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Local Ecology Research Papers

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St. Olaf College, 1500 St. Olaf Ave, Northfield, MN 55057

Tree diameter and growth rate comparisons of southern MN trees in density-variable *Fraxinus sp* deciduous forest plots

Wesley Braker, Biology, St. Olaf College, 1500 St. Olaf Ave, Northfield, MN 55057

Growth rates and diameters of trees in restored deciduous forest in southeastern Minnesota, USA, were examined over a three-year period. The diameter at breast height of ~215 individually tagged trees were collected using protocol of the EREN Permanent Forest Plot study on *Fraxinus sp*. The plots used were planted with variable high and low densities of *Fraxinus americana* to study the effects of *Agrilus planipennis* as it moves into the area. Tree composition was dominated by *Fraxinus americana, Quercus sp, Acer sp,* and *Ulmus americana*. Species with largest diameter over all study plots were *Quercus alba, Quercus rubra, Fraxinus americana,* and *Tilia americana.* Overall tree diameter increased over two years, with an average growth rate of 4.4 mm per year. Species with the highest growth rate in the last year were *Ulmus americana, Acer rubrum,* and *Tilia americana.* High density *Fraxinus* plots displayed high mean diameter for *Fraxinus americana,* while low density *Fraxinus* plots displayed high mean diameter for *Quercus alba, Quercus rubra,* and *Tilia americana.* As *Agrilus planipennis* invades, *Fraxinus sp* are expected to decline drastically in numbers.

Introduction

In the state of Minnesota there are four major biomes ((MNDNR 2017a)). Tallgrass aspen parkland occupies a small area in the far northwest corner of the state. Prairie grassland covers the west and southwest corner and is notable in have a scarcity of trees. Coniferous forest dominates the entire northeast quarter of the state as the North Woods. Finally, deciduous forest runs between the other three biomes in a northwest-southeast band. Temperate deciduous forests are a unique biome in that they serve as a buffer biome between prairies and coniferous forests, and all deciduous individuals lose all leaf cover when the growing season is over. As a biome, deciduous forests provide habitat for many forest-bound songbirds, owls, squirrels, chipmunks, snakes, many ephemeral flowers, shrubs, understory trees, and larger mammals. Additionally, deciduous forests produce large quantities of seeds and nuts, supplying many animals with an abundant food source. When compared to the neighboring prairies, deciduous forest burns relatively infrequently, allowing for individuals to regularly grow to maturity ((Stambaugh et al. 2015)). With a lack of fire as a main disturbance factor, deciduous forests have other methods for creating disturbance. Deciduous forests exhibit disturbance in a succession based pattern, where older trees die, younger trees fill in the gaps made by them, maintaining forest diversity by allowing shade intolerant species a chance to succeed (Bray 1956). Mainly because of human intervention, many biomes (aquatic and terrestrial) have some sort of alien or invasive species (Branstrator et al. 2017, Lym et al. 2017, Romero-Alvarez et al. 2017, Staples et al. 2017, Vink et al. 2017, Youngquist et al. 2017).

An invasive species that puts deciduous forest diversity at risk is the Emerald Ash Borer (EAB), which feeds on the inner layer of bark on ash trees, cutting off nutrient flow to the leaves, usually killing a tree in 1-3 years (MNDNR 2017b). Originating from Asia, EAB has moved from the east coast towards the Midwest, decimating ash tree populations and removing them as a species from deciduous forests completely. While there is plenty of data available on the effects and current and past range of EAB (Herms and McCullough 2014, Koenig and Liebhold 2017), there is not much known about the effects of EAB on deciduous forest composition (Kuers 2014).

The Ecological Research Education Network (EREN) established the Permanent Forest Plot Project (PFPP) in order to track and observe the effects of EAB on ash trees and forests (Kuers 2014). EREN has 46 participating institutions around the United States and Canada that have set forest plots aside for this research. St. Olaf College in Northfield, MN, has four plots set aside for EREN PFPP research. These plots are located in two 1990 forest plantations just to the westt of the main portion of St. Olaf College campus and were planted in former agricultural land. 2 plots were planted with low ash tree density and 2 plots were planted with high ash tree density to allow for comparisons of both situations. Along with *Fraxinus americana*, the plots also included a wide variety of deciduous hardwood species that would typically be found in the greater Northfield area. An important aspect of these plots is that EAB has not yet been recorded in the area, allowing these plots to be observed throughout the entire process of EAB devastation.

While this study is building off of previously started research, I hope to improve the findings of previously done studies and surveys. In this study, I 1) participated in and provided accurate and representative EAB data for the EREN PFPP and 2) analyzed forest plots with varying ash density for difference in diameter breast height and growth rates.

