Using Herbarium Specimens to Measure the Influence of Climate Change on Phenological Responses of Minnesota Flora

Alexia Rodriguez[1], Katie Noren[2], George D. Weiblen, Ph.D.[2]

[1]College of Biological Sciences, University of Minnesota

[2]Bell Museum and Department of Plant & Microbial Biology, University of Minnesota

College of Biological Sciences
University of Minnesota
Driven to Discover

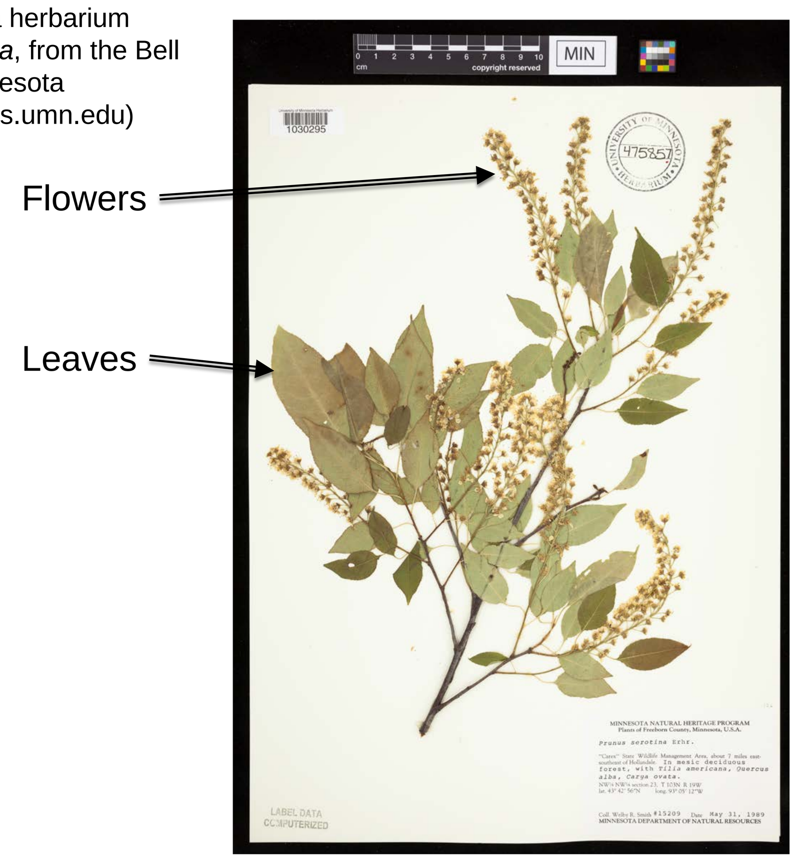
Introduction

Anthropogenic climate change is affecting biological systems around the world. Phenological responses, such as flowering times and bird migrations, are notably the most detectable responses to climate change. Plants across England and North America have shown to be flowering between a week to a month earlier than they did in the early 20th century. Such phenological responses could expose plants to frost, pollinator mismatch, and shifting competition dynamics. This may lead to changes in distribution of flora including economically important species such as white pine, aspen, sugar maple, and balsam fir. We sought to understand the shifts in reproductive timing of native Minnesota flora in reference to a warming climate. Long term records of flowering times are rare but the University of Minnesota herbarium has a 120-year old collection of native flora. We analyzed 10,875 specimens representing 123 woody plant species.

Methods

- Extracted phenological information and distribution data data from digital images of Bell Museum specimens.
- Georeferenced specimens and scored phenological status.
- States included buds breaking, expanding leaves (flushing), flower buds, and flowers open.
- Used JMP, a statistical software, to graph relationships between phenology characteristics and measures of climate – mean winter temperature, lake ice-out date, and the latitude where each specimen was collected.

Figure 1. An example of a herbarium specimen, *Prunus serotina*, from the Bell Museum taken from Minnesota Biodiversity Atlas (bellatlas.umn.edu)



Results

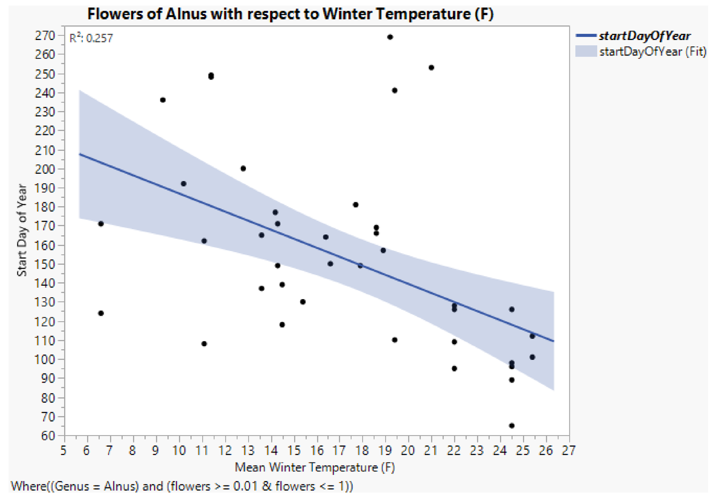


Figure 2. Response of flowering to mean winter temperature for *Alnus*.

