A Quantitative Analysis of the Effects of Urbanization, Mesophication and Prescribed Burns on Oak Woodlands in the Chicago Metropolitan Area

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Abstract

Urban expansion has had devastating impacts on forest ecosystems, especially within the past century. Human attempts to dominate nature have diminished natural disturbance regimes, which have maintained the biodiversity and historic composition of these ecosystems. Fires have been a prominent force in maintaining the structure of oak, hickory and other heliophytic (sun loving and fire-adapted) forest systems. Human induced fire suppression has led to mesophication across North America. Mesophication is the transition from drier conditions with open canopies to wetter conditions with closed canopies. These new conditions decrease the survival rates of these important species and begin to favor mesophytic and invasive species. Without fires to fight off these competitors, the positive feedback loop that is mesophication ensues. In urbanized areas where mesophication has been occurring, forest managers are working to mimic nature by implementing prescribed burns and other restoration techniques. The purpose of this study was to determine the effectiveness of prescribed burns within the Chicago metropolitan area, specifically at Blackwell Forest Preserve in Winfield, Illinois. By comparing the species composition within three forest patches at Blackwell that receive varying amounts of prescribed burns, the results helped to determine whether mesophication is occurring and whether the burns are working to combat these issues. The results showed that mesophication has been occurring within this preserve and that implementing prescribed burns does help to maintain historic biodiversity. The forest patch that received the least amount of burns (0) had the lowest Shannon Diversity Index and species evenness values, indicating less biodiversity compared to the sites that

received more frequent burns. This is significant for forest managers due to the inevitable loss of biodiversity in urbanized areas experiencing the impacts of mesophication.

Introduction

When European settlers arrived in the United States, the natural disturbance regimes among ecosystems in many regions were rapidly and dramatically altered (Nowacki and Abrams 2008). Native Americans are known to have carried out low-severity burns however, the intensity and regularity of these burns are not well known. The human actions that have caused this shift include clear cutting forests, creating roads, timber harvesting and more (Nowacki and Abrams 2008). Fire is known to have been one of the more prominent forces in disturbance regimes in certain areas, which is especially significant for oak forests (Abrams 1992). Alterations to the landscape by humans combined with urbanization and suppression of fire have had a major impact on the vegetation and forest ecology across the United States. In northern Illinois flatwoods, there have been studies done that show a correlation between the suppression of fire and the transition from dry/xeric forests dominated by oaks and hickories to moist/mesic forests that begin to favor mesophytic (shade-tolerant) and competitive invasive species (Bowles et al. 2003). Sites that have remained xeric allow for greater oak regeneration than in sites with moist conditions (Thomas-Van Gundy et al. 2014). As the natural structure of these forests change, there has also been a shift in the dominant and legacy species such as oak and hickory that occupy these forests. Forests that were once dominated by oaks and other sun-loving species are now being succeeded by shade-tolerant and fire-sensitive species. In turn, this reduces biodiversity due to the lack of regeneration of oaks and other heliophytic species (Bowles et al. 2003). These longstanding ecosystems have provided habitats for many different species. Now that these ecosystems are becoming more and more fragmented, they are straying from their natural state. This causes the biodiversity of the ecosystem to decrease due to the endangerment and displacement of species. These species are unable to contend with the aggressive and competitive nature of invasive species (Bowles et al. 2003). A decrease in biodiversity increases the risk of disease to spread within an ecosystem, a decline in productivity within the ecosystem and allows for invasive species to become more dominant (Vander Yacht et al. 2017). Common invasive species include Common Buckthorn, Honeysuckle, Burning Bush, Japanese Barberry and Garlic Mustard (Blackwell, Forest Preserve District of DuPage County 2018). Studies done over the past twenty years at The Morton Arboretum in Lisle, Illinois indicate that in forest patches that receive low-severity prescription burns on an annual basis allows for a more open canopy, which allows more light to reach the ground, greater soil nutrients and a minimal trace of invasive species (Bowles et al. 2003).

Throughout different forest patches within the DuPage County Forest Preserve District in Illinois, efforts have been made to implement prescription burns on a small scale (Blackwell, Forest Preserve District of DuPage County 2018). However, there are minimal public records related to the effectiveness of these prescribed burns and the severity of invasive species is not well known to the public. A reason for the lack of information on prescribed burns in DuPage County could be a result of the relatively low performance of prescribed burns. DuPage County is a highly populated suburban area, which is a major cause for a lack of burns due to safety risks and financial reasons (Schweitzer et al. 2014). This study will build on previous studies done throughout the Midwest that have focused on the effectiveness of prescribed burns or lack there of. This study will help to provide better understanding of the effectiveness of prescription burns and other restoration techniques on forest health. Techniques such as mid-story/shrub layer clearing are important to restoration and are executed within the DuPage County Forest Preserve District. However, prescribed burns have proven to be the most efficient way to sustain the health of the ecosystem, which is why the burns are the focus of this study. The findings of this study could provide insight as to whether prescription burns are sufficient enough to combat mesophication and the invasion of exotic plants. Studies have shown that mesophytic species that have been considered to be intolerant to fire are now tolerant of moderate and low-severity burns (Franklin et al. 2003). This could mean that the infrequent low-severity burns alone may not be able to significantly benefit these ecosystems. Some research also predicts that many ecosystems will not be able to sustain large-statured, long-living trees (Fahey et al. 2012). This study will also compare the prescription burn sites within the Blackwell Forest Preserve in Warrenville, Illinois to an area that has received no prescription burns in at least twenty years. This data will help in creating a trajectory for different sites within Blackwell Forest Preserve, which will show how the forest patch will continue to change over time if there are no restoration efforts.

Study Area

As mentioned previously, this study took place within the DuPage County Forest Preserve District in northern Illinois. This study focused on the Blackwell Forest Preserve in Winfield, Illinois, comprised of more than 1,300 acres of wetlands, ponds, lakes, woodlands, grasslands, prairies, trails, parking lots and other amenities for visitors. Blackwell Forest Preserve is located near several agricultural areas, which are known to receive few to no burns (Nowacki and Abrams 2008). This site is significant due to popularity and it is one of the largest forest preserves in DuPage County. The research sites included an area that experiences occasional prescribed burns, an area that frequently receives prescribed burns, and an area where prescribed burns have been non-existent since the year 2000. The two test sites have experienced four and seven burns since the year 2000, respectively (Test Site #1 and Test Site #2). This allowed for a sufficient comparison between the effects of prescribed burns within the Blackwell Forest Preserve. The site that receives moderately occurring prescribed burns acted as a control to compare the frequent burn site to the non-burn site (Control Site). The Control Site had a very dense understory that was difficult to traverse, which in turn did not allow for much sunlight to reach the forest floor (Figure 1). Instead, the high density of vegetation (mainly Black Cherry, Honeysuckle and Buckthorn) allowed for a shady and humid environment. Test Site #1 and #2 both had a less dense understory than that of the Control Site (Figure 2 & 3). All three sites are located near water sources (streams and lakes), which provides the potential for increased moisture, leading to mesophication (Figure 5). A shift in species composition is likely to occur in areas with fertile and deep soils with great water capacity (Nowacki and Abrams 2008). The study area is similar to that of several case studies in the

Chicago metropolitan area, which will be discussed later. These case studies will help when comparing the results of my study to previous literature related to mesophication within urbanized areas.

Blackwell's Urban History

As stated above, Blackwell Forest Preserve is located within the Chicago metropolitan area. As urbanization has increased in surrounding areas, these changes have in turn affected the forest preserve in different ways. It is also important to note urban changes within the forest preserve itself. In the 1830's, one of the founders of Winfield Township, Erastus Gary, began to operate a gristmill within the boundaries of what is now the Blackwell Forest Preserve. In the mid-twentieth century, the land was then bought by DuPage County who then refurbished an old quarry on the south side of the preserve into a lake. There was also a county landfill in operation at Blackwell Forest Preserve from 1965 to 1973. The landfill is now known as Mounty Hoy, which is used for a variety of reasons including hiking and winter tubing (Blackwell, Forest Preserve District of DuPage County 2018). It is clear to see that there have been several drastic changes to the land cover within the forest preserve as well as in surrounding areas. Inevitably, these changes have impacted many characteristics of the forest preserve including the composition of ecosystems and the availability of habitat and food sources. What remains unknown is the extent to which these land cover changes have affected the surrounding areas.

Site Photos

Figure 1. Control Site, July 2017.

Figure 2. Test Site #1, June 2017.

Figure 3. Test Site #2, July 2017. This was the only site with physical evidence (ash and charcoal) of prescribed burns

Figure 4. Test Site #1, November 2017. All of the green vegetation is invasive Honeysuckle. Honeysuckle is one of the last species to lose their leaves in the Chicago region.

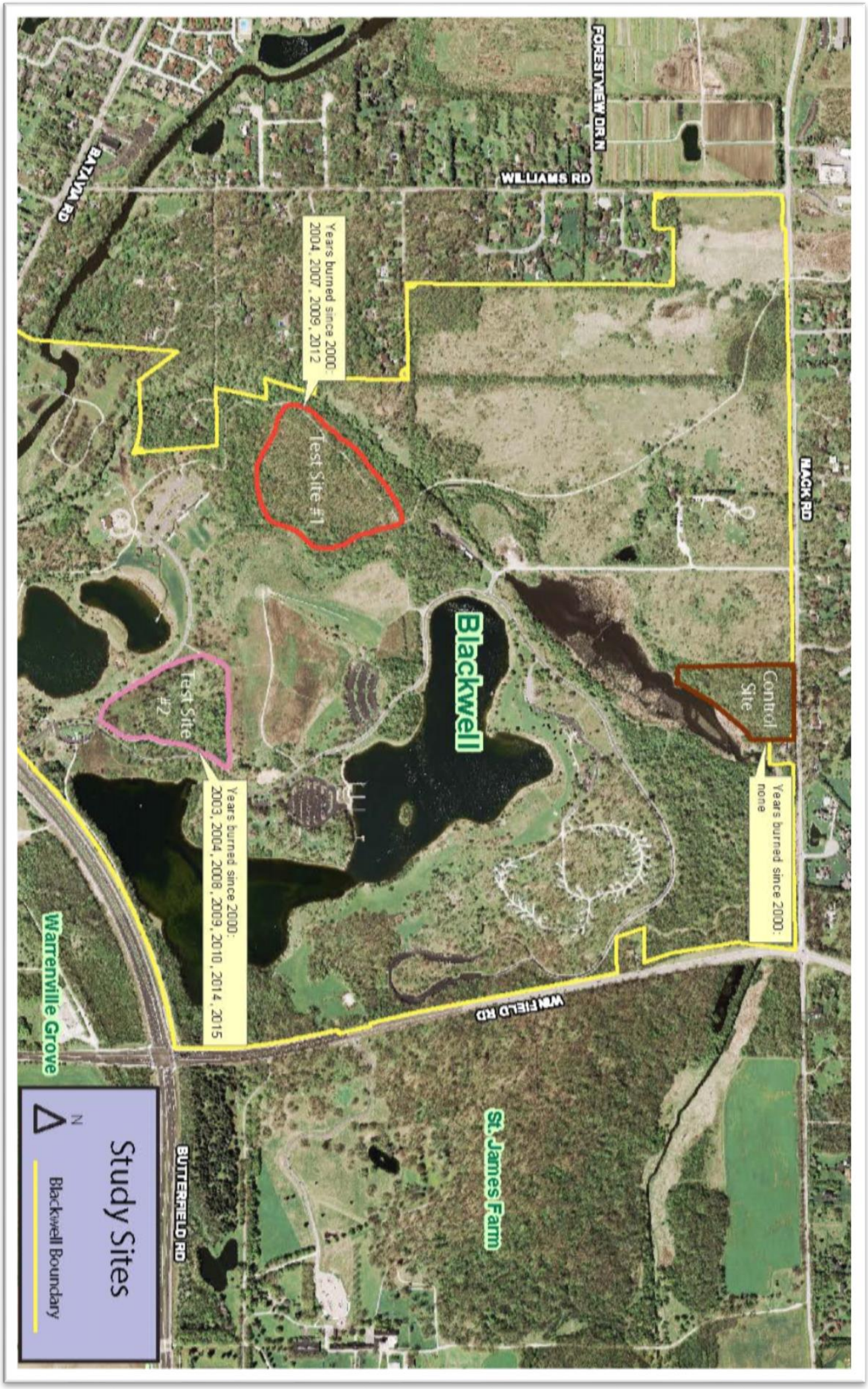


Figure 5. Map of study sites with statistics on prescribed burn frequency within Blackwell Forest Preserve.

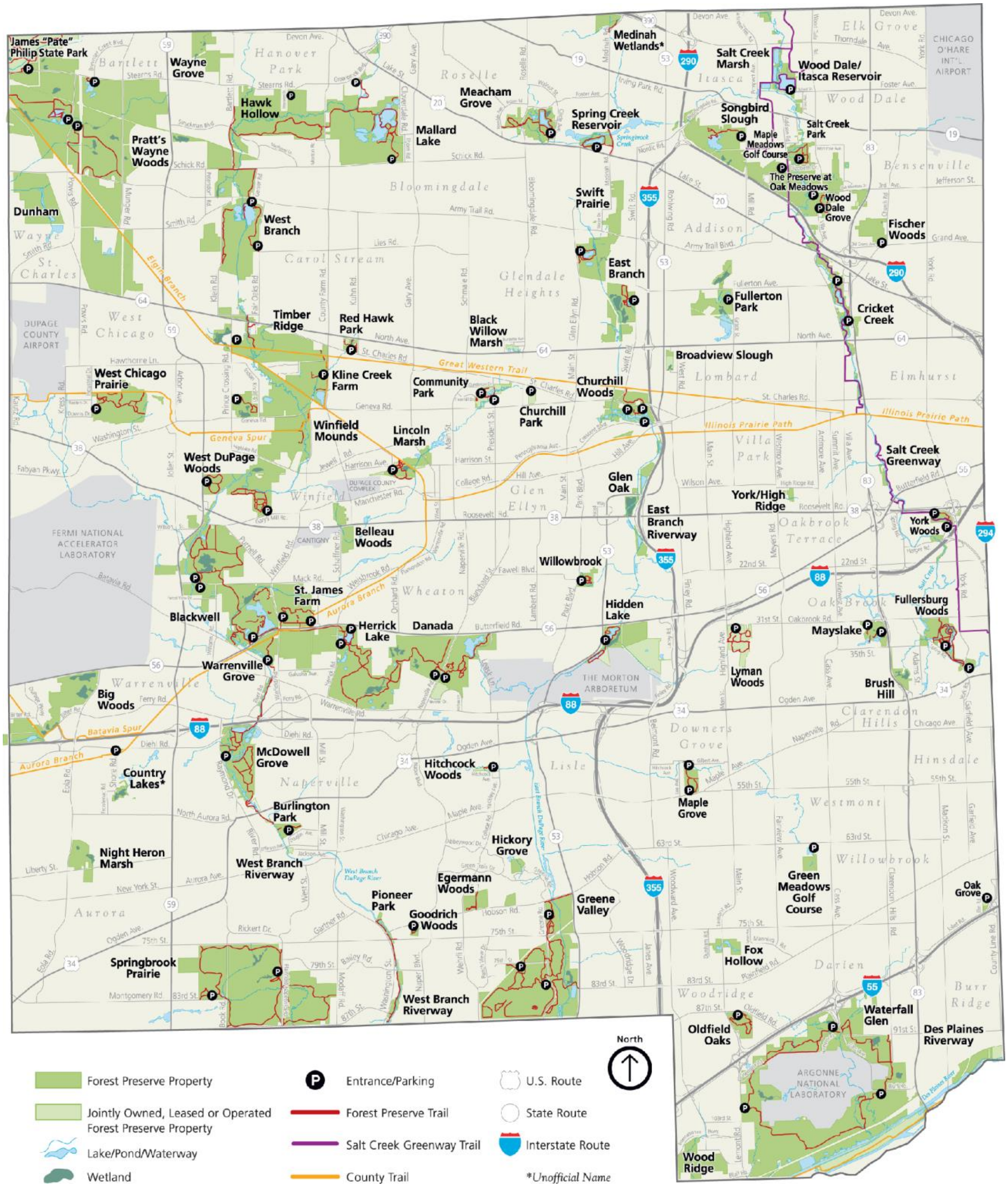


Figure 6. Map of forest preserves in DuPage County. Blackwell Forest Preserve is located near the eastern edge of the county. Source: Blackwell Forest Preserve webpage.

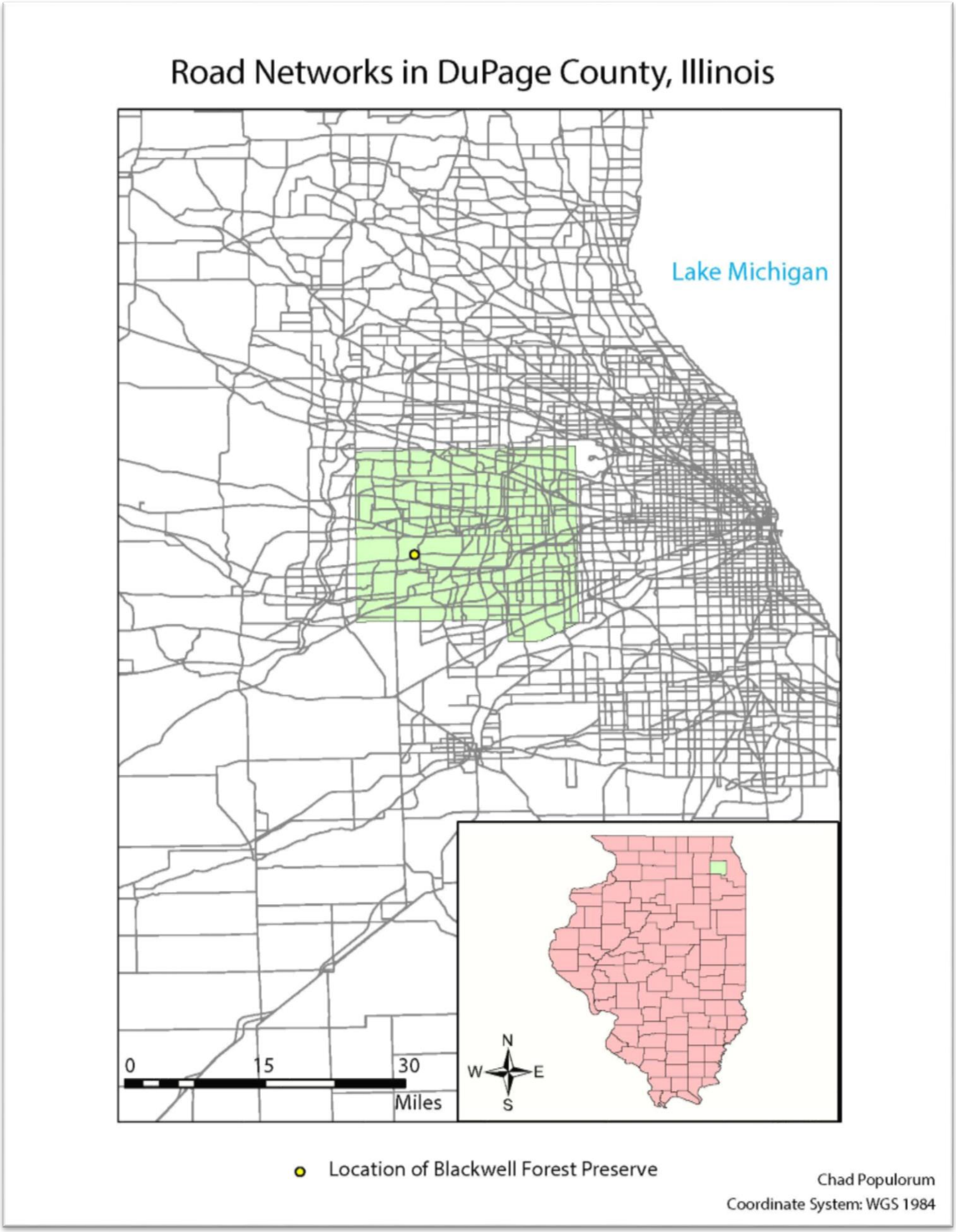


Figure 7. Road network map within DuPage County and surrounding areas. This map expresses the vast urbanization that has occurred in the Chicagoland area.