Methods

Research was conducted during the fall of 2017 after all leaves had fallen. EREN PFPP uses specific protocols that are universal across all participating institution's plots (Kuers 2014). Plots were visited one by one usually by myself but occasionally I was accompanied by a helper. Plots were checked for correct labeling by analyzing maps made in previous years of mature trees. Once plots were matched up with a corresponding map data was collected. The dbh (diameter breast height) of each tree was determined using a dbh stick (1.37 meters) to determine the height of measurement and a diameter tape. If a tree had more than one stem each stem was measured and noted individually. Data was collected on data collection sheets provided by EREN for the PFPP in the protocol. The data collection sheets ask for information on tree damage and height to help assess EAB impact, but since EAB is currently not known to reside in the local area these measurements were not recorded. Once the dbh was measured, the level of dbh measurement was marked on the tree using a high-temperature paint marker. If a new tree was found the tree was given the next sequential number not in use, a tag, and a marked location on the map. These steps were repeated for each of the four plots.

Once all data was collected, data was input into an Excel spreadsheet using the format that EREN requires for data submission. This years (2017) dbh was combined into an Excel spreadsheet with dbh data from 2015 and 2016. From these dbhs, growth rates for individual stems were calculated for 2015-2016, 2016-2017, and 2015-2017. To simplify analysis, the largest stems of individual stems were used. In addition, EREN protocol asks that species names be given as the first three letters of the genus and the first three letters of the species (e.g. sugar maple, *Acer saccharum* = ACESAC). For simplicity this taxonomic labeling scheme was used in analysis and is included in this paper.

EREN PFPP protocol asks that each stem be labeled with a tag and labeled in numerical order. For multi-stemmed individuals, stems should be labeled with decimals (ex. 1.1, 1.2, 1.3, etc.). In past data collection for these EREN PFPP ash plots proper labeling protocol was not followed, so multi-stemmed individuals were labeled. Once data was collected and input it was clear that the lack of stem labels caused discrepancies in measuring the same trunk every year. Data was redefined by looking at the dbh of multi-stemmed individuals and updating dbh trends to reflect normal tree growth (i.e. increase/no growth as opposed to negative growth).

Data were analyzed and cleaned using readr, dplyr, and tidyr packages in R Studio. An ANOVA test was run to test a comparison of total mean dbh from each year data were collected. Bar graphs were created to look at the differences in species dbh and growth rates. Overall species growth rates were compared between plots with high and low densities of ash density using an ANOVA to test the effects of *Fraxinus sp* density on forest composition. A comparison of ash dbh and growth rates in plots with high and low densities of ash was done using an ANOVA.

Results

Based on the total species within the plots, the mean dbh of all species between 2015, 2016, and 2017 were compared (Table 1). An ANOVA test found that there were significant differences between the mean dbh of these years ($p = <2e-16$). Bar graphs of the dbh and growth rate of all species regardless of plot were created to compare the dbh and grow rates of species (Figure 1 and 2). Figure 1 showed that red oak, white oak, and basswood were the largest species found across all plots. Figure 2 showed that red oak and red maple were the fastest growing species across all plots.

An ANOVA comparing growth rates of all species divided by ash density plots showed that there is an insignificant but slight trend for trees to grow faster in plots with lower densities of ash (Figure 3, $p = 0.0989$). When analyzed alone, ash trees displayed higher dbh in plots with lower densities of ash, compared to ash trees in higher ash density plots (Figure 4, $p = 2.28e-06$). Ash trees in plots with low ash density also showed higher growth rates than ash trees in plots with high ash density (Figure 5, $p = 0.0721$).

Discussion

Based on the comparison of the mean dbh of trees in all plots, there was a clear positive trend in the size of trees (Table 1). This means that trees continue to grow in the EREN plots in this study and the forest is maturing. Since these plots were planted in 1990 (and at the time of this study were 27 years old), the forest has likely not yet reached full maturity and trees will continue to grow bigger, given a stable environment (College 2016). As long as the mean tree dbh is always positive or over several years has a positive trend, there is a high probability that the forest is still moving towards being a mature forest. If the mean dbh eventually reaches a ceiling and does not continue to get bigger, the forest has likely become a mature forest.

When looking at the overall makeup of the forest there are 17 separate species that make up the composition. Of these species, basswood, red oak, and white oak species have the highest mean dbh across all plots regardless of density (Figure 1). Red oak was also the fastest growing species among all forest plots, with red maple also growing at a faster rate than other trees (Figure 2). While the mature deciduous forests of southeastern Minnesota are primarily dominated by basswood and maple trees, these data may suggest that in ecosystems where there are no fully mature maple or basswood trees other tree species may have more of a chance to survive. Oak trees are known for growing on edges and more specifically in oak savannah ecosystems, where light is more readily available. Because these forest plots did not already contain any mature individuals and there was an incredible amount of light available to all species, the dominant nature of maples and basswoods may have been negligible. Maple trees are well adapted to take advantage of gap phase disturbances and maintain their dominance through short periods of disturbance (Bray 1956). Basswoods mainly reproduce through clonal spreading, which does not readily happen in a new forest.

