The status of *Fraxinus americana* and the effect of emerald ash borer infestation on forest succession on UMBS property

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The Emerald Ash Borer infestation is causing widespread mortality in *Fraxinus spp,* across the US. We measured the health status of *Fraxinus americana* on UMBS property and surveyed the understory composition to estimate what might succeed in the canopy gaps of this species. We also surveyed the current overstory composition and compared our data to Pearsall's overstory survey from the 1980s to get a baseline of how the overstory on UMBS property has changed over time due to natural forest succession. We found mostly insignificant change in overstory composition and abundance from Pearsall's data to our current data, showing the slow and nonlinear process of natural forest succession. However, in three of our plots, we found significant difference, which shows some turn over from early to later succession species. To predict how the overstory will change after the succession due to loss of the *Fraxinus americana,* we used the species with the highest relative abundance in the understory as our predicted succession species. We found that *Acer saccharum* and *Fagus grandifolia* are the most likely succession species. Since the decimation of *F. americana* due to this invasive pest will happen relatively quickly, it could accelerate the rate of succession on UMBS property. Since EAB is affecting millions of *Fraxinus* trees around the country, more baseline surveys like this need to done to determine how forests will change to do the loss of this species. More research should also be done to study the ecological role of *Fraxinus* and how their loss will be impacting different ecosystems.

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Ecology 381 Research Project

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The Emerald Ash Borer infestation is causing widespread mortality in *Fraxinus spp,* across the US. We measured the health status of *Fraxinus americana* on UMBS property and surveyed the understory composition to estimate what might succeed in the canopy gaps of this species. We also surveyed the current overstory composition and compared our data to Pearsall's overstory survey from the 1980s to get a baseline of how the overstory on UMBS property has changed over time due to natural forest succession. We found mostly insignificant change in overstory composition and abundance from Pearsall's data to our current data, showing the slow and nonlinear process of natural forest succession. However, in three of our plots, we found significant difference, which shows some turn over from early to later succession species. To predict how the overstory will change after the succession due to loss of the *Fraxinus americana,* we used the species with the highest relative abundance in the understory as our predicted succession species. We found that *Acer saccharum* and *Fagus grandifolia* are the most likely succession species. Since the decimation of *F. americana* due to this invasive pest will happen relatively quickly, it could accelerate the rate of succession on UMBS property. Since EAB is affecting millions of *Fraxinus* trees around the country, more baseline surveys like this need to done to determine how forests will change to do the loss of this species. More research should also be done to study the ecological role of *Fraxinus* and how their loss will be impacting different ecosystems.

Introduction

The Emerald Ash borer (EAB), *Agrilus planipennis,* is an invasive pest of many different species of *Fraxinus* first introduced to North America in 2002 in metro Detroit. This pest has now extended its range all over the US and has been killing millions of *Fraxinus* in effected areas (Gandhi 2009). EAB was accidentally introduced to the US from its natural habitat in Northeastern Asia. In this region, natural predators and parasites of EAB have coevolved and worked to regulate EAB infestations. However, since EAB is non-native to the US, they have no natural predators and parasites to regulate their population growth, which has created an enemy free zone for the EAB to decimate the *Fraxinus* populations (Jennings et. *al* 2015).

In a study conducted by Knight et. *al,* they studied the EAB infestation rate on tree stands in Ohio and discovered that within six years after EAB colonization, there was complete mortality of *Fraxinus spp.* from EAB infestation. Furthermore, they discovered an inverse relationship between density of the host species (*Fraxinus spp.)* and mortality rate due to EAB infestation. This is because with lower host densities, the pest is heavily concentrated on the few *Fraxinus* within the site (Knight et. *al* 2011). This study has implications for the eventual local extinction of *Fraxinus spp.* in areas with relatively low density because of the higher mortality rate. Furthermore, the smaller the *Fraxinus* population is to begin with, the higher the chances are for local extinction. Looking into the future, how will forests inhabited by *Fraxinus spp.* in relatively low densities change after the loss of the *Fraxinus* due to EAB infestation?

On UMBS property, White ash (*Fraxinus americana)* is present in lower densities in many of the Northern Hardwood forest ecosystem types (Pearsall 1995). In the last 1900s, Douglas Pearsall established dozens of 15x30 meter plots within UMBS property in all ecosystem types and took a comprehensive survey of the species composition, soil properties and glacial history. This created a complete data set for all of the forest types we have on property (Pearsall 1995). However, with the introduction of EAB in the early 2000s, the *F. americana* population has experienced infestation on property since Pearsall's study. This means that since the *F. americana* are present on property with low densities and are infested with EAB, the overstory composition of these Pearsall plots have most likely changed and will continue to change as the *F. americana* continue to die. Our research aims to answer how the Pearsall plots that contain *F. americana* will change in overstory composition since the initial survey that could be the result of the EAB infestation.

