Abstract: *Managers and scientists have expressed concern regarding the ongoing homogenization of mixed hardwood forests in the Upper Midwest as early successional stands mature. Specifically, sugar maple (Acer saccharum) has become overabundant in the forest understory and canopy. These trends have occurred simultaneously with losses in forest understory biodiversity, and some scientists place the blame on sugar maple. This study seeks to investigate the interactions sugar maple and five other common forest trees have with seedling composition and understory species richness. Additionally, this study aims to understand how elevation and successional gradients influence understory communities. Fifty sites at the University of Notre Dame Environmental Research center in Gogebic County, Michigan were sampled using a rigorous vegetation inventory schema. Results suggest that canopy and understory sugar maple outcompetes other tree species, increasing homogenization and biodiversity loss. Additionally, sugar maple stands poised to colonize maturing early successional stands, removing an important booster of floral biodiversity from the landscape. Finally, this research suggests that sugar maple is strongly associated with elevation gradients, preferring highland stands to lowland stands.*
Keywords: *Acer saccharum, understory species richness, elevation gradients, Northern Midwest*

REALIZING THE IMPORTANCE OF THE MUNDANE

The Impact of Local Elevation, Canopy Species Composition, and Successional Gradients on Tree Sapling Diversity and Understory Species Richness in Northern Mixed Hardwood Forests

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INTRODUCTION:

Forests across the eastern deciduous forest type biome are currently suffering through an unprecedented biodiversity crisis. Understory sapling diversity has decreased across late and mid successional forests, resulting in an unnatural overabundance of shade tolerant species' saplings (Schumacher and Carson, 2013). Since these young trees represent the future forest canopy, this diversity crisis stands to impact forests for decades to come (Schumacher and Carson, 2013). Research conducted at the University of Wisconsin has shown "mesification" of early successional forest stands towards maple dominated canopies drastically decreases understory species diversity in southwestern Wisconsin (Rogers et al., 2008). This trend occurs in northern Wisconsin as well. A study conducted in part in Vilas County, Wisconsin, reported an average loss of 18.5% of original understory floral diversity

(Rooney et al., 2004). This study also suggested that common generalist species have become overabundant, leading to the loss of biodiversity (Rooney et al., 2004).

Sugar maple (*Acer saccharum*) is such a species. It is common in mid-successional forests and exhibits a degree of shade tolerance that allows it to thrive in shaded, closed canopy forests (Berkowitz et al., 1995). This species is also an aggressive competitor. A study conducted on the maple-beech forests of New York's Hudson Valley indicated that survival of maple saplings was improved by the presence of intact understory vegetation, regardless of species richness, suggesting that sugar maple effective compete against other saplings and woody plants even in densely crowded areas (Berkowitz et al., 1995). Canopy sugar maples were also shown to negatively impact the growth of neighboring balsam fir (*Abies balsamea*), red spruce (*Picea rubens*), white pine (*Pinus strobes*), and red oak (*Quercus rubra*) in the canopies New England maple-beech forests, demonstrating a strong competitive effect on these species vitality (Canham et al., 2006). Sugar maple canopy influence can also be negatively correlated with American beech (*Fagus grandifolia*) and eastern hemlock (*Tsuga canadensis*) sapling abundance across the hemlock-northern hardwood forest type (Woods, 1985). These studies suggest that an overabundance of sugar maples in Wisconsin forests may contribute to the observed loss in understory biodiversity through the shade tolerance and the competitive advantage of sugar maple.

Forest structure in Wisconsin has long been thought to be driven primarily by the related factors of disturbance regimes, land use history, and successional gradients (Peek and Loucks, 1977). Before intensive European and American settlement, the landscapes of northern Wisconsin and Michigan were characterized by unbroken stretches of virgin northern mixed hardwood forests (Rhemtulla et al., 2009). Almost the entirety of these forest were clear-cut during over the course of a half a century during the heady golden years of logging (Rhemtulla et al., 2009) The slash was burnt over several times by large, occasionally catastrophic fires, but eventually allowed to reforest naturally (Rhemtulla et al., 2009). The forests of the "Northwoods" today reflect that reseeding following a marginally apocalyptic disturbance.

Therefore, forest succession plays a critical role in understanding stand dynamics in these woodlands. Aspen and paper birch benefitted greatly from clear-cutting, easily colonizing newly opened sites (Rhemtulla et al., 2009). Aspen increased the most in the far northern reaches of Wisconsin, but peaked in 1930, and has been declining ever since (Rhemtulla et al., 2009). As these early-successional stands of aspen reach the end of their relatively short life-spans, new mid-successional tree species will take their place in the canopy. However, managers have expressed concern over increasing species homogeneity, specifically in regards to sugar maple, as these mid-successional trees mature (Schumacher and Carson, 2013). If the maturation of these early successional communities to mid-successional stands poses a threat to species richness and floral biodiversity, then the amount of early successional species such as aspen should correlate positively with increased understory species richness, as well as increase in mid-succession tree sapling stem density.

Previous studies in other eastern deciduous forest settings have demonstrated the deterministic role topography plays in species distributions, especially with regards to sugar maple (Shanks, 1953). One such study in northwestern Lower Michigan which specifically investigated the relationship between glacial topography and *Acer* canopy composition reported that sugar maple prefer glacial moraines over outwashes, and outcompete closely related red maple (*Acer rubrum*) saplings in these areas (Host and Pregitzer, 1987). Due to the unique history of glaciations and dearth of extreme topography in the landscapes of the Upper Midwest, the varied local terrain plays an important role in water, acidity, and nutrient gradients, impacting forest species' compositions in turn (Rencz and Sangster, 1992). Research conducted in Vilas County attempting to use satellite data to investigate local topography and qualify its usefulness as a metric predicting forest type found that using terrain satellite data does improve classification accuracy of forest types (Rencz and Sangster, 1992). Topography appears to impact forest composition in Wisconsin, but what role it plays on the distributions of common tree species and general understory species richness has not yet been explored. However,

synthesizing the species distribution studies conducted outside of Wisconsin and northern Michigan with the local terrain studies conducting in Upper Midwest suggest that elevation will exert a deterministic effect on the abundance and composition of sugar maples. Specifically, sugar maples may avoid the lowland and bottoms of forest regions, instead preferring ridges and highlands.

This study sought to examine how forest understory species richness and tree sapling recruitment varies along elevation and canopy species composition gradients. To investigate this question, I measured species richness and stem density of six understory species common to the mixed-hardwood forests of the Upper Midwest: sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), quaking aspen (*Populus tremuloides*), balsam fir (*Abies balsamea*), ash species (*Fraxinus spp.*), and cherry species (*Prunus spp.*).

I hypothesized that: 1) sugar maple saplings would show a strong relationship with elevation gradients, and specifically demonstrate a marked aversion to low elevation sites; 2) sugar maple canopy percent composition would negatively correlate with the other tree species understory percent composition and general species richness; 3) Early successional species presence in the forest canopy would correlate positively with general species abundance and tree seedling composition.

METHODS AND MATERIALS:

Data Collection:

For this project, I sampled fifty points at the University of Notre Dame Environmental Research Center in Land 'O Lakes, Wisconsin, using a random stratified sampling design. First, I created a fishnet in ArcGIS across the property, composed of fifty meter by fifty meter cells (Figure 1). Then, all cells that contained any part of a lake, stream, or road were removed to ensure that only terrestrial and relatively isolated sites would be sampled. Next, I attributed all the remaining cells with the average elevation within the cells, based off of an elevation raster file (National Elevation Data 10 meter, USDA/NRCS -

National Geospatial Center of Excellence). These cells were then classified into five categories based upon their average elevation using the Jenks natural breaks method, which highlights the organic divisions in the data set. This method does not, however, create classes that are equal in size. I ranked these classes from one to five, with five being the highest average elevation and one being the lowest. I used a random number generator to select twenty points from each class to sample (Figure 1). Due to time constraints, I only surveyed half of the points from each class, but the study design and objectives helped ensure that this complication did not create any bias, specifically because I was largely unaware of forest conditions before visiting these points (Figure 2).

In the field, I navigated to the center of each of these cells using the smart-phone application Avenza Maps. At the cell's center, I marked my location in the application and filled out the pre-loaded study schema. I created this schema before I began sampling and loaded it onto my smart device. The schema contained the following measurements for the midpoint: days since last precipitation, class, sample point number, replication, temperature, relative humidity, cloud cover, soil pH, soil moisture content, solar irradiance, canopy coverage, tree basal area, species of trees counted in basal area, understory species richness, four most prevalent understory species, and stem density of these four species (Figure 2). I also indicated in my notes whether a point occurred in a wetland community. I used a Kestrel 3500 handheld weather instrument to record temperature and relative humidity. I used a Kelway Soil Tester to measure soil pH and soil percent moisture saturation. Then, I used a Dwyer Solar Power Meter to measure maximum solar irradiance in Watts per square meter over a ten second period. To ensure that I accurately represented the available solar irradiance at the point, I held the meter above my head and rotated it 360 degrees, so as to sample the entire horizon. I later normalized these values to account for differences in weather and time of day during field sampling. I recorded canopy coverage using a simple densiometer. To measure basal area, I used the more crude method of thumb measurements over a basal area prism. However, I am not concerned that this will affect my results,

since I am comparing the sites to each other, and not to benchmarks from other sites or literature. I used a 1.25 cord to act as the radius for a circle around the midpoint. I counted the stem density of the four most numerous woody plant morphospecies that occurred in this circle. Preference was given to tree seedlings over shrubs (Figure 2).

Four more points were taken five meters away from the center point, one in each cardinal direction. All the same measurements were taken at the northern and southern points, with the exception of basal area. I took all the same measurements at the eastern and western points, excepting basal area, understory stem density, and species richness (Figure 2).

Data Processing:

This data was compiled in ArcGIS 10.4, processed, and refined in Excel. Recorded basal area was multiplied by ten to adjust the data to square feet per acre. Canopy coverage was also transformed to a measure of canopy percentage measurement of canopy openness that was used for subsequent analyses. I also calculated percent composition values for every understory and canopy species based upon their stem density. I then averaged the attributes for each recorded statistic test, excepting stem density, from the five replications taken at a sample cell. I calculated "understory derived species richness" by performing a count of the species represented at all three points. While each of the three points could at most contribute four species to the overall understory derived species richness, the metric revealed differences in species richness between the three replication points obscured by averaged species richness. With the exception of average species richness and basal area, these average values were used in my analysis. Of the thirty three understory species represented in the stem density data, the six most common understory tree sapling species were considered. These species were sugar maple, red maple, quaking aspen, balsam fir, *Fraxinus* species, and cherry species. These six species, besides being the most common, and therefore the most robust for analysis, also play different roles in

forest composition and illuminate different facets of stand dynamics. I also focused on these six species percent composition in the canopy. I pooled quaking aspen records with bigtooth aspen (*Populus gradidentata*) records due to the difficulty in correctly identifying these species in the field. This pooled *Populus* canopy composition considered equivalent to quaking aspen saplings, since only one site was shown to have a bigtooth aspen sapling.

Statistical Analysis:

The following variables were used in my analyses: elevation class, average canopy openness, adjusted basal area, canopy percent composition of sugar maple, red maple, *Populus* species, balsam fir, *Fraxinus* species, and black cherry, understory average species richness, understory derived species richness, and understory species percent composition for sugar maple, red maple, quaking aspen, balsam fir, *Fraxinus* species, and cherry species. All of these variables were not normally distributed, with the exception of understory average species richness. Finding normalizations for these variables was unrealistic due to the extreme negative positive skew caused by frequent null values. Therefore, all the analyses I conducted relied upon non-parametric tests, specifically Kruskal-Wallace and Kendall correlation rank tests. Because of the limitations of non-parametric tests and the variability inherently tied to field observational studies lacking experimental manipulation, I chose to use the 90% significance level rather than the more stringent 95% significance level. This choice was purely methodological in nature, as many of my tests showed significance at the 95% level. To me, it seems unrealistic to be 95% confident of any trend in a forest setting, because it is simply too complicated and complex for that regimented of an analysis.