Implications

As of 2009, there were only 256 employees in DuPage County working in fields associated with forestry, fishing and other related activities. This represents virtually 0% of the total employees within the county. There are over 26,000 acres of land under the DuPage County Forest Preserve District but only about one-third is actively managed (Department of Economic Development and Planning, 2011). This shows that there is a clear lack of manpower in terms of efforts to reverse or slow down mesophication and the inevitable impacts of changes in composition of forest ecosystems. As a result of this project, I hope to provide the Forest Preserve District of DuPage County a more clear depiction of the problems associated with mesophication in Blackwell Forest Preserve. This will help forestry employees to know which areas may need greater management. More likely than not, the other forest preserves within the county are also experiencing forest composition changes due to mesophication. Further studies must be conducted to determine the validity of this assumption. Since there are not many people working on ecosystem management, it is crucial that these workers are spending their time wisely and focusing on the most important problems within the forest patches.

Methods

It is evident that rapid urbanization within the United States since European settlement has had serious effects on forest ecosystems for several reasons. Fires that once cleared forest understories of mesophytic and invading species have been greatly reduced due to human intervention. Although the short-term consequences of an invading species may not seem very threatening, the long-term implications of growing populations of these species can have severe consequences on a forest ecosystem. If little or no management is conducted within these ecosystems, they are placed on a path that leads to a reduction in biodiversity and other beneficial ecosystem services.

Field Work

To assess the overall health and effectiveness of prescribed burns, I used different techniques to gather my data. These data collecting methods were replicated from the projects done in ENVR 380 in the fall of 2016, which was led by Dr. Matthew Fockler and Dr. Michael Reisner at Augustana College in Rock Island, Illinois. The data collection period took place between early June and late July of the summer of 2017. After deciding which forest patches of the Blackwell Forest Preserve to conduct my research in based on the rate prescribed burns, I then chose eight random points per forest patch to gather my data with each point being at least 25 meters apart. This ensured that my sample was representative of the entire forest patch. At each of these eight points, I split each point into four equal quadrants using two PVC pipes. These pipes were placed perpendicular to each other with one pipe pointing north using a compass. The first quadrant was in the top right and the quadrants ascended clockwise. The longitude and latitude of each point was tracked using GPS. At each quadrant, I measured the distance in meters to the nearest invasive species, sapling tree and mature tree. A rolling measuring tape was used to track the distance. I then measured the diameter of the sapling and mature trees using a Diameter at Breast Height measuring tape. Sapling trees were classified as being between two-and-a-half centimeters and ten centimeters. Trees greater than ten centimeters were classified as mature. Each species, including the invasive species, were recorded by using a four-digit-code using the first two letters of both words in the scientific name. For example, the code for Swamp White Oak would be QUBI (*Quercus bicolor)*.

Data Analysis

After collecting the data from all eight points in each forest patch, I then used those measurements to compute several equations, which provides a sense of the dominant, expanding and declining species in each forest preserve ecosystem. Each forest patch's data was given its own Excel sheet that contains a template for computing these equations. Invasive shrub dominance was determined by accumulating the point-to-plant distance at each patch. A lower point-to-plant distance value signifies a higher abundance of invasive species. After going through many steps to determine the importance values (level of dominance) of these species, I created bar graphs for the mature trees, the sapling trees and invasive species, which are located in Appendices B through J. These graphs display the results of the computed equations including absolute density, absolute frequency, absolute basal area, relative density, relative frequency, relative basal area, and absolute and relative importance values. It is important to note that the importance value takes into account relative density, relative density and relative basal area. For the sake of clarity, I chose to focus on the importance values because they incorporate several vital values. As expected, these graphs display a clear trend in relation to the dominant and expanding species within these forest patches. The Shannon Diversity Index was also utilized to display the evenness and diversity of mature and sapling species in each plot (Figure 9). The data and bar graphs help to support the claim for why the patches in this forest preserve that experience prescribed burns would have richer biodiversity. These areas could be able to provide more ecosystem services than forest patches that do not experience the same applications of prescribed burns by management personnel.

Literature Review

Many studies have dealt with researching the history of land-use change over time and its relation to the more dominant vegetation that exists in the area. There have also been multiple recent studies related to the effectiveness of prescribed burns and how these burns have an impact on the ecosystem in which they are performed. The purpose of this project is to understand the ideal conditions in which restoration techniques such as burns, canopy thinning, and clearing of the understory are most effective. Compiling and comparing case studies based on restoration techniques will help to provide a more clear vision for how to go about proper restoration of local forest ecosystems, which may not receive appropriate management.

Historic Vegetation

Many studies have been conducted to determine the history of change within certain ecosystems throughout the United States. For the purpose of this project, the focus will be aimed towards the changes in forest ecosystems in the Midwest (specifically with the Chicago-region flat woods). Oak and hickory species are known to have dominated dry and arid forests in the Chicago area in the pre-settlement times and provided plenty of ecosystem services for wildlife as well as humans (Fahey et al. 2012). These services include but are not limited to habitat for animals and lumber resources. As conditions have become less favorable for heliophytic (sun-loving and fire-adapted) species, oak seedlings and saplings are not able to survive for decades in the understory, as they were able to do more than 300 years ago (Thomas-Van Gundy et al. 2013). This prevents heliophytic species from entering larger size classes. With the encroachment and high competition of shade-tolerant invasive species such as Honeysuckle, oak seedlings and young saplings are easily outperformed (Thomas-Van Gundy et al. 2013). This causes a positive feedback loop to begin, which may be difficult to reverse (Nowacki and Abrams 2008). Intruding mesophytic species include Black Cherry and American Basswood (Vose and Elliot 2016). Other mesophytic species include Black Walnut, Box Elder, Hackberry, Siberian Elm and American Elm (Fockler and Reisner 2016). Mesophication is likely to be occurring within the Chicago region and other Midwestern areas but has not been documented sufficiently (Bowles et al. 2003). Pre-settlement conditions would most likely be the most desirable however, there are not sufficient records of these historic conditions (Bowles et al. 2003) Also, there is no way to be certain of the magnitude of historic fires so, it may be difficult to maintain the correct intensity.

Gap in Knowledge

An important question for many restoration projects is how to maximize the regeneration of oaks and other heliophytic species while minimizing the threat by mesophytic species? It has proven to be difficult for restoration efforts to mimic the forces of nature adequately. There is uncertainty in knowing the most suitable conditions for carrying out restoration especially in terms of prescribed burns (Thomas-Van Gundy et al. 2013). Prescribed burns are also not performed on a very large scale; for many reasons, prescribed burns may only occur within a small portion of a given study area (Vose et al. 2016). These reasons could include the relative proximity of the burn area to residential homes, agricultural fields, etc. This causes a problem because it may be difficult to reverse mesophication due to the restricted ability to implement fires in urbanized areas (Fahey et al. 2012). What makes this problem worse it that urbanization happens on a faster scale than natural processes (species' ability to acclimate) within forest ecosystems so, there may be a lag time in how we can measure and understand changes within a landscape (Fahey et al. 2012). This means that adaptive management is needed especially in the modern era of unpredictable climate change (Vose and Elliot 2016). Adaptive management involves taking these uncertainties into account so that trials and errors of past management can be changed for future management.

Efficient Management

Creating large gaps in the canopy might increase the diversity of trees within the ecosystem by allowing species of varying shade tolerance to exist together (Thomas-Van Gundy et al. 2013). Oaks require these larger gaps to enter the overstory because they are intermediate in shade tolerance. To be able to grow into larger size classes, oaks must have abundant access to light (Thomas-Van Gundy et al. 2013). Royo et al. (2010) case study revealed that creating canopy gaps and introducing prescribed burns was able to increase species richness, cover and the diversity of herbaceous species (Thomas-Van Gundy et al. 2013). These authors also found that controlling deer populations and creating gaps increased the importance value of oak saplings in both burned and non-burned areas. This suggests that major disturbances to the canopy will allow for oaks to remain in these ecosystems (Thomas-Van Gundy et al. 2013). However, multiple burns may be necessary for these ecosystems to resume favoring oak species over mesophytic species. Woody growth in understory (shrubs) must be managed in order for best restoration (Vander Yacht et al. 2017). Removing unwanted understory species can be done through the use of fire, mechanical removal, applying herbicide, or a combination of these techniques. By reducing the influence and density of mesophytic species, longstanding oak forest ecosystems will be more resilient to unpredictable changes in climate. Oaks are known for their ability to withstand fires and droughts unlike mesophytic species (Vose and Elliot 2016). These are all important factors to consider when planning for restoration.

Results

Overall, my results line up with previous literature in terms of recorded species, presence of invasive species and the threat of mesophication. There is a significant difference between the results of the Control Site and the two Test Sites. Test Site #1 and #2 both had visibly greater diversity of plants in the understory compared to the Control Site (Figures 1-3). As stated before, the Shannon Diversity Index provides a sense of the biodiversity in each forest patch: the greater the value, the higher the level of biodiversity. Both Test Sites indicate higher levels of biodiversity and greater species evenness than the Control Site. These findings represent the general composition of each forest patch, not every tree and shrub was cataloged.

<u>Control Site</u>

This site was incredibly dense and difficult to traverse through. A dense canopy caused for a humid environment. There was a very low point-to-plant distance for invasive shrubs, which means that their abundance is high. The Control Site had the lowest point-to-plant distance total of all study sites. The importance value was highest for Black Cherry for both mature and sapling trees. White Oak and Swamp White Oak had the second and third highest importance values for mature trees, respectively. Almost all of the recorded sapling trees were Black Cherry. This could mean that as the older, heliophytic species begin to die off they will be succeeded mainly by mesophytic species and that this site will favor shade tolerant species over sun loving species. There were only two heliophytic sapling trees recorded in this forest patch both of which were oak species. However, there were multiple mature oak species are present and they were quite large in size compared to the younger Black Cherry. This explains the high values for basal area in this patch. Common Buckthorn accounted for two-thirds of invasive shrubs while Honeysuckle accounted for the other third.

Test Site #1

Most of this area was fairly easy to traverse through. Honeysuckle was the dominant invasive species in this area. A majority of the area has been cleared of invasive shrubs however, there is a large portion of this area that is infested with Honeysuckle as seen in Figure 4. Honeysuckle was the dominant invasive shrub at this site. There was a larger point-to-plant sum for invasive shrubs, which means that the abundance of invasive species was lower than in the Control Site. For the mature trees, Black Cherry and other mesophytic species still had significant importance values however, Swamp White Oak accounted for the highest importance value at this site. As for the sapling trees, Mockernut Hickory was the only heliophytic species accounted for and it had a lower importance value than Siberian Elm and Black Cherry. Multiple oak seedlings were found within the understory. These were mainly Red Oaks, which is surprising due to the absence of documented Red Oak sapling and mature trees within the forest patches. These seedlings were very small so there is no guarantee that they will survive long enough to enter larger size classes. The Shannon Diversity Index value and species evenness value were higher than that of the Control Site.

Figure 8. Red Oak seedling surrounded by leaf litter of various oak species. Photo taken in November, 2017. Located in Test Site #1.

Test Site #2

The two highest importance values for mature trees were American Basswood and Hackberry, which are both mesophytic. The next highest importance values were Mockernut Hickory, Bur Oak and White Oak, respectively. It was surprising to find that the heliophytic species were not more dominant in this site due to the frequency in prescribed burns. Not surprisingly, Mockernut Hickory had the highest importance value for the sapling trees at this site. This could mean that heliophytic sapling species will have greater chances of entering the overstory. This site had the largest point-to-plant distance, which means that the abundance of invasive shrubs was lowest at this site compared to the other sites. This site was the only site where invasive shrubs were not documented at certain quadrants because the nearest shrub was greater than 25 meters away. This was also true for several sapling trees, which could explain the decrease in the sapling species evenness value from Test Site #1 to Test Site #2. Nevertheless, the value for sapling species evenness was greater in both Test Sites compared to the Control Site. It is important to note that there were several young oak trees planted near the western edge of the forest patch. However, these trees fell outside of the 25-meter range for each plot point and were potentially too small to be classified as saplings. Red Oak seedlings were also present at this site.

Mature Tree Community
Control Site
Richness (n = # species) = 7
H_{max} = ln(n) = 1.94591015
(∑) Sum of p_i x ln(p_i) = -1.2785255
H (Shannon Diversity Index) = - ∑ p_i x ln(p_i) = **1.2785255**
Evenness (H/H_{max}) = 1.2785255/1.94591015 = **0.657032**

Test Site #1
Richness (n = # species) = 7
H_{max} = ln(n) = 1.94591015
(∑) Sum of p_i x ln(p_i) = -1.542625
H (Shannon Diversity Index) = - ∑ p_i x ln(p_i) = **1.542625**
Evenness (H/H_{max}) = 1.542625/1.94591015= **.79275**

Test Site #2
Richness (n = # species) = 7
H_{max} = ln(n) = 1.94591015
(∑) Sum of p_i x ln(p_i) = -1.7259709
H (Shannon Diversity Index) = - ∑ p_i x ln(p_i) = **1.7259709**
Evenness (H/H_{max}) = 1.7259709/1.94591015 = **0.88697**

Sapling Tree Community
Control Site
Richness (n = # species) = 5
H_{max} = ln(n) = 1.60943791
(∑) Sum of p_i x ln(p_i) = -.6415518
H (Shannon Diversity Index) = - ∑ p_i x ln(p_i) = **.6415518**
Evenness (H/H_{max}) = .6415518/1.60943791 = **0.39862**

Test Site #1
Richness (n = # species) = 4
H_{max} = ln(n) = 1.38629436
(∑) Sum of p_i x ln(p_i) = -1.2124399
H (Shannon Diversity Index) = - ∑ p_i x ln(p_i) = **1.2124399**
Evenness (H/H_{max}) = 1.2124399/1.38629436 = **.87459**

Test Site #2
Richness (n = # species) = 6
H_{max} = ln(n) = 1.79175947
(∑) Sum of p_i x ln(p_i) = -1.2824525
H (Shannon Diversity Index) = - ∑ p_i x ln(p_i) = **1.2824525**
Evenness (H/H_{max}) = 1.2824525/1.79175947 = **.71575**

Figure 9. Shannon Diversity Index values and species evenness values.

Discussion

Although I was not present at any of these prescribed burns, I was able to gain some insight on the specific conditions in which this management strategy is utilized. This information was received directly from the Manager of Natural Resources at Forest Preserve District of DuPage County (Scott Meister). He informed me that prescribed burns are the most effective management technique that the Forest Preserve District utilizes. Active burns are conducted in the fall and spring. If a burn is conducted in the fall then, there cannot be a burn the following spring. An ample amount of oak leaf litter is necessary in order for the fire to carry through the understory. If oak-dominated woodland forests begin to be succeeded by mesophytic species, the potential for oak leaves to be used as prescribed burn fuel diminishes. A dense understory of invasive shrubs must be removed as a precursor to burning otherwise the fires would not spread through the woodlands whatsoever. Meister emphasized the importance of utilizing multiple management strategies including mechanical removal, application of chemicals, and controlling sustainable levels of deer populations. Other optimal conditions for prescribed burns include carrying out the burn when temperatures are above freezing with no overnight frost, wind speed of 5-15 mph (up to 20 mph), and 30-65% humidity.

This study has now created a strong base for future students to build off of for their own research projects. The methods used in this study have proven to be reliable. Therefore, they could be implemented in a new study area or even replicated at Blackwell Forest Preserve in order to track the change of biodiversity and species abundance/dominance into the future. Future studies could also gather information about the Blackwell Forest Preserve (or other Chicago-region forest patches) that I was not able to record myself. This includes but is not limited to cataloging all species (trees, shrubs, grasses, etc.) within a given study area. This could help to reaffirm the dominant species within the study site. Measuring the ages of trees by taking tree core samples could be helpful by providing specific time frames in which certain species have been present within the study site. A way to verify the efficiency of restoration in the Chicago-region would be to witness prescribed burns and other techniques. This could help to provide an idea for the scale in which these techniques are carried out. Since there seems to be a lack of manpower in terms of forest management, it would be important to see the Forest Preserve District of DuPage County in action.

Conclusion

There is a significant difference between the results of the Control Site and both Test Sites. It is clear to see that the composition of these forest patches are quite different based on the frequency in implementation of management techniques with prescribed burns being the most efficient management technique. Test Sites #1 and #2 show increases in Shannon Diversity Index values and in species evenness values compared to that of the Control Site. This supports the claim that when conducted frequently, prescribed burns and other restoration techniques are able to maintain levels of biodiversity. Even when burns are implemented, the presence and dominance of mesophytic species still lingers. There is also a significant threat of invasive species. This exemplifies the importance of utilizing multiple management strategies. This requires sufficient manpower and money, which could be lacking within the Forest Preserve District of DuPage County. The results of this study will help to shine a light on the problems associated with mesophication because there is a gap in knowledge of this issue within the Chicago metropolitan area. Without receiving proper attention, other forested areas may be threatened by mesophication, leading to an eventual decrease in overall biodiversity. These problems will not disappear overnight. The restoration process is a lengthy one and management techniques may need to be altered to better fit the needs of different forest ecosystems. Without immediate attention, these ecosystems may reach a point of no return in which restoration may be next to impossible.

Acknowledgements

I would first like to thank Dr. Fockler and Dr. Reisner for inspiring this research project, providing me with guidance and supplying the equipment to carry out this research. I would also like to thank Dr. Burnham, Dr. Heine and Dr. Strunk for helping me through the research and write-up process. Also, my classmates were great sources for advice, revision and camaraderie. Lastly, a special thanks goes to my dad, Thomas Rebecca and Katherine Nenninger for helping me collect data in the field during the dog days of summer, accompanied by the inevitable swarm of mosquitoes. This process has not been an easy one. With the help from my professors, classmates, family and friends, I was able to complete this lengthy yet rewarding research.

