Modeling Population Dynamics of *Castanea dentata* Near the Historical Range Limits in Southwestern Tennessee and Western New York

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Introduction

- The American chestnut (*Castanea dentata*), has suffered significant population decline over the past century, due in part to the introduction of an invasive fungal pathogen, *Cryphonectria parasitica* in the early 20th century (Jacobs et al. 2013)
- Remnant populations at the historical range limits may experience unique demographic processes and harbor novel genetic variation important for conservation and restoration (Dalgleish et al. 2016)
- By constructing demographic models for populations near the historical northern and SW limits of the distribution we can evaluate population health and guide conservation priorities (Davelos and Jarosz 2004)
- We predict that the SW Tennessee population will decline rapidly as the majority of the individuals are sprouts and resprouts. In contrast, we expect the W New York population to persist for many decades as many of the individuals are saplings and trees.

Methods

- We constructed a demographic model for a population of American chestnut in SW Tennessee and W New York using a stage-structured matrix model to investigate the potential for the population to persist, remain stable, or grow
- We estimated population sizes by calculating our population density for each region and multiplying it by a rough estimate of suitable are for each location (1/5 of total land)
- We used R to resample the populations using the bootstrap method to approximate the true population demographic distribution and used MATLAB to generate population structures over a 100 year period

Size Classes

Size Class	DBH (cm)	Count (TN)	Count (NY)
Resprouts	0 – 1.0	13	0
Sprouts	1.1 – 2.5	8	6
Saplings	2.6 – 10.0	5	43
Trees	10.1 – 25.0	0	14
Full Trees	25.1+	0	1

Transition Rates (T) & Blight (B)

(Elwood 2014)

$$T = \begin{pmatrix} 0.598 & 0 & 0 & 0.693 & 2.167 \\ 0.402 & 0.773 & 0 & 0 & 0 \\ 0 & 0.227 & 0.866 & 0 & 0 \\ 0 & 0 & 0.134 & 0.957 & 0 \\ 0 & 0 & 0 & 0.043 & 0.987 \end{pmatrix} \quad B = \begin{pmatrix} 1-R & 0 & 0 & 0 & 0 \\ 0 & 1-P & 0 & 0 & 0 \\ 0 & 0 & 1-A & 0 & 0 \\ 0 & 0 & 0 & 1-T & 0 \\ 0 & 0 & 0 & 0 & 1-F \end{pmatrix}$$

R = proportion of resprouts with blight
P = proportion of sprouts with blight
A = proportion of saplings with blight

T = proportion of trees with blight
F = proportion of full trees with blight

Bootstrapped populations to increase sample sizes

Solutions: $x_{n+1} = B*T*x_n$

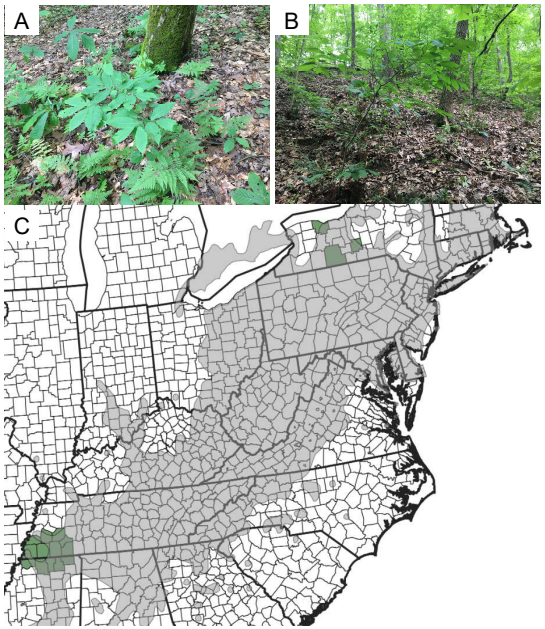

Figure 1: Examples of American chestnut A) resprout and B) sapling. C) The historical distribution of American chestnut in eastern North America (gray shading) extends from the Mississippi R. to S. Maine. We collected demographic information from trees in SW Tennessee and W New York (green-shaded counties).

