climate data and annual growth can be found using a response function analysis, as conducted in the software program DENDROCLIM2002 (F. Biondi 2004). By inputting precipitation values, maximum temperature values, and a standardized chronology for each site, DENDROCLIM2002 draws correlations between monthly climatic factors and tree growth, and assigns significance on a 95% confidence interval. As shown in Table 2, each site had a positive significant response to precipitation in varying summer months. This supports findings in another study that state the most significant relation of growth in *P.* strobus in the Boundary Waters Canoe Area Wilderness to precipitation during June and July, but most prominently June (Kipfmueller 2010). Significant response was not found in relation to temperature, likely due to the moderating effect of Lake Superior.

Table 2. Significant relationships between annual growth at each site and precipitation during the previous August, the current May, June, and August.

	Gooseberry Falls	Tettegouche	Cascade River	Judge C.R. Magney
Aug. of **last** year	/	/	/	+
May of **this** year	+	+	/	/
June of **this** year	+	+	+	+
Aug. of **this** year	+	/	+	+

Conclusions

As the climate continues to change, encouraging Minnesota *P. strobus* to migrate northeast into Ontario, we should expect to see an increase in sensitivity to climate on a southwest-northeast gradient, meaning Gooseberry Falls should show the highest sensitivity to climate, and Judge C.R. Magney should express the least. What we learned:

- Although all sites showed an Average Mean Sensitivity that is appropriate for climate analysis, there was not a trend showing southwestern sites to have a higher average mean sensitivity.
- At the sample sites, there is no significant relationship between *P. strobus* growth and monthly maximum temperature. This is likely due to the moderating effect on temperature of Lake Superior.
- Although all sites showed a positive significant relationship between *P. strobus* growth and precipitation in either the previous August, the current June, May, or August, there was no trend signifying that southwestern sites were more dependent on precipitation events for growth than northeastern sites.

The migration of Minnesota *P. strobus* that has been predicted is not being realized in annual growth patterns in sites along the North Shore of Lake Superior. It is possible that Lake Superior plays too large of a moderating effect on near ecosystems, and that sites throughout the state may show increased climate sensitivity. In addition, this work underscores the large importance precipitation plays in affecting the growth of this species, suggesting that future projections of species ranges need to place a greater emphasis on future patterns of precipitation, as opposed to warming temperatures.

Bibliography

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