Tree Growth, Mortality, and Recruitment in a Mixed Hardwood Forest in the New Jersey Highlands

Niki Bajracharya, Noah Sgaramella, and Eric Wiener

School of Theoretical and Applied Sciences, Ramapo College of New Jersey

Introduction

- Various stressors have been impacting the health and regeneration of numerous tree species in forests throughout much of the northeastern United States.
  - Pests and pathogens include the emerald ash borer, beech bark disease, beech leaf disease, hemlock woolly adelgid, gypsy moth, anthracnose, and more (Lovett et al., 2016; Potter et al., 2019).
  - High levels of seedling browsing by white-tailed deer also reduce tree recruitment in many forests (Habeck and Schultz, 2015).
  - Increased frequency of extreme weather events has been leading to higher rates of tree mortality in recent decades, as well (Mitchell, 2013).
- Given so many ecological stressors impacting trees in the region, monitoring the growth, mortality, and recruitment of trees within permanent forest survey plots can be especially helpful for understanding how forest tree communities are changing over time.

Objectives

- The purpose of this study was to examine the growth, mortality and recruitment for all tree species within a 3.6 ha permanent forest plot in a mixed-hardwood forest in the New Jersey Highlands.
  - The specific objectives of this study were to:
    - examine patterns of growth, mortality, and recruitment across tree species from 2011 to 2017 and 2017 to 2023;
    - compare spatial patterns among the most common tree species;
    - determine which species are in decline, stable, or increasing in abundance.

Methods

- Study Area (see maps): Ramapo Valley County Reservation, Mahwah, New Jersey
  - 3.6-hectare permanent plot, southeast facing slope
    - Divided into 0.1 hectare subplots (n = 36)
- Survey Methods:
  - All trees $\geq$ 10 cm trunk diameter (dbh) were evaluated, mapped on an x/y grid and measured for dbh in 2011, 2017, and 2023.
- Statistical Analyses:
  - For each species, Wilcoxon Signed-Rank Test was used to determine if there were statistically consistent differences between the trunk diameter growth of trees in 2011-2017 versus 2017-2023.
  - Spearman's Correlation Analysis was used to determine whether the spatial distribution of the most common species were correlated across the 36 subplots.

Maps: Location of the Ramapo Valley County Reservation, Mahwah, NJ (left) and a map of the study area (right).

Key	Scientific Name	Common Name	Alive	Dead	Recruited	Relative Density (%)	Relative Basal Area (%)	Relative Frequency (%)
As	*Acer saccharum*	Sugar Maple	421	39	68	40.7	43.3	100.0
Ar	*Acer rubrum*	Red Maple	143	24	13	13.8	8.9	77.8
Bl	*Betula lenta*	Black Birch	107	7	14	10.3	5.8	47.2
Fa	*Fraxinus americana*	White Ash	14	66	0	1.4	0.9	25.0
Sa	*Sassafras albidum*	Sassafras	51	9	13	4.9	1.8	44.4
Cf	*Cornus florida*	Flowering Dogwood	39	15	4	3.8	0.6	36.1
Cg	*Carya glabra*	Pignut Hickory	53	0	5	5.1	6.7	61.1
Fg	*Fagus grandifolia*	American Beech	40	5	11	3.9	1.5	41.7
Qv	*Quercus velutina*	Black Oak	36	6	1	3.5	9.7	50.0
Ct	*Carya tomentosa*	Mockernut Hickory	36	4	4	3.5	2.1	52.8
Qm	*Quercus montana*	Chestnut Oak	31	2	0	3.0	6.7	50.0
Qr	*Quercus rubra*	Red Oak	21	3	0	2.0	6.9	41.7
Ns	*Nyssa sylvatica*	Black Gum	11	0	0	1.1	1.5	19.4
Lt	*Liriodendron tulipifera*	Tulip Tree	8	0	0	0.8	1.8	16.7
Qa	*Quercus alba*	White Oak	8	0	1	0.8	1.3	16.7
Aa	*Ailanthus altissima*	Tree of Heaven	4	0	2	0.4	0.1	8.3
Ta	*Tilia americana*	American Basswood	2	2	0	0.2	0.1	5.6
Cc	*Carya cordiformis*	Bitternut Hickory	2	1	2	0.2	0.0	2.8
Ov	*Ostrya virginiana*	Ironwood	3	0	3	0.3	0.0	5.6
Co	*Carya ovata*	Shagbark Hickory	1	1	0	0.1	0.2	2.8
Rp	*Robinia pseudoacacia*	Black Locust	2	0	0	0.2	0.3	5.6
Ap	*Acer platanoides*	Norway Maple	1	0	0	0.1	0.2	2.8
Ars	*Aralia spinosa*	Devils' Walking Stick	1	0	1	0.1	0.0	2.8
		Total	1035	184	142			