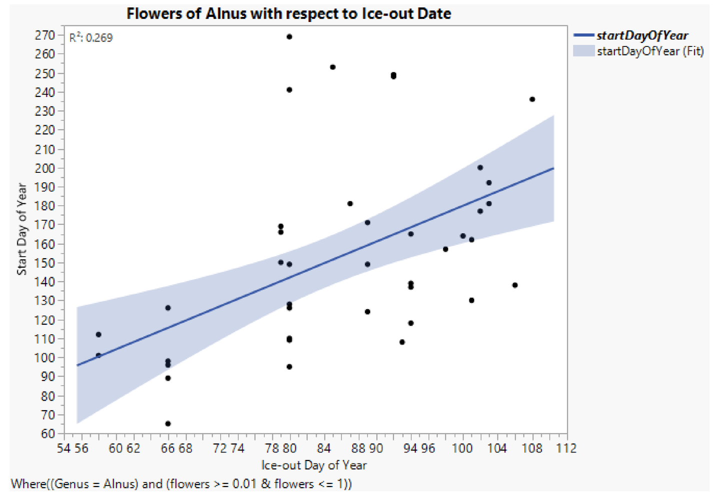


Figure 3. Response of flowering to ice-out date for *Alnus*.

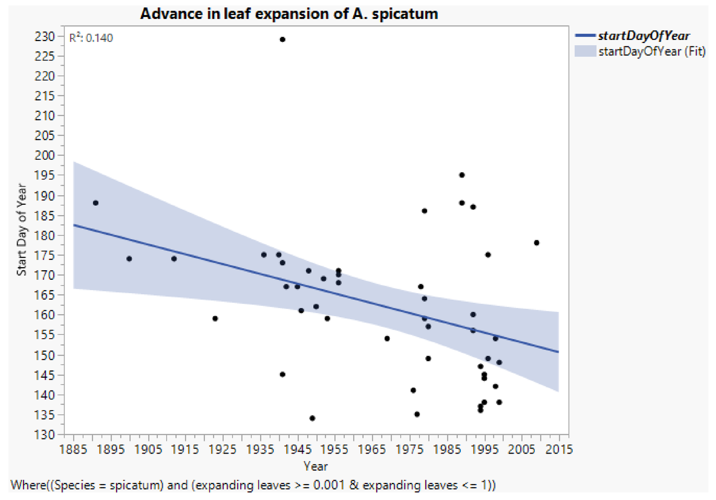


Figure 4. Advance in leaf expansion of *Acer spicatum* from 1885 to 2005 – roughly 33 days.

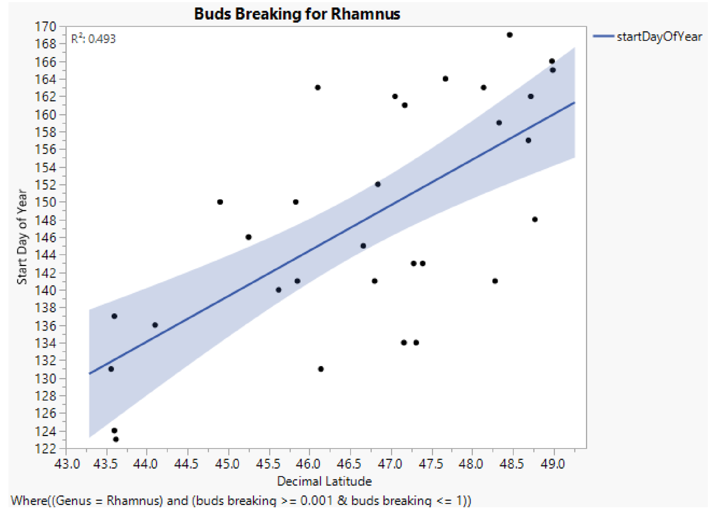


Figure 5. Relationship of buds breaking to decimal latitude for the genera *Rhamnus*.