My inferential statistics were calculated in R (R Core Team, 2016). First, a Kruskal-Wallace test was conducted comparing the six understory tree species percent compositions with elevation class. Then, two series of Kendall rank correlation tests comparing these species percent compositions with

both canopy openness percentage and adjusted basal area. Next, I ran a battery of thirty six Kendall tests comparing the canopy percent composition of these six species with their understory percent composition. Finally, a series of twelve Kendall tests was run to investigate relationships between these six species canopy percent composition and both measures of species richness.

Following this initial analysis, the "wetland" sample points were removed from the data set, and the analysis was run again. This change was to satisfy concerns from the original analysis that the wetland points were so different from non-wetland sites in composition and structure that an apples-to-apples comparison would skew the data and obscure other important correlations. The same tests were applied in the same manner to this truncated data set.

RESULTS

Before beginning the analysis proper, I executed a Chi-Squared test that indicated that the abundance of points characterized as "wetland" sites was not independent of elevation class (X^2 = 26.107, df = 4, p-value = <0.001; Figure 3). Due to the low number of wetland points (11 total), I conducted a second Chi-Squared test that used 2000 replications to simulate a p-value similar to the original. This Chi-Squared supported the dependence suggested by the earlier test (X^2 = 26.107, df = NA, p-value = <0.001).

I continued investigating elevation class and its correlations. First, I compared elevation class to canopy tree species percent composition. These six Kruskal-Wallace tests indicated a statistically significant value for both sugar maple and balsam fir (sugar maple: Kruskal-Wallis Chi-Squared = 14.865, df = 4, p-value = 0.004989; balsam fir: Kruskal-Wallis Chi-Squared = 11.449, df = 4, p-value = 0.02196). Total sugar maple canopy stem density showed a strong positive trend with elevation class (Figure 4). Balsam fir showed an opposite preference with the second elevation class (Figure 4). I then ran twelve Kendall correlation rank tests aimed at uncovering relationships between the six canopy species. This

analysis returned a significant negative correlation between sugar maple and red maple canopy stem density (p-value = 0.002, tau = -0.344; Figure 5). It also reported two positive correlations for cherry with *Fraxinus* and *Populus* species (*Fraxinus*: p-value = 0.096, tau = 0.207; *Populus*: p-value = 0.034, tau = 0.269).

A second series of Kruskal-Wallace tests returned significant positive correlation between elevation class and understory species percent composition for two of the six tree sapling species I focused on, sugar maple and quaking aspen (sugar maple: Kruskal-Wallace Chi-Squared = 9.870, df = 4, p-value = 0.043; quaking aspen: Kruskal-Wallace Chi-Squared = 9.283, df = 4, p-value = 0.054; Figure 6).

Then I switched focus to forest stand characteristics. A Kendall rank correlation test demonstrated sugar maple understory percent composition to be negatively correlated with canopy openness (p-value = <0.001, tau = -0.383; Figure 7). Two more Kendall tests demonstrated a significant positive correlation between sugar maple and cherry understory percent compositions and basal area (sugar maple: p-value = 0.003, tau = 0.308; cherry: p-value = 0.08, tau = 0.188). Kendall tests comparing the six studied understory tree sapling species' relationships with each other indicated that sugar maple and red maple were negatively correlated (p-value = 0.039, tau = 0.224).

A set of 36 tests investigating any correlation between the percent composition of the six understory tree species and the percent composition of these same species in the canopy returned eleven significant results. Canopy sugar maple composition was shown to be positively correlated with understory sugar maple percent composition (p-value = 0.001, tau = 0.362; Figure 7). Canopy sugar maple was also negatively correlated with red maple and balsam fir understory percent composition (red maple: p-value = 0.023, tau = -0.247; balsam fir: p-value = 0.07, tau = -0.2; Figure 7). Red maple canopy composition and balsam fir understory composition were also positively correlated (p-value = 0.046, tau = 0.231). The *Populus* canopy class positively correlated with sugar maple, quaking aspen, and *Fraxinus* understory percent compositions (sugar maple: p-value = 0.02, tau = 0.328; quaking aspen: p-

value = 0.043, tau = 0.241; *Fraxinus*: p-value = 0.001, tau = 0.296). Balsam fir canopy percent composition also had three positive correlations: between quaking aspen, balsam fir, and *Fraxinus* understory percent composition (quaking aspen: p-value = 0.003, tau = 0.367; balsam fir: p-value = 0.002, tau = 0.362; *Fraxinus*: p-value = 0.081, tau = 0.202). Finally, cherry canopy percent composition was positively correlated with cherry understory percent composition (p-value = 0.016, tau = 0.301).

The canopy percent composition of some of these six species also was correlated with both metrics of understory species richness. Sugar maple canopy percent composition was shown by a Kendall correlation test to be negatively correlated with understory average species richness (p-value = 0.068, tau = -0.192; Figure 9). *Populus* canopy density showed a positive correlation with both understory average species richness and understory derived species richness (average species richness: p-value = <0.001, tau = 0.412; derived species richness: p-value = 0.012, tau = 0.278; Figure 10). Understory average species richness also demonstrated positive correlations with red maple, quaking aspen, *Fraxinus*, and cherry percent compositions (red maple: p-value = 0.03, tau = 0.232; quaking aspen: p-value = 0.073, tau = 0.206; *Fraxinus*: p-value = 0.083, tau = 0.188; cherry: p-value = 0.003, tau = 0.323). Understory derived species richness also showed a significant relationship with *Fraxinus* and cherry percent composition (*Fraxinus*: p-value = 0.03, tau = 0.245; cherry: p-value = 0.002, tau = 0.354).

The second phase of the analysis, which entailed applying the exact same tests to the data set purged of “wetland” points, yielded significantly different results from its forbearer. First, the Kruskal-Wallace test comparing elevation class to each species’ canopy percent composition continued to show correlation with sugar maple and balsam fir. It also indicated a third correlation with cherry (Kruskal-Wallis chi-squared = 7.9915, df = 4, p-value = 0.09189). The series of test between canopy species compositions revealed two new negative correlations for sugar maple between *Populus* and balsam fir (*Populus*: p-value = 0.027, tau = -0.263; balsam fir: p-value = 0.04, tau = -0.256). The test also indicated

that balsam fir positively correlated with cherry (p-value = 0.065, tau = 0.262). Two of cherry's previous correlations between *Populus* and *Fraxinus* also no longer appeared to be significantly correlated.

failed to report any correlation between class and either sugar maple of quaking aspen, unlike the original test (sugar maple: Kruskal-Wallace $X^2 = 5.07$, df = 4, p-value = 0.280; quaking aspen: Kruskal-Wallace $X^2 = 2.962$, df = 4, p-value = 0.564). Instead of detecting the previous correlations, this test returned a new positive correlation with balsam fir (Kruskal-Wallace $X^2 = 9.071$, df = 4, p-value = 0.0594). The Kendall test between canopy openness and understory tree species percent composition also detected correlation where there had not previously been any. This test indicated that red maple shared a positive correlation with canopy openness (p-value = 0.034, tau = 0.253). Also, the correlation value for sugar maple and canopy openness, while still significant, was less negative than the original test indicated (p-value = 0.09, tau = -0.194.

In the next revised Kendall test, sugar maple fell out of statistical significance with basal area, but remained trending in that direction (p-value = 0.142, tau = 0.171). Cherry remained positively correlated with basal area (p-value = 0.053, tau = 0.235).

The battery of thirty six Kendall tests examining correlation between the six species compositions in the understory and canopy changed the most after removing the wetland points. Canopy sugar maple's relationships with understory sugar maple, red maple, and balsam fir all became not statistically significant (sugar maple: p-value = 0.951, tau = 0.007; red maple: p-value = 0.162, tau = -0.172; balsam fir: p-value = 0.465, tau = -0.095). Canopy sugar maple did pick up a new negative correlation with cherry understory percent composition (p-value = 0.02, tau = -0.286). Red maple lost one and gained two correlations. A Kendall test indicated that canopy red maple correlated positively with understory red maple (p-value = 0.09025, tau = 0.219). Canopy red maple also gained a positive correlation with understory cherry (p-value = 0.015, tau = 0.316). Another Kendall test also revealed that canopy red maple was no longer correlated with understory balsam fir (p-value = 0.7, tau = -0.05).

Populus lost all of its statistically significant correlations with sugar maple, quaking aspen, and *Fraxinus* (sugar maple: p-value = 0.921, tau = -0.012; quaking aspen: p-value = 0.445, tau = 0.1; *Fraxinus*: p-value = 0.828, tau = 0.026). The Kendall test reported that balsam fir no longer was correlated with understory quaking aspen, but also that it remained positively correlated with understory balsam fir and *Fraxinus* (quaking aspen: p-value = 0.182, tau = 0.183; balsam fir: p-value = 0.095, tau = 0.214; *Fraxinus*: p-value = 0.003, tau = 0.382). *Fraxinus* was shown to correlate negatively with understory red maple, which it did not previously (p-value = 0.043, tau = -0.279). Finally, canopy cherry remained positively correlated with understory cherry percent composition (p-value = 0.061, tau = 0.261).

Moving finally to understory average and derived species richness, the number of correlations with canopy tree species percent composition grew by one. Understory derived species richness was no longer correlated with *Populus* composition (p-value = 0.753, tau = -0.039). However, understory derived species richness gained two correlations, a negative correlation with sugar maple and a positive correlation with red maple (sugar maple: p-value = 0.026, tau = -0.274; red maple: p-value = 0.074, tau = 0.233). Additionally, the two previously extant correlations between understory average species richness and the percent canopy compositions of sugar maple and *Populus* remained statistically significant (sugar maple: p-value = 0.008, tau = -0.316, *Populus*: p-value = <0.001, tau = 0.472).

DISCUSSION

The results of this observational study confirmed several of my initial hypotheses. First, sugar maple's presence in the canopy adequately predicted lower species richness values, lower tree seedling percent compositions, and lower canopy species diversity. Places with more sugar maple in the canopy were generally less species rich, and the species present generally were less abundant. These results corroborate the findings reported in several studies conducted across the native range of sugar maple. And while the Kendall rank correlation test technically can only determine correlation, not causality,

ecological common sense and suggests that species richness or understory percent composition does not cause the canopy composition. This corroborates research published by a number of ecologists who have argued that the sugar maple monocultures of the Upper Midwest harm biodiversity (Schumacher and Carson, 2013). Basal area and stem density in these areas remained high, however, supporting the conclusion that sugar maple saplings were outcompeting other species, due in part to their remarkable shade tolerance. Unpublished data collected suggests that understory sugar maple correlates negatively with canopy openness, while most other understory tree species show the opposite trend (Watter, unpublished 2017). This may lock forests in an increasingly homogenous novel climax community, where normal floral, and therefore faunal, assemblages cannot thrive. Sugar maple, therefore, acts as a foundation species in the forests of the Upper Midwest.

Sugar maple competes so effectively with other tree species thanks to its fine-tuned adaptation to mid-successional forest communities (Schumacher and Carson, 2013). My findings demonstrate sugar maple seedlings preference or bias towards forest stands with high basal area and low canopy openness. Sugar maple also spreads very effectively. Sugar maple seedlings occurred in 31 of 50 sites, accounted for 30% of the overall understory percent composition, and had the greatest total stem density of any species at 977. Sugar maple saplings were also the most abundant understory species by stem density at every elevation class except the lowest (Figure 6). The over abundance of sugar maple will only become more apparent as the early successional quaking aspen and big toothed aspen stands of the Midwest mature and die off. The *Populus* species demonstrated a very strong positive correlation with both measures of species richness (Figure 10). This may be due to their unique leaf structure, which could allow more light to reach the forest understory. However, they also showed a positive correlation with percent composition of sugar maple saplings. In fact, the two classes with the highest stem density of sugar maple saplings also had the highest canopy density of *Populus* trees. *Populus* trees dominated the three middling elevation classes, which demonstrates how large of a gap for sugar maple these trees

will leave when they eventually fall. These young trees will someday replace the short-lived aspen, perpetuating the homogenization of northern woodlands.