Appendices

Appendix A. Shannon Diversity Index and Species Evenness Values

Mature Tree Community				
Control Site				
Species	**Relative Density**	**pi^2**	**ln(pi)**	**pi x ln(pi)**
Species 1	0.594	0.35254	-0.521296923	-0.30952
Species 2	0.188	0.03516	-1.673976433	-0.3138706
Species 3	0.094	0.00879	-2.367123614	-0.2219178
Species 4	0.031	0.00098	-3.465735902	-0.1083042
Species 5	0.031	0.00098	-3.465735902	-0.1083042
Species 6	0.031	0.00098	-3.465735902	-0.1083042
Species 7	0.031	0.00098	-3.465735902	-0.1083042
	1.000			-1.2785255
Richness (n = # species) = 7				
H_{max} = ln(n) = 1.94591015				
(∑) Sum of p_i x ln(p_i) = -1.2785255				
H (Shannon Diversity Index) = - ∑ p_i x ln(p_i) = 1.2785255				
Evenness (H/H_{max}) = 1.2785255/1.94591015 = 0.657032				

Mature Tree Community				
Test Site #1				
Species	**Relative Density**	**pi^2**	**ln(pi)**	**pi x ln(pi)**
Species 1	0.344	0.11816	-1.067840630	-0.3670702
Species 2	0.313	0.09766	-1.163150809	-0.3634846
Species 3	0.188	0.03516	-1.673976433	-0.3138706
Species 4	0.063	0.00391	-2.772588722	-0.1732868
Species 5	0.031	0.00098	-3.465735902	-0.1083042
Species 6	0.031	0.00098	-3.465735902	-0.1083042
Species 7	0.031	0.00098	-3.465735902	-0.1083042
	1.000			-1.542625
Richness (n = # species) = 7				
H_{max} = ln(n) = 1.94591015				
(∑) Sum of p_i x ln(p_i) = -1.542625				
H (Shannon Diversity Index) = - ∑ p_i x ln(p_i) = 1.542625				
Evenness (H/H_{max}) = 1.542625/1.94591015= .79275				

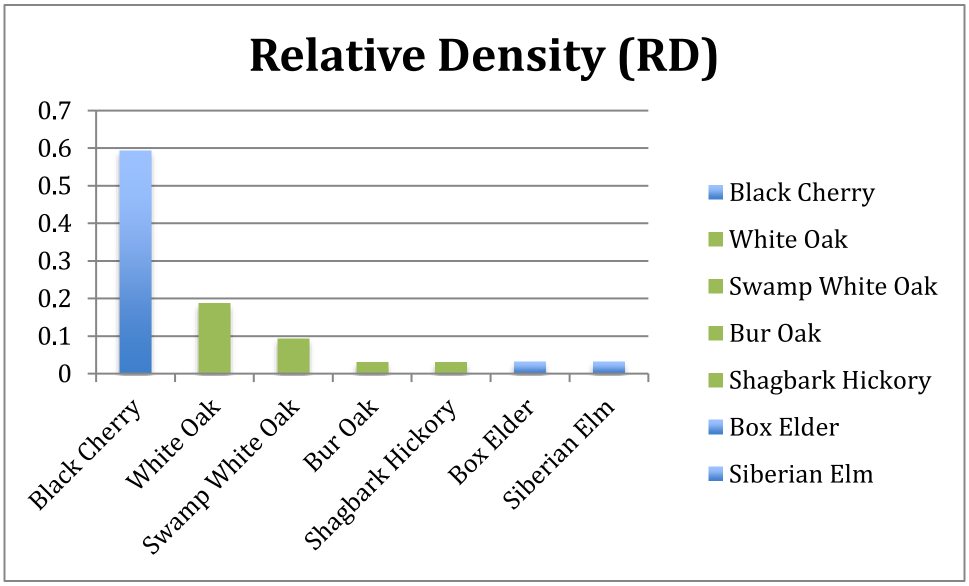
Mature Tree Community				
Test Site #2				
Species	**Relative Density**	**pi^2**	**ln(pi)**	**pi x ln(pi)**
Species 1	0.344	0.11816	-1.067840630	-0.3670702
Species 2	0.250	0.06250	-1.386294361	-0.3465736
Species 3	0.094	0.00879	-2.367123614	-0.2219178
Species 4	0.094	0.00879	-2.367123614	-0.2219178
Species 5	0.094	0.00879	-2.367123614	-0.2219178
Species 6	0.063	0.00391	-2.772588722	-0.1732868
Species 7	0.063	0.00391	-2.772588722	-0.1732868
	1.000			-1.7259709
Richness (n = # species) = 7				
H_{max} = ln(n) = 1.94591015				
(∑) Sum of p_i x ln(p_i) = -1.7259709				
H (Shannon Diversity Index) = - ∑ p_i x ln(p_i) = 1.7259709				
Evenness (H/H_{max}) = 1.7259709/1.94591015 = 0.88697				

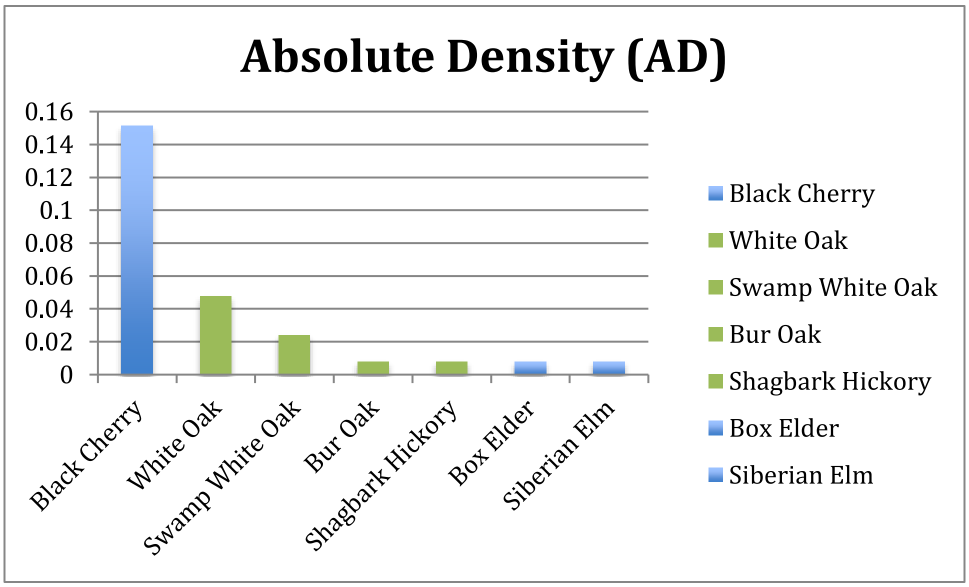
Sapling Tree Community				
Control Site				
Species	**Relative Density**	**pi^2**	**ln(pi)**	**pi x ln(pi)**
Species 1	0.844	0.71191	-0.169899036	-0.1433523
Species 2	0.063	0.00391	-2.772588722	-0.1732868
Species 3	0.031	0.00098	-3.465735902	-0.1083042
Species 4	0.031	0.00098	-3.465735902	-0.1083042
Species 5	0.031	0.00098	-3.465735902	-0.1083042
	1.000			-0.6415518
Richness (n = # species) = 5				
H_{max} = ln(n) = 1.60943791				
(∑) Sum of p_i x ln(p_i) = -.6415518				
H (Shannon Diversity Index) = - ∑ p_i x ln(p_i) = .6415518				
Evenness (H/H_{max}) = .6415518/1.60943791 = 0.39862				

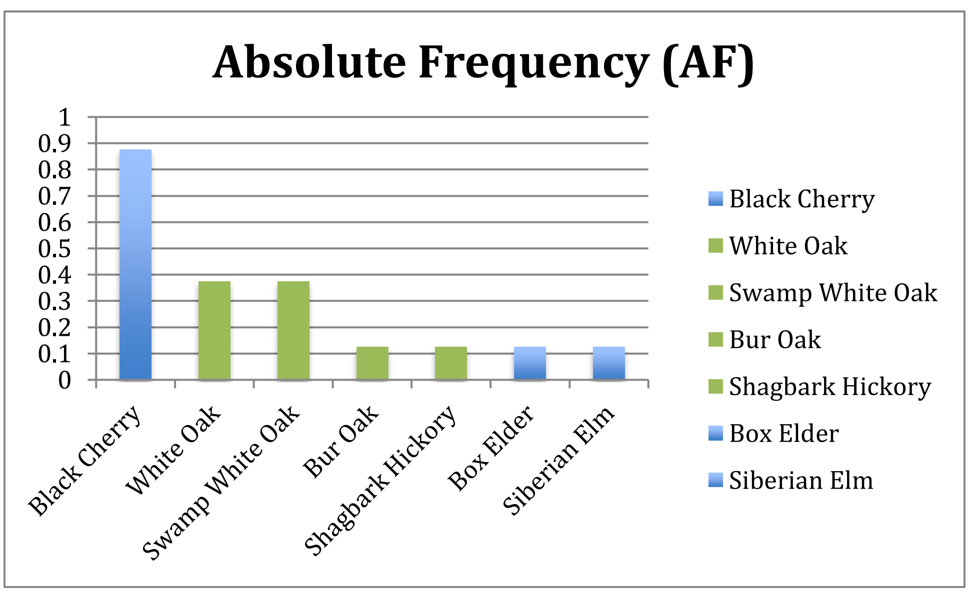
Sapling Tree Community				
Test Site #1				
Species	**Relative Density**	**pi^2**	**ln(pi)**	**pi x ln(pi)**
Species 1	0.438	0.19141	-0.826678573	-0.3616719
Species 2	0.313	0.09766	-1.163150809	-0.3634846
Species 3	0.188	0.03516	-1.673976433	-0.3138706
Species 4	0.063	0.00392	-2.771451712	-0.1734128
	1.000			-1.2124399
Richness (n = # species) = 4				
H_{max} = ln(n) = 1.38629436				
(∑) Sum of p_i x ln(p_i) = -1.2124399				
H (Shannon Diversity Index) = - ∑ p_i x ln(p_i) = 1.2124399				
Evenness (H/H_{max}) = 1.2124399/1.38629436 = .87459				

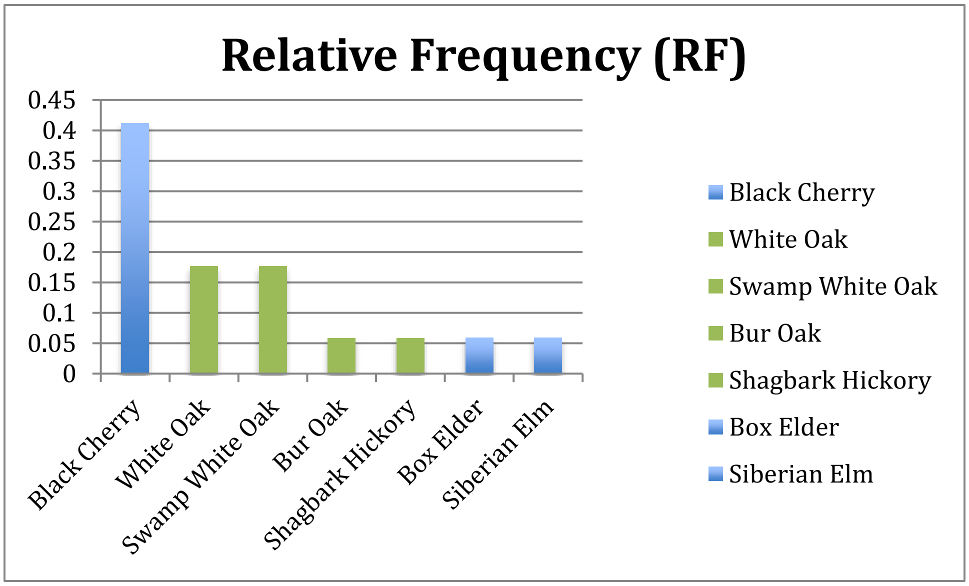
Sapling Tree Community				
Test Site #2				
Species	**Relative Density**	**pi^2**	**ln(pi)**	**pi x ln(pi)**
Species 1	0.281	0.07910	-1.268511325	-0.3567688
Species 2	0.188	0.03516	-1.673976433	-0.3138706
Species 3	0.094	0.00879	-2.367123614	-0.2219178
Species 4	0.063	0.00391	-2.772588722	-0.1732868
Species 5	0.031	0.00098	-3.465735902	-0.1083042
Species 6	0.031	0.00098	-3.465735902	-0.1083042
	0.688			-1.2824525
Richness (n = # species) = 6				
H_{max} = ln(n) = 1.79175947				
(∑) Sum of p_i x ln(p_i) = -1.2824525				
H (Shannon Diversity Index) = - ∑ p_i x ln(p_i) = 1.2824525				
Evenness (H/H_{max}) = 1.2824525/1.79175947 = .71575				

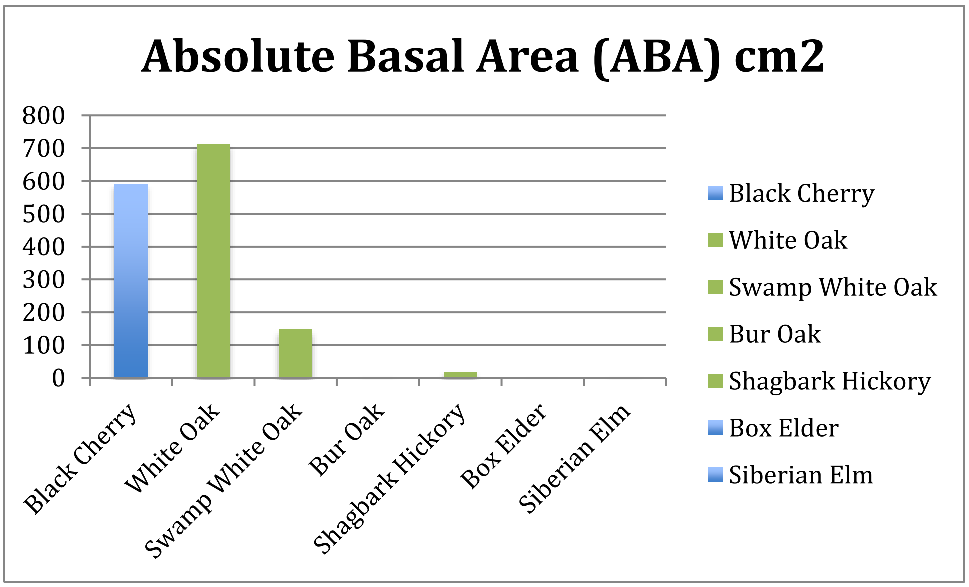
Appendix B. Control Site Mature Tree Bar Graphs

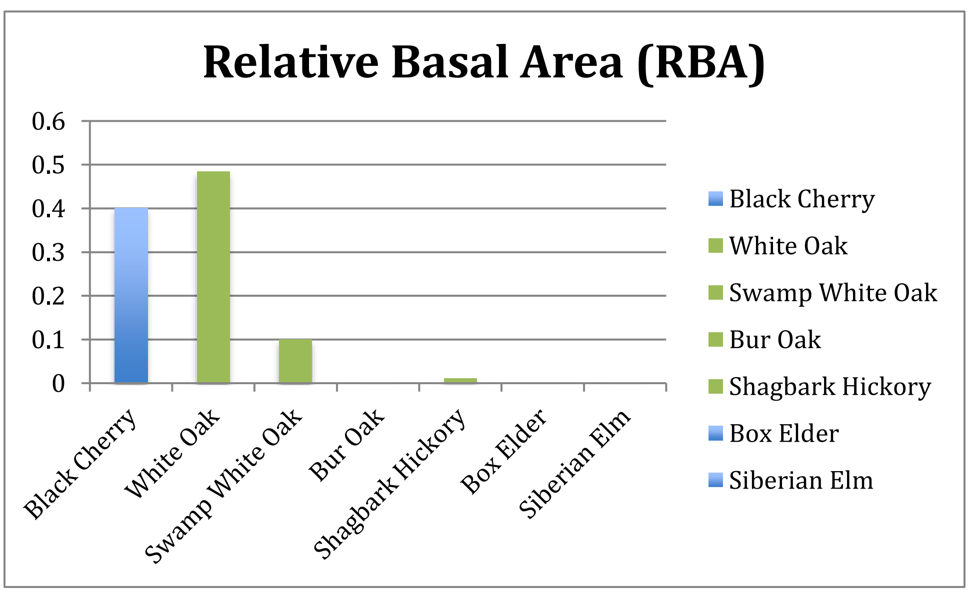


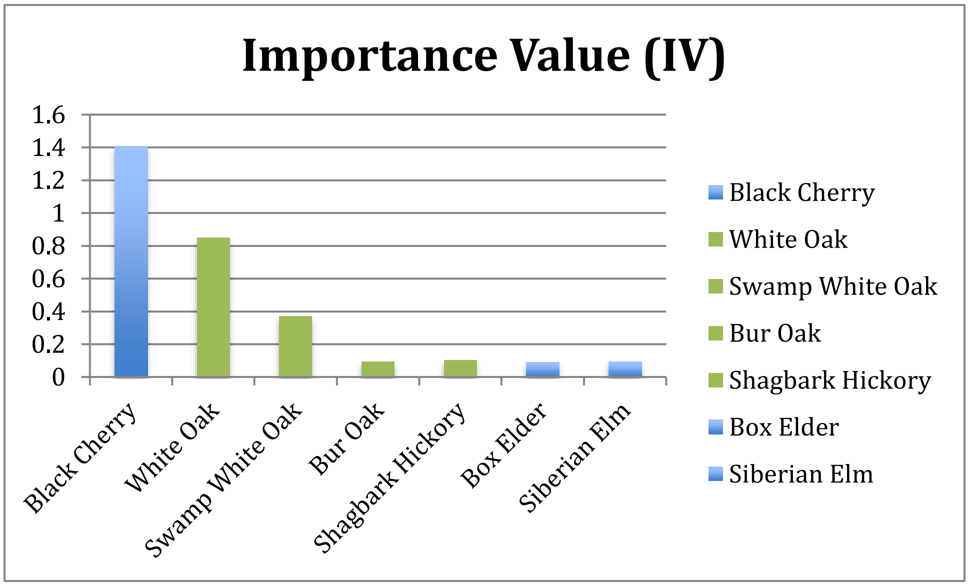


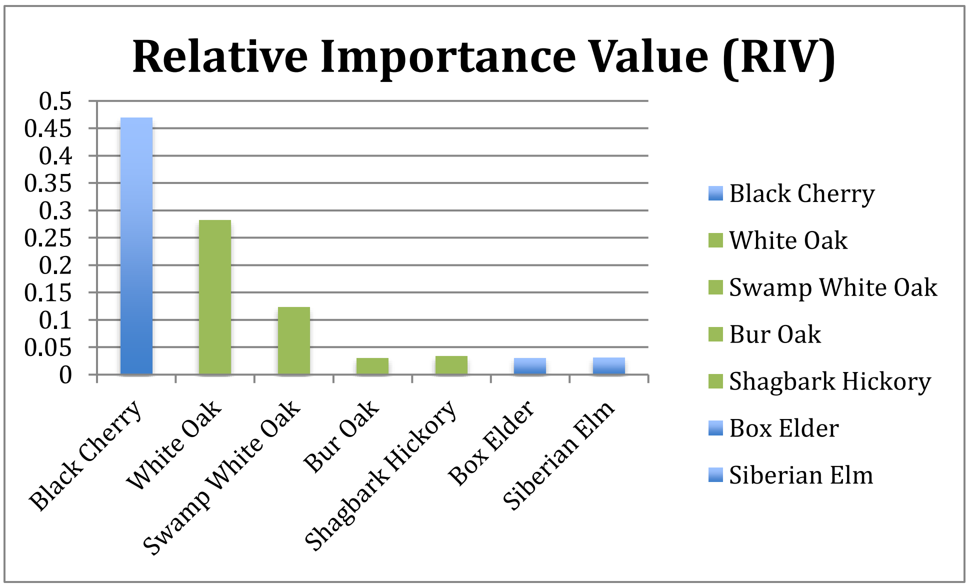



Relative Frequency (RF)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Black Cherry
White Oak
Swamp White Oak
Bur Oak
Shagbark Hickory
Box Elder
Siberian Elm
Black Cherry
White Oak
Swamp White Oak
Bur Oak
Shagbark Hickory
Box Elder
Siberian Elm

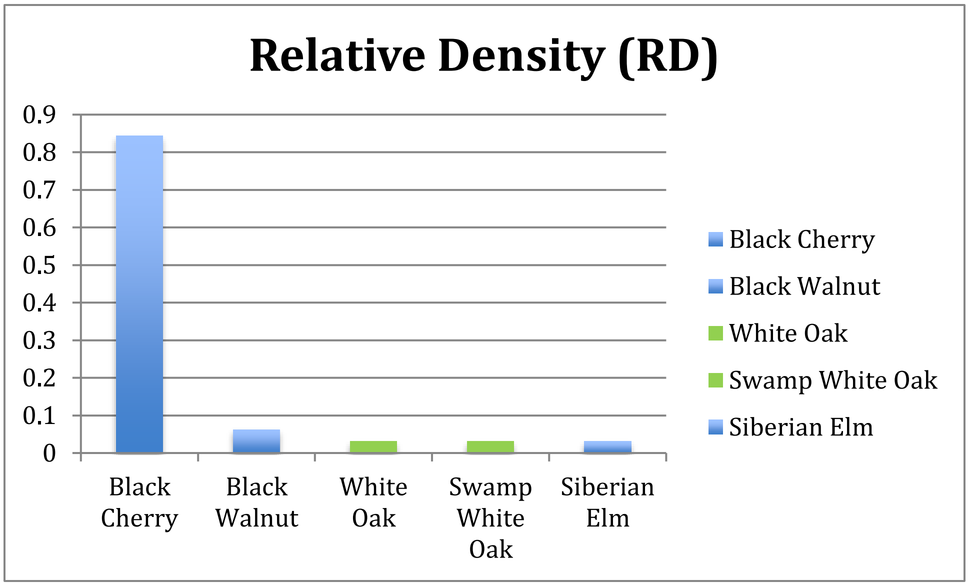

Absolute Basal Area (ABA) cm2
800
700
600
500
400
300
200
100
0
Black Cherry
White Oak
Swamp White Oak
Bur Oak
Shagbark Hickory
Box Elder
Siberian Elm
Black Cherry
White Oak
Swamp White Oak
Bur Oak
Shagbark Hickory
Box Elder
Siberian Elm