Ash trees in Minnesota are at risk of becoming prey to Emerald Ash Borer, so there is thought that as ash die out the composition of deciduous forests will change. Figure 3 compared the growth rate of all species based on high and low ash density plots and found that while there was a positive change in growth rate with lower ash density, the change in growth rate was insignificant ($p = 0.0989$). When ash trees are decimated by Emerald Ash Borer there likely will be more growth from other species to fill in the gaps, as happens with succession (Bray 1956). While this change will happen, the composition of deciduous forests is unlikely to change outside of the disappearance of ash trees.

Ash trees themselves are particularly susceptible to interspecies competition. The dbh and growth rates of ash trees were found to be negatively affected by higher ash densities (Figure 4, Figure 5). This pattern is visible in most species, where increased competition by other individuals of a similar species causes a decline in fitness of individuals in the same population. While this pattern of interspecific competition is not beneficial for individuals in a healthy population, there may be benefits to the population as a whole in high density forests. Evolutionary change occurs when a pressure is placed on a species and the pressure of a pest can sometimes cause a mutation that renders some individuals of a population resistant to such a pest (Li et al. 2016, Sniezko and Koch 2017). A location in which individuals are more dense may provide enough individuals and pressure that the odds for a resistant mutation might be plausible, however more research should be completed to determine whether such a mutation is actually possible.

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Tables and Graphs

Table 1. Changes in diameter breast height (dbh) in centimeters over three years (p = <2e-16, Residual standard error = 1.781526).

Year	DBH (cm)
2015	8.206683
2016	8.804455
2017	9.030693

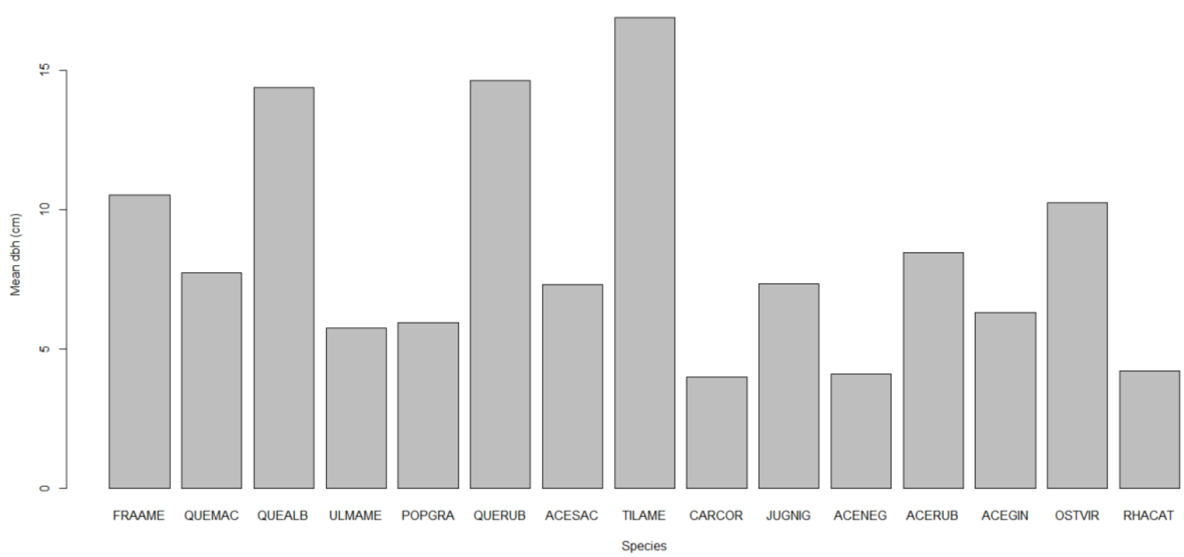

Figure 1. Diameter breast height (dbh) of all species found in permanent forest plantation plots in 2017.

