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Genevieve Alexander '14
Illinois Wesleyan University, galexand@iwu.edu

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Assessing the Biodiversity and Susceptibility of Trees in Maxwell Park to Future Invasive Tree Pest Outbreaks

Genevieve Alexander
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Abstract

The purpose of this project was to assess tree susceptibility to invasive tree pest outbreaks in a Central-Illinois urban park. Tree biodiversity in Maxwell Park, located in the Town of Normal, Illinois, was evaluated assuming that the greater the tree biodiversity in a park, the more resilient the park would be to future invasive tree pest outbreaks. The Town of Normal Parks and Recreation Department served as the community partner for this project. By determining Maxwell Park's current level of biodiversity, proposed new trees for future replacement plantings could be identified to help increase biodiversity and decrease the potential for invasive tree pest outbreaks. From these findings, municipal policies could be developed to help decrease park susceptibility to future pest outbreaks through planting new trees that would help increase biodiversity. The research investigated the question **"How can tree inventories help mitigate future invasive tree pest outbreaks?"**

To answer this question, several quantitative and qualitative research methods were used. First, a literature review was conducted to: 1) establish an overview of the history of invasive tree pest outbreaks on urban trees in the United States and evaluate lessons learned, 2) understand the importance of biodiversity in alleviating the severity of future invasive tree pest outbreaks, and 3) review the usefulness of tree inventories for determining biodiversity and its relationship with the severity of future invasive tree pest outbreaks. Second, interviews with key informants were conducted to gain a variety of perspectives regarding the impact of invasive tree pest outbreaks on a range of professions and localities. Third, the tree biodiversity of the Town of Normal was estimated through a complete tree inventory of a selected public park, Maxwell Park. The findings from this research suggest that *increasing biodiversity* is the most important approach for minimizing the effects of invasive tree pest outbreaks. The 10-20-30 species-genus-family rule discussed in the literature review was applied to tree inventory data collected from Maxwell Park to determine resistance to future invasive tree pest outbreaks. As a whole, the results of the tree inventory showed that Maxwell Park had sufficient diversity at low taxonomic levels; however in the future it was suggested that future tree plantings be diversified further among higher taxonomic levels. In particular, the proportion of oaks and maples being planted should be slightly reduced. Six program recommendations for the Town of Normal given by this study were provided to help reduce the possibility of future insect epidemics: 1) encourage public awareness of the dangers of transporting firewood; 2) be aware of symptoms of invasive tree pest threats whilst conducting tree inventories; 3) consult the Illinois Forest Health Highlights brochure to remain up-to-date on current threats to Illinois trees; 4) take part in professional training workshops offered by the Illinois Department of Natural Resources; 5) develop landscape design standards for public parks that would help increase biodiversity; and 6) conduct an inventory of all trees located in the Town of Normal public parks to determine areas most susceptible to invasive tree pests.

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Acknowledgements

Firstly, I would like to thank the Town of Normal Parks and Recreation Department for their assistance with this project. In particular, this project would not have been possible without the assistance of Randy Thorndyke and Bobby Jones, whose help in the tree identification process was invaluable. Special thanks to Mercy Davidson and Garry Little, for helping me define my project scope and design. I would also like to thank the Town of Normal Engineering Department for allowing me to use their GPS, as well as for providing me with the tree inventory data in the ArcGIS format. Lastly, I would like to extend my gratitude to Dr. Laurine Brown, Dr. Edgar Lehr, and Chris Sweet, as well as my fellow classmates, for their guidance and advice during my writing process.

Introduction

In the last 100 years, the United States has suffered from a multitude of invasive tree pest species that have decimated native tree populations. As defined by National Invasive Species Information Center (2006), an invasive species is an organism that is non-native to the ecosystem and whose introduction causes environmental harm. It is estimated that over 50,000 non-native species have been introduced to the United States, with a total cost of $120 billion dollars per year (Pimentel et al. 2005). Invasive tree pest species can be any living organism, including plants, animals, fungus, bacteria, and insects, such as the Emerald ash borer (*Agrilus planipennis*). The Emerald ash borer alone has an estimated yearly cost of $25.1 billion dollars to the United States government. This study is focused on determining how to avoid and/or minimize the potential for invasive[1] tree pest outbreaks through minimizing potential host habitat for these species.