However, there are local limits to the natural distribution of sugar maple stands within a forest community. One of these limits in the forests of the Upper Midwest appears to be elevation. Sugar maple stem canopy density increased at each elevation class, reaching its peak at the highest elevations sampled (Figure 4). The highest elevation class possessed almost 380% more sugar maples than any of the next most common species (Figure 4). Conversely, sugar maples were virtually nonexistent in the lowest elevation class, averaging less than one tree a site. This is due to the effects local terrain exerts on water gradients. The Upper Midwest's unique history of glaciations created a landscape rich with ridges, eskers, drumlins, and especially important to this research, kettles (Leitner et al., 1991). Kettles are low spots carved by glaciers (Leitner et al., 1991). They collected water from the melting glaciers, and continue to pool rainwater runoff today. My research has shown that elevation can predict the abundance of these wetland communities and the unique floral communities tied to them (Figure 3). These communities have distinct tree and understory assemblages of species that cannot be found in other types of forest stands. Sugar maple simply cannot compete with the species in these more mesic areas, especially red maple. I recorded 63 red maple saplings in the lowest elevation class, compared to only fourteen sugar maple saplings. Red maple appears more tolerant to wetland environments, in which sugar maple cannot persist. Therefore, sugar maple should tend to skew away from areas of lower elevation and instead associate with the uplands of the glacial landscape. My research supports that hypothesis. Sugar maple tends to be more common in the two highest elevation classes than in the two lowest, demonstrating a preference that can be statistically supported.

As shown previously, my data suggests that red maple and sugar maple compete, and which species succeeds depends on a number of factors, including basal area, canopy openness and composition, and soil moisture content. Red maple, unlike sugar maple, lacks the negative associations

with other tree species' seedlings and species richness. It also appeared more correlated with canopy openness and solar irradiance percentage than sugar maple (Watter, unpublished 2017). Currently, red maple appears to be limited in its distribution in part by competition with sugar maple. Statistical analysis reported strong negative correlations between the two species, regardless of where the species' location was considered. This confirms the second portion of my second initial hypotheses: that sugar maple and red maple occupy different roles and niches, and compete when these niches overlap. Further studies should be conducted investigating the strength and nature of competition between these two species, especially along soil moisture and light gradients, which will undoubtedly change due to climatic shifts.

Having investigated the role water and wetlands play in regulating sugar maple distributions, I was intrigued to see how removing the "wetland" points would change my results. Removing these points resulted in a decrease in statistically significant correlations and the uncovering of some potentially hidden relationships. Many of the loss in points can be attributed to the overall decrease in sample size. Eleven points fell into the "wetland" category, so removing these sites essentially removed a fifth of the sample size, and almost every point from the first elevation class. However, removing these points focused the subsequent statistical inquiries into the relationships and interactions in the other four non-wetland elevation classes. This strengthened the case indicting sugar maple of decreasing diversity by zooming in on the relationships exclusively in forest communities. The correlations that remained were shown to be robust, and most likely accurate. One of the most interesting takeaways from this second analysis is the difference in correlation to understory derived species richness between the two maple species. Sugar maple demonstrated a negative correlation with understory derived species richness, while red maple had a positive relationship.

Red maple and sugar maple, however, are only two species from a total of six analyzed and thirty three recorded. What role do the other species represented in this study play in forests? Common

sense might suggest that the clonal nature of *Populus'* life history would reduce species richness. Yet, at least in mature *Populus* stands, the forest understory appears to be diverse and thriving. These mature aspen trees demonstrated positive associations with *Fraxinus* species and balsam firs, suggesting that these three may form a common species assemblage in northern forests. These relationship between species richness and *Populus* canopy composition marks them as an important, albeit maturing, foundation species. Other species, such as *Fraxinus* and cherry, serve as important indicator species, signaling increasing biodiversity. Areas where these species could be found were generally more species rich than areas without these species.

In the forests of Wisconsin and Northern Michigan, the species composition of tree seedlings in the understory is influenced by many factors. The type of trees making up the canopy plays a role in richness and composition of the understory. Elevation, and factors such as wetland community that occur with elevation, also influence the assemblages of understory species. Finally, the characteristics of the forest itself shape the community's nature. Which of these factors plays the most significant role in understory characteristics is not yet known, but each is important for its own unique ecological reasons.

Forests, though slow-growing, are dynamic systems, biological machines in a sense. The forest of tomorrow grows today underneath the boughs of maturing trees gradually reaching the time to retire their spot in the sun to the next generation of trees. Since we have seen how the tree canopy composition can impact biodiversity and floral and faunal communities, it is important that as managers we take care to create diverse and healthy understories. With this kind of foresight, we can take steps today to counteract the harmful effects humans have had on our woodlands. In doing so, we leave a lasting legacy to our posterity and avoid the trap of that age-old adage: "missing the forest for the trees".

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TABLES AND FIGURES:

			Analysis with Wetlands	Analysis without Wetlands
	Test	**Comparison**	**Statistical results**	**Statistical results**
Canopy percent composition vs Elevation class	Kruskal-Wallace	Sugar Maple (SM)	KW = 14.865, df = 4, p-value = 0.005	KW = 11.06, df = 4, p-value = 0.026
	Kruskal-Wallace	Red Maple (RM)	KW = 4.695, df = 4, p-value = 0.320	KW = 4.535, df = 4, p-value = 0.338
	Kruskal-Wallace	*Populus spp.*(POP)	KW = 6.596, df = 4, p-value = 0.159	KW = 2.932, df = 4, p-value = 0.569
	Kruskal-Wallace	Balsam Fir (BF)	KW = 11.449, df = 4, p-value = 0.022	KW = 8.256, df = 4, p-value = 0.083
	Kruskal-Wallace	*Fraxinus spp.*(FRAX)	KW = 3.389, df = 4, p-value = 0.495	KW = 4.03, df = 4, p-value = 0.402
	Kruskal-Wallace	Cherry spp.	KW = 6.871, df = 4, p-value = 0.143	KW = 7.99, df = 4, p-value = 0.092
Canopy species percent composition vs Canopy species percent composition	Kendall	SM vs RM	p-value = 0.002, tau = -0.344	p-value = <0.001, tau = -0.466
	Kendall	SM vs POP	p-value = 0.449, tau = -0.082	p-value = 0.027, tau = -0.263
	Kendall	SM vs BF	p-value = 0.136, tau = -0.167	p-value = 0.04, tau = -0.256
	Kendall	SM vs FRAX	p-value = 0.225, tau = 0.144	p-value = 0.461, tau = 0.098
	Kendall	SM vs Cherry	p-value = 0.37, tau = -0.109	p-value = 0.155, tau = -0.192
	Kendall	RM vs POP	p-value = 0.922, tau = -0.011	p-value = 0.774, tau = -0.036
	Kendall	RM vs FRAX	p-value = 0.131, tau = -0.188	p-value = 0.261, tau = 0.148
	Kendall	RM vs Cherry	p-value = 0.35, tau = 0.119	p-value = 0.109, tau = -0.227
	Kendall	POP vs BF	p-value = 0.153, tau = 0.162	p-value = 0.901, tau = 0.368
	Kendall	POP vs FRAX	p-value = 0.618, tau = -0.06	p-value = 0.313, tau = 0.127
	Kendall	POP vs Cherry	p-value = 0.092, tau = 0.207	p-value = 0.306, tau = 0.139
	Kendall	BF vs FRAX	p-value = 0.529, tau = -0.078	p-value = 0.323, tau = -0.139
	Kendall	BF vs Cherry	p-value = 0.034, tau = 0.269	p-value = 0.065, tau = 0.262
	Kendall	FRAX vs Cherry	p-value = 0.278, tau = -0.146	p-value = 0.273, tau = -0.167
Understory species percent composition vs Elevation class	Kruskal-Wallace	SM	KW = 9.87, df = 4, p-value = 0.043	KW = 5.07, df = 4, p-value = 0.043
	Kruskal-Wallace	RM	KW = 2.551, df = 4, p-value = 0.636	KW = 2.96 df = 4, p-value = 0.564
	Kruskal-Wallace	Quaking Aspen (QA)	KW = 9.283, df = 4, p-value = 0.054	KW = 5.38, df = 4, p-value = 0.251
	Kruskal-Wallace	BF	KW = 5.283, df = 4, p-value = 0.26	KW = 9.071, df = 4, p-value = 0.059
	Kruskal-Wallace	FRAX	KW = 7.55, df = 4, p-value = 0.11	KW = 4.62, df = 4, p-value = 0.329
	Kruskal-Wallace	Cherry	KW = 2.376, df = 4, p-value = 0.667	KW = 5.641, df = 4, p-value = 0.228
Canopy percent openness vs Understory species percent composition	Kendall	SM	p-value = <0.001, tau = -0.383	p-value = 0.09, tau = -0.194
	Kendall	RM	p-value = 0.121, tau = 0.162	p-value = 0.034, tau = 0.253
	Kendall	QA	p-value = 0.158, tau = -0.159	p-value = 0.613, tau = -0.064
	Kendall	BF	p-value = 0.921, tau = -0.011	p-value = 0.239, tau = 0.14
	Kendall	FRAX	p-value = 0.366, tau = -0.096	p-value = 0.606, tau = 0.061
	Kendall	Cherry	p-value = 0.844, tau = 0.021	p-value = 0.664, tau = 0.052
Basal area vs Understory species percent composition	Kendall	SM	p-value = 0.003, tau = 0.308	p-value = 0.142, tau = 0.171
	Kendall	RM	p-value = 0.832, tau = -0.023	p-value = 0.749, tau = -0.039
	Kendall	QA	p-value = 0.964, tau = -0.11	p-value = 0.878, tau = 0.020
	Kendall	BF	p-value = 0.67, tau = 0.046	p-value = 0.222, tau = -0.147
	Kendall	FRAX	p-value = 0.217, tau = 0.133	p-value = 0.752, tau = 0.039
	Kendall	Cherry	p-value = 0.08, tau = 0.188	p-value = 0.053, tau = 0.235
Canopy species percent composition (O) vs Understory species percent composition (U)	Kendall	SM (O) vs SM (U)	p-value = <0.001, tau = 0.362	p-value = 0.951, tau = 0.007
	Kendall	SM (O) vs RM (U)	p-value = 0.023, tau = -0.247	p-value = 0.162, tau = -0.172
	Kendall	SM (O) vs QA (U)	p-value = 0.378, tau = -0.104	p-value = 0.465, tau = -0.095
	Kendall	SM (O) vs BF (U)	p-value = 0.07, tau = -0.2	p-value = 0.908, tau = -0.014
	Kendall	SM (O) vs FRAX (U)	p-value = 0.816, tau = 0.026	p-value = 0.352, tau = -0.113
	Kendall	SM (O) vs Cherry (U)	p-value = 0.261, tau = -0.124	p-value = 0.019, tau = -0.286
	Kendall	RM (O) vs SM (U)	p-value = 0.228, tau = -0.135	p-value = 0.686, tau = 0.05
	Kendall	RM (O) vs RM (U)	p-value = 0.184, tau = 0.151	p-value = 0.09, tau = 0.219
	Kendall	RM (O) vs QA (U)	p-value = 0.261, tau = 0.138	p-value = 0.335, tau = 0.133
	Kendall	RM (O) vs BF (U)	p-value = 0.046, tau = 0.231	p-value = 0.695, tau = -0.05
	Kendall	RM (O) vs FRAX (U)	p-value = 0.359, tau = 0.106	p-value = 0.523, tau = 0.082
	Kendall	RM (O) vs Cherry (U)	p-value = 0.91, tau = 0.105	p-value = 0.015, tau = 0.316
	Kendall	POP (O) vs SM (U)	p-value = 0.002, tau = 0.328	p-value = 0.921, tau = -0.012
	Kendall	POP (O) vs RM (U)	p-value = 0.133, tau = 0.166	p-value = 0.886, tau = -0.018
	Kendall	POP (O) vs QA (U)	p-value = 0.043, tau = 0.241	p-value = 0.445, tau = 0.1
	Kendall	POP (O) vs BF (U)	p-value = 0.917, tau = 0.012	p-value = 0.877, tau = -0.019
	Kendall	POP (O) vs FRAX (U)	p-value = 0.008, tau = 0.296	p-value = 0.828, tau = 0.026