Table 1. Summary data from the 2023 survey. Species are ordered from most abundant to least abundant. Relative density, basal area and frequency are based on numbers of alive trees. Relative frequency refers to the proportion of subplots where each species was present.

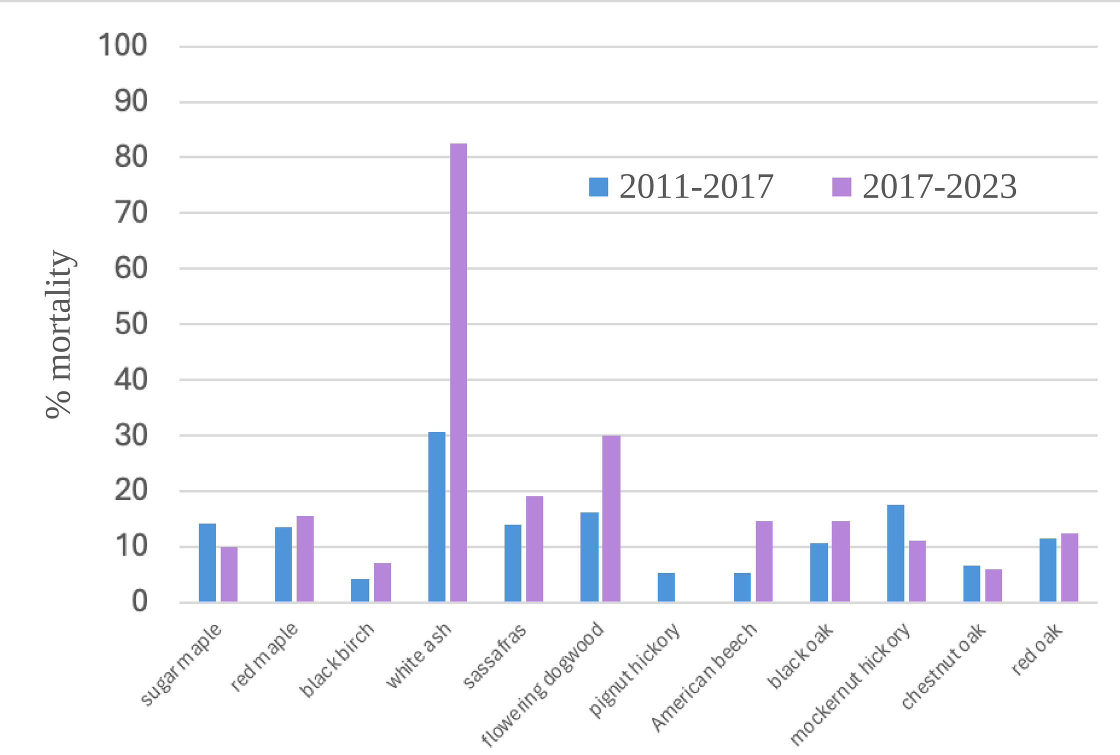

Figure 1. Percent mortality during the two time periods for the 12 most common species.