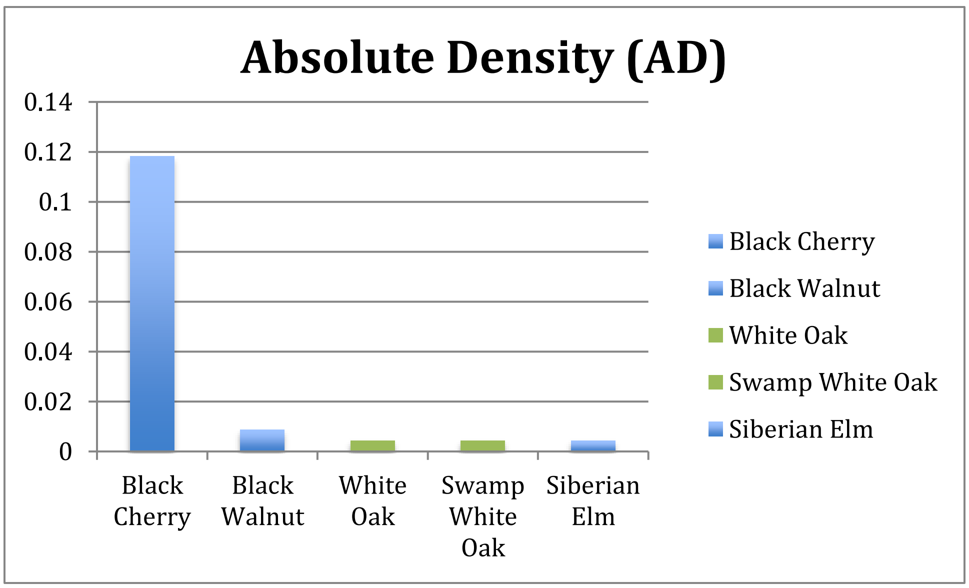

Relative Basal Area (RBA)
0.6
0.5
0.4
0.3
0.2
0.1
0
Black Cherry
White Oak
Swamp White Oak
Bur Oak
Shagbark Hickory
Box Elder
Siberian Elm
Black Cherry
White Oak
Swamp White Oak
Bur Oak
Shagbark Hickory
Box Elder
Siberian Elm

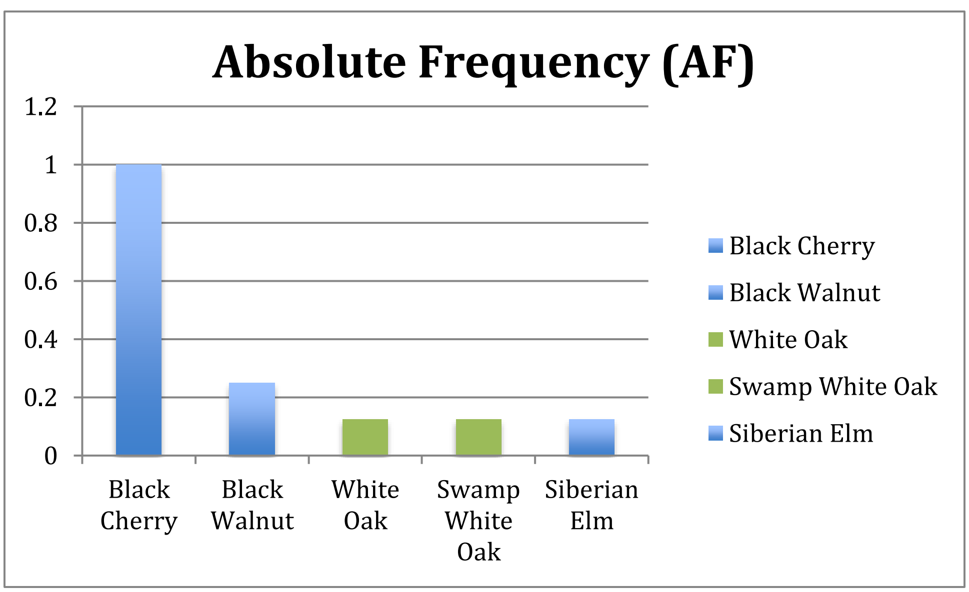

Importance Value (IV)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Black Cherry
White Oak
Swamp White Oak
Bur Oak
Shagbark Hickory
Box Elder
Siberian Elm
Black Cherry
White Oak
Swamp White Oak
Bur Oak
Shagbark Hickory
Box Elder
Siberian Elm

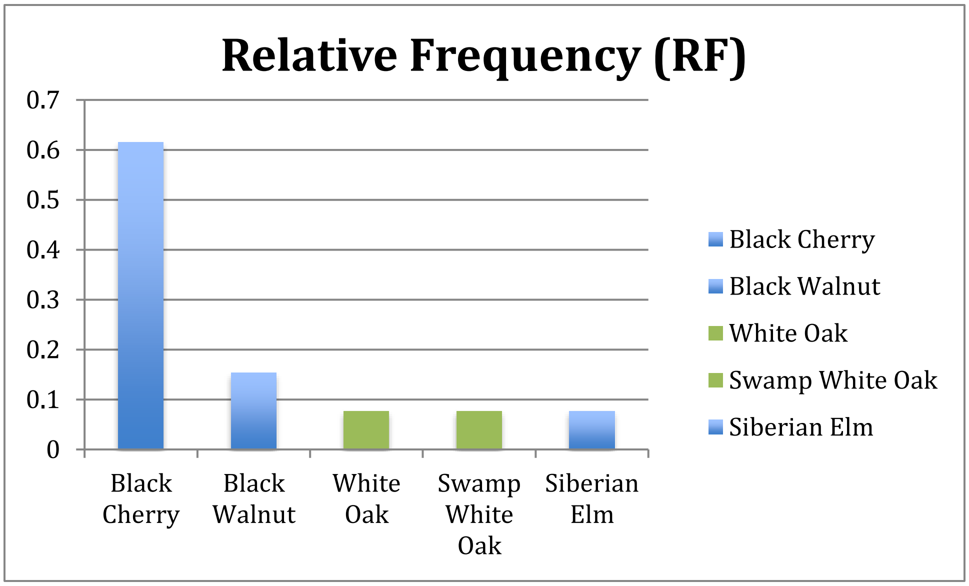

Relative Importance Value (RIV)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Black Cherry
White Oak
Swamp White Oak
Bur Oak
Shagbark Hickory
Box Elder
Siberian Elm
Black Cherry
White Oak
Swamp White Oak
Bur Oak
Shagbark Hickory
Box Elder
Siberian Elm

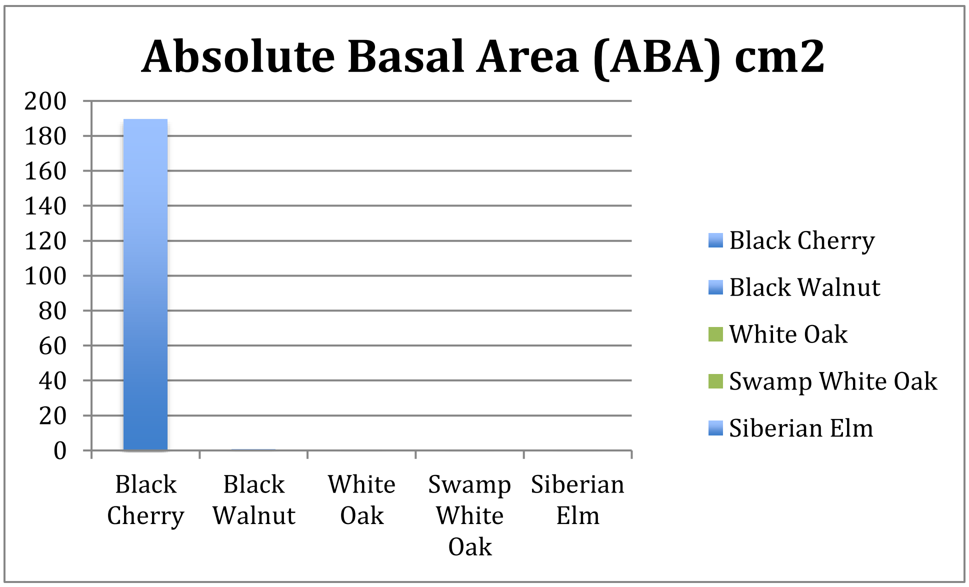
Appendix C. Control Site Sapling Tree Bar Graphs

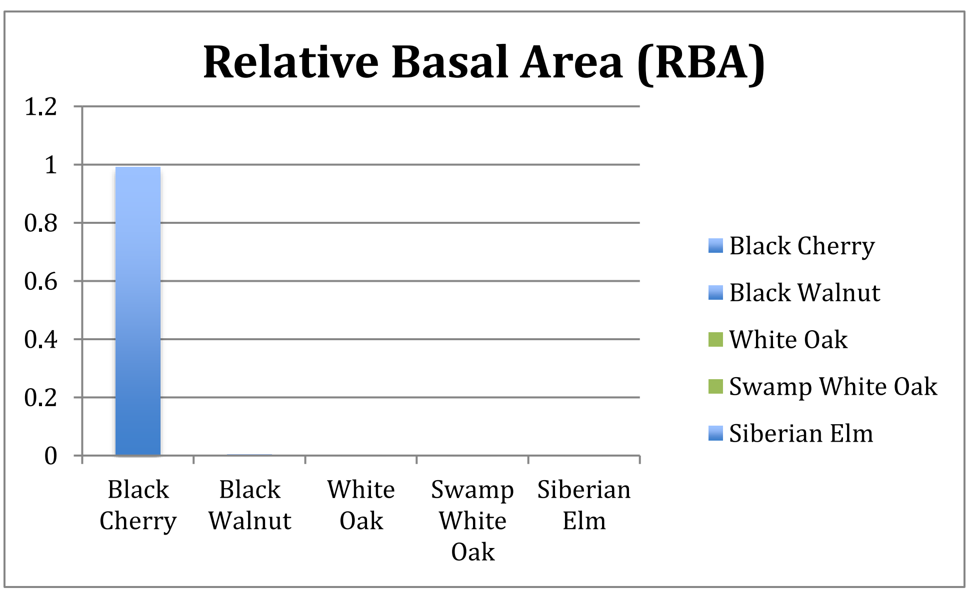


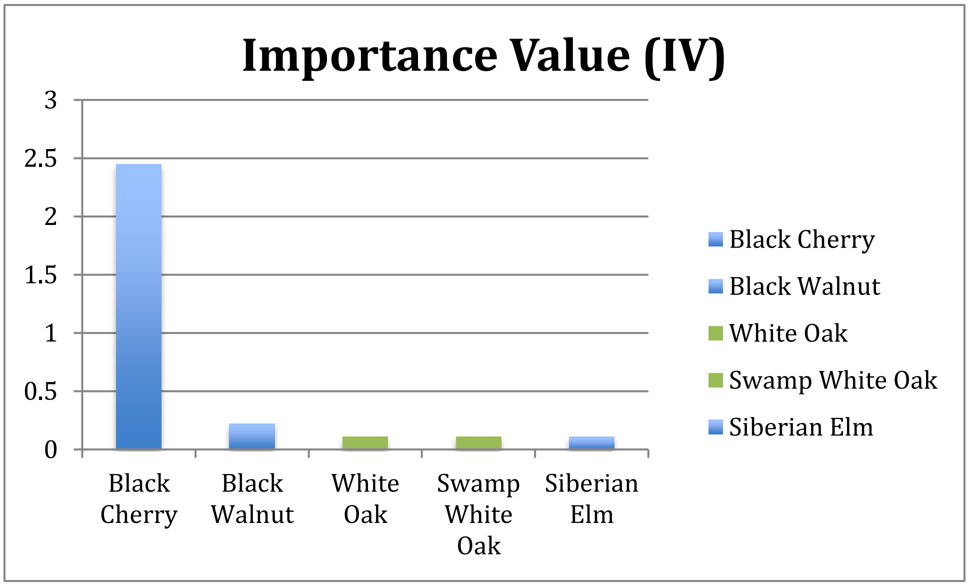


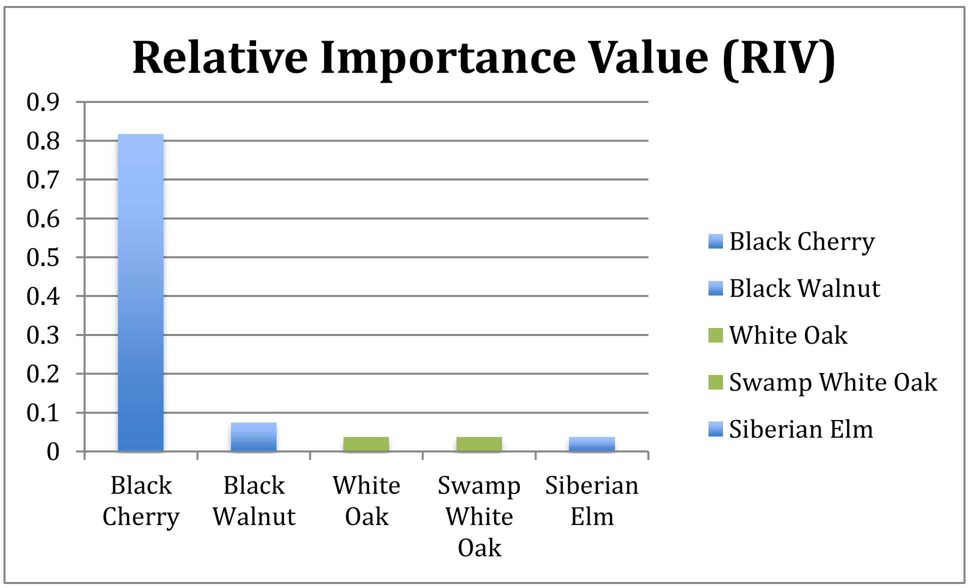



Relative Frequency (RF)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Black Cherry
Black Walnut
White Oak
Swamp White Oak
Siberian Elm
Black Cherry
Black Walnut
White Oak
Swamp White Oak
Siberian Elm

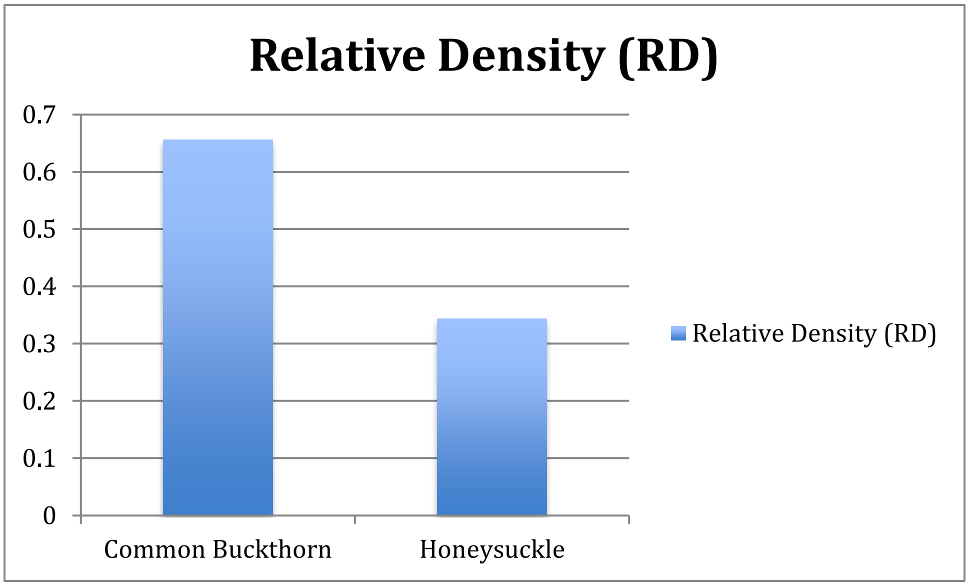

Absolute Basal Area (ABA) cm2
200
180
160
140
120
100
80
60
40
20
0
Black Cherry
Black Walnut
White Oak
Swamp White Oak
Siberian Elm
Black Cherry
Black Walnut
White Oak
Swamp White Oak
Siberian Elm

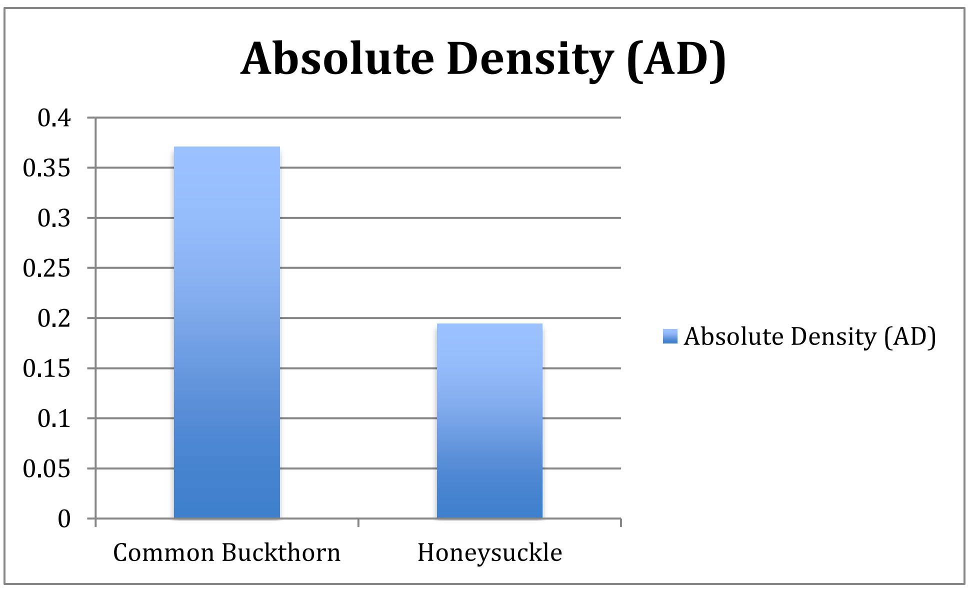

Relative Basal Area (RBA)
1.2
1
0.8
0.6
0.4
0.2
0
Black Cherry
Black Walnut
White Oak
Swamp White Oak
Siberian Elm
Black Cherry
Black Walnut
White Oak
Swamp White Oak
Siberian Elm

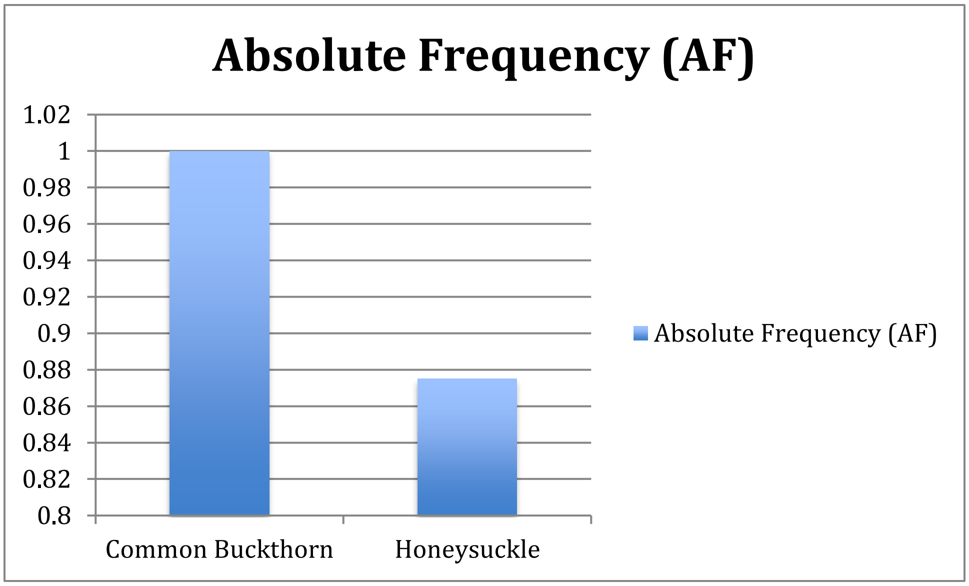

Importance Value (IV)
3
2.5
2
1.5
1
0.5
0
Black Cherry
Black Walnut
White Oak
Swamp White Oak
Siberian Elm
Black Cherry
Black Walnut
White Oak
Swamp White Oak
Siberian Elm