We would predict that the overstory would not only change due to the loss of *F. americana,* but also due to understory succession in the canopy gaps of these dead trees. Light is a limiting factor in forests with a dense canopy, therefore canopy gaps caused by dying trees allow for development of the understory to eventually establish a spot in the overstory (Beckage et. *al* 2008). This can change the species richness and abundance of the overstory. Therefore, we would like to study the understory and woody ground cover surrounding the *F. americana* within the Pearsall plots to determine what succession of these gaps might look like. This would provide a prediction of the future overstory composition for these plots and how it will differ from Pearsall's original survey.

Our null hypothesis is there will be no change in overstory species composition and abundance in the Pearsall plots containing *Fraxinus americana* between Pearsall's overstory survey and following the succession of the dying *Fraxinus americana.* Our alternative hypothesis is there will be a significant change in overstory species composition and abundance in the Pearsall plots containing *Fraxinus americana* between Pearsall's overstory survey and following the succession of the dying *Fraxinus americana.* We would predict that since EAB is an unregulated pest species, the death of the *F. americana* due to the EAB would accelerate the rate of succession, causing changes in overstory composition.

Methods

To measure the change in overstory richness and abundance of the Pearsall plots, we searched the plot data for all the plots on UMBS property that contained at least 2 *Fraxinus americana* and found 8 plots scattered across the property. We used the following plots as our study sites: 8813, 9327, 9149, 9225, 9271, 9329, 9331, and 9401. Each of these plots are 15x30 meters and are permanent plots labeled with a T stake. In each of the plots, we measured the diameter at breast height (DBH) and recorded species name for all the overstory trees, which Pearsall classified as >10cm. We ran 8 chi-squared tests to determine if there has been any significant change in relative density of each species in the overstory from the Pearsall study to today in all 8 of our plots. We then ran 3 chi-squared tests comparing Pearsall's, our data and the overlapping surveyed plots from Raleigh Ricart's 2014 research. We used Raleigh's data to show any changes over shorter time intervals. To visualize these data, we made pi charts showing to densities of each species per plot. These data can also serve as baseline data of overall change in the overstory composition due to change in forest succession stage.