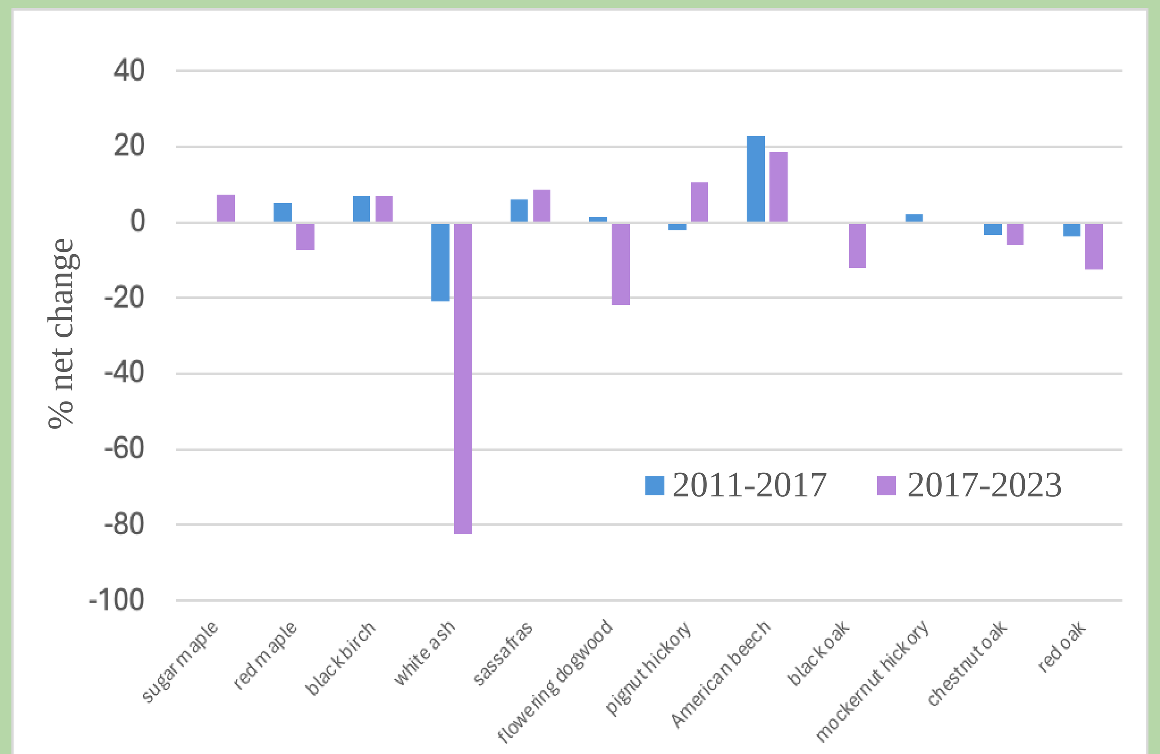

Figure 3. Percent net change (% recruitment - % mortality) during the two time periods for the 12 most common species.