The composition of an urban tree population can play an important role in minimizing the potential for invasive tree pest outbreaks, because these species typically prey on trees of a specific species or genus, as is the case with the Emerald ash borer. Through maximizing tree biodiversity in urban areas, communities can strengthen their overall resistance of urban trees to future invasive tree pest outbreaks. Biodiversity is defined as "the variability among living organisms, [including] diversity within and between species, and of ecosystems" (Convention on Biological Diversity Article 2 1992). The first step to maximizing biodiversity is to understand current tree species distribution in a given area. A tree inventory is a method that can be used to determine current tree biodiversity. Thus, city planners can use a tree inventory to assess an area's vulnerability to future pest invasions. From these findings, policy recommendations can be developed. Trees are viewed as a crucial aesthetic and natural component of urban environments, and unlike most city infrastructure, the value of a tree increases with its maturity (Davey Tree Resource 2009).

Tree inventories can also help quantify benefits provided by trees. Unlike trees located in forests, tree placement and biodiversity in urban areas is largely human-determined. Therefore, assessments of tree inventories can provide information about the successes and weaknesses of human management of this natural resource. Carbon benefits directly correlate with woody biomass and leaf surface area, so large trees offset higher levels of carbon dioxide. In addition to carbon sequestration, trees help improve air quality, reduce stormwater runoff, serve as windbreaks, and provide valuable wildlife habitat (Davey Tree Resource 2009). Trees in recreational parks and public areas also serve important community functions, such as education, recreation, and aesthetic enjoyment.

According to Garry Little, the Director of the Parks and Recreation Department in the Town of Normal, Illinois, trees are an important component of the urban environment, and by increasing

[1] Although the term 'invasive species' can refer to both invasive tree species as well as invasive species which prey on native tree populations, the focus of this paper will be on the latter. Thus, for the purposes of this paper, invasive species is narrowly defined as an introduced pest which negatively effects tree species.

biodiversity, the natural beauty of the park setting can be enhanced (pers. comm., 2013). However, currently, 15 percent of Bloomington-Normal's tree cover could be lost due to the invasive Emerald ash borer (*Agrilus planipennis*) (Mercy Davison, pers. comm., 2013). As a result, the Town of Normal is currently removing ash (*Fraxinus* spp) trees infected with Emerald ash borer as a human safety and liability concern, as well as to help prevent the spread of this invasive species. Due to the widespread removal of mature ash trees infected with the Emerald ash borer and replacement with immature saplings of other tree species, the urban forest tree profile is in a period of transition.

The purpose of this project was to research and assess the susceptibility of trees in a public park located in Normal, Illinois to future invasive tree pest outbreaks. To achieve this purpose, a tree inventory of the park was conducted to identify existing tree biodiversity and to determine which tree species should be reduced. In addition, interviews with key informants involved with urban tree management were conducted. Maxwell Park, a public park located in Normal, Illinois, was chosen as the study site for the tree inventory assessment. By determining Maxwell Park's current level of biodiversity, proposed new trees for future replacement plantings could be identified that would help decrease the park's susceptibility to invasive tree pest outbreaks. An additional goal of the tree biodiversity assessment was to develop municipal policies to help decrease park susceptibility to future invasive tree pest outbreaks. It is important to take a proactive stance in combating invasive species to ensure that the benefits provided by trees in public parks are available to the community for many future generations.

This project was done in collaboration with the Town of Normal Parks and Recreation Department. The tree inventory also served as a pilot project for the Normal Parks Department to determine the feasibility of training students to perform a complete inventory of all trees located in public parks within the Town of Normal. If training students is possible, the Town could receive valuable information provided by the inventory that they would not otherwise have the funds to conduct.