	Kendall	POP (O) vs Cherry (U)	p-value = 0.171, tau = 0.153	p-value = 0.189, tau = -0.162
	Kendall	BF (O) vs SM (U)	p-value = 0.153, tau = 0.017	p-value = 0.433, tau = -0.097
	Kendall	BF (O) vs RM (U)	p-value = 0.976, tau = 0.003	p-value = 0.967, tau = -0.005
	Kendall	BF (O) vs QA (U)	p-value = 0.003, tau = 0.367	p-value = 0.182, tau = 0.183
	Kendall	BF (O) vs BF (U)	p-value = 0.002, tau = 0.362	p-value = 0.095, tau = 0.214
	Kendall	BF (O) vs FRAX (U)	p-value = 0.081, tau = 0.202	p-value = 0.003, tau = 0.382
	Kendall	BF (O) vs Cherry (U)	p-value = 0.103, tau = -0.188	p-value = 0.607, tau = 0.066
	Kendall	FRAX (O) vs SM (U)	p-value = 0.362, tau = 0.108	p-value = 0.188, tau = 0.173
	Kendall	FRAX (O) vs RM (U)	p-value = 0.452, tau = -0.091	p-value = 0.043, tau = -0.279
	Kendall	FRAX (O) vs QA (U)	p-value = 0.972, tau = 0.005	p-value = 0.336, tau = -0.141
	Kendall	FRAX (O) vs BF (U)	p-value = 0.317, tau = -0.123	p-value = 0.97, tau = -0.005
	Kendall	FRAX (O) vs FRAX (U)	p-value = 0.579, tau = 0.068	p-value = 0.547, tau = 0.082
	Kendall	FRAX (O) vs Cherry (U)	p-value = 0.376, tau = 0.108	p-value = 0.349, tau = -0.129
	Kendall	Cherry (O) vs SM (U)	p-value = 0.321, tau = 0.12	p-value = 0.833, tau = 0.028
	Kendall	Cherry (O) vs RM (U)	p-value = 0.959, tau = 0.006	p-value = 0.366, tau = 0.126
	Kendall	Cherry (O) vs QA (U)	p-value = 0.947, tau = -0.009	p-value = 0.46, tau = -0.11
	Kendall	Cherry (O) vs BF (U)	p-value = 0.109, tau = 0.2	p-value = 0.727, tau = 0.048
	Kendall	Cherry (O) vs FRAX (U)	p-value = 0.144, tau = 0.183	p-value = 0.448, tau = 0.105
	Kendall	Cherry (O) vs Cherry (U)	p-value = 0.016, tau = 0.301	p-value = 0.016, tau = 0.302
Canopy species percent composition vs Species richness (Average)	Kendall	SM	p-value = 0.933, tau = -0.009	p-value = 0.008, tau = -0.316
	Kendall	RM	p-value = 0.068, tau = -0.192	p-value = 0.872, tau = 0.02
	Kendall	POP	p-value = <0.001, tau = 0.412	p-value = <0.001, tau = 0.472
	Kendall	BF	p-value = 0.963, tau = 0.005	p-value = 0.642, tau = -0.058
	Kendall	FRAX	p-value = 0.821, tau = 0.026	p-value = 0.443, tau = 0.102
	Kendall	Cherry	p-value = 0.399, tau = 0.1	p-value = 0.528, tau = 0.085
Canopy species percent composition vs Species richness (Derived)	Kendall	SM	p-value = 0.24, tau = -0.129	p-value = 0.026, tau = -0.274
	Kendall	RM	p-value = 0.805, tau = 0.028	p-value = 0.074, tau = 0.233
	Kendall	POP	p-value = 0.012, tau = 0.278	p-value = 0.753, tau = -0.039
	Kendall	BF	p-value = 0.909, tau = 0.013	p-value = 0.374, tau = 0.115
	Kendall	FRAX	p-value = 0.332, tau = 0.118	p-value = 0.824, tau = 0.031
	Kendall	Cherry	p-value = 0.061, tau = 0.232	p-value = 0.966, tau = -0.006

Table 1: A complete list of all trials, with the corresponding statistical tests conducted for this analysis, and their results. Significant results are highlighted gray

	Canopy Species Percent Composition						**Understory Species Percent Composition**					
Point	**SM**	**RM**	**POP**	**BF**	**FRAX**	**Cherry**	**SM**	**RM**	**QA**	**BF**	**FRAX**	**Cherry**
1.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.2	62.50	0.00	0.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00
1.3	16.67	0.00	0.00	0.00	0.00	0.00	3.13	9.38	0.00	0.00	0.00	0.00
1.4	0.00	0.00	0.00	0.00	0.00	0.00	1.72	1.72	0.00	0.00	0.00	0.00
1.5	NULL	NULL	NULL	NULL	NULL	NULL	0.00	34.62	0.00	0.00	0.00	7.69
1.6	0.00	18.18	9.09	0.00	0.00	0.00	0.00	70.59	0.00	0.00	0.00	0.00
1.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	47.62	0.00	21.43	0.00	9.52
1.8	0.00	23.53	17.65	5.88	0.00	11.76	28.57	9.52	0.00	28.57	0.00	11.90
1.9	0.00	5.56	0.00	16.67	5.56	0.00	0.00	35.90	0.00	28.21	0.00	0.00
1.10	0.00	0.00	6.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.78
2.1	82.35	0.00	0.00	0.00	0.00	0.00	34.38	0.00	0.00	25.00	0.00	0.00
2.2	0.00	37.50	0.00	62.50	0.00	0.00	0.00	0.00	3.70	22.22	0.00	0.00
2.3	18.18	0.00	54.55	18.18	0.00	9.09	27.50	20.00	10.00	12.50	22.50	5.00
2.4	18.52	40.74	37.04	3.70	0.00	0.00	78.26	0.00	1.45	4.35	7.25	8.70
2.5	14.29	0.00	21.43	21.43	0.00	0.00	18.18	31.82	40.91	9.09	0.00	0.00
2.6	0.00	0.00	60.00	20.00	0.00	20.00	0.00	2.44	0.00	26.83	21.95	4.88
2.7	18.75	0.00	62.50	18.75	0.00	0.00	17.46	65.08	0.00	3.17	14.29	0.00

2.8	0.00	60.00	0.00	30.00	0.00	0.00	3.57	3.57	10.71	0.00	82.14	0.00
2.9	20.00	53.33	6.67	6.67	0.00	13.33	64.79	2.82	0.00	4.23	9.86	15.49
2.10	0.00	4.35	95.65	0.00	0.00	0.00	0.00	36.84	0.00	2.63	22.37	22.37
3.1	42.86	0.00	0.00	0.00	23.81	0.00	16.67	0.00	0.00	0.00	16.67	16.67
3.2	100.00	0.00	0.00	0.00	0.00	0.00	94.44	0.00	0.00	0.00	0.00	0.00
3.3	28.57	7.14	50.00	7.14	0.00	7.14	89.19	0.00	0.00	0.00	2.70	8.11
3.4	33.33	66.67	0.00	0.00	0.00	0.00	0.00	34.29	0.00	0.00	0.00	5.71
3.5	5.88	11.76	70.59	11.76	0.00	0.00	30.30	40.91	0.00	0.00	10.61	0.00
3.6	23.08	0.00	61.54	7.69	7.69	0.00	47.06	0.00	0.00	5.88	11.76	2.94
3.7	0.00	20.00	0.00	0.00	0.00	0.00	0.00	67.86	0.00	3.57	3.57	3.57
3.8	20.83	0.00	75.00	4.17	0.00	0.00	90.91	0.00	2.02	0.00	3.03	2.02
3.9	94.12	0.00	5.88	0.00	0.00	0.00	64.15	26.42	0.00	0.00	0.00	3.77
3.10	0.00	25.00	0.00	8.33	0.00	0.00	0.00	0.00	0.00	66.67	0.00	0.00
4.1	12.50	0.00	0.00	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00
4.2	0.00	35.71	60.71	0.00	0.00	0.00	60.64	0.00	2.13	0.00	4.26	14.89
4.3	0.00	5.88	94.12	0.00	0.00	0.00	46.46	22.22	0.00	0.00	6.06	2.02
4.4	29.41	17.65	52.94	0.00	0.00	0.00	48.10	8.86	0.00	0.00	20.25	5.06
4.5	0.00	21.43	57.14	0.00	14.29	0.00	18.60	29.07	8.14	13.95	0.00	19.77
4.6	93.75	0.00	6.25	0.00	0.00	0.00	70.73	0.00	0.00	0.00	0.00	0.00
4.7	95.45	0.00	0.00	0.00	4.55	0.00	66.67	0.00	0.00	0.00	0.00	4.55
4.8	31.58	0.00	52.63	15.79	0.00	0.00	76.27	8.47	0.00	6.78	6.78	0.00
4.9	31.03	3.45	37.93	20.69	0.00	0.00	16.67	0.00	16.67	27.78	0.00	0.00
4.10	0.00	60.00	0.00	30.00	0.00	0.00	0.00	12.50	0.00	62.50	25.00	0.00
5.1	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.2	77.78	0.00	11.11	11.11	0.00	0.00	52.17	0.00	0.00	39.13	0.00	0.00
5.3	0.00	45.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00
5.4	27.78	0.00	0.00	0.00	11.11	0.00	82.76	0.00	0.00	0.00	0.86	9.48
5.5	45.00	0.00	15.00	20.00	20.00	0.00	79.10	2.99	2.99	0.00	10.45	1.49
5.6	45.45	0.00	9.09	0.00	0.00	0.00	18.75	0.00	0.00	6.25	18.75	0.00
5.7	95.65	0.00	4.35	0.00	0.00	0.00	18.18	0.00	0.00	0.00	0.00	9.09
5.8	96.43	3.57	0.00	0.00	0.00	0.00	0.00	60.87	0.00	8.70	21.74	0.00
5.9	30.00	0.00	70.00	0.00	0.00	0.00	42.19	35.94	1.56	1.56	17.19	0.00
5.10	26.67	0.00	40.00	0.00	33.33	0.00	24.39	14.63	0.00	0.00	0.00	0.00
Total	***1438.42***	***566.91***	***1145.52***	***352.97***	***145.33***	***61.33***	***1431.97***	***736.93***	***100.28***	***531.00***	***400.03***	***214.49***
Mean	***29.36***	***11.57***	***23.38***	***7.20***	***2.97***	***1.25***	***28.64***	***14.74***	***2.01***	***10.62***	***8.00***	***4.29***
SD	***34.11***	***18.99***	***29.55***	***11.87***	***7.51***	***4.01***	***31.40***	***20.75***	***6.49***	***20.01***	***14.22***	***5.95***
Var.	***1163.47***	***360.75***	***873.01***	***141.00***	***56.46***	***16.11***	***986.02***	***430.73***	***42.18***	***400.45***	***202.30***	***35.38***

Table 2: Canopy and understory percent composition for the six studies tree species (sugar maple, red maple, *Populus*/quaking aspen, balsam fir, *Fraxinus spp.*, and cherry).