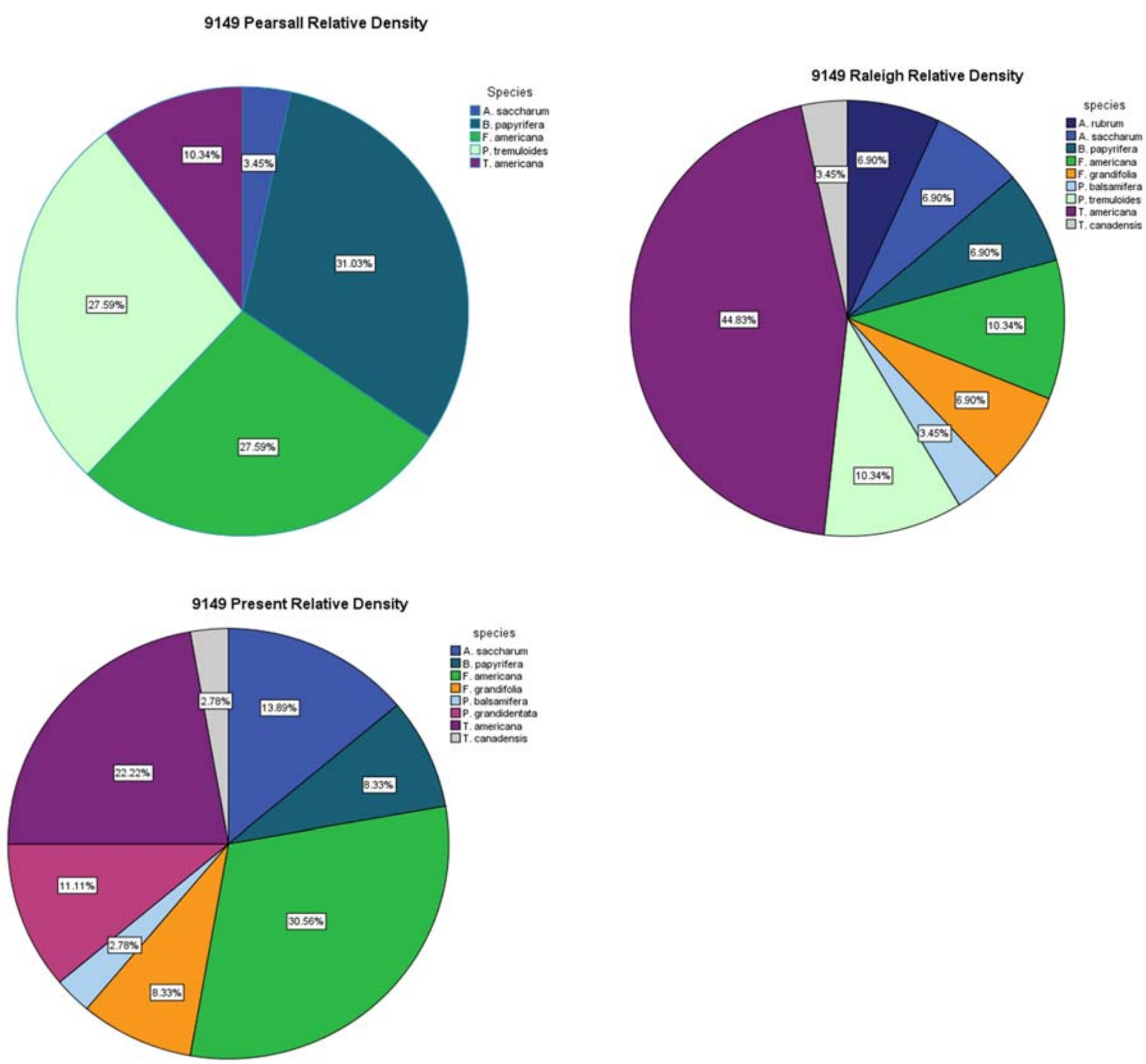
To determine the health status of all the *F. americana*, we used a simple numeric system: Class 1=alive and health, Class 2=alive but with minor leaf dieback, Class 3=dying with major leaf dieback, Class 4=completely dead, either snag or downed logged. Since the EAB infestation is now widespread across Michigan (Gandhi 2009), we made an assumption that the cause of death was from EAB infestation. We calculated the health stage of *F. americana* to create a baseline status for future studies to quantify change in severity and progression of the EAB on UMBS property. This also allowed us to make a qualitative analysis if succession from the *F. americana* death has already taken place due to its health status.

To determine what species could possibly succeed in the gaps left by dead *Fraxinus americana,* we calculated the drip line of the *F. americana,* which is the space in the overstory that is taken up by either the alive tree crown or the open gap left by the dead crown. We added 1 meter to each side of the drip line to insure we included everything that might encroach into the open gap. We measured all of the understory and woody groundcover within the extended drip line area. We measured the DBH of the understory (<10cm) and the percent coverage of the woody groundcover (<DBH). To make a prediction about what could possibly succeed the *F. americana,* we calculated the relative dominance of each species in the understory and woody groundcover within the *F. americana* drip line. We then used the most dominant species as the most likely candidate to replace *F. americana* in the future overstory.