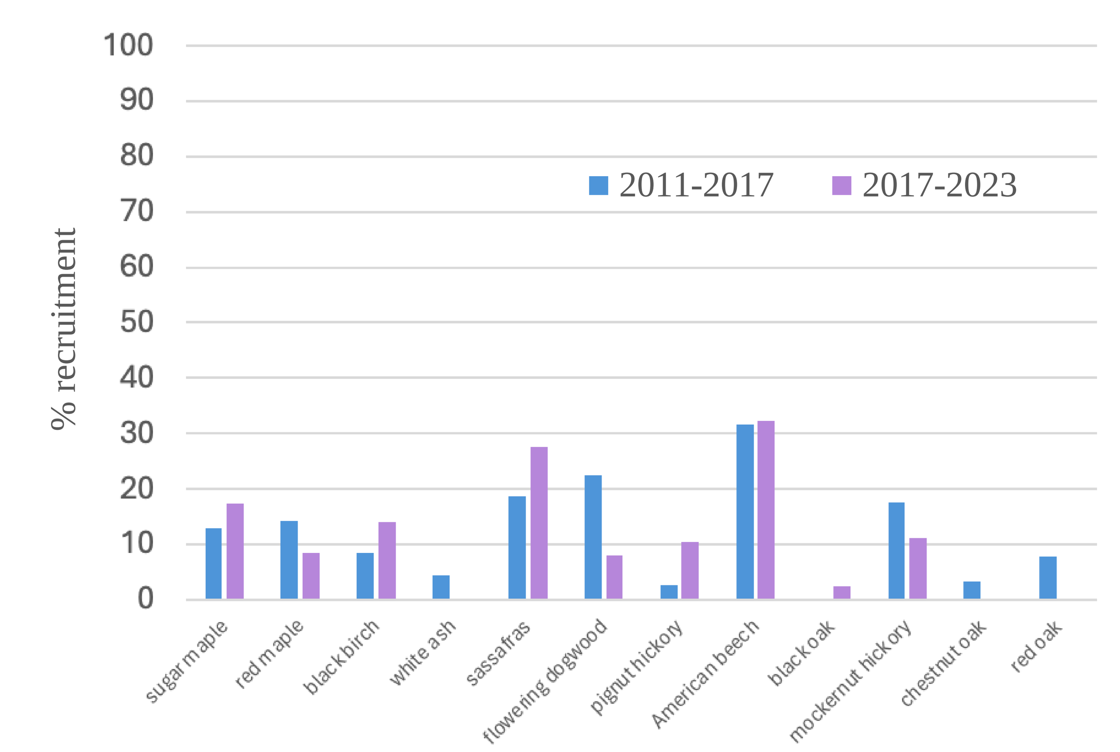

Figure 2. Percent recruitment during the two time periods for the 12 most common species.