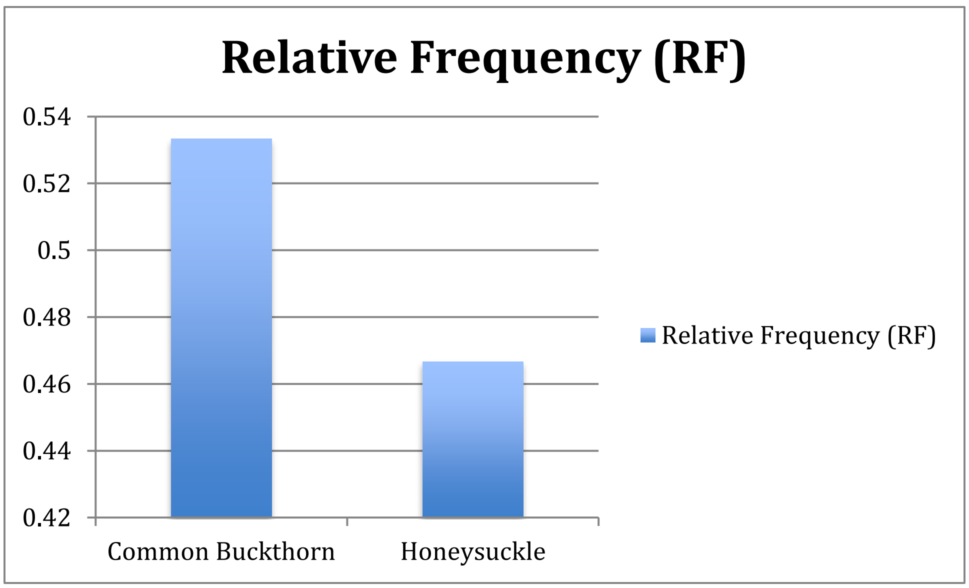

Relative Importance Value (RIV)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Black Cherry
Black Walnut
White Oak
Swamp White Oak
Siberian Elm
Black Cherry
Black Walnut
White Oak
Swamp White Oak
Siberian Elm

Appendix D. Control Site Invasive Shrub Bar Graphs

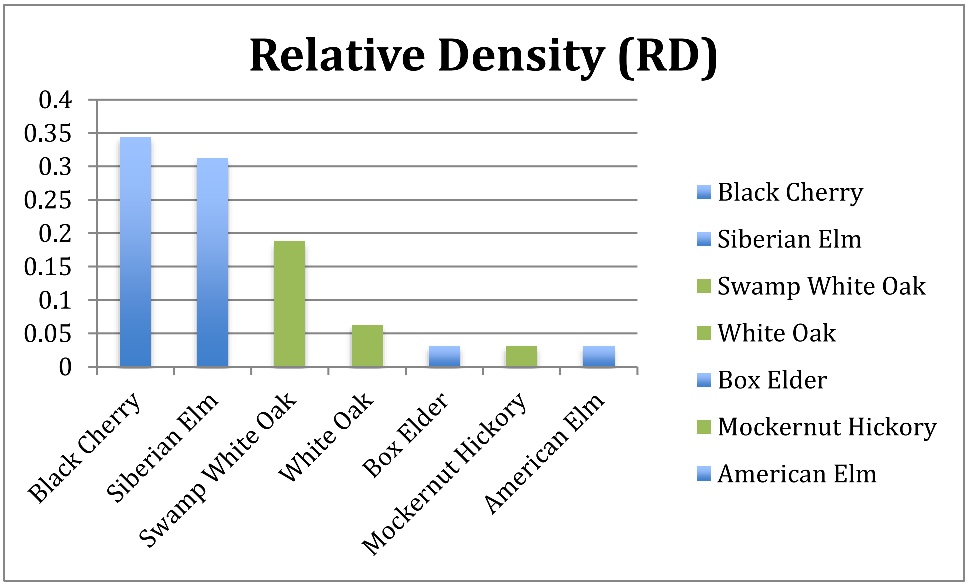


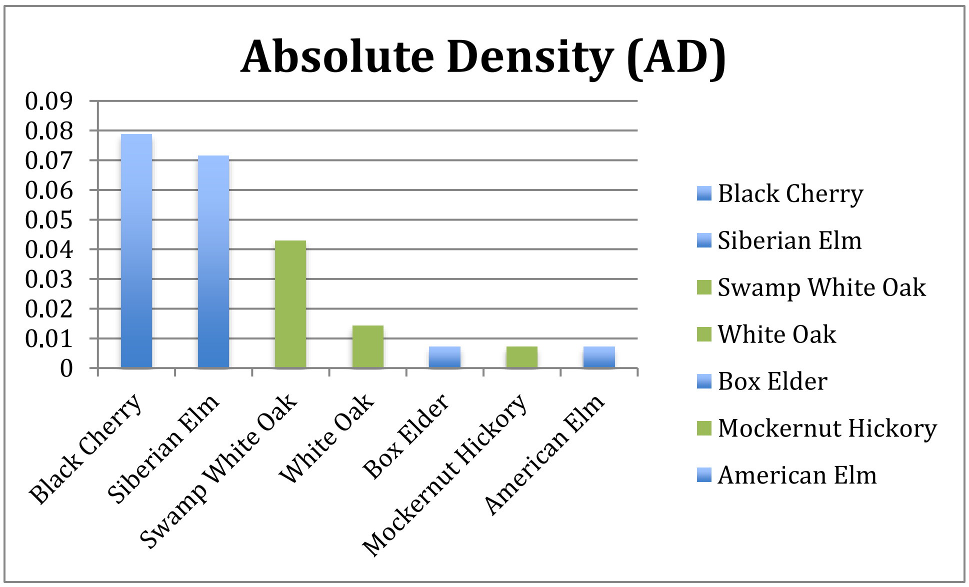


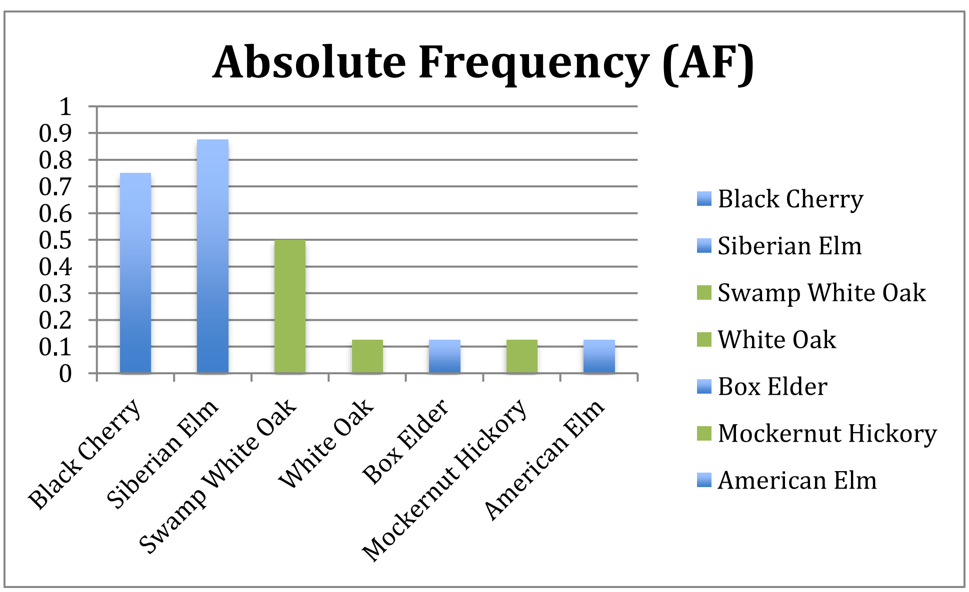

Absolute Frequency (AF)
1.02
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0.84
0.82
0.8
Common Buckthorn
Honeysuckle
Absolute Frequency (AF)

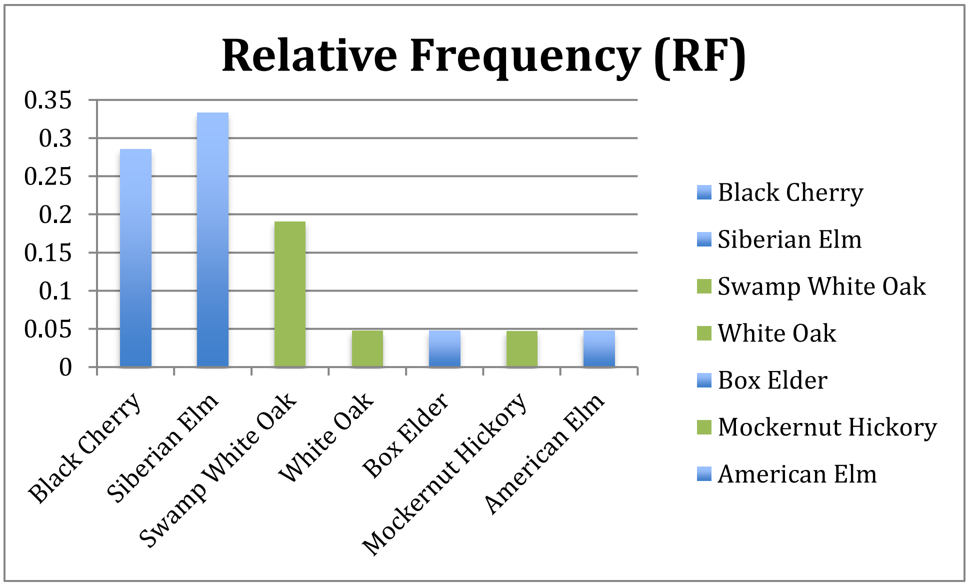

Relative Frequency (RF)
0.54
0.52
0.5
0.48
0.46
0.44
0.42
Common Buckthorn
Honeysuckle
Relative Frequency (RF)

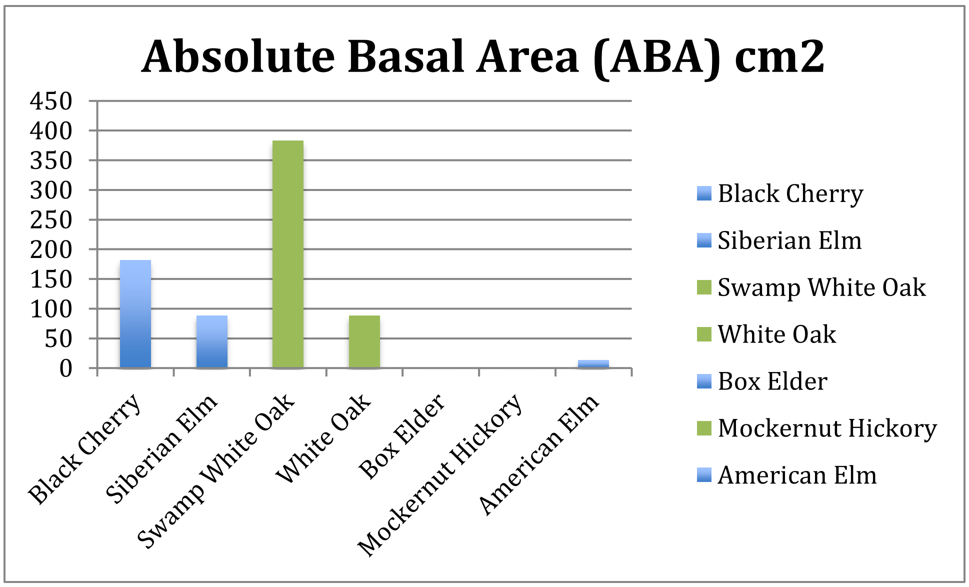
Appendix E. Test Site #1 Mature Tree Bar Graphs

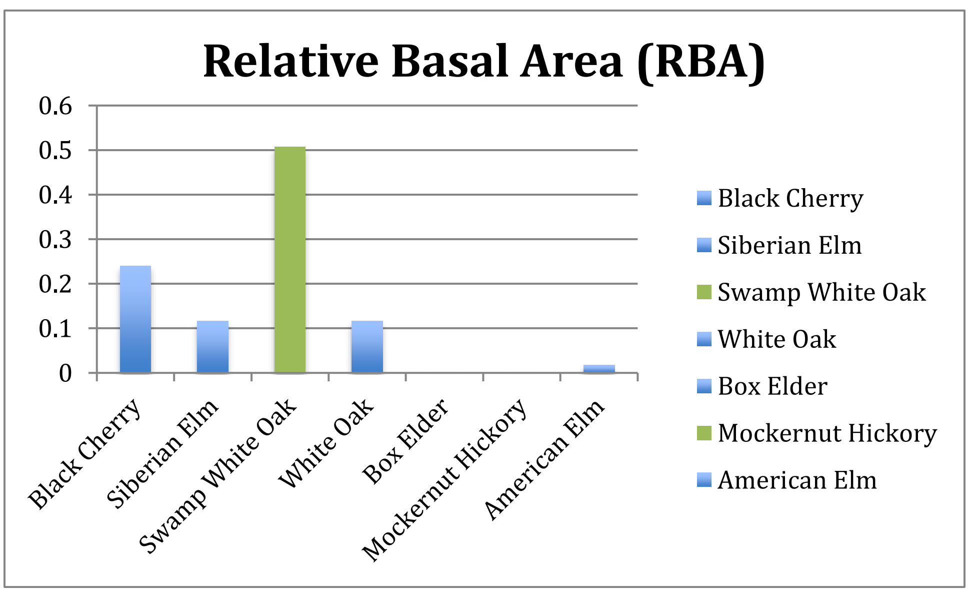


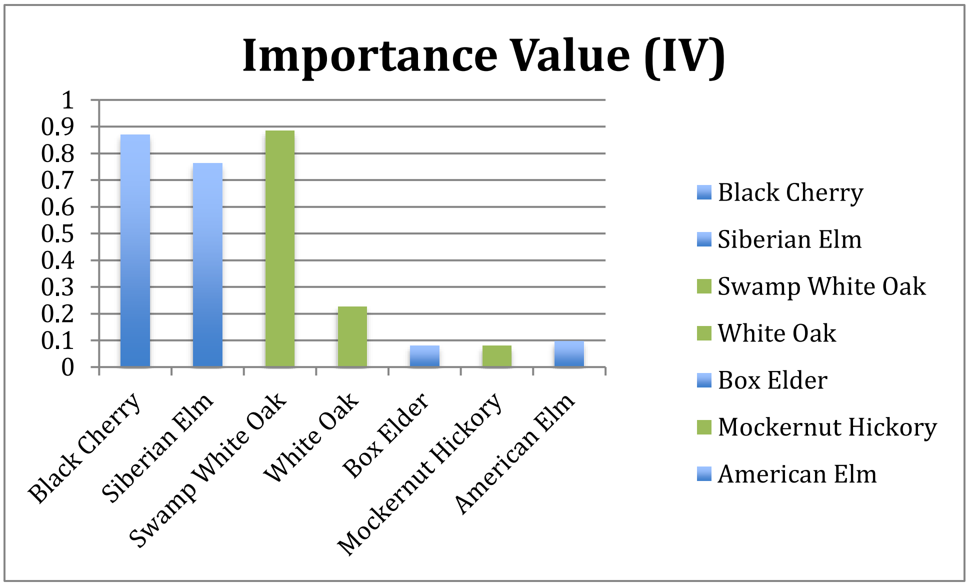


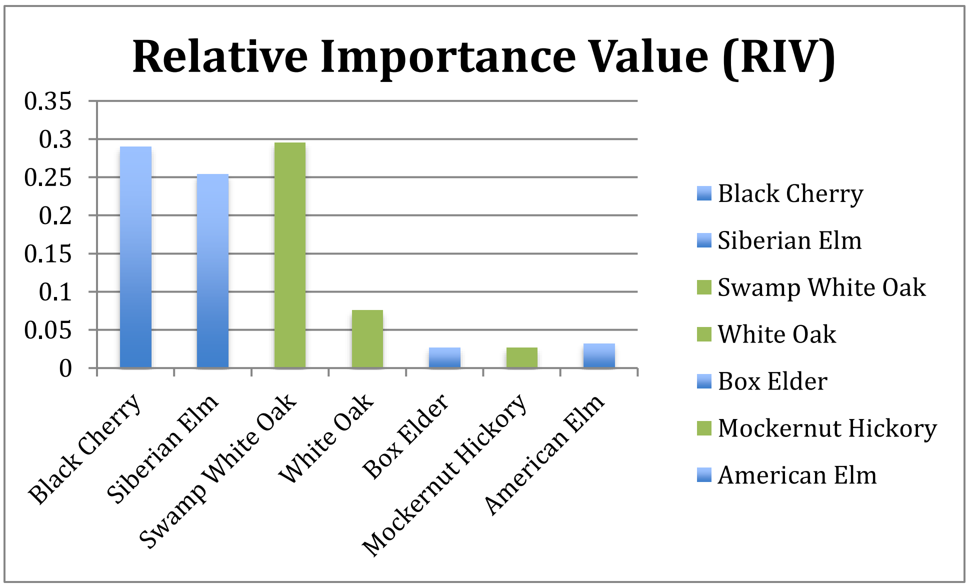



Relative Frequency (RF)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Black Cherry
Siberian Elm
Swamp White Oak
White Oak
Box Elder
Mockernut Hickory
American Elm
Black Cherry
Siberian Elm
Swamp White Oak
White Oak
Box Elder
Mockernut Hickory
American Elm

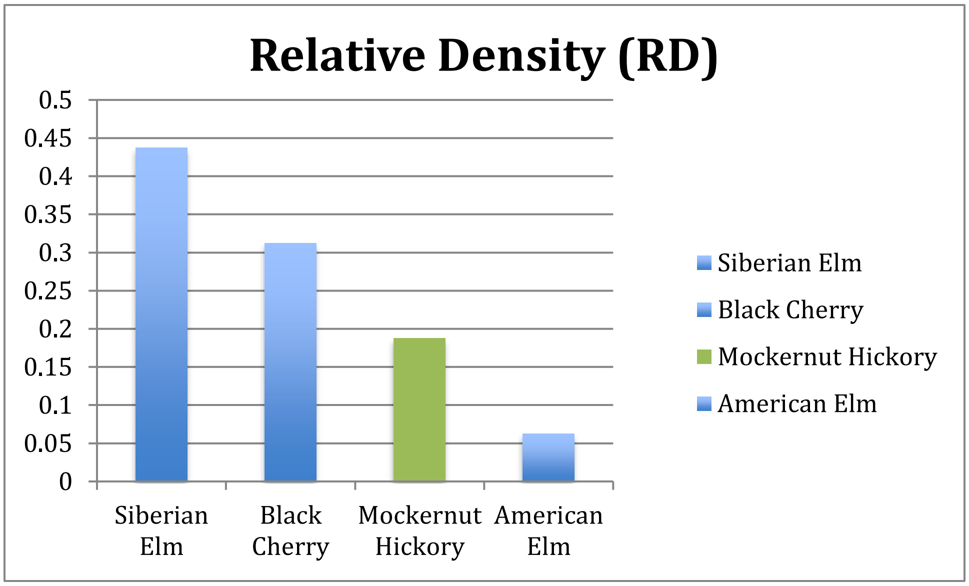

Absolute Basal Area (ABA) cm2
450
400
350
300
250
200
150
100
50
0
Black Cherry
Siberian Elm
Swamp White Oak
White Oak
Box Elder
Mockernut Hickory
American Elm
Black Cherry
Siberian Elm
Swamp White Oak
White Oak
Box Elder
Mockernut Hickory
American Elm