The literature review provided in Appendix A provides a history of selected tree pest outbreaks, highlights the importance of tree inventories, and describes the usefulness of biodiversity in preventing large-scale future invasive tree pest outbreaks. In the research design section, a description of the study site is provided, along with a summary of the methods used for the tree inventory, and an overview of key informant interviews. Interviews with key officials as well as data from the tree inventory of Maxwell Park were analyzed and conclusions were drawn regarding the current ability of the park's existing tree landscape to withstand future invasive tree pest outbreaks. Lastly, suggestions are provided about future planting options for the Town of Normal.

Research Design and Methodology

A variety of qualitative and quantitative methods were used to investigate the research question of **"How can tree inventories help mitigate future invasive tree pest outbreaks?"** First, the literature review (provided in Appendix A) served three functions: 1) establishing an overview of the history of invasive tree pest outbreaks on urban trees in the United States and discussing

lessons learned from previous outbreaks, 2) exploring the importance of biodiversity in alleviating the severity of future invasive tree pest outbreaks, and 3) investigating the usefulness of tree inventories to document existing biodiversity and vulnerability to future invasive tree pest outbreaks.

Second, interviews with key informants were conducted to gain a variety of perspectives regarding the impact of invasive tree pest outbreaks on a range of professions and localities.

Third, the tree biodiversity of the Town of Normal was estimated through a complete tree inventory of a selected public park. To understand the management needs involved in preparing the Town of Normal, Illinois for future invasive tree pest outbreaks, an analysis of the biodiversity of the Town's tree population was needed. Since gathering information on all trees over a large area was often not feasible, biodiversity was estimated through use of a sample population, such as an urban park. In this case, the biodiversity of the Town of Normal was estimated through a complete tree inventory of a selected public park.

Description of study area

This research study took place in McLean County, Illinois in the Town of Normal during the months of September to November 2013. Normal is the seventh most populous city in Illinois, with an estimated population of 52,497 (2010 census). Although two thirds of Illinois was originally comprised of tallgrass prairie, this ecotype has largely been lost due to conversion to agricultural lands. Forests occurring in Illinois are typically dominated by oak, hickory, and maple. The Town of Normal has an area of 18.4 miles^2, with a total of 24 parks, facilities and trails.

Maxwell Park is a 125-acre recreational public park located at the edge of Normal, Illinois. This park was chosen as an inventory site for two reasons: 1) Two groves belonging to the Children and Elders Forest are located inside Maxwell Park. In these areas, all the trees possess an ID tag identifying the species. This area is an ideal location to become familiar with tree identification. 2) Maxwell Park has the largest population of ash trees in town. These ash trees are infected and dying, but have not yet been removed, unlike most other ashes in Normal at this time. In addition, Maxwell Park is a popular area for Frisbee golf, where some of the large ash trees are used as obstacles for players. Thus, the removal of ash trees may alter the course for Frisbee golf participants. Appendix B provides a map of Maxwell Park that was created using the data collected from this study.

Children and Elders Forest is a charitable organization with tree stands located in Bloomington and Normal. Their mission is to celebrate the bonds between generations and improve the health of people and ecosystems by planting trees. Each tree is planted by a team consisting of at least one child and one elder. Currently, the organization has planted over 500 trees in nine groves. The organization planted two groves located at the north end of Maxwell Park. Turtle Grove was the organization's first tree plot, which was created in partnership and sponsored by the Normal Parks and Recreation Department in 2005. Eagle Grove was established a year later, and was designed by Bobby Jones with the Parks and Recreation Department. Eagle Grove and Turtle Grove were the first stands to be been mapped as part of this project, and the organization plans

to eventually map all of its groves. Although the trees in Maxwell Park located within the Children and Elders Forest were previously mapped by this organization, the Normal Parks and Recreation Department does not have this information in their database.

Key informant interviews

In addition to quantitative methods used during tree data collection of Maxwell Park, qualitative methods were used during interviews with municipal officials and other key informants to obtain background information about the Town of Normal's current tree management programs, as well as to learn about research being conducted on the spread of invasive tree pests. Beyond the scope of this biodiversity project, the interviews served a key purpose of providing a comprehensive understanding of the true impact of invasive species on society and the environment.

To understand selection and management concerns for urban trees, short interviews (less than one hour) were conducted with seven key informants from the Town of Normal, Illinois, the City of Bloomington, Illinois, and the City of Ann Arbor, Michigan. Interviews were conducted in person, by phone, or by email. Key issues discussed included the past and current management of urban trees, future invasive tree pest threats, and tree inventories. The questions were tailored to address the subject's particular areas of expertise. For a complete list of all informants interviewed and question guides, see Appendix C. Many of the interviews had a particular focus on obtaining information about the specific challenges that occurred in Normal regarding the management of invasive tree pests. A representative from Owen Nursery was contacted to represent the viewpoint of a plant nursery about the impacts of invasive tree pest species. Two faculty members at Illinois State University were also contacted to learn about current research conducted by the University regarding spatial distribution models of the spread of invasive tree pest species. In addition to representatives from the Town of Normal, urban forestry experts from communities outside of Bloomington-Normal were sought out. Although a multitude of communities of various sizes and regions were contacted, representatives from only one city (Ann Arbor, Michigan) were available for comment.

Tree inventory process

A total of 14 hours was spent actively conducting the tree inventory of Maxwell Park from September 24 to October 23 2013. Tree inventory data, including geographic position, species, and diameter at breast height (DBH), was recorded using a Trimble GPS unit provided by the Town of Normal Engineering Department. In the Children and Elders Forest, tree species were identified using the identification tags present on each tree. For trees not located in the Children and Elders Forest, assistance with tree identification was provided by Bobby Jones (certified horticulturalist) or Randy Thorndyke (certified arborist). Characteristics used to identify trees included presence of a compound or simple leaf, arrangement and shape of leaflets, appearance of the leaf edge, amount and presence of lobes, and texture and consistence of the bark. The data collected from the inventory was added to the Normal tree information database, and a map of Maxwell Park was created using ArcGIS. From the data collected, alpha, beta, and gamma tree diversity was calculated, along with order, family, genus, and species information. Tree DBH was used as an estimation of age structure of the current trees at the park. The amount of time for

the inventory was also recorded to serve as a reference for scheduling and planning future park inventories.

Results

The results of this study are divided into two sections: 1) key informant interview results and 2) results of the tree inventory of Maxwell Park. For an overview of the findings from the literature review, please see Appendix A.

Key informant interview results

Seven key informants were interviewed to gain information on a variety of subjects, ranging from the benefits of urban trees to the impact of climate change on the spread of invasive species. For a complete list of interview questions, see Appendix D. The information gained from the interviews is sorted by topic and, in most cases, includes responses from more than one key informant.

Key informants interviewed include:

- Garry Little, Director of the Town of Normal Parks and Recreation Department, IL
- Mercy Davison, Town Planner for Normal, IL
- Jonathan Thayn, Professor at Illinois State University, Normal, IL (received NSF grant to study the spread of the Gypsy moth in the Apostle Islands, Wisconsin)
- John Kostelnick, Professor at Illinois State University, Normal, IL (studied the spread of the Emerald ash borer in Chenoa, IL with the United States Department of Agriculture)
- Mark Stahl, Garden Center Manager of Owen Nursery, located in Bloomington, IL
- Randy Thorndyke, Certified Arborist for the Town of Normal, IL
- Kerry Gray, Urban Forestry & Natural Resources Planning Coordinator for the city of Ann Arbor, MI

Provided below is a summary of information obtained from these interviews by topic, as well as background information on the history of tree management in Normal and overall community tree values.

Benefits/disadvantages of urban trees

It is widely known that urban trees provide a multitude of benefits to city dwellers. These benefits can include better air quality, reduction of stormwater runoff, and traffic control. In addition, people tend to spend more money when there are more trees present (Mercy Davison, pers. comm., 2013). Not only have trees help lower the energy bills for communities by cooling the urban environment during summer months, but trees can also provide habitat for native animals. Negative aspects of urban trees include waterline breakages, interference with sewers, pipes, and pavement (Mercy Davison, pers. comm., 2013).

History and current management of ash trees in Normal, Illinois

In the past, ash was planted heavily by the former Director of the Parks and Recreation Department in Normal, Illinois because it was considered to be a hardy and beautiful tree species (Garry Little, pers. comm., 2013). This planting strategy has led to a multitude of management problems today, as the Emerald ash borer has begun to decimate ash trees across North America. Currently, the Normal Parks Department is sponsoring a variety of methods to sustainably manage its ash trees. The Town educated the public about its Emerald ash borer policy by conducting public workshops. The residents of Normal are supportive of the Parks and Recreation Departments effort to minimize the spread of the Emerald ash borer, and have recognized the need to remove the infected ash trees (Randy Thorndyke, pers. comm., 2013). In addition, the Parks and Recreation Department is combating the Emerald ash borer by planting 200 replacement trees each fall and spring. However, despite planting efforts, it is inevitable that a large amount of tree canopy will be lost as a result of the Emerald ash borer infestation, which is highly lethal to most ash cultivars. Efforts to remove infected ash trees began three years ago, and hundreds have already been removed. As a result, along the streets of Normal, less than 50 ash trees remain. Before removing ash trees, new trees were planted in between the remaining ash trees. White ash trees seem to be faring better than Green ash trees in response to the Emerald ash borer. Along with Ironwood Golf Course, Maxwell Park has the largest concentration of ash trees in Normal. It is expected that all ash trees will be removed within a couple of years (Randy Thorndyke, pers. comm., 2013).

The Town of Normal has two highly qualified tree professionals involved in the tree planting decision-making process: Randy Thorndyke and Bobby Jones[2] (Mercy Davison, pers. comm., 2013). Randy has been involved with forests and trees for over 35 years. Thorndyke and Jones often serve as important links between the public and the Normal Parks and Recreation Department.

Tree planting guidelines in Normal, Illinois

Although there are no specific tree planting guidelines for public properties in the Town of Normal, all key informants seemed to agree that biodiversity was an important aspect to consider when selecting trees for planting. Garry Little emphasized that tree diversity should always be considered, including diversity of age class (pers. comm., 2013). Mercy Davison helped to develop a zoning code that required a certain amount of landscaping in private areas (pers. comm., 2013). The number of trees required to be planted in these areas is based on the size of the site. The zoning code requires some level of diversity, but it is not well-defined. Although there are no specific ordinances for landscaping on public lands, the Town designed the recently built public works facility to conform to private zoning code standards. The zoning code also does not apply to trees along streets, and does not require the planting of trees on properties containing a single family house (Mercy Davison, pers. comm., 2013).

There are several benefits to planting native trees, including their hardiness in their home environment, as well as the fact that native trees are less susceptible to native pathogens

[2] Note: although I was able to have at least three meetings with Bobby in late September, he was not available for interviewing after this time period due to the arrival of the tree planting season

(Jonathan Thayn, pers. comm., 2013). According to Little, the Normal Parks and Recreation Department prefers to plant native trees using a variety of species. They want as many different species planted as possible (pers. comm., 2013).

Key management issues for Normal, Illinois

According to Mark Stahl, Garry Little, and Randy Thorndyke, there are many different threats to trees in Normal currently. Little believes that the largest management concern that they have experienced in parks is the invasive Emerald ash borer. This year will be the first year that the Parks Department is cutting down more trees than they are planting, due to the Emerald ash borer's devastating effect (pers. comm., 2013). Little ranked the top threats to the Parks Department as 1) the Emerald ash borer, 2) Pine wilt disease, and 3) Versilian wilt disease. The Parks and Recreation Department has been attempting to control the pine wilt nematode for 20 years. Versilian wilt disease is a common problem in maples (Garry Little pers. comm., 2013). According to Mark Stahl, the Garden Center Manager for Owen Nursery, the top three threats to Illinois trees in the upcoming years will be 1) the Emerald ash borer, 2) the Asian longhorned beetle, and 3) the Gypsy moth (pers. comm., 2013). Randy Thorndyke also lists the number one invasive species in Illinois as the Emerald ash borer. He also mentioned oak wilt as a serious concern (pers. comm., 2013).

Plant nursery information (Bloomington, Illinois)

The Town of Normal obtains its trees from a variety of plant nurseries throughout the Midwest. The trees are typically purchased when they reach a DBH of 1-1.5 inches (Garry Little, pers. comm., 2013). At Owen Nursery, located in Bloomington, Illinois, Garden Center Manager Mark Stahl has noticed that invasive tree pest outbreaks have impacted trees sold in the nursery. Employees must search for pests on trees when new shipments are received, as well as throughout the growing season (Mark Stahl, pers. comm., 2013). The criteria that Owen Nursery uses to select trees includes native status, popularity, size, shape, overall appearance, price, or a combination of the above. Owen Nursery emphasizes variety to its customers, since it considers biodiversity important to the environment. According to Stahl, the 2008 ban on the sale of ash trees in McLean County, Illinois has not had that great of an impact on Owen Nursery since most customers have adjusted to selecting other trees in the absence of ash. In order to provide customers with a variety of choices for ash replacement species, the nursery has attempted to expand their collection of shade-tolerant trees. Since the ban on ash trees in Illinois, Owen Nursery has noticed that the Red maple tree has experienced the biggest increase in sales (Mark Stahl, pers. comm., 2013).

Future invasive tree pest threats to Central Illinois

In addition to the current management problem of the Emerald ash borer, there are many other invasive tree pests that may pose a threat to Illinois trees in the future. Little has heard that the Asian longhorned beetle may become a threat to urban forests (pers. comm., 2013). New invasive tree pests can often remain unnoticed for long periods of time. Usually the outbreaks occur in forested areas, such as in mountains, and are therefore difficult to observe (Jonathan Thayn, pers. comm., 2013). In addition, forests often contain less biodiversity (in terms of number of tree species and species richness) than their urban counterparts. Therefore, invasive tree pest outbreaks are often more fatal in naturally occurring forests (John Kostelnick, pers.

comm., 2013). The transport of firewood is often to blame for the rapid dispersal of pest species to locations where they had not previously been found.

In the future, the Gypsy moth may pose a significant problem to Midwestern trees. Although the Gypsy moth is not yet present in central Illinois, the species was observed in northern Wisconsin (Jonathan Thayn, pers. comm., 2013). Little noted that Jones had previously mentioned the Gypsy moth, but there are other threats that the Parks Department viewed as of higher concern (pers. comm., 2013). Distance between trees is important to Gypsy moths because the female cannot fly, which impacts where the insect can lay its eggs. Therefore, it is possible that the Gypsy moth may not have an impact on urban areas, such as Maxwell Park, where trees are located farther apart. However, the management implications of a Gypsy moth invasion may become more severe if the pest invades Funk's Grove and Moraine View State Park, two of the largest remaining natural areas in Central Illinois. Usually, the Gypsy moth does not kill the host tree; instead the insect merely damages the tree by chewing its leaves, which are necessary for the tree's photosynthesis. As a result, trees decrease their leafy output by 80 percent the following year. Thayn predicted that the Gypsy moth may also affect neighborhoods that contain older trees, if the trees were already weakened (pers. comm., 2013).

Potential impact of climate change on trees and invasive tree pests

As temperatures rise, insects generally fare better than trees. With the rise in temperature that is predicted as climate change, it can be expected that invasive insect species will flourish, while native trees will be exposed to additional stress due to water shortages. However, it is important to note that, as the climate gets warmer, it is actually *not* the increase in temperature that provides the main benefit to insects. Instead, the main benefit to insects occurs as a result of the longer summers that are *associated* with an increase in temperature (Jonathan Thayn pers. comm., 2013). Any time an area experiences a rapid change in climate, the advantage is shifted towards organisms with a shorter generation time, such as insects and bacteria. Furthermore, this increases the likelihood that a new pathogen may develop. Stahl commented that weather-related events (particularly that of drought) would likely become a concern to Owen Nursery in the near future (pers. comm, 2013). The drought experienced in Illinois during the summer of 2012 may have exacerbated the problem of the Emerald ash borer, since trees were already weakened by the lack of water (Randy Thorndyke, pers. comm. 2013).

Important attributes to record during a tree inventory

When monitoring the effects of climate change or other urban forest disturbances, it is important to have a consistent procedure while conducting a tree inventory. Three of the most basic variables that are typically assessed during tree inventories include tree species, size, and age (Garry Little, pers. comm., 2013). Age is important to include because, if this attribute were not recorded, the trees could not be managed over time. In other words, if age (or DBH) were not recorded, then the Town would have no information about which tree species were older and in need of replacement with younger saplings. The primary attributes recorded as part of an Ann Arbor, Michigan tree inventory included species (common and scientific name), DBH (ranges: 0-5", 6-10", 11-15"… >35"), height (ranges: 0-10', 11-20'…), condition, maintenance need (pruning, removal, etc), location (GPS, street address, and streets between), presence of overhead utilities (yes or no), and potential sawlog (yes or no- for wood utilization options) (Kerry Gray, pers. comm., 2013). In addition to commonly recorded tree inventory variables, Thayn suggested

recording the distance of trees from water sources. From this information, town officials could predict tree species and locations that were likely to suffer from drought (pers. comm, 2013).

Tree inventory advice from other communities

A representative involved in a large-scale tree inventory conducted in the city of Ann Arbor, Michigan, in May 2009 was contacted to learn about their tree inventory process and experiences. The results of the tree inventory conducted by the city are available to the public on the Ann Arbor forestry website. Davey Resource Group was hired to conduct the tree inventory. Gray stated that she believed the company had used Trimble GPS units, which contained a downloaded aerial image of the city. This method was selected because, due to the blockage of satellite signal by trees and buildings, it was not always possible to obtain exact GPS coordinates (Kerry Gray, pers. comm., 2013). According to Gray, there were no major problems that the city experienced while conducting this large-scale tree inventory. She credits Davey Tree Resource with ensuring that the process went smoothly. In order to inform citizens about the tree inventory process, the city conducted many public education programs. In addition, the Forestry Department informed the police about who would be working on the street.

In addition to discussing Ann Arbor's experiences conducting its own tree inventory, Gray offered two pieces of advice to a town interested in conducting its own public tree inventory. First, Gray recommended ensuring that the people conducting the inventory were well trained and knowledgeable about trees. Second, she recommended conducting the tree inventory during the winter months. Although trees would be more difficult to identify due to the absence of leaves, it would be easier for surveyors to determine the overall health of the tree if the leaves are not present (Kerry Gray, pers. comm., 2013).

As part of a study on the spread of the Emerald ash borer in another central Illinois town, Kostelnick and other researchers partnered with the United States Department of Agriculture to conduct a tree inventory of all ash trees located in Chenoa, Illinois. A total of 784 ash trees were recorded. The DBH of ash trees was recorded, as well as the presence of five Emerald ash borer infestation symptoms. These included: 1) the presence of canopy dieback (on a scale of 1-5); 2) the presence of bark splitting; 3) the presence of D-shaped exit holes in the bark; 4) the presence of epicurmic shoots; and 5) the presence of serpentine galleries (John Kostelnick, pers. comm., 2013). By conducting an inventory of only one tree species, the results are different than what one might expect from an inventory that includes all tree species. The focus was shifted away from obtaining a broad overview of urban trees, and instead highlighted one key variable of tree populations. Conducting a tree inventory that focuses on one tree species may be more useful than conducting a complete tree inventory if the primary goal of the study is to search for a specific invasive tree pest outbreak. Kostelnick noted that after a tree inventory is completed, it is important to develop an action plan (pers. comm., 2013). This will ensure that the information gained from the tree inventory is practically applied. An additional benefit of conducting a tree inventory is that, if a city were to discover an invasive tree pest outbreak after conducting a tree inventory, they could potentially use their data as justification to apply for federal or state funding to combat the invasive tree pest.

Feasibility of conducting a complete tree inventory of public parks in Normal, Illinois
The Town of Normal has wanted to conduct a tree inventory for some time, however cost has remained a barrier. Usually, software is the most expensive part of a tree inventory. A complete tree inventory of the Town of Normal has never previously been attempted. The only publicly-available small-scale inventory that was completed in Normal was conducted by the Children and Elders Forest organization of Turtle and Eagle Grove, located in Maxwell Park. If the Town chose to conduct a tree inventory of all publicly owned trees, either a grant or local taxes would be necessary to fund the effort. If a complete tree inventory of Normal were to be conducted, Little felt it would be helpful to know the tree varieties that are present in Normal, in addition to the age distribution of the trees. In Fell Park (another public park located in Normal, Illinois) many trees are considered old. These older trees will need a succession of younger trees to replace those that will begin to die from old age and a variety of natural causes (Garry Little, pers. comm., 2013).

Results of Maxwell Park tree inventory

A total of 375 trees were inventoried in Maxwell Park, consisting of 13 orders, 18 families, 30 genera, and 57 species. See Appendix B for the map of Maxwell Park created with this tree inventory. For a list of the orders, families, genera, and tree species found in Maxwell Park, refer to Figures 1 through 4. All figures are located in Appendix C. The most common order of trees found in Maxwell Park was Fagales, with 108 individuals (trees) and 28% of the total tree population (Figure 1). Some common trees included in the Fagales order are birch, beech, oak, and alder. The top three orders found in Maxwell Park (Fagales, Sapindales, and Pinales) comprise 62% of the trees found in Maxwell Park. Similar to the most common order found in Maxwell Park, the most common family was Fagaceae, with 93 of the 375 individuals and 25% of the total population (Figure 2). The most common genus found in Maxwell Park was Quercus (oak), with a 24% abundance (Figure 3). The only other genus with a frequency greater than 10% was Acer (maple), with a 15% abundance. There were 21 Fraxinus (ash) trees in the Park, making it the fourth most common genus. The most abundant species present in Maxwell Park was the Sugar maple, representing 7.7% of the total population (Figure 4). The second and third most abundant species in Maxwell Park were the Shagbark hickory and the Red oak, respectively. It is important to note that the order, family, and genus categorization of each species was provided by the USDA plant database, and some of these categories have since been reorganized. Thus, the classifications included in this inventory analyses may not be up to date with the current taxonomic classification system.

By extrapolating the amount of time needed to conduct the Maxwell Park tree inventory, it is possible to estimate the amount of time it will take for the Town of Normal to conduct an inventory of all trees located in the parks of Normal. It took a total of 14 hours to inventory 375 individuals. If future inventories take the same amount of time, and if the number of trees present in other parks in Normal are similar to the number present at Maxwell Park, then it will take 168 hours to inventory all the trees in all the public parks in Normal (12 other parks x 14 hours for each park).

Native and introduced tree species in Maxwell Park
Out of the 375 total trees present in Maxwell Park, 14% were introduced and 86% were native species (Figure 5). The nativity of a species was defined using the USDA plant database inventory. In order to be considered native, the species must be listed as native to Illinois. If a tree species was not listed in the inventory (such as the Eastern red cedar), the Morton Tree Arboretum (specifically for elm cultivars), as well as the USDA US national arboretum, were consulted. Hybrid elm (excluding the American elm) and maple cultivars developed by the Morton Arboretum were considered to be introduced.

Alpha, beta, and gamma diversity of trees in Maxwell Park
Gamma diversity is a measure of the total number of species, or species richness, present in the larger study area. In this case, the gamma diversity of Maxwell Park was 57 species. Beta diversity measures differentiation among habitats. The amount of species that were different, or that occurred in only one of the two areas, is known as beta diversity. In this study, the two habitats used for beta and alpha diversity analysis of the trees were 1) Children and Elders Forest and 2) the area of Maxwell Park that excluded Children and Elders Forest. For these two areas, beta diversity was 45, thus there were 45 species that only occurred in either Children and Elders Forest or outside of Children