Point	Elevation Class	Wetland	Canopy Percent Openness	Adjusted Basal Area	Understory Species Richness (Average)	Understory Species Richness (Derived)
1.1	1	Yes	60.11	70	2.67	3
1.2	1	Yes	27.04	80	0.67	2
1.3	1	Yes	10.19	60	3.00	6
1.4	1	Yes	11.44	110	3.67	6
1.5	1	Yes	84.66	0	2.67	4
1.6	1	Yes	32.24	110	1.67	2
1.7	1	No	34.53	170	4.67	5
1.8	1	No	9.98	170	4.33	7
1.9	1	Yes	9.78	180	3.33	6
1.10	1	Yes	41.81	150	4.00	5
2.1	2	No	11.02	170	2.00	4
2.2	2	No	57.41	80	2.67	5
2.3	2	No	11.65	110	5.33	7
2.4	2	No	6.66	270	5.00	5
2.5	2	No	10.61	140	3.67	4
2.6	2	No	12.69	50	4.67	7
2.7	2	No	15.60	160	5.33	4
2.8	2	No	5.20	100	2.33	4
2.9	2	No	12.06	150	2.67	6
2.10	2	No	7.28	230	3.67	6
3.1	3	No	15.81	210	2.33	5
3.2	3	No	8.53	110	2.00	3
3.3	3	No	4.16	140	2.67	3
3.4	3	Yes	15.81	60	4.33	6
3.5	3	No	6.86	170	4.33	4
3.6	3	No	6.45	130	6.33	8
3.7	3	No	33.07	100	4.67	7
3.8	3	No	5.41	240	4.33	6
3.9	3	No	5.62	170	3.00	5
3.10	3	Yes	21.01	120	0.33	2
4.1	4	Yes	16.02	80	5.00	5
4.2	4	No	6.66	280	5.33	6
4.3	4	No	6.66	170	5.67	6
4.4	4	No	9.78	170	6.00	7
4.5	4	No	6.24	140	7.67	7
4.6	4	No	6.03	160	3.67	3
4.7	4	No	9.15	220	2.67	5
4.8	4	No	13.10	190	2.33	5
4.9	4	No	4.37	290	2.67	5
4.10	4	No	4.37	200	1.33	3
5.1	5	No	9.57	90	1.67	3
5.2	5	No	6.03	90	2.00	3
5.3	5	No	6.45	110	0.33	1
5.4	5	No	6.45	180	4.67	6
5.5	5	No	7.49	200	3.67	6
5.6	5	No	6.03	110	3.33	7
5.7	5	No	2.08	230	1.33	3
5.8	5	No	7.28	280	2.67	5
5.9	5	No	10.82	100	5.67	6
5.10	5	No	7.07	150	2.67	4
Total			***746.30***	***7450***	***172.67***	***243.00***
Average			***14.93***	***149.00***	***3.45***	***4.86***
Standard Deviation			***16.12***	***64.56***	***1.60***	***1.63***
Variance			***259.86***	***4168.37***	***2.57***	***2.65***

Table 3: Environmental measurements used in the analysis alongside the percent compositions outlined in Table 2.

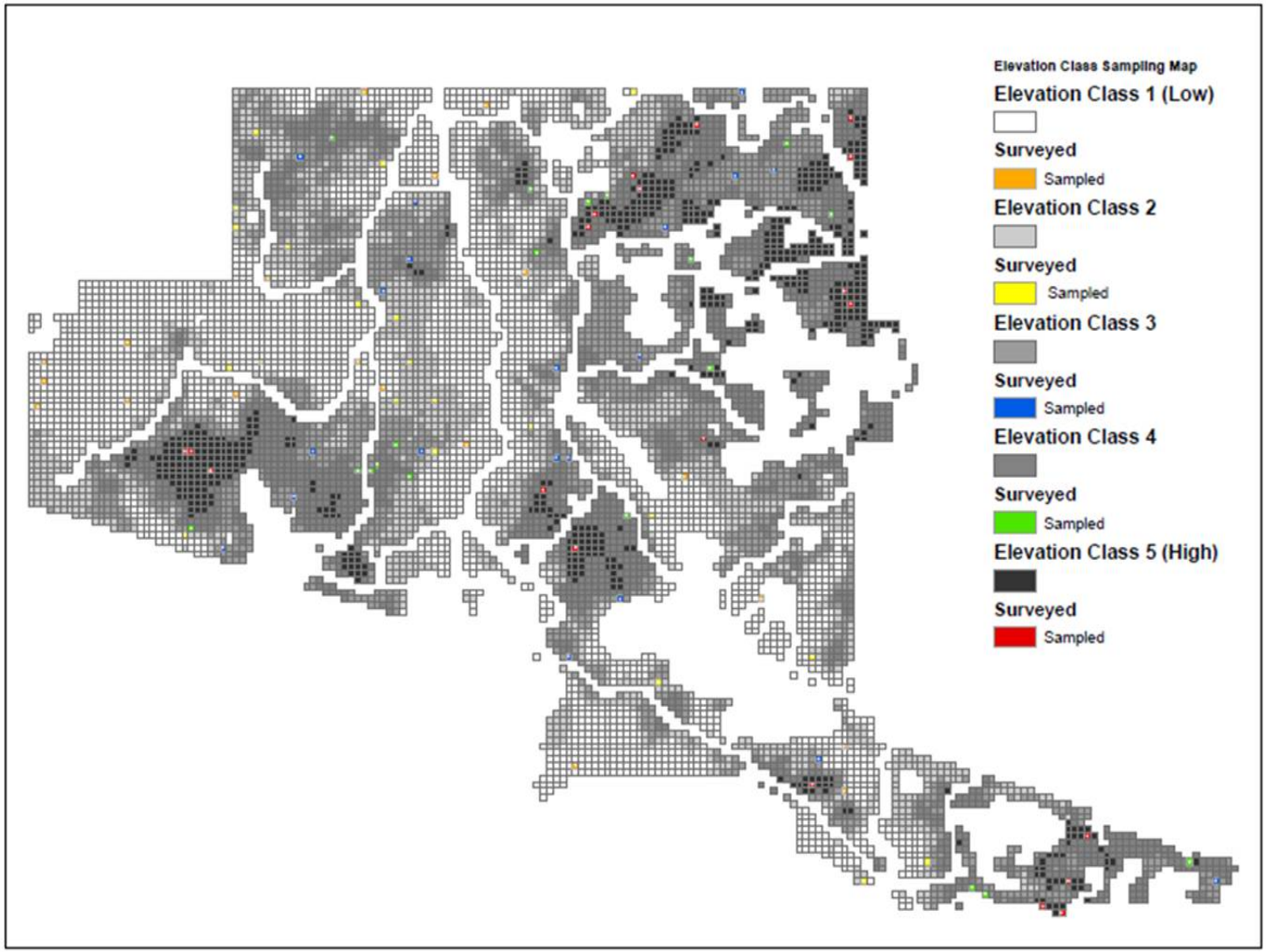


Figure 1: Sampling map of the University of Notre Dame Environmental Research Center study site detailing fishnet elevation design and randomly selected plots.

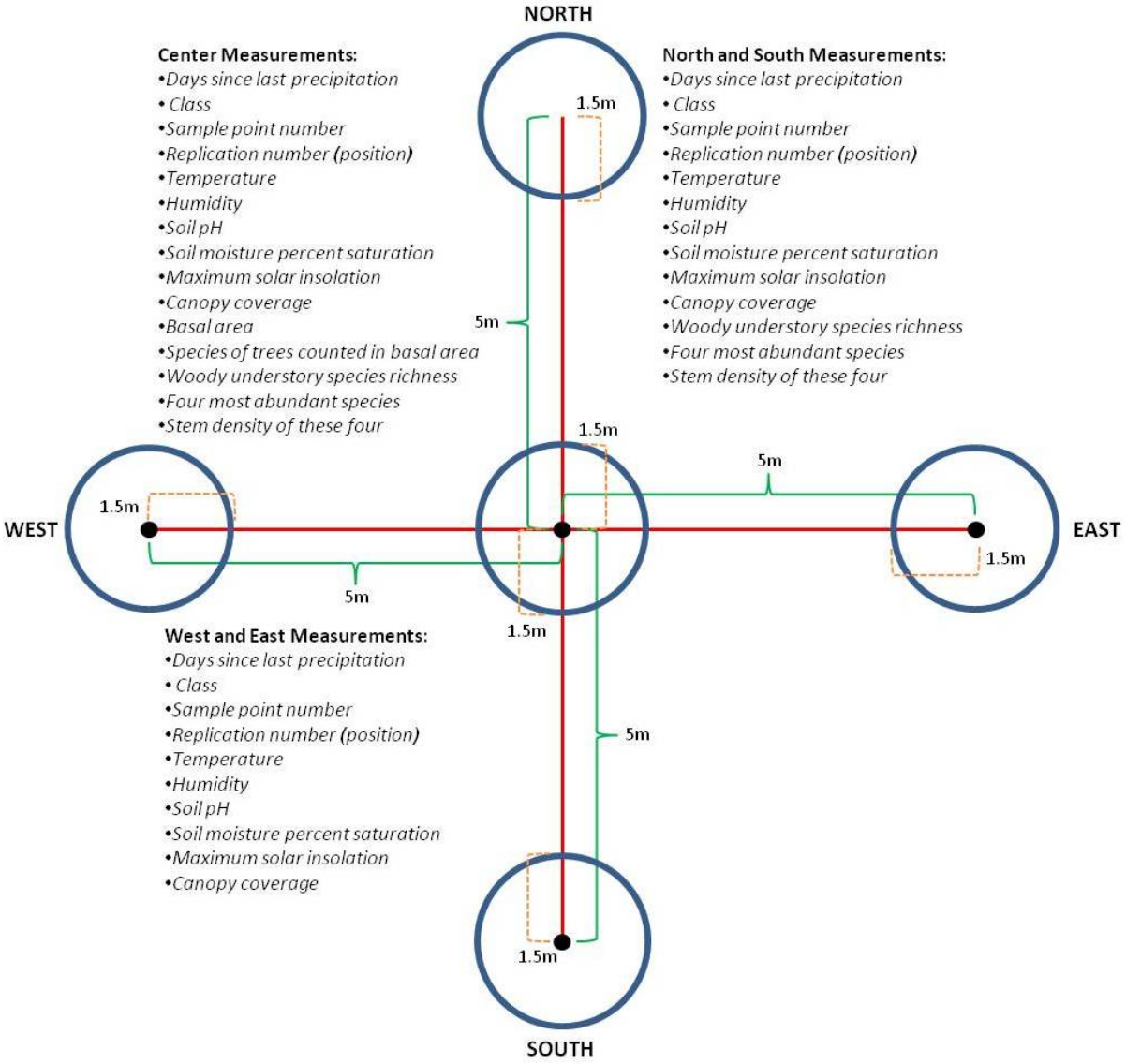


Figure 2: Field work sampling design outlining which tests were performed on which points and the critical distances used for measurements