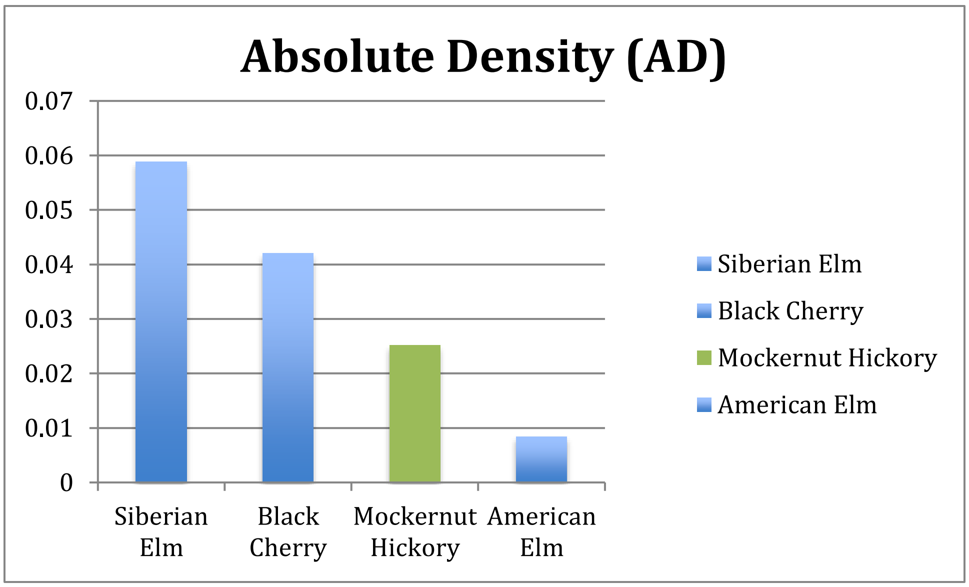

Relative Basal Area (RBA)
0.6
0.5
0.4
0.3
0.2
0.1
0
Black Cherry
Siberian Elm
Swamp White Oak
White Oak
Box Elder
Mockernut Hickory
American Elm
Black Cherry
Siberian Elm
Swamp White Oak
White Oak
Box Elder
Mockernut Hickory
American Elm

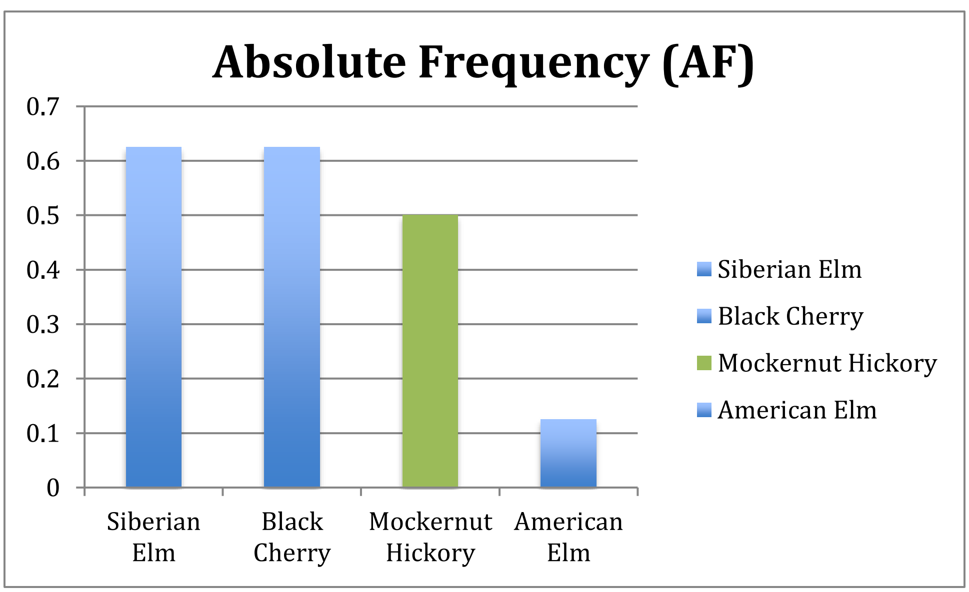

Importance Value (IV)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Black Cherry
Siberian Elm
Swamp White Oak
White Oak
Box Elder
Mockernut Hickory
American Elm
Black Cherry
Siberian Elm
Swamp White Oak
White Oak
Box Elder
Mockernut Hickory
American Elm

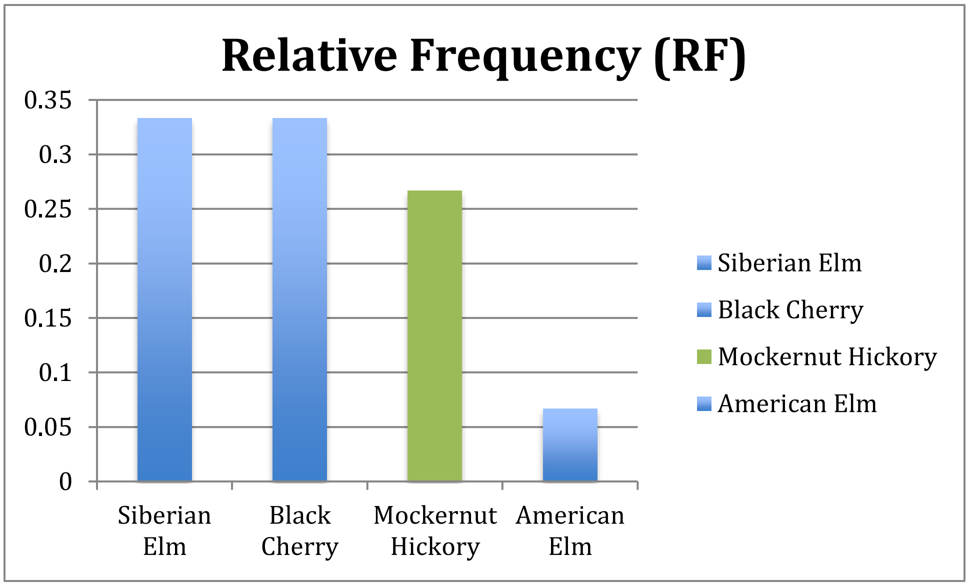

Relative Importance Value (RIV)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Black Cherry
Siberian Elm
Swamp White Oak
White Oak
Box Elder
Mockernut Hickory
American Elm
Black Cherry
Siberian Elm
Swamp White Oak
White Oak
Box Elder
Mockernut Hickory
American Elm

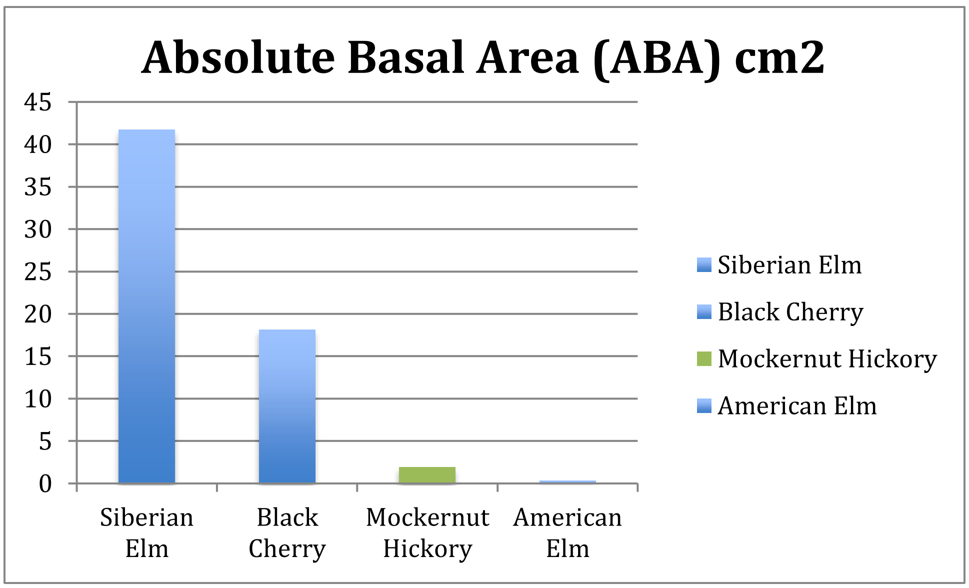
Appendix F Test Site #1 Sapling Tree Bar Graphs

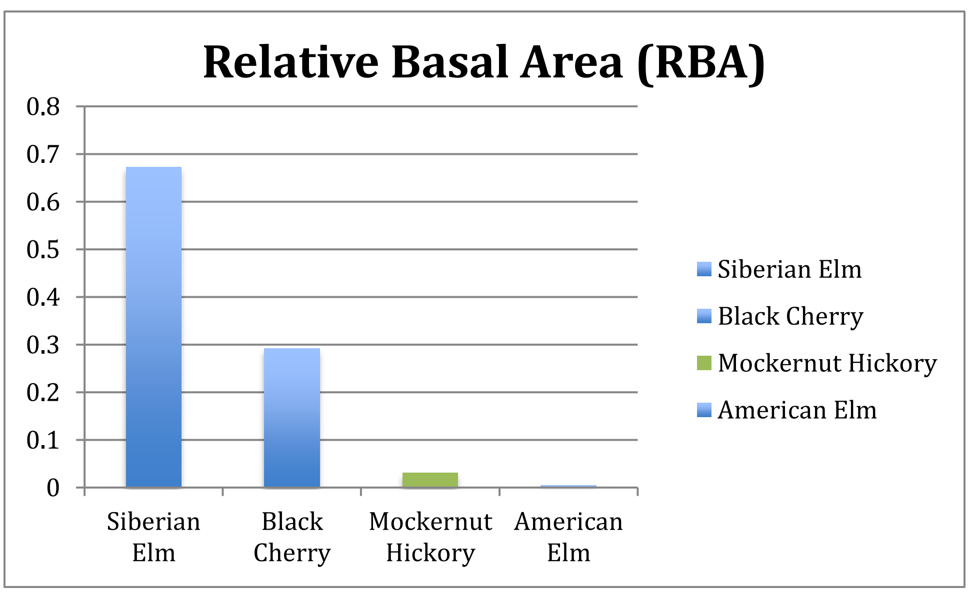


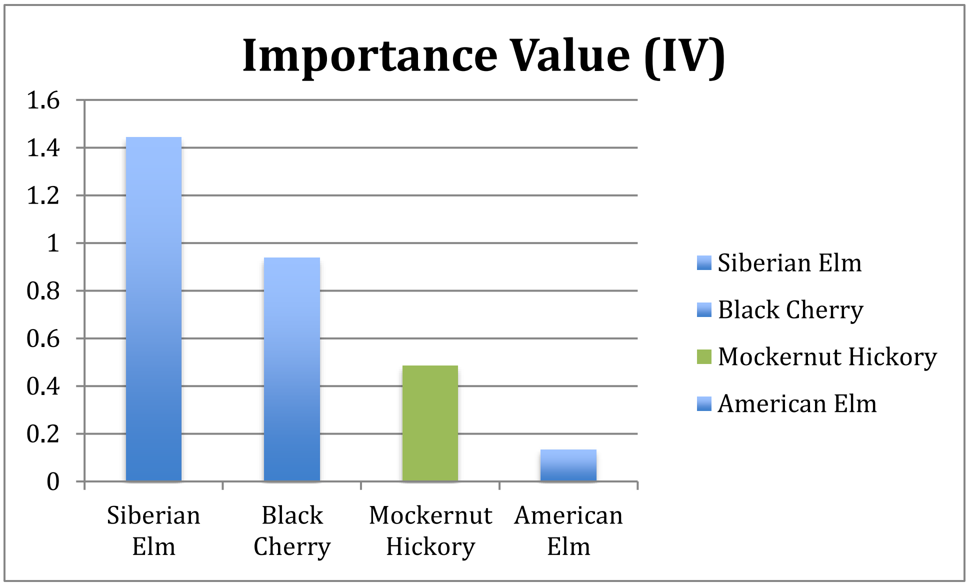


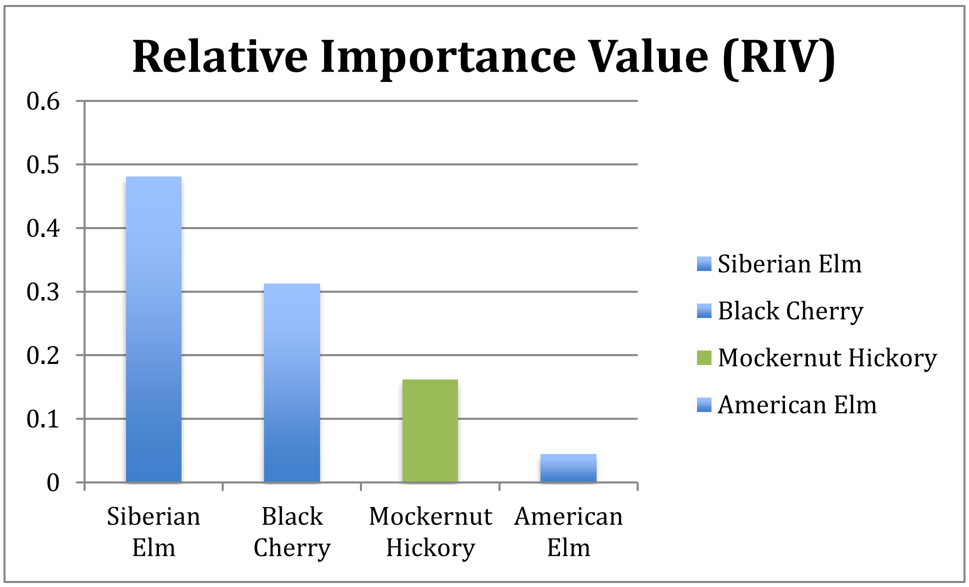



Relative Frequency (RF)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Siberian Elm
Black Cherry
Mockernut Hickory
American Elm
Siberian Elm
Black Cherry
Mockernut Hickory
American Elm

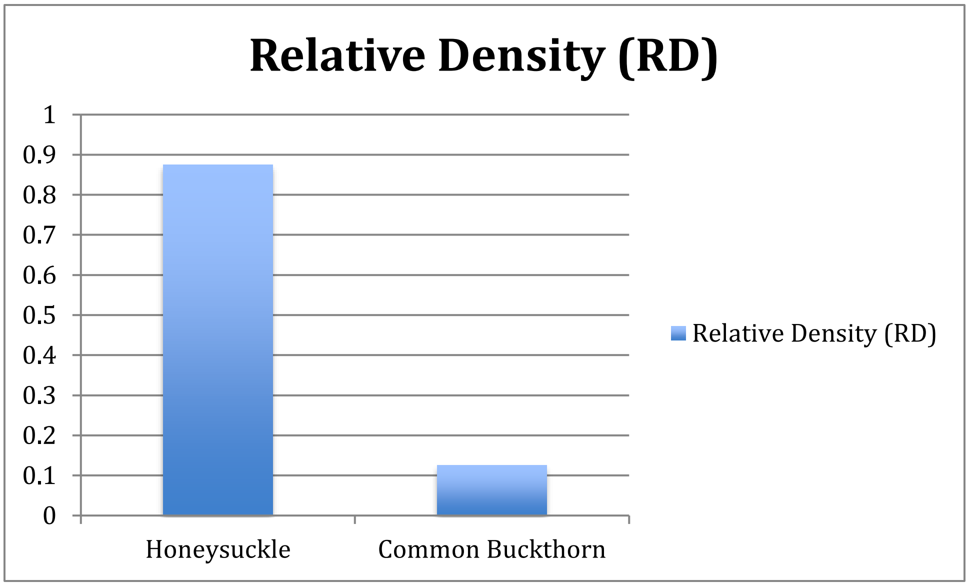

Absolute Basal Area (ABA) cm2
45
40
35
30
25
20
15
10
5
0
Siberian Elm
Black Cherry
Mockernut Hickory
American Elm
Siberian Elm
Black Cherry
Mockernut Hickory
American Elm

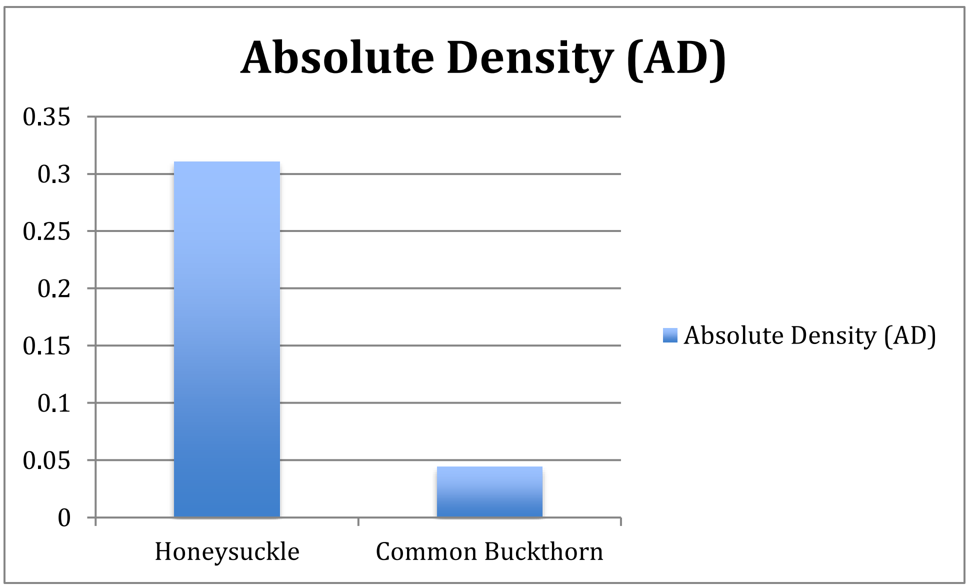

Relative Basal Area (RBA)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Siberian Elm
Black Cherry
Mockernut Hickory
American Elm
Siberian Elm
Black Cherry
Mockernut Hickory
American Elm

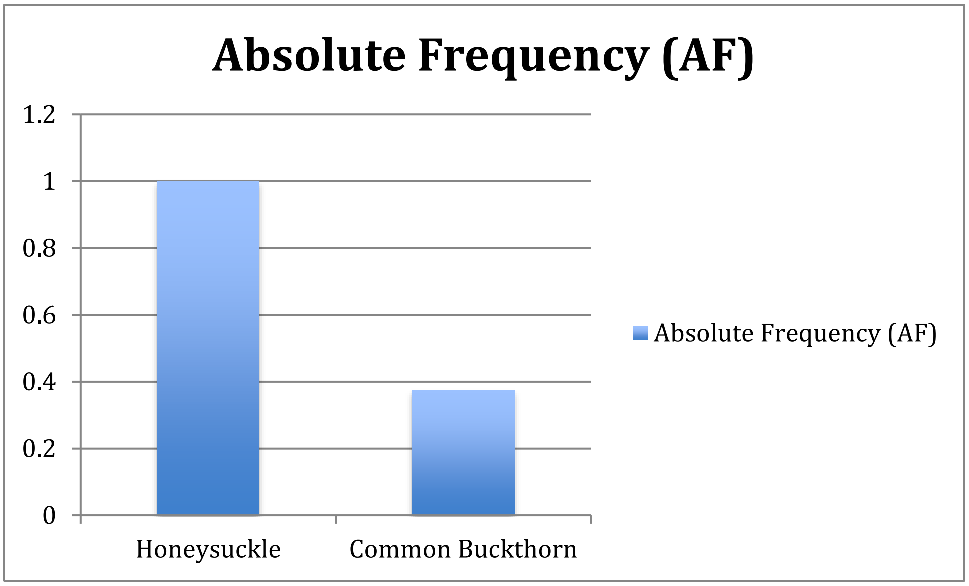

Importance Value (IV)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Siberian Elm
Black Cherry
Mockernut Hickory
American Elm
Siberian Elm
Black Cherry
Mockernut Hickory
American Elm

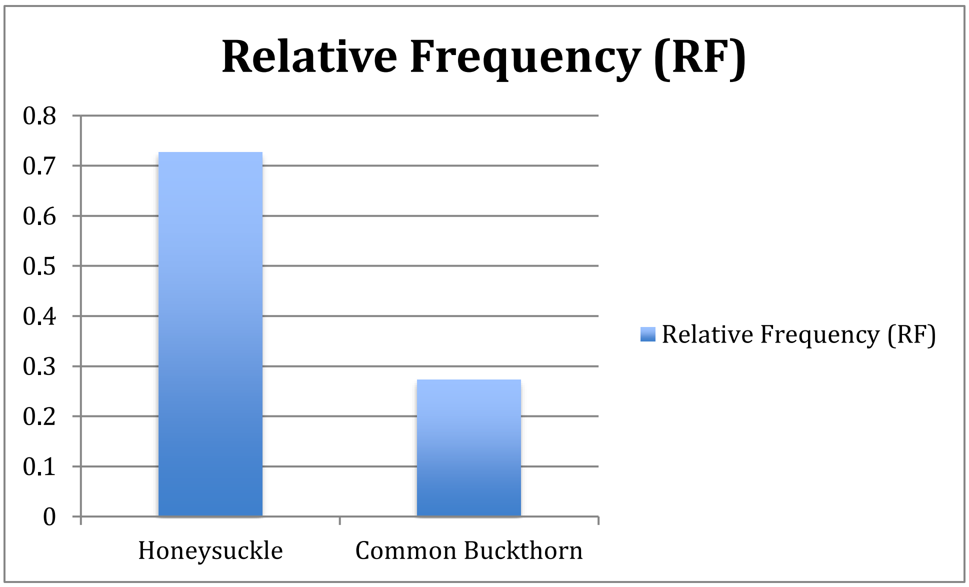

Relative Importance Value (RIV)
0.6
0.5
0.4
0.3
0.2
0.1
0
Siberian Elm
Black Cherry
Mockernut Hickory
American Elm
Siberian Elm
Black Cherry
Mockernut Hickory
American Elm