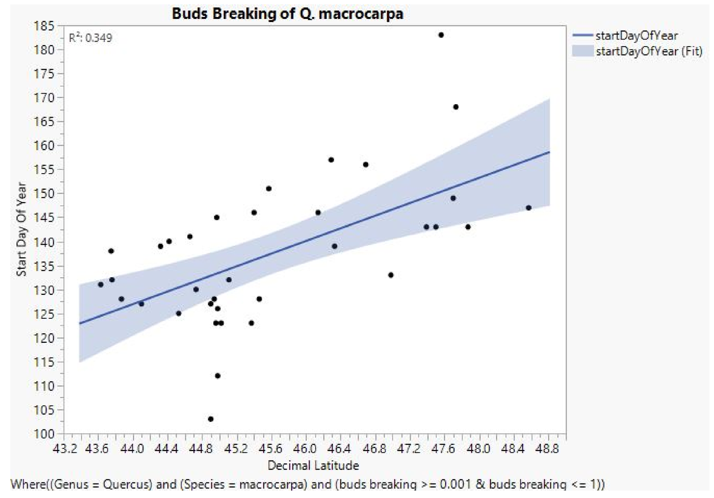


Figure 6. Relationship of buds breaking to decimal latitude for the species *Quercus macrocarpa*.

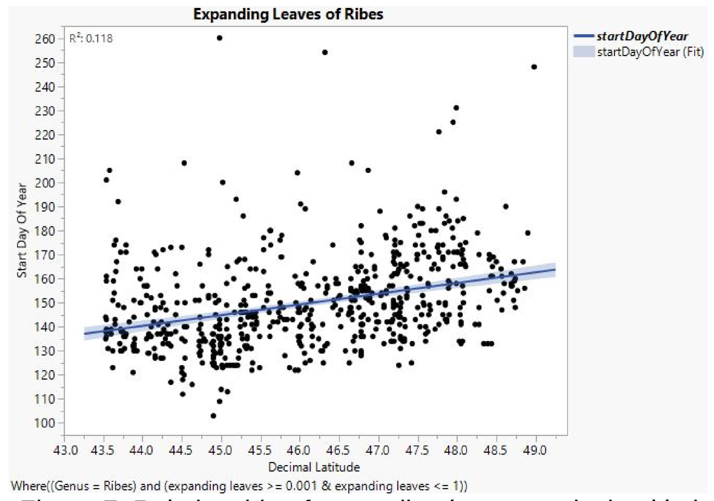


Figure 7. Relationship of expanding leaves to decimal latitude for the genera *Ribes*.

- Alder (*Alnus)* seemed to flower earlier in years with higher mean winter temperature but the range of flowering dates is suspicious. (Fig. 2)
- Alder also seemed to flower earlier in years with earlier ice-out dates (see discussion). (Fig. 3)
- Mountain maple (*Acer spicatum*) appeared to be flowering approximately one month earlier on average than 125 years ago. (Fig 4)
- Phenology also varies with the latitude where specimens were collected with phenological events occurring later in the year at higher latitudes than at lower latitudes.
- Bud break was later on average at higher latitudes for buckthorn (*Rhamnus species*) and bur oak (*Quercus marcocarpa*). (Fig 5-6)
- Leaf expansion was later on average at higher latitudes for currants (*Ribes* species). (Fig 7)
- Allegheny blackberry (*Rubus allegheniensis*) flowered later on average at higher latitudes. (Fig 8)

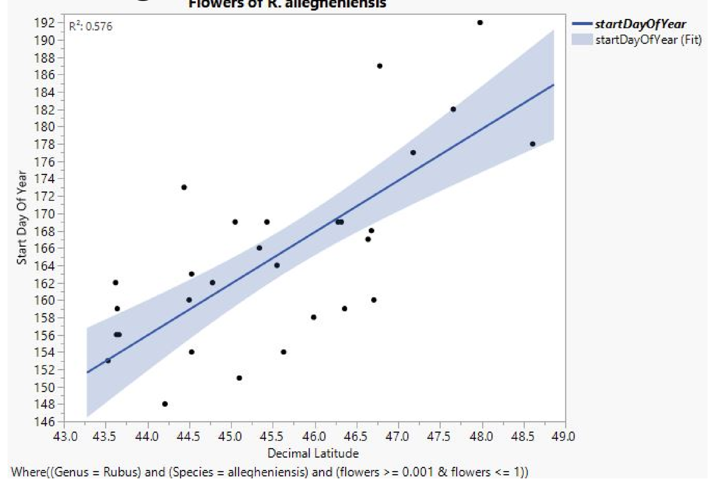


Figure 8. Relationship of flower presence to decimal latitude for the species *Rubus allegheniensis*.