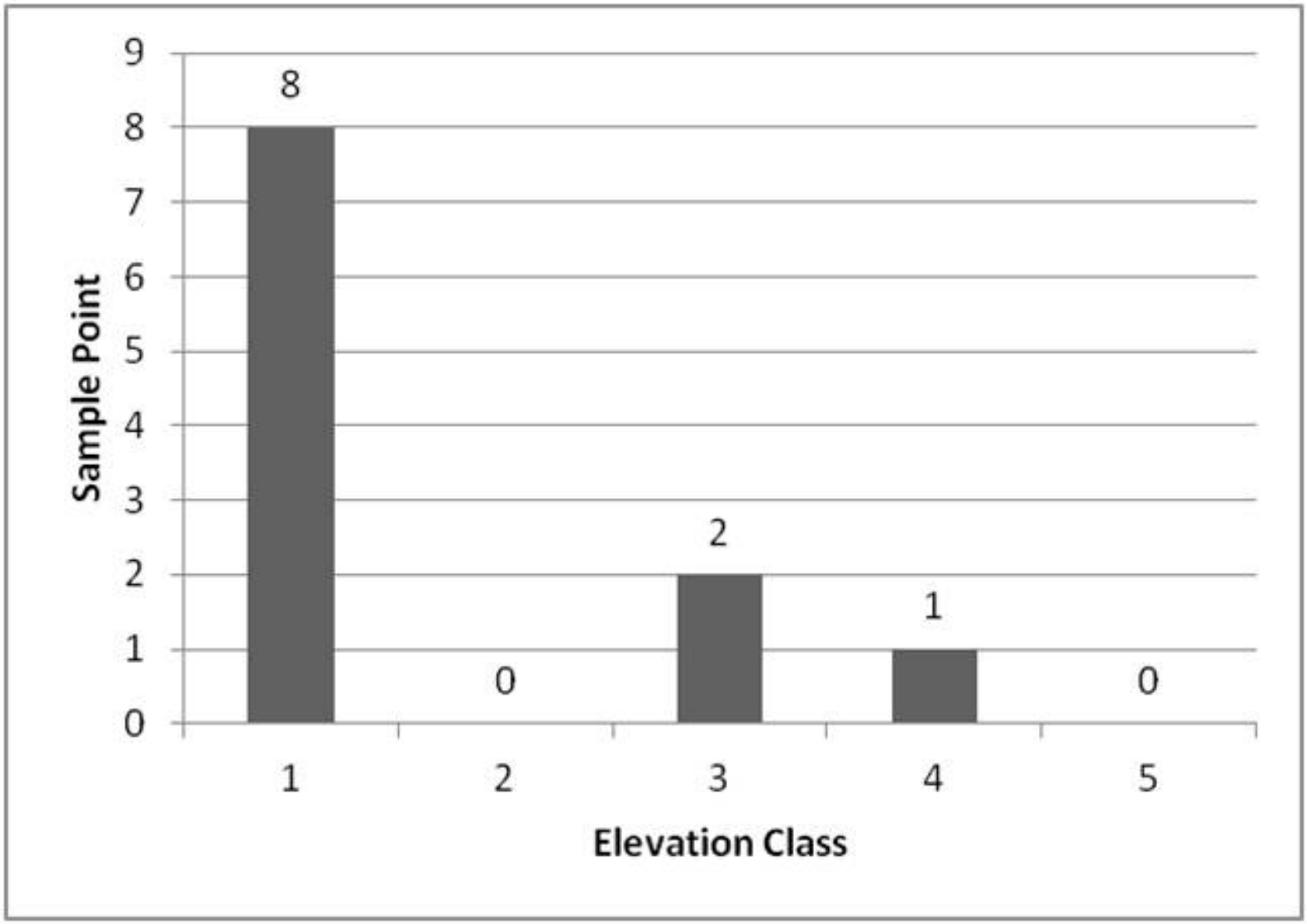


Figure 3: Number of wetland sample points per elevation class

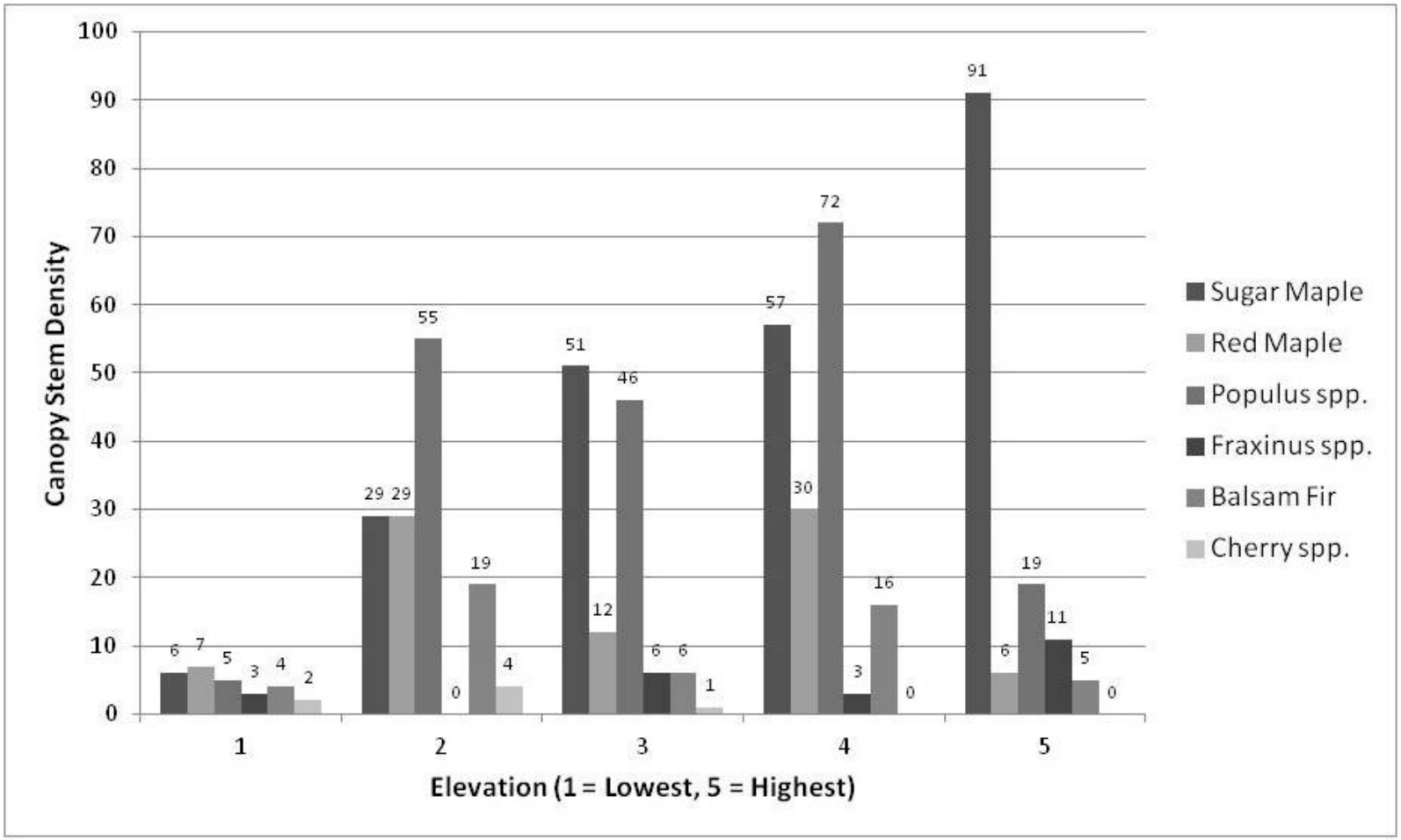


Figure 4: Canopy stem densities for the six studies tree species across the five elevation classes

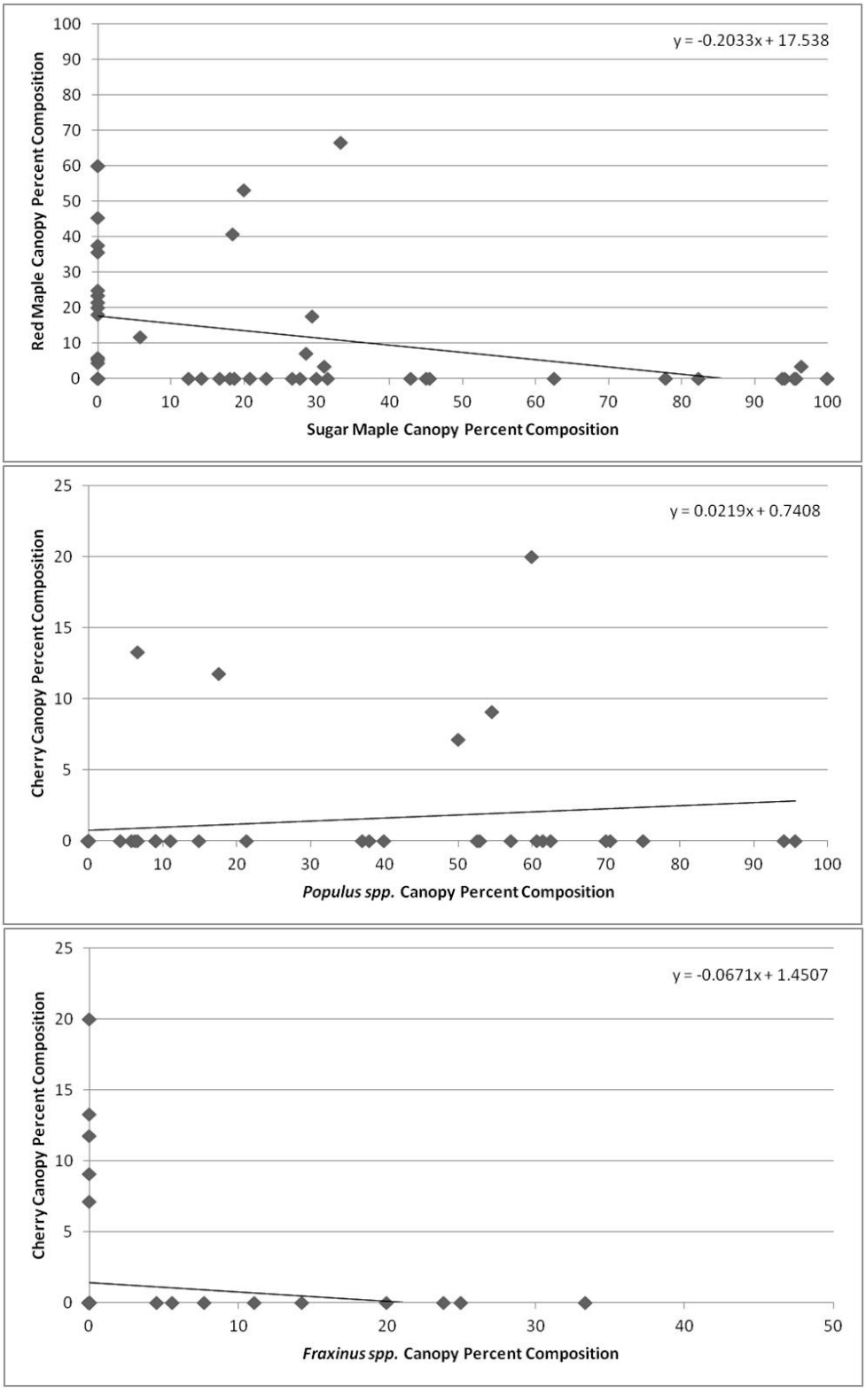


Figure 5: Graphs of the three statistically significant relationships amongst canopy stem density for the six studied trees.