Appendix G. Test Site #1 Invasive Shrub Bar Graphs

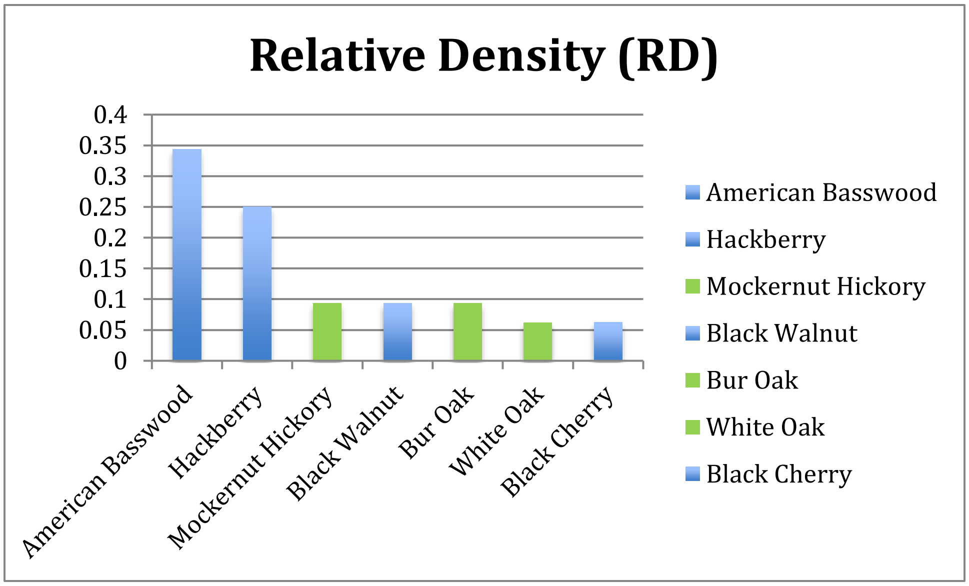


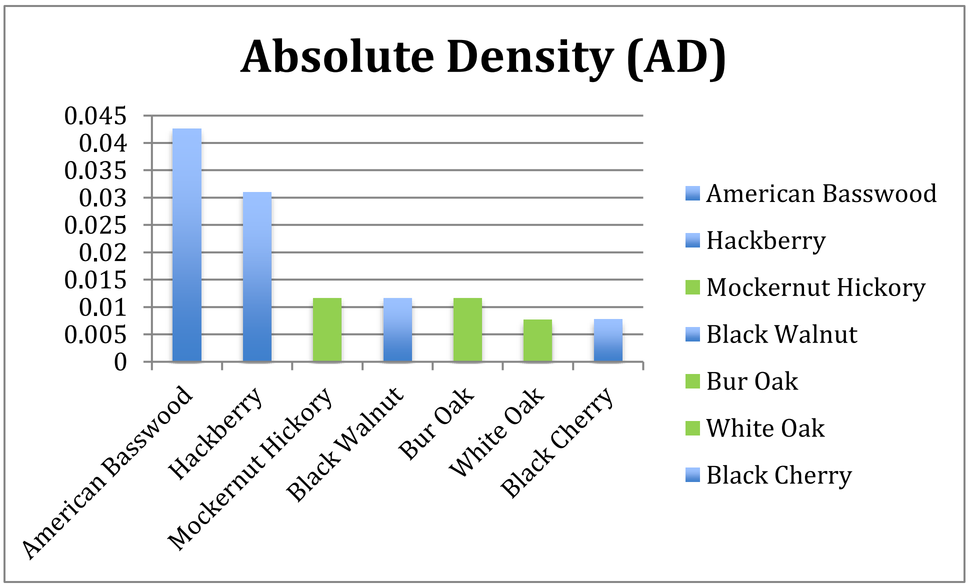


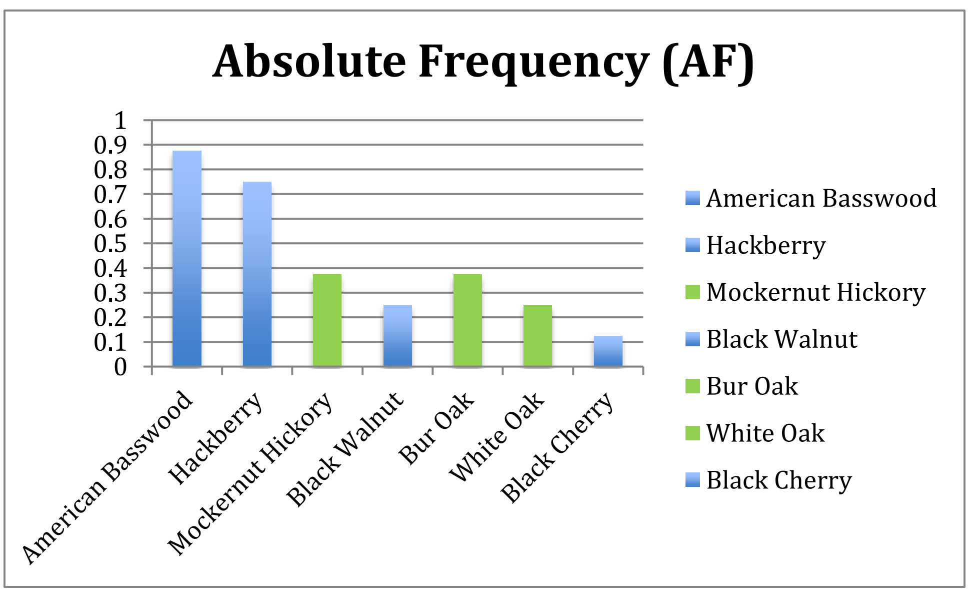

Absolute Frequency (AF)
1.2
1
0.8
0.6
0.4
0.2
0
Honeysuckle
Common Buckthorn
Absolute Frequency (AF)

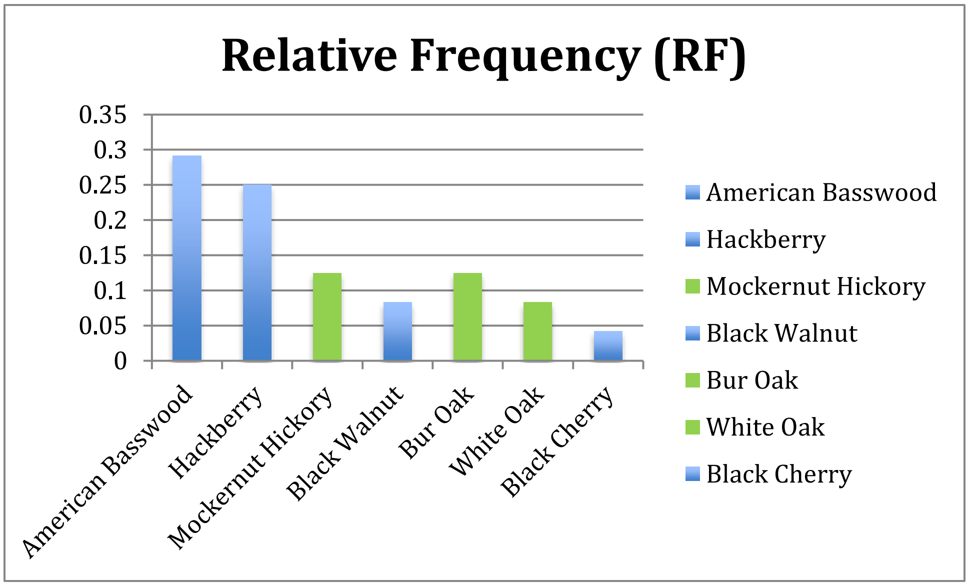

Relative Frequency (RF)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Honeysuckle
Common Buckthorn
Relative Frequency (RF)

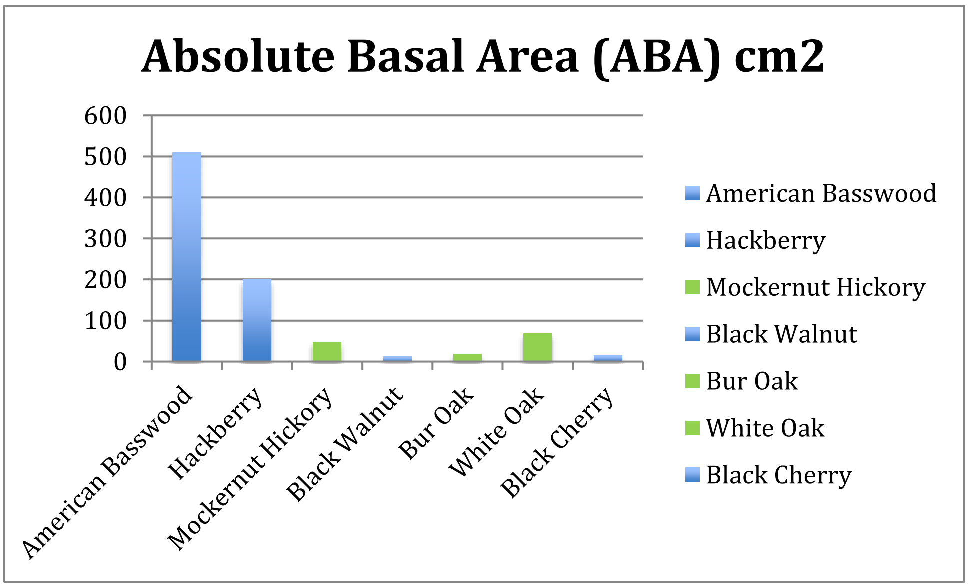
Appendix H. Test Site #2 Mature Tree Bar Graphs

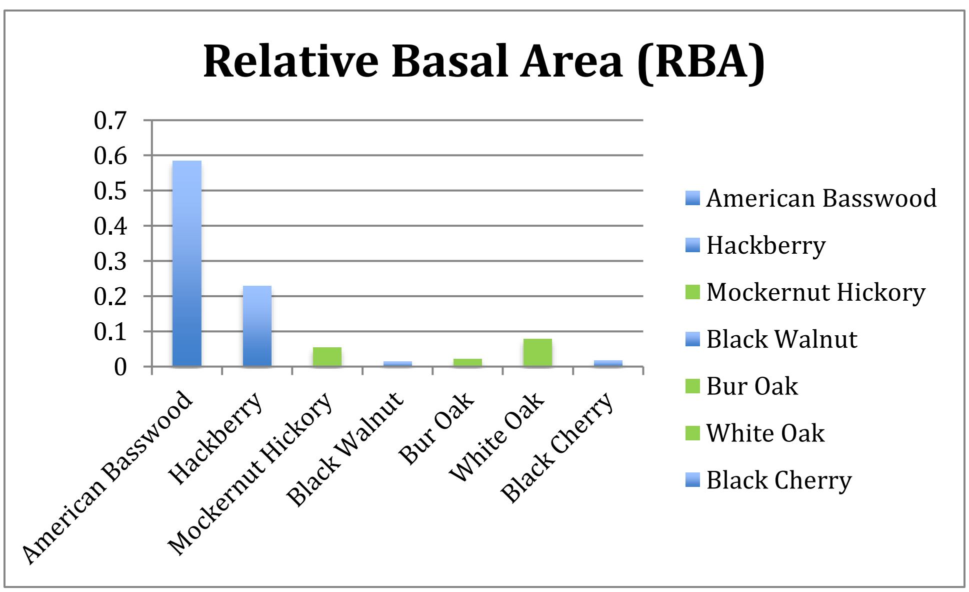


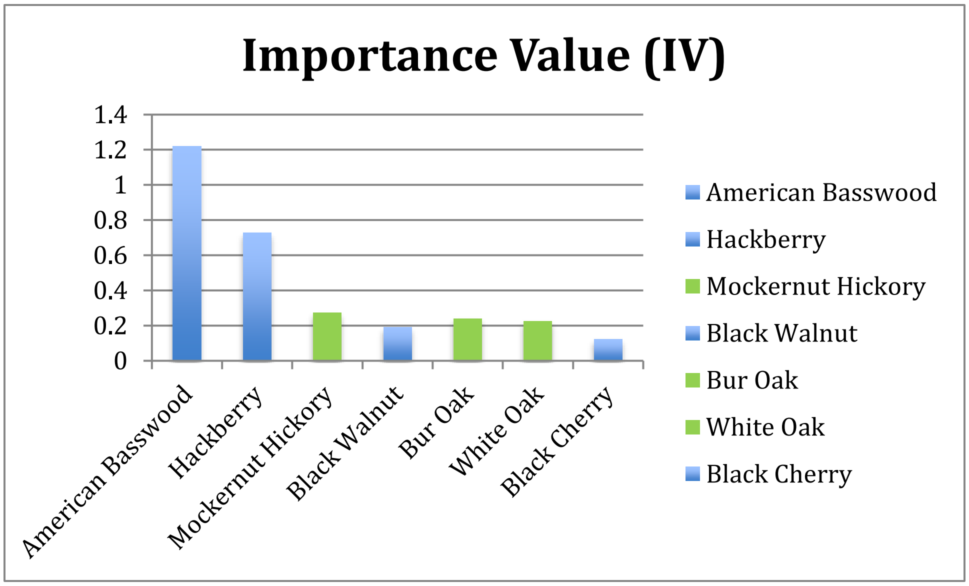


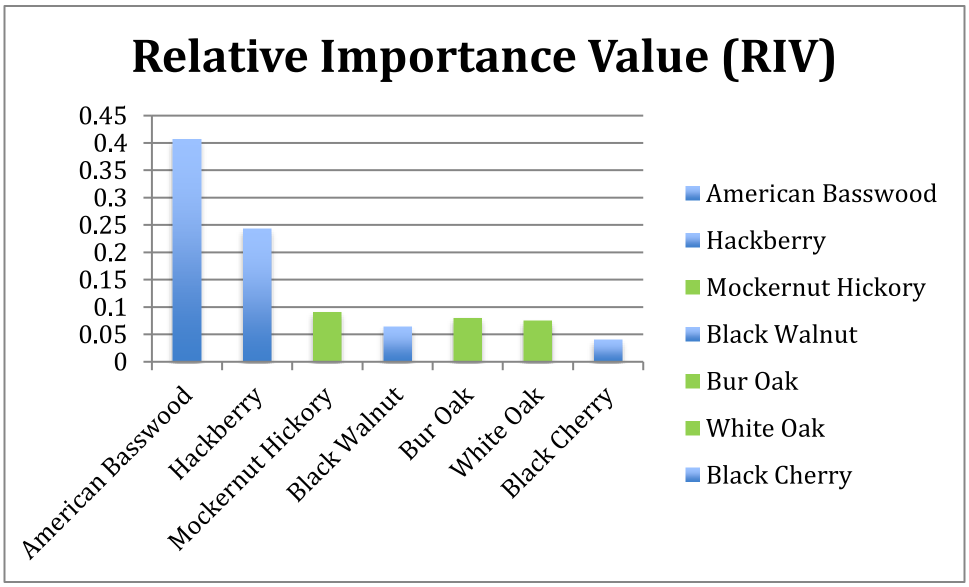



Relative Frequency (RF)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
American Basswood
Hackberry
Mockernut Hickory
Black Walnut
Bur Oak
White Oak
Black Cherry
American Basswood
Hackberry
Mockernut Hickory
Black Walnut
Bur Oak
White Oak
Black Cherry

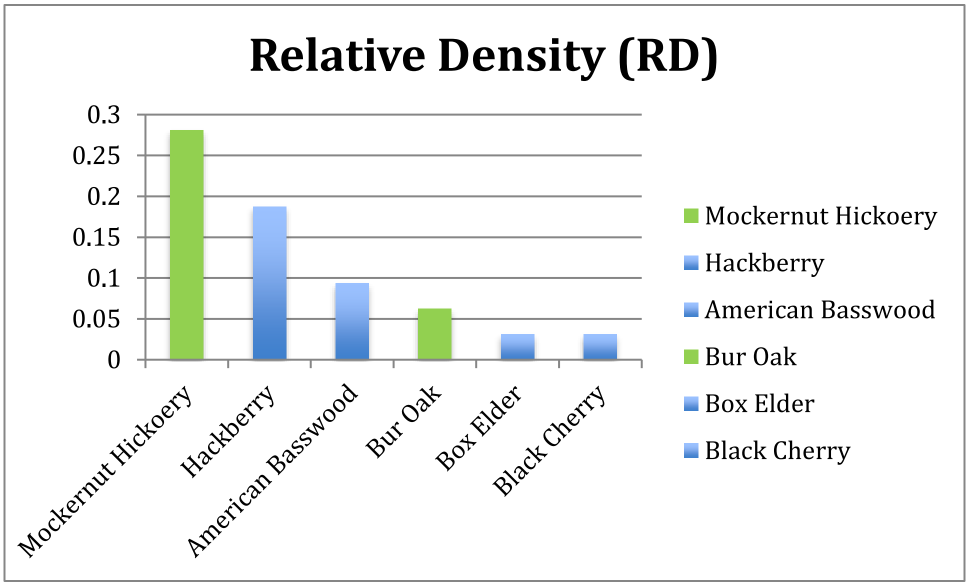

Absolute Basal Area (ABA) cm2
600
500
400
300
200
100
0
American Basswood
Hackberry
Mockernut Hickory
Black Walnut
Bur Oak
White Oak
Black Cherry
American Basswood
Hackberry
Mockernut Hickory
Black Walnut
Bur Oak
White Oak
Black Cherry

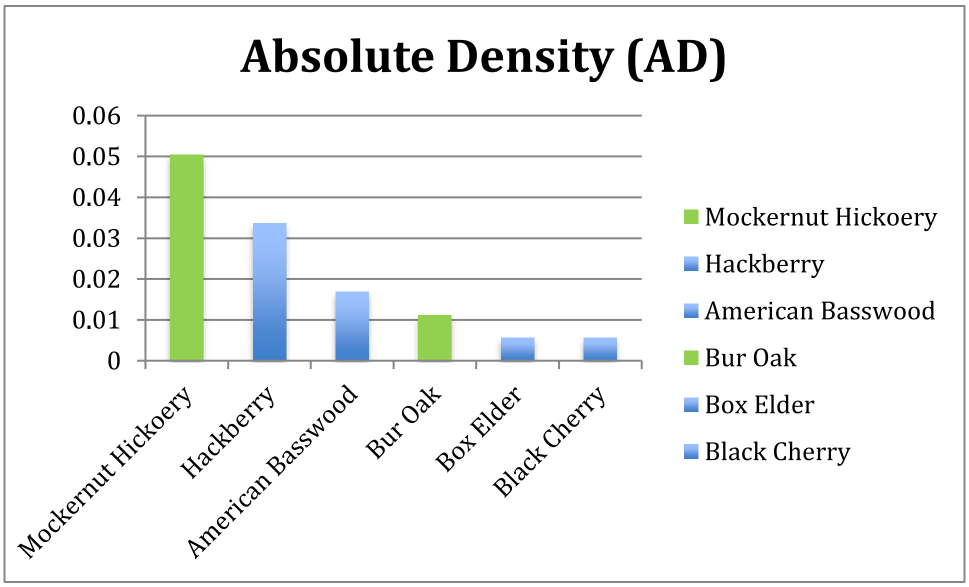

Relative Basal Area (RBA)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
American Basswood
Hackberry
Mockernut Hickory
Black Walnut
Bur Oak
White Oak
Black Cherry
American Basswood
Hackberry
Mockernut Hickory
Black Walnut
Bur Oak
White Oak
Black Cherry