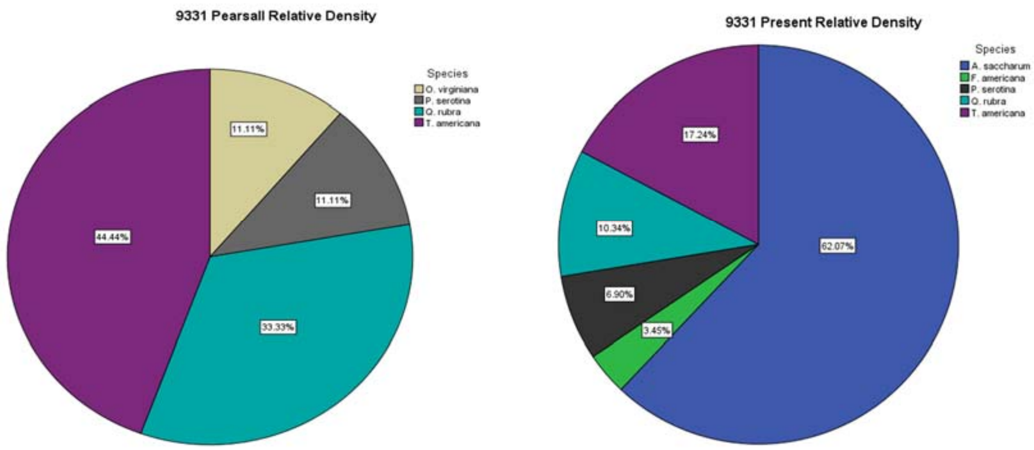
Results

In our chi-squared tests to determine difference in relative density for each species within our plots between Pearsall's survey and our present survey, we found 3 plots that showed a significant difference and 5 that did not. Our significant plots were 9331 (X^2=14.857 df=5 P-value=. 011), 9149 (X^2=25.706 df=8 P-value=. 001) and 9271 (X^2=15.875 df=7 P-value=. 026) (Fig. 1). Our insignificant plots were 8813 (X^2=11.954 df=7 P-value=.102), 9329 (X^2=1.68 df=2 P-value=.432), 9225 (X^2=2.401 df=4 P-value=.662), 9401 (X^2=. 599 df=3 P-value=.897) and 9327 (X^2=8.31 df=6 P-value=.216). In the plots we compared Pearsall's, Ricart's and our data, there was significant difference between Pearsall vs. Ricart in plot 9149 (X^2=21.9 df=9 P-value=.005) (fig. 1), and no difference between Pearsall and Ricart in 9329 (X^2=.682 df=2 P-value=.711) and 9271 (X^2=9.11 df=6 P-value=.167). There was also no significant between Ricart and the present survey in 9149 (X^2=13.8 df=9 P-value=.13), 9329 (X^2=.741 df=2 P-value=.69) and 9271 (X^2=11.2 df=2 P-value=.132).

A.



B.



C.

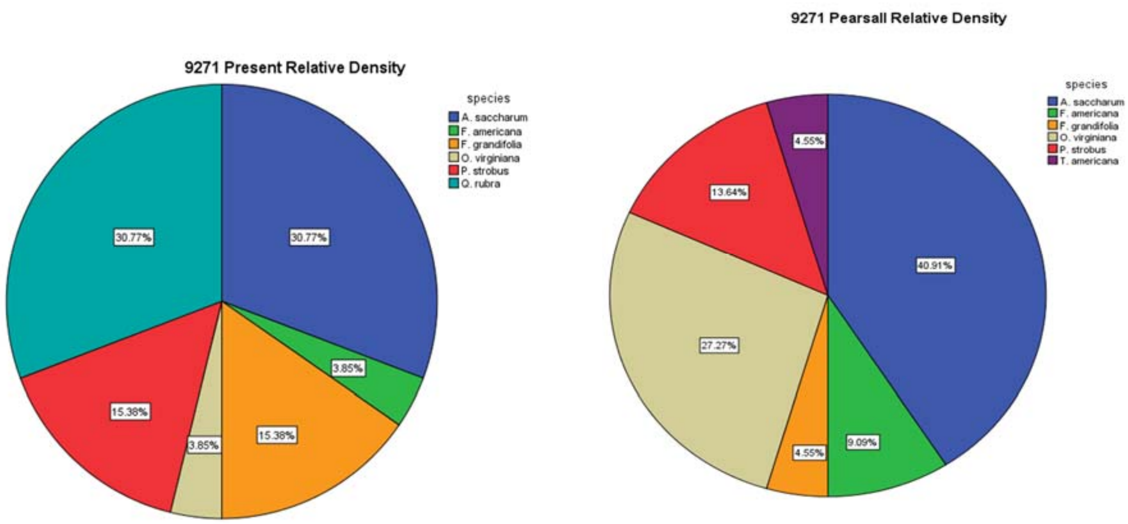


Figure 1: A. Pi charts showing significant difference in relative density per species between Pearsall's, Ricart's and our current survey for plot 9149 . B and **C:** Pi charts showing significant difference in relative density between Pearsall's data and our current survey in plots 9331 and 9271 respectively.

To measure the health status of our trees, we recorded a total number of 32 *F. americana* across all 8 of our plots: 2 were class 1, 7 were class 2 and 3, and 16 were class 4. 3 of those 16 were downed logged with a class 1 downed woody debris status. 50% of our sampled *F. americana* were completely dead and 71% were completely dead or showing extreme canopy dieback.

To determine what species we would predict might succeed the dying *F. americana,* we chose the most dominant species in the drip line understory. In plots 8813, 9225, 9327, 9331 and 9401 *Acer saccharum* had the highest relative dominance and in plots 9149, 9271 and 9329 *Fagus grandifolia* had the highest relative dominance. All but one of the plots already contained the succession species, which provides a speculative observation of a decline of species richness due to the loss of *F. americana.* In plot 9329, *Fagus grandifolia* is predicted to succeed *F. americana* but is not present in the current overstory.