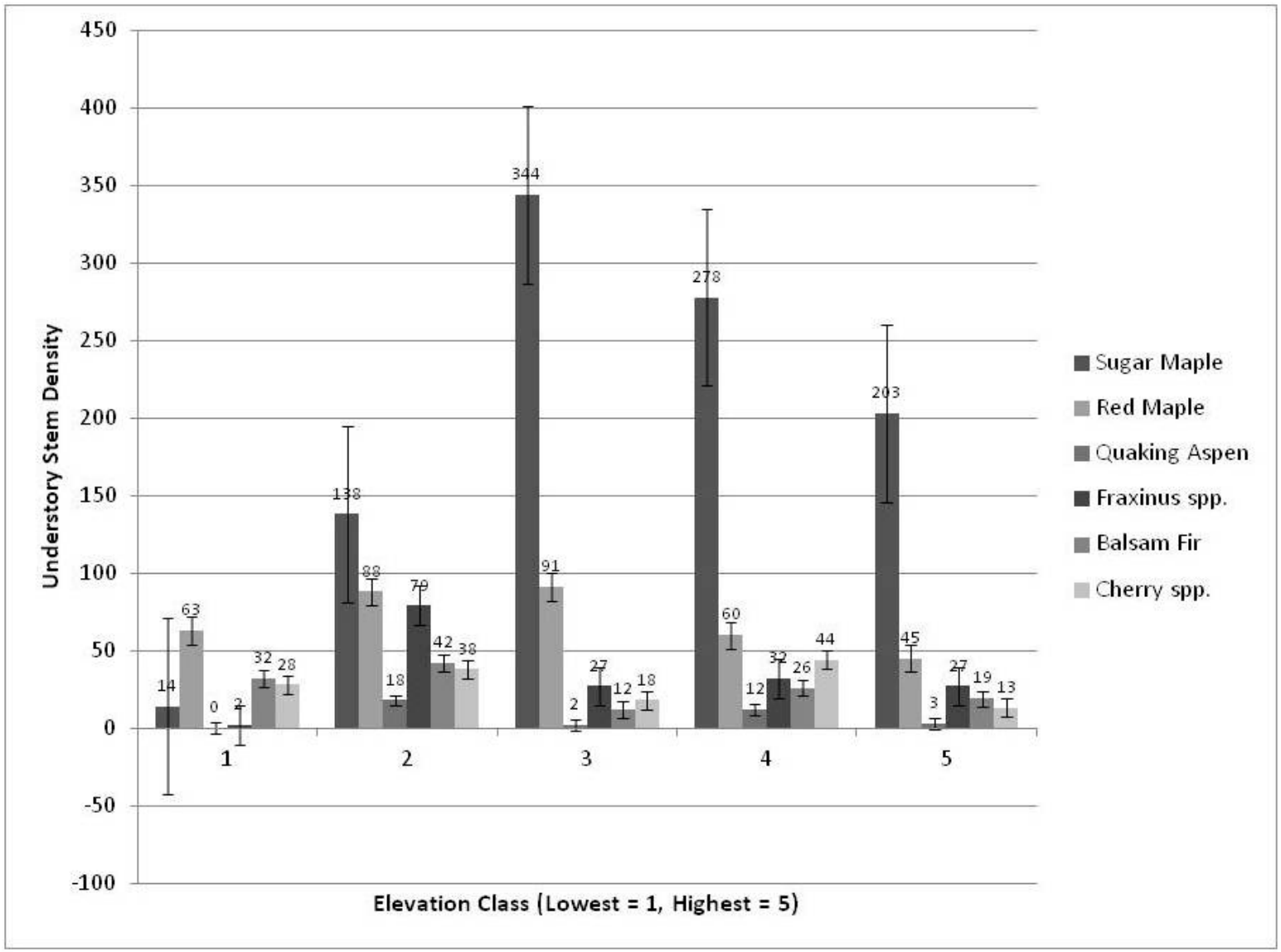


Figure 6: Understory stem density of the six studied tree species by elevation class

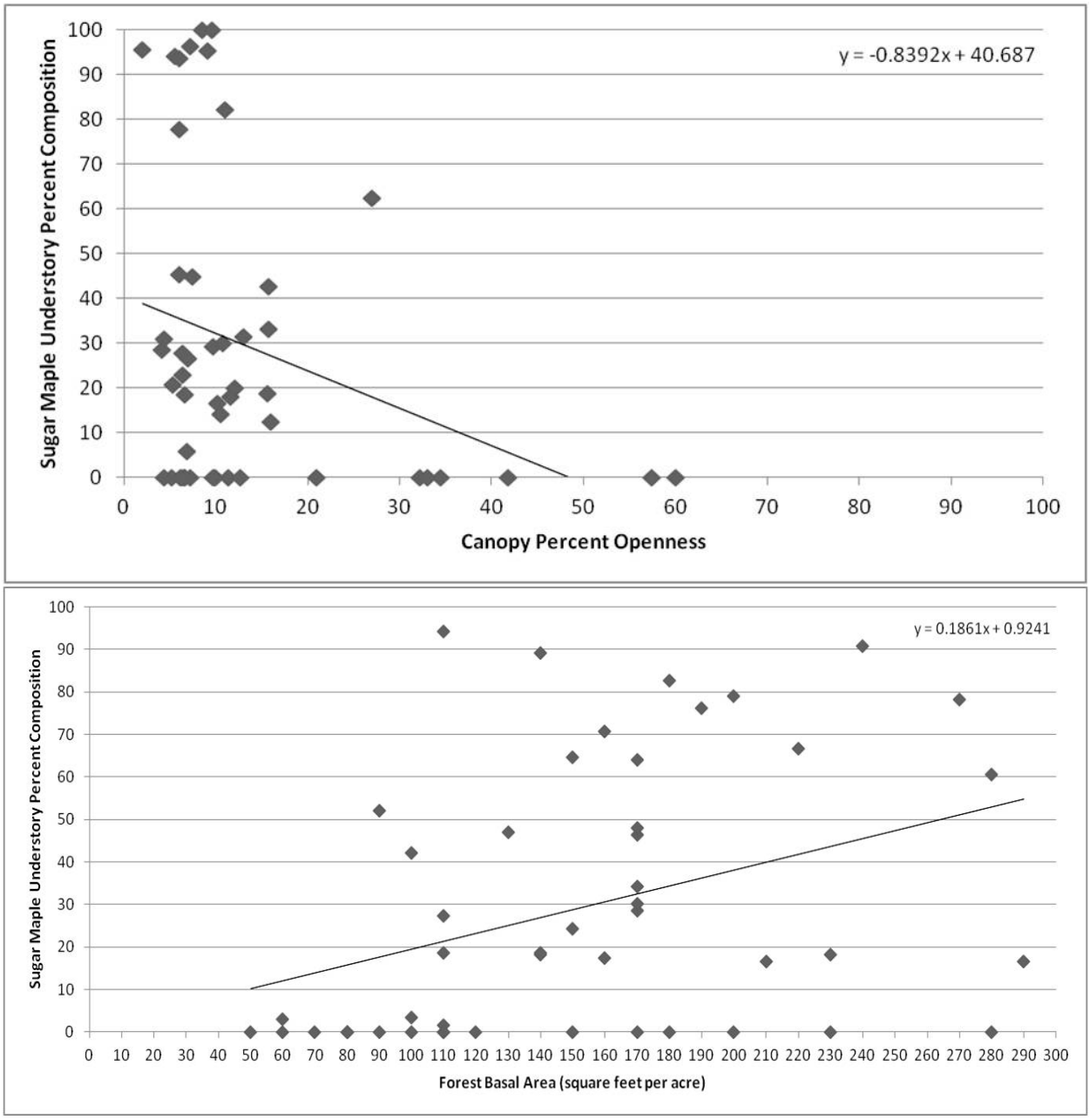


Figure 7: Sugar maples' statistically significant correlations with canopy percent openness and basal area. These trends help explain why sugar maples are such effective competitors in maturing forests.

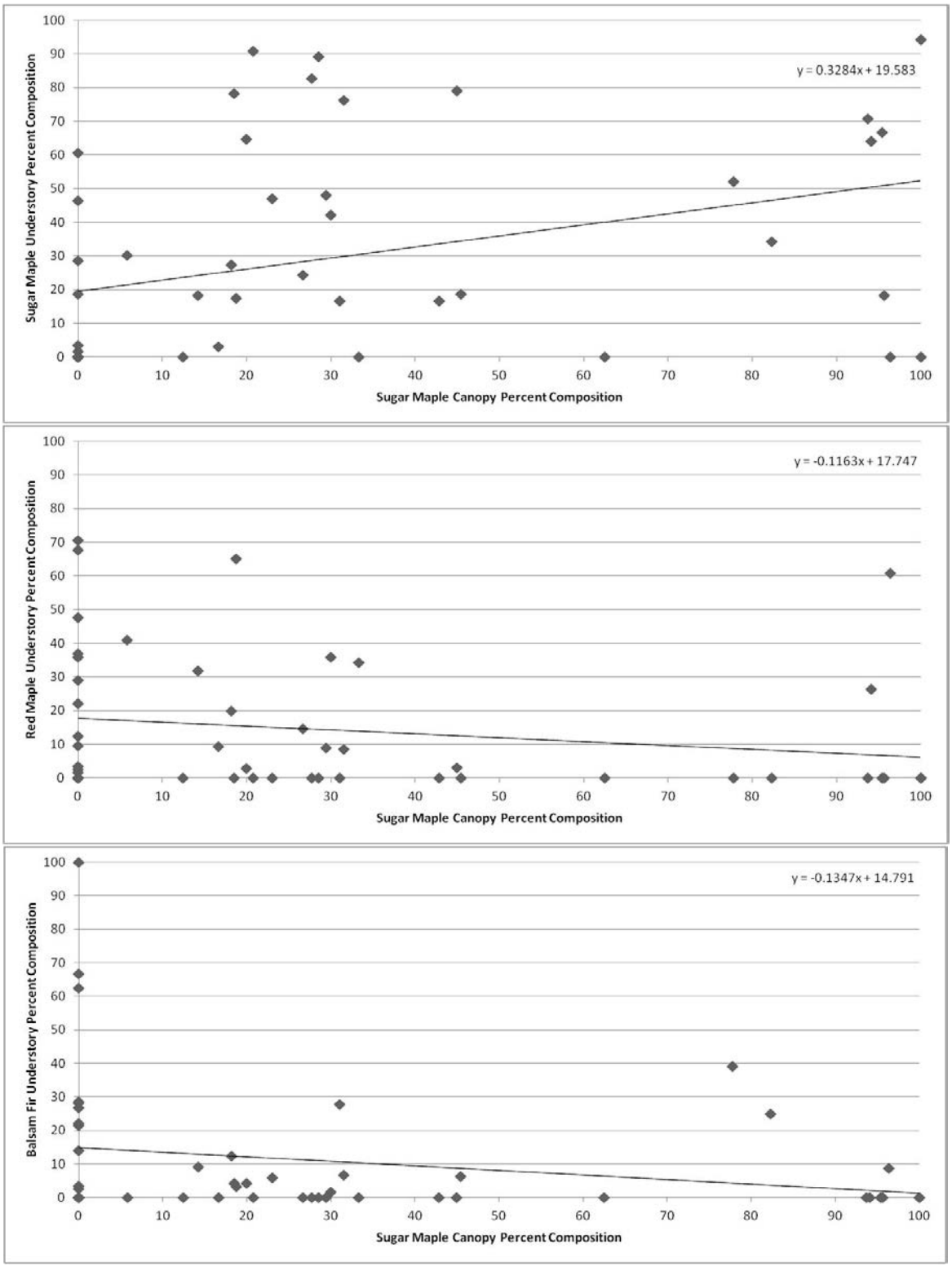
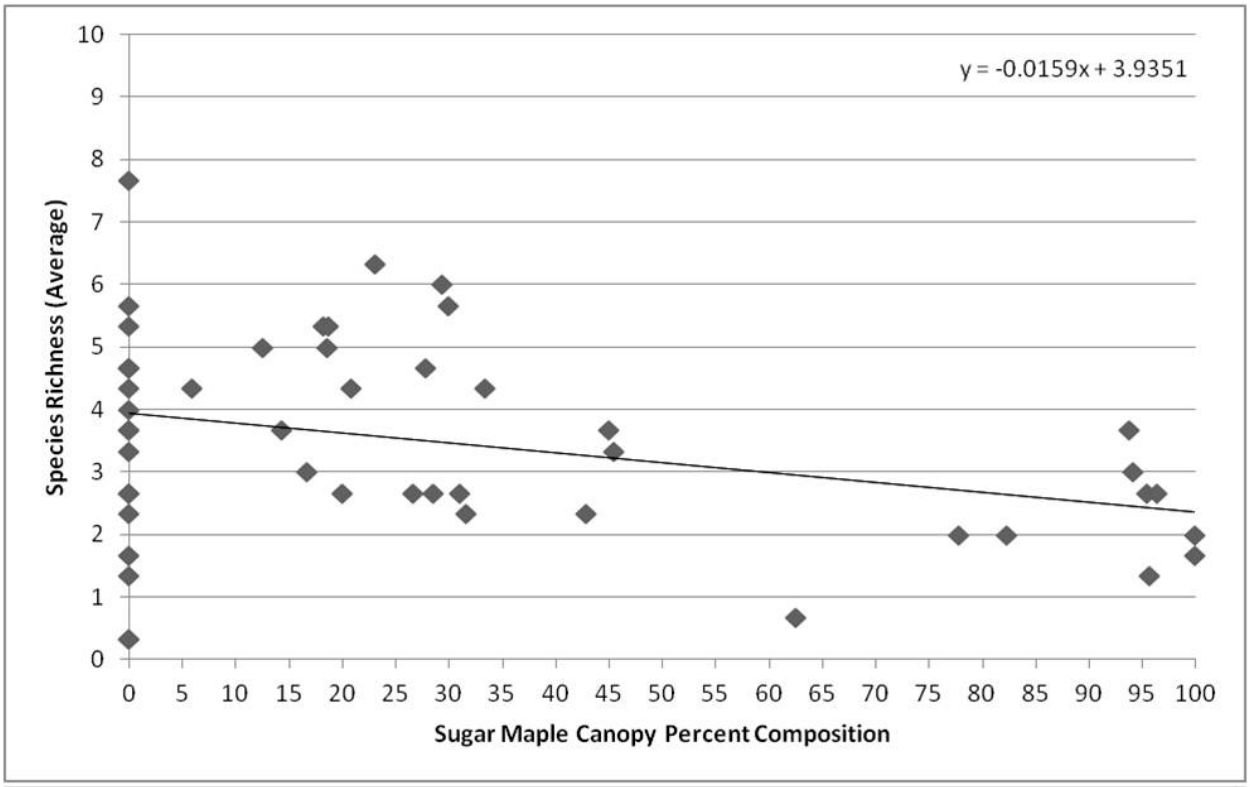