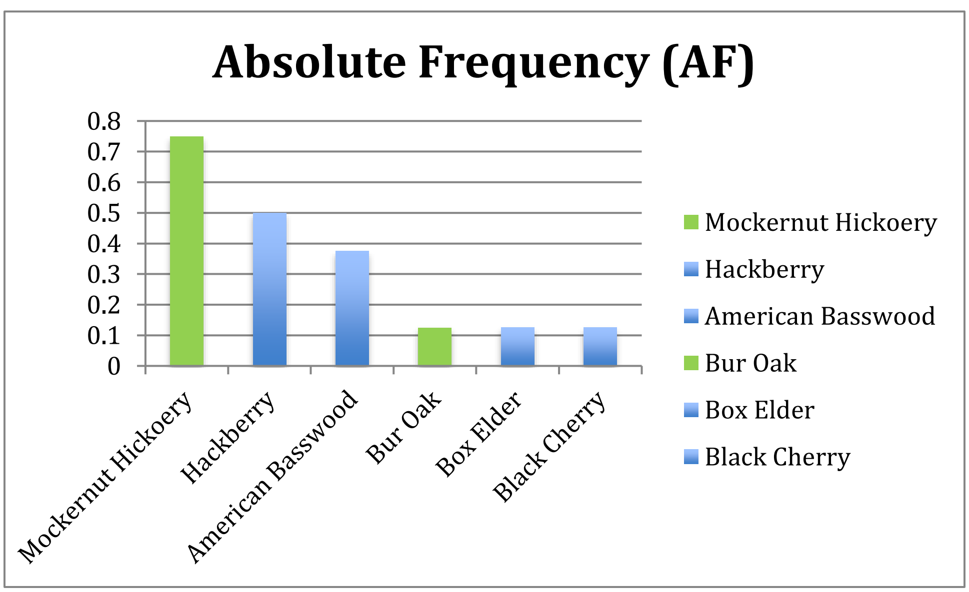

Importance Value (IV)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
American Basswood
Hackberry
Mockernut Hickory
Black Walnut
Bur Oak
White Oak
Black Cherry
American Basswood
Hackberry
Mockernut Hickory
Black Walnut
Bur Oak
White Oak
Black Cherry

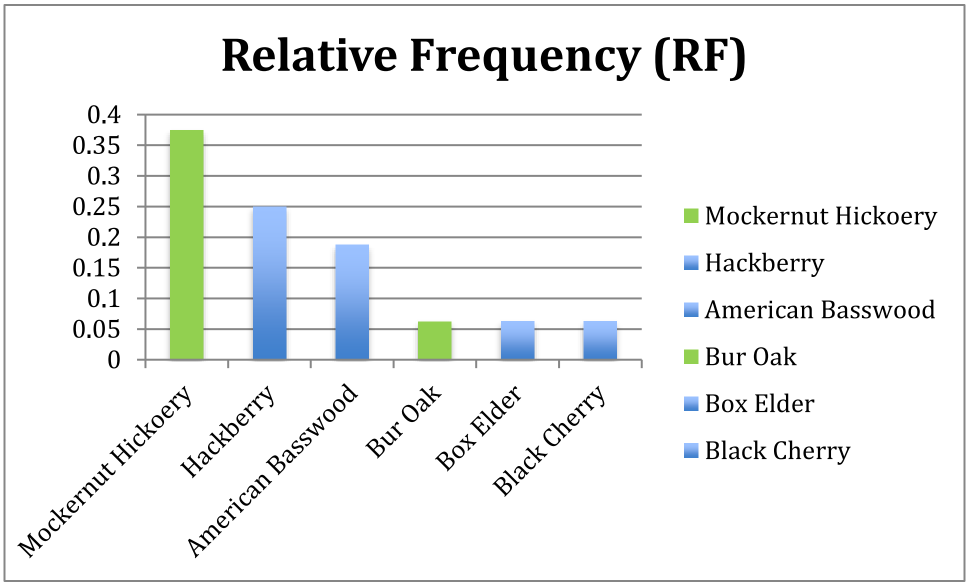

Relative Importance Value (RIV)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
American Basswood
Hackberry
Mockernut Hickory
Black Walnut
Bur Oak
White Oak
Black Cherry
American Basswood
Hackberry
Mockernut Hickory
Black Walnut
Bur Oak
White Oak
Black Cherry

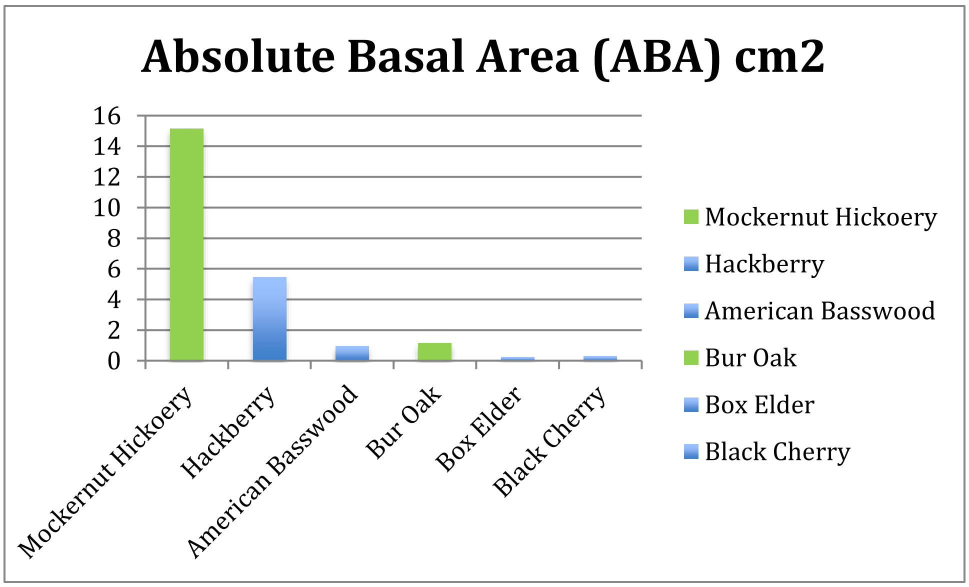
Appendix I. Test Site #2 Sapling Tree Bar Graphs

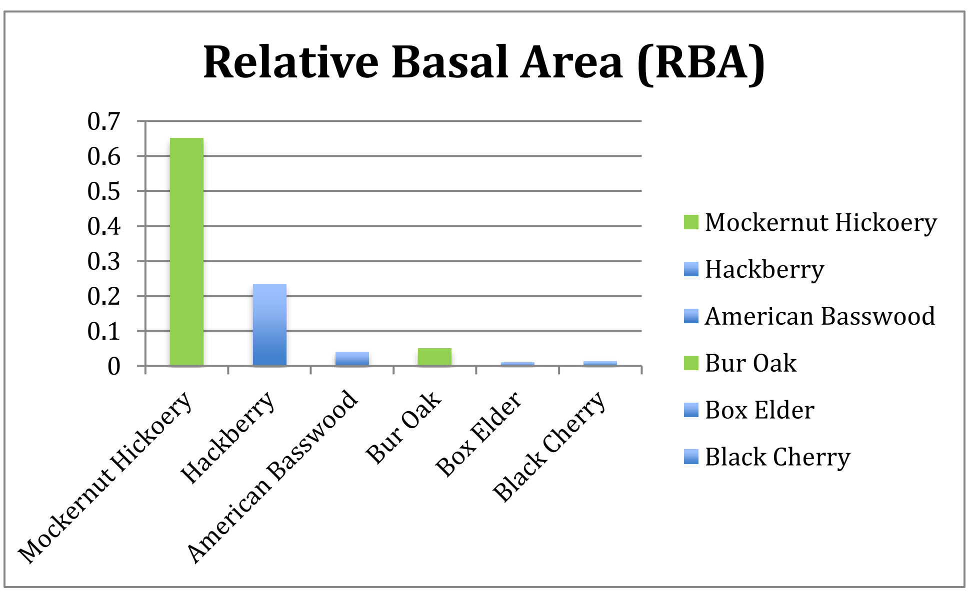


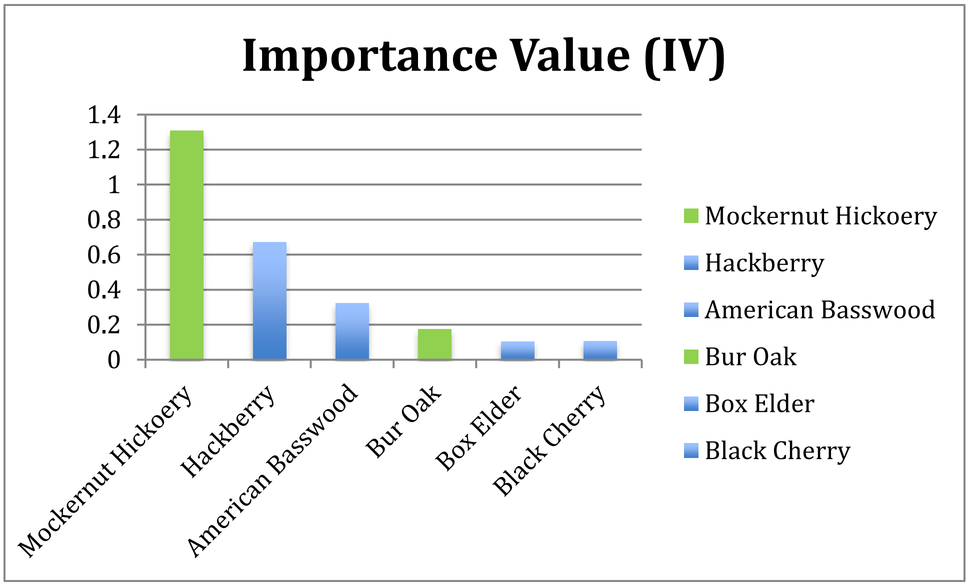


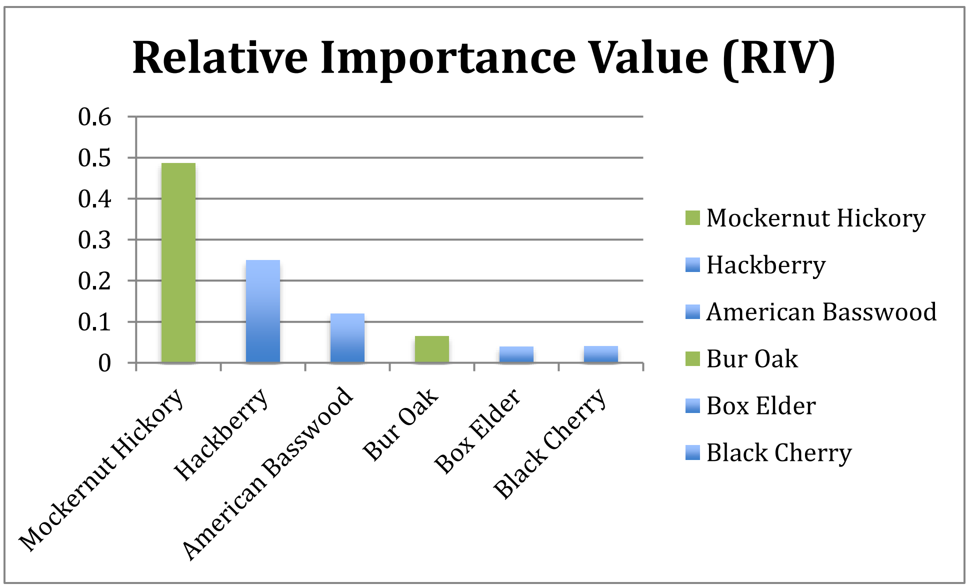



Relative Frequency (RF)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Mockernut Hickoery
Hackberry
American Basswood
Bur Oak
Box Elder
Black Cherry

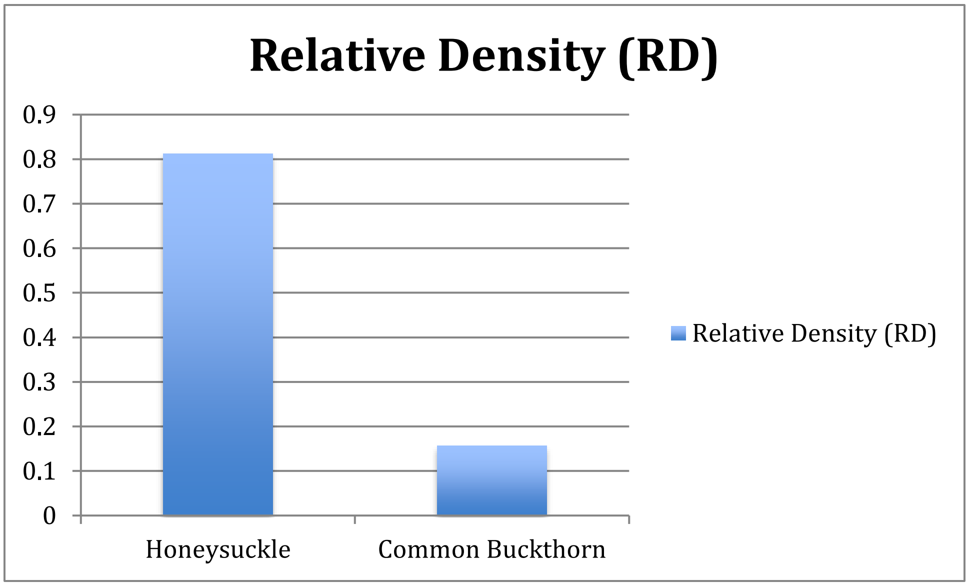

Absolute Basal Area (ABA) cm2
16
14
12
10
8
6
4
2
0
Mockernut Hickoery
Hackberry
American Basswood
Bur Oak
Box Elder
Black Cherry

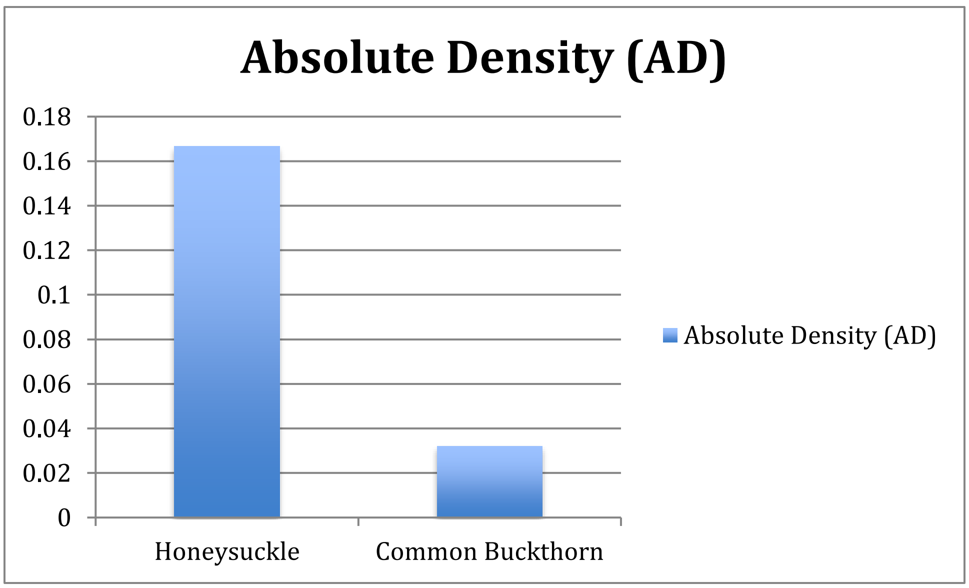

Relative Basal Area (RBA)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Mockernut Hickoery
Hackberry
American Basswood
Bur Oak
Box Elder
Black Cherry

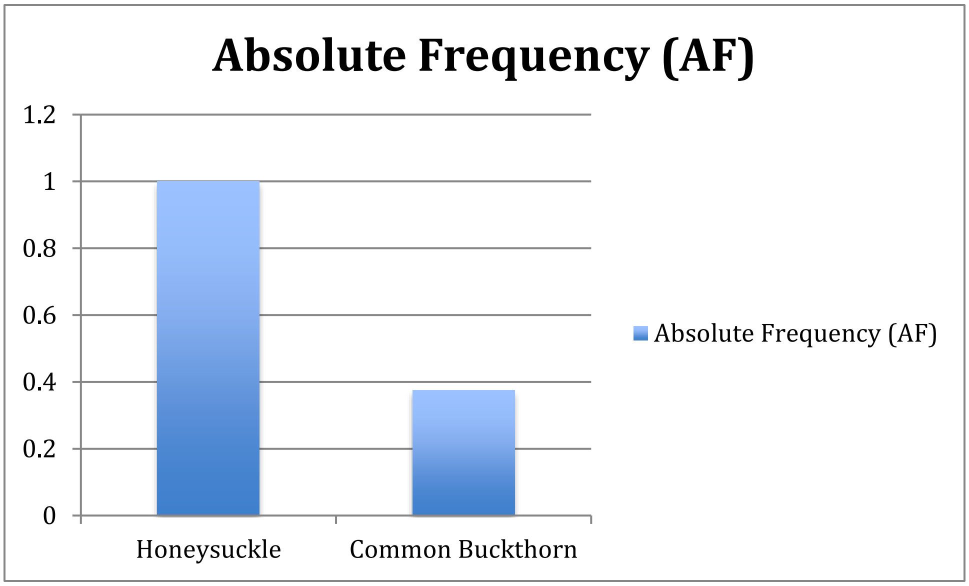

Importance Value (IV)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Mockernut Hickoery
Hackberry
American Basswood
Bur Oak
Box Elder
Black Cherry
Mockernut Hickoery
Hackberry
American Basswood
Bur Oak
Box Elder
Black Cherry

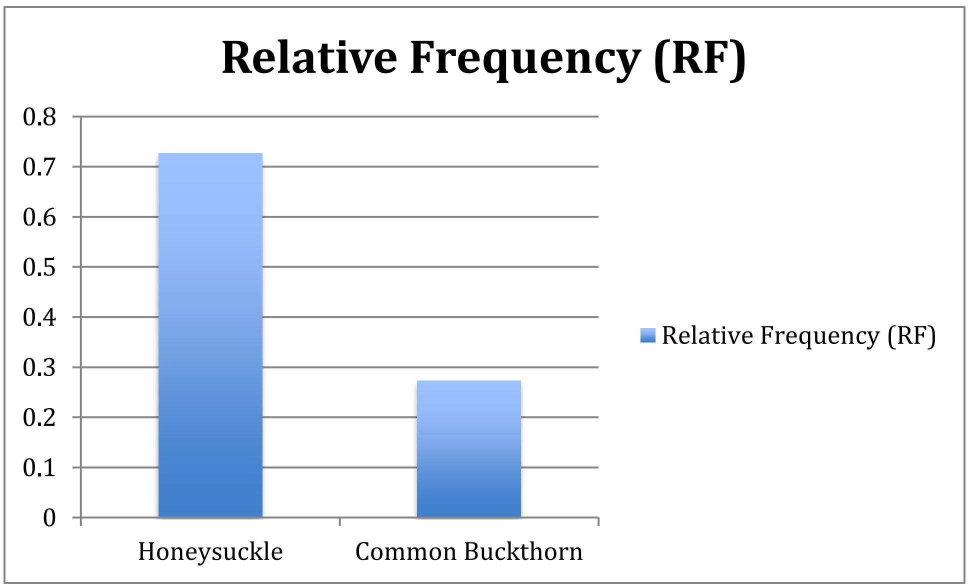

Relative Importance Value (RIV)
0.6
0.5
0.4
0.3
0.2
0.1
0
Mockernut Hickory
Hackberry
American Basswood
Bur Oak
Box Elder
Black Cherry
Mockernut Hickory
Hackberry
American Basswood
Bur Oak
Box Elder
Black Cherry

Appendix J. Test Site #2 Invasive Shrub Bar Graphs






Absolute Frequency (AF)
1.2
1
0.8
0.6
0.4
0.2
0
Honeysuckle
Common Buckthorn
Absolute Frequency (AF)


Relative Frequency (RF)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Honeysuckle
Common Buckthorn
Relative Frequency (RF)

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