Discussion

By looking at our results from Pearsall's survey in the late 1900's, Ricart's data from 2014 and our present survey, we saw that the majority of the plots did not show significant change in species composition and abundance. This could be showing that the rate of undisturbed forest succession is a slow process and does not show significant changes within a 20-30 year time period (Barnes 1998). This could also be showing that species turnover and change in abundance is not exclusively a linear process. The boundaries between natural succession stages can be overlapping and non distinct, especially over a short time period (Barnes 1998).

However, we did discover significant differences in overstory composition and abundance in three of our plots. These plots did show signs of changes in succession stages because of turn over from earlier to later succession species. In plot 9331, Pearsall did not record any overstory *Acer saccharum* and our current survey showed this species present with 62.07% relative density. *A. saccharum* is a later succession species (Barnes 2004), so we would expect this species to become more prominent in the overstory as succession continues. Similarly in plot 9149, Pearsall recorded *Betula papyrifera,* an early successional species (Barnes 2004), with 31.03% relative density and our current survey showed a decline to 8.33% relative density. In addition, our current survey at this site showed the presence of three late successional species, *A. saccharum, Fagus grandifolia* and *Tsuga canadensis* (Barnes 2004), all of which were either not present or present in lower densities in Pearsall's survey. These data show that although the process of forest succession is slow and somewhat chaotic, there still are clear trends and changes in species composition through time. Furthermore, these data for past overstory changes can serve as baseline data to be compared with the future overstory of these plots following the succession of the *F. americana.*

In our plot survey, we discovered that the majority of the *F. americana* were dead or almost completely dead due to the emerald ash borer. This shows that in the near future, *F. americana* might not be apart of the species composition on UMBS property. Studies have shown that an infected *F. americana* will die in about six years on average, but this will vary depending on age and size (Knight et.

al 1995). This means that the 20 *F. americana* trees we saw that were not completely dead will most likely be gone in a just a few years, changing the canopy composition across UMBS property. Although we discovered a majority of class 4 *F. americana,* only 3 of those were downed logged and none of those showed signs of complete understory succession to the canopy layer. This means that succession due to the death of *F. americana* is in the near future, but the overstory composition has not yet changed due to the disturbance caused by the EAB.

To predict what the future overstory might become after the succession of the *F. americana,* we chose the understory species with the highest relative dominance found in the drip line of the *F. americana.* Generally we saw that *F. americana* will be succeeded by either *Acer saccharum* or *Fagus grandifolia,* decreasing species richness of the plot due to the current presence of these species in the overstory. However, we predict that in plot 9329, *Fagus grandifolia,* which is not present in the overstory, might succeed the *F. americana,* creating a replacement to maintain species richness. Although these data are speculative, this shows that over the past 20-30 years, species composition and abundance has only changed slightly due to natural forest succession, but in the next few years following the succession of the *F. americana,* the overstory composition could quickly change due to the relatively sudden loss of this species. Since EAB is an invasive species and has no natural predators, it is unregulated in the ecosystem (Jennings et. *al* 2015), causing the *F. americana* to be decimated in a much shorted time period than naturally occurring forest succession. This is consistent with a study done to measure changes in carbon sequestrations in forests with infected *Fraxinus.* They showed that the colonization of EAB created a significant acceleration in forest growth following the *Fraxinus* mortality (Flower et. *al* 2012).

Since these future data are speculative, our limitation is that we could be wrong about how succession of the *F. americana* will occur. Understory succession may not even occur if the canopy gap is too small and therefore the present overstory will encroach into the gap. There are inconclusive estimates for the minimum gap size required for understory succession to occur (Kneeshaw 1998) and therefore we decided to assume understory succession would occur in our plots. Despite this potential error, 20 of the 32 *F. americana* we surveyed were clumped together in the plot, creating overlapping canopy gaps the size of two to four trees. With the large size of these gaps, we predict that understory succession is very possible.

Since EAB is widespread in North America, this kind of baseline research needs to be done in all areas of the United States with *F. americana* to determine how forest succession is going to change due to the loss of this species. Furthermore, *F. americana* mortality is not just going to impact the forest composition; studies have shown that it causes a negative impact on several arthropod species that are associated only with *Fraxinus spp.* for feeding and breeding (Gandhi 2009). This means that *F. americana* has an ecological role in its ecosystems in difference parts of the country. Further research should be done to determine these ecological impacts with associated organisms and study how ecosystems might be able to recover from the loss of the *F. americana.*

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