Figure 8: Graphs describing the statistically significant relationships between sugar maple percent canopy composition and understory species percent composition for sugar maple, red maple, and balsam fir.



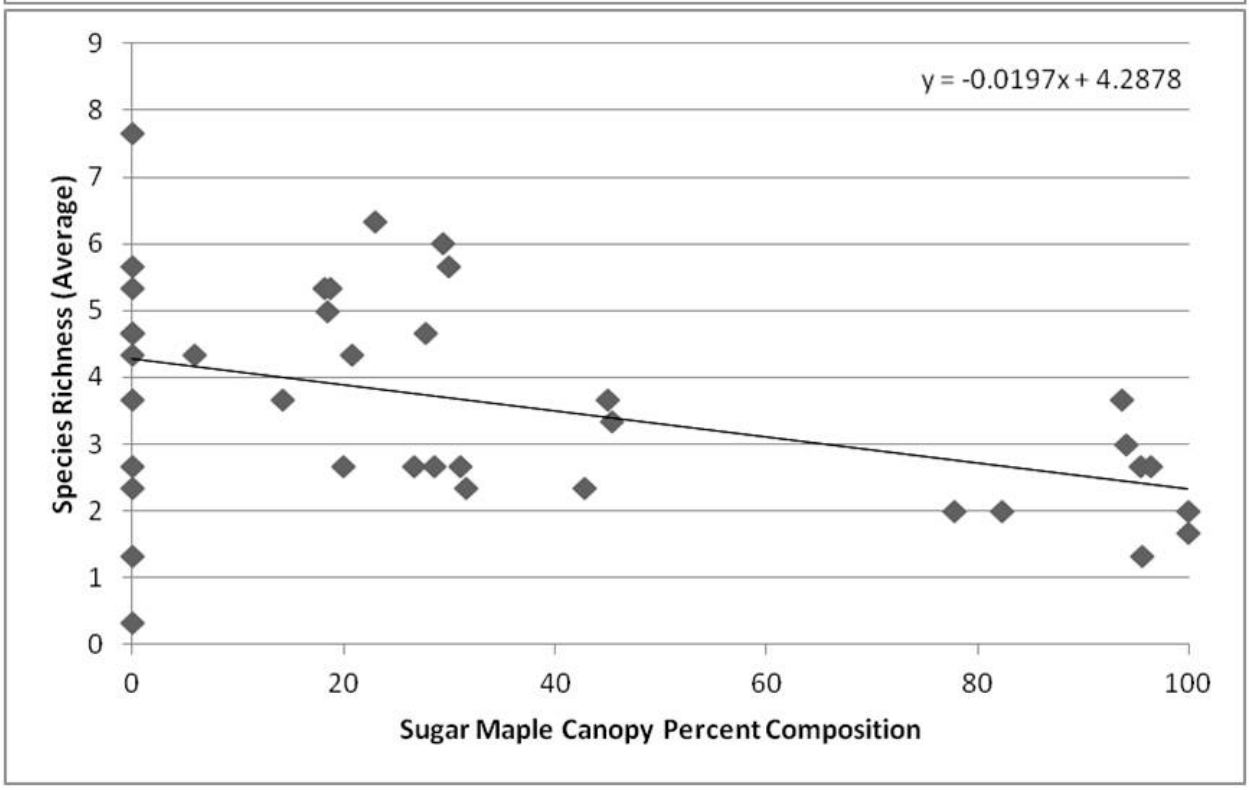
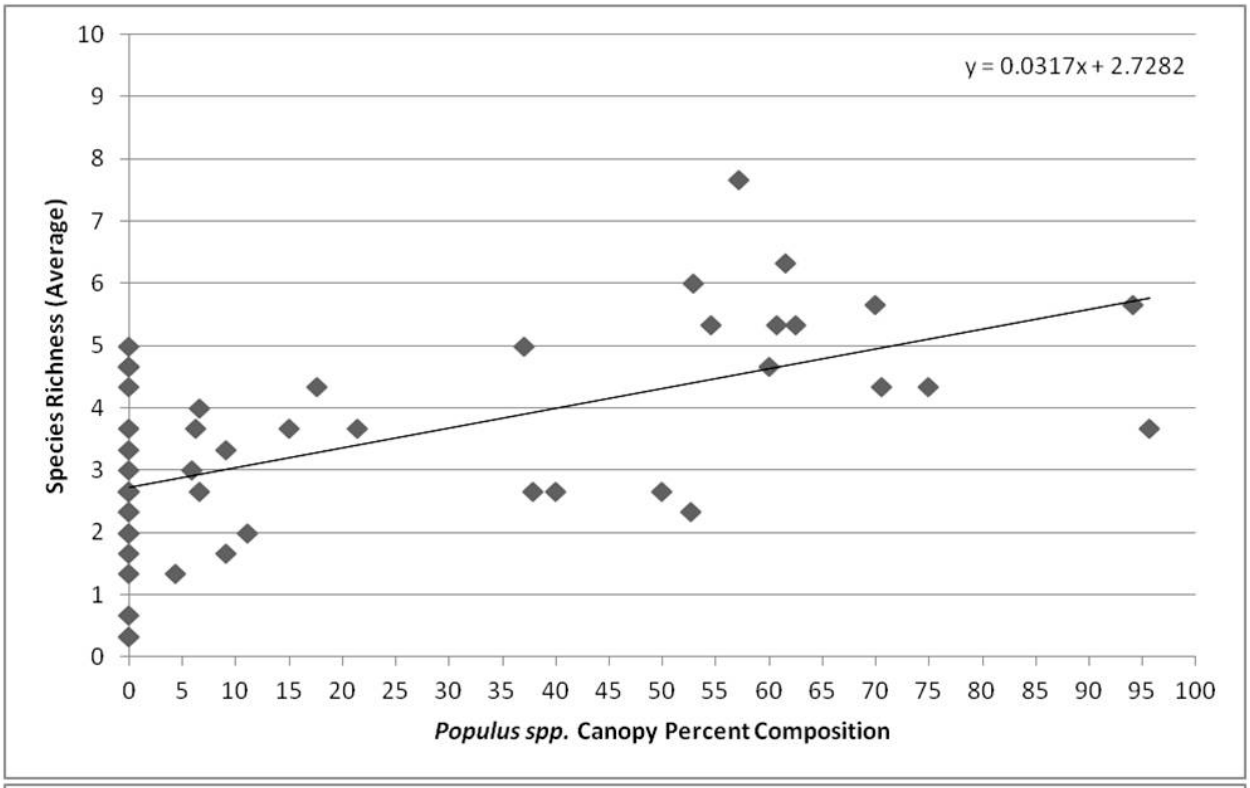


Figure 9: Two graphs illustrating the negative correlation canopy sugar maple percent composition on both average and derived species richness



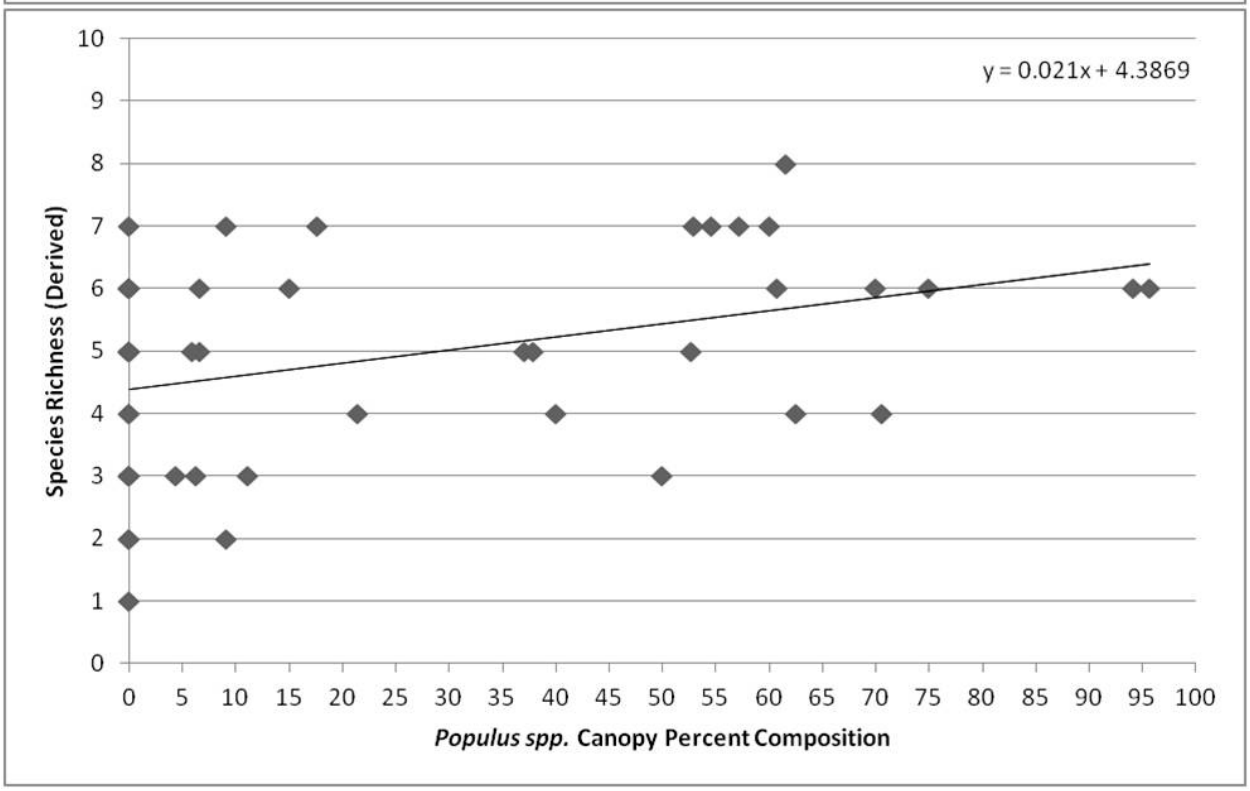


Figure 10: Two graphs outing the positive correlation between *Populus spp.* Canopy percent composition and both average and derived species richness