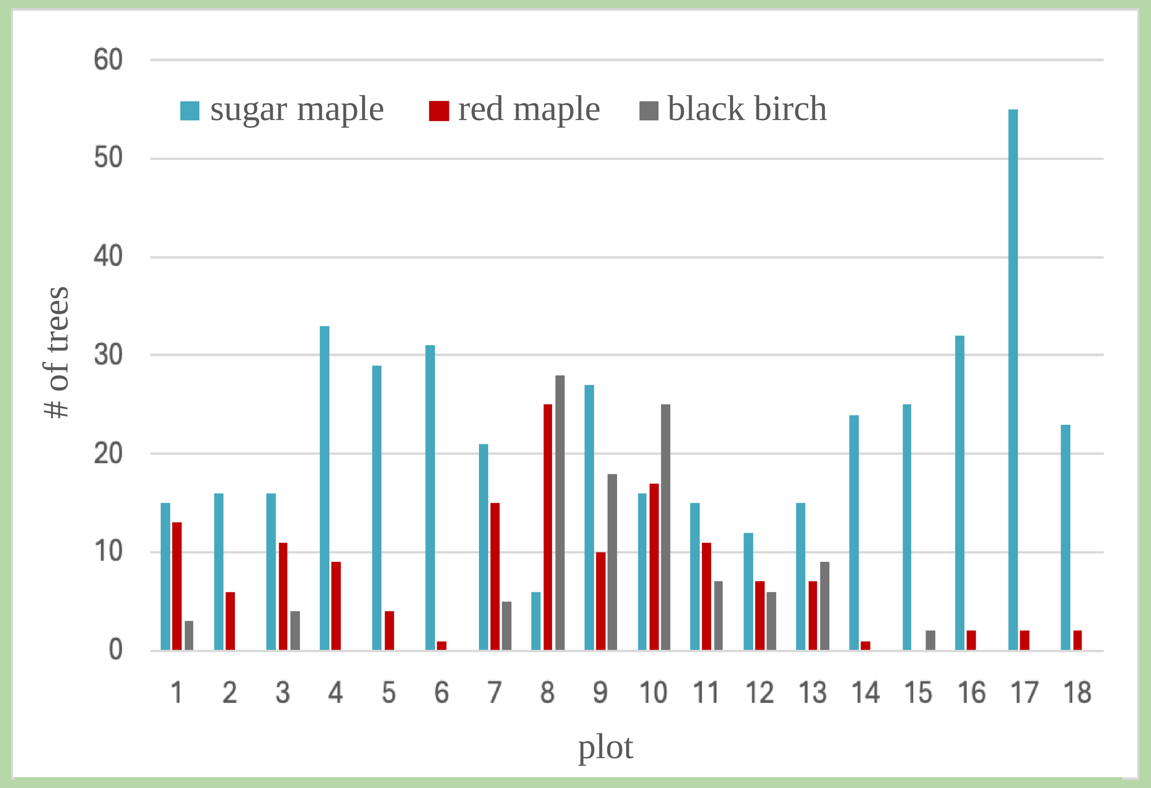

Figure 4. Number of alive trees per plot in 2023 for the three most common species.

Results

- Mortality rates and recruitment rates varied dramatically among the twelve most common tree species in the study plot.
  - By far the highest mortality rates were experienced by white ash, followed by flowering dogwood and sassafras (Figure 1). All three of these species, as well as American beech, experienced higher mortality rates in the more recent time period in the study (Figure 1)
  - The highest recruitment rates occurred for American beech and sassafras (Figure 2). Notably, higher recruitment rates occurred in the most recent time period for sassafras, sugar maple, and black birch, while substantial declines in recruitment occurred for red maple and flowering dogwood (Figure 2).
  - When considering the mortality and recruitment rates together, the population of white ash experienced the most dramatic decline, while populations of flowering dogwood and all of the oak species were also in decline (Figure 3).
    - Species with increasing populations included American beech, sassafras, and black birch (Figure 3). The trends for the remaining species, including the most abundant species (sugar maple), were either less consistent or appeared to be more stable (Figure 3).
- Trunk diameter growth was statistically consistently lower in 2017-2023 than in 2011-2017 for most species ($p < 0.05$), while no statistically significant trends were observed between the two time periods for flowering dogwood, sassafras, and black oak.
- Statistically significant spatial correlations existed between the three most common species (Figure 4). There was a positive correlation between the spatial distribution of black birch and red maple ($p < 0.0002$), and negative correlations between the spatial distribution of sugar maple versus red maple ($p < 0.00181$), and sugar maple versus black birch ($p < 0.0028$).

Discussion

- White ash and flowering dogwood populations appear to be in steep decline, while the populations of all three common oak species are also in decline.
  - After decades of gradual decline in the white ash population due to fungal diseases, a much more rapid decline has occurred in recent years following the arrival of emerald ash borers in the region.
  - Dogwood anthracnose, caused by *Discula destructiva*, has plagued flowering dogwood in the region for several decades. The more recent uptick in mortality rates suggest that flowering dogwoods may soon become ecologically extinct at the study site.
  - While oak populations were previously in steep decline due to gypsy moth outbreaks, the current gradual level of decline appears to be a combination of background mortality rates together with low recruitment, which is most likely due to overbrowsing of seedlings by deer (Kelly, 2019).
- Although black birch and sassafras populations appeared to be increasing at the site, the high positive net change in the American beech population will almost certainly be short lived now that deadly beach leaf disease has recently infected beech trees in the study plots. Similarly, black birch populations, as well as the highly abundant sugar maple population, are also expected to eventually decline due to climate change (Butler-Leopold et al, 2018).
- The nearly community wide decrease in growth rates in the most recent time period may have been caused by a strong drought in 2022 or by other factors that deserve further study.
- In conclusion, the forest tree community at the study site is clearly in a dynamic state. The population decline of several species will translate into an overall decline in biodiversity. Future surveys in the permanent plot at the study site, as well as research on forest dynamics throughout the region, will be essential for documenting how forest communities change in the coming decades.

Acknowledgments

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