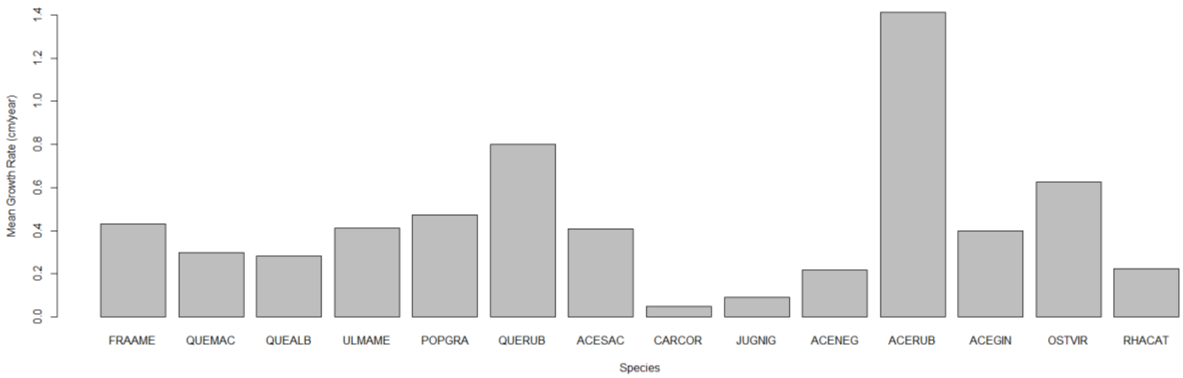

Figure 2. Growth rates of all species found in permanent forest plantation plots between 2015 and 2017.

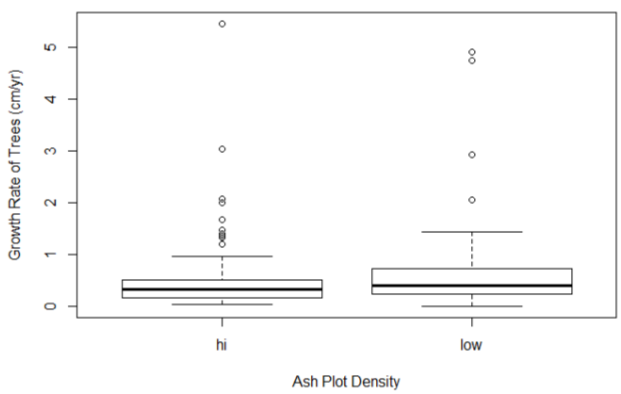

Figure 3. The density of *Fraxinus sp* does not significantly influence the growth rates of other species in maple basswood forests (p = 0.0989, Residual Standard Error = 0.7393).

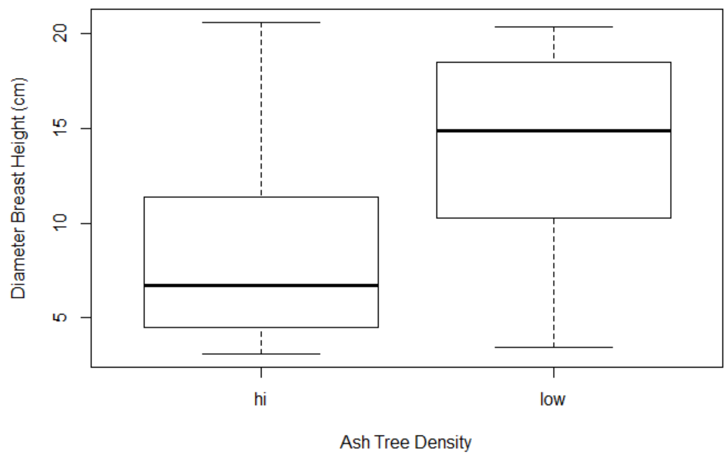

Figure 4. *Fraxinus sp.* grow larger in forest plots with lower density of *Fraxinus sp* (p = 2.28e-06).

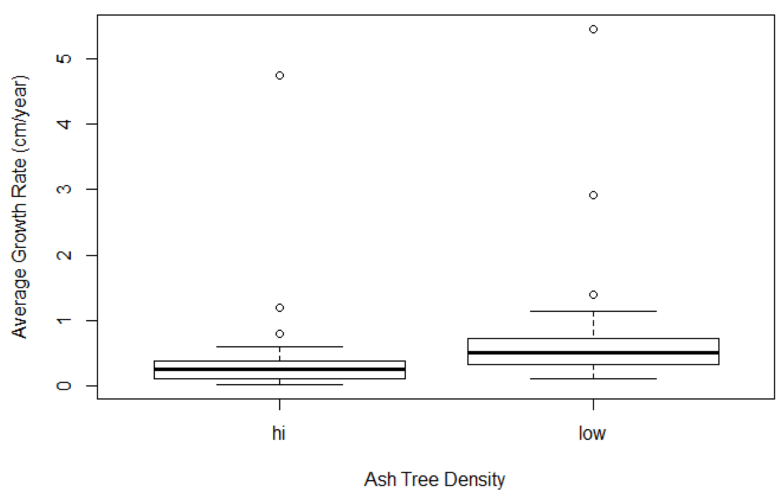

Figure 5. *Fraxinus sp.* grow more quickly in forest plots with lower densities of *Fraxinus sp.* (p = 0.0721).