Results & Discussion

- Populations in both locations are predicted to decline precipitously within the next 10-20 years, going nearly extinct within 100 years
- Population decline is predicted to occur more rapidly in SW Tennessee (smaller pop.) than in W New York (larger pop.)
- Predominantly small resprouts are predicted to persist the longest, with larger trees being nearly completely lost from W New York
- Rapid decline of remnant American chestnut populations threatens conservation and restoration efforts, as *C. parasitica* continues to devastate American chestnut
- genetic work should prioritize identifying novel variation for breeding and transgenic approaches ASAP!

Some Good News!

- American chestnut populations in W New York and SW Tennessee predicted to persist for decades, providing time for conservation/restoration efforts
- Most of the identified trees occur in parks where they are partly protected from human disturbance, additional protections and active management could increase longevity of the natural remnant populations

Future Directions

- Follow-up efforts to include more trees from each of these populations would improve the models
- Examine genetic variation within these populations to identify potentially important local adaptation
- Continued development of demographic model to investigate potential mitigation strategies and effects on population dynamics

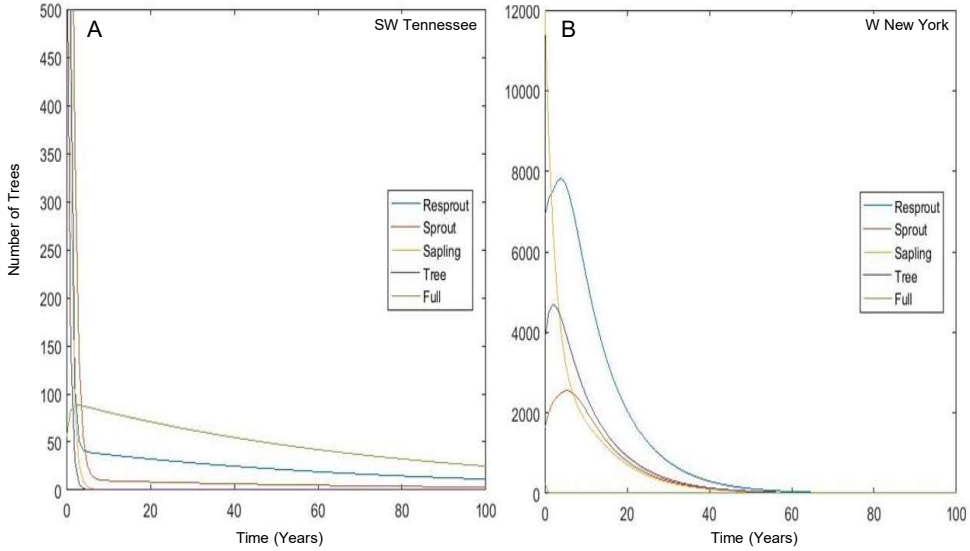

Figure 2. Graphs displaying the demographic model outputs for the southwest Tennessee population (A) and the western New York population (B). Colored lines correspond to the different size classes comprising each population.

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References

Dalgleish, H.J., C.D. Nelso, J.A. Scrivani, and D.F. Jacobs. 206. Consequences of shifts of abundance and distribution of American chestnut for restoration of a foundation forest tree. *Forests* 7(4) doi: 10.3390/f7010004
Davelos, A.L. and A.M. Jarosz. 2004. Demography of American chestnut populations: effects of a pathogen and a hyperparasite. Journal of Ecology 92: 675-685.
Elwood, E.C. 2014. Population matrix model for American Chestnut (*Castanea dentata*) and the implications for re-introduction. Undergraduate Honors Theses. Paper 88. The College of William and Mary. https://scholarworks.wm.edu/honorstheses/88
Jacobs, D.F., H.J. Dalgleish, and C.D. Nelson. 2013. A conceptual framework for restoration of threatened plants: the effective model of American chestnut (*Castanea dentata*) reintroduction. *New Phytologist* 197: 378-393 doi: 10.1111/nph.12020