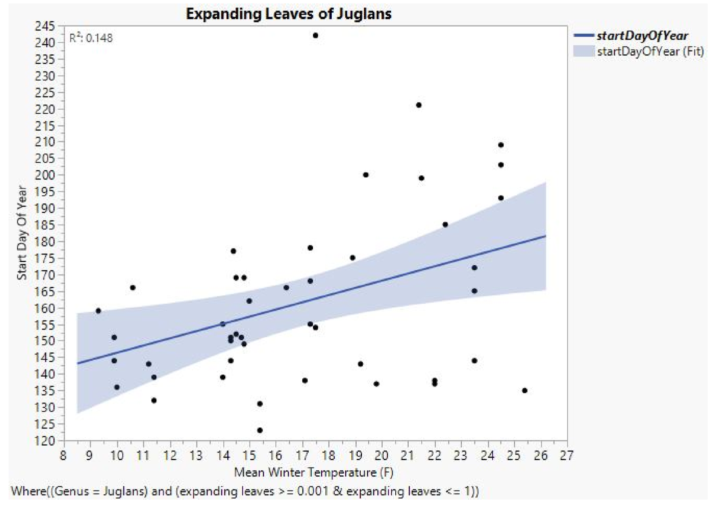


Figure 9. Response of expanding leaves to mean winter temperature for *Juglans*.

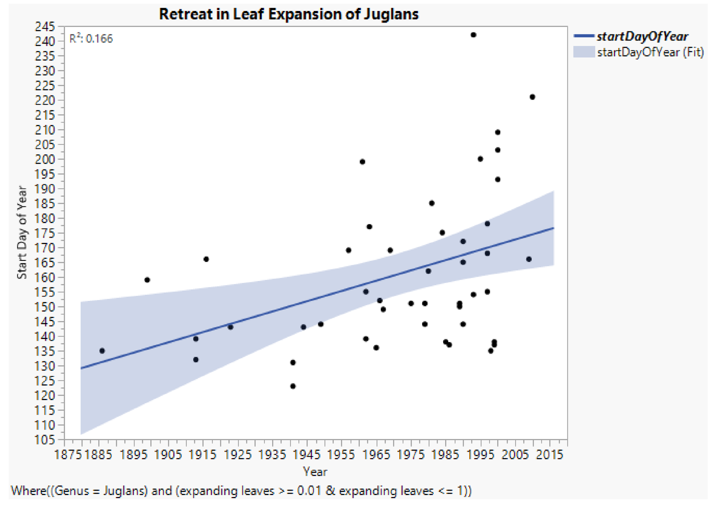


Figure 10. Retreat of leaf expansion of *Juglans* since 1880 by roughly 48 days.

- Walnuts (*Juglans* species) produced leaves later on average in warmer years and appears to be be leafing out 48 days later on average than in 1880. (Fig. 9-10)

Discussion

- Alder (*Alnus)* showed the strongest flowering response among the woody plant genera we examined but there is reason to doubt the accuracy of the result because this genus forms flower buds in the fall and retains fruits over the winter that can easily be mistaken for flower clusters. Our conclusions are based on other species where we have greater confidence in the accuracy of the data.

Conclusion

- Some species showed strong flowering responses to winter temperature and ice-out date but did not show long-term change in flowering time.
- We might use mean winter temperature and ice-out date to predict which species are likely to be indicators of long term response to climate warming.
- Differences in phenology at varying latitudes may be explained by differences in the climate of northern and southern Minnesota.
- *Juglans* appears to be leafing out later today that it did a century ago, contrary to expectation.

Acknowledgments

I thank Dr. George Weiblen for his support and guidance and Katie Noren for teaching me how to use the Bell Museum atlas and the herbarium. I would like to thank the University of Minnesota for supporting this research and funding the work through the Undergraduate Research Opportunity Program.

References

Miller-Rushing, A. J., Primack, R. B., Global Warming and Flowering Tiems in Thoreau's Concord: A Community Perspective. *Ecology* **2008,** *89* (2), 332-41.

Miller-Rushing, A. J., Primack, R. B., Primack, D., Mukunda, S., Photographs and Herbarium Specimens as Tools to Document Phenological Changes in Response to Global Warming. *Amer. Journal of Botany* **2006,** *93* (11), 1667-74.

NOAA National Centers for Environmental Information, State of the Climate: Global Analysis for January 2016, published online February 2016, retrieved on February 25, 2016 from http://www.ncdc.noaa.gov/sotc/global/201601.

Primack, D., Imbres, C., Primack, R. B., Miller-Rushing, A. J., Del Tredici, P., Herbarium Specimens Demonstrate Earlier Flowering Times in Response to Warming in Boston. *Amer. Journal of Botany* **2004,** *91* (8), 1260-64.

Weiblen, pers. Comm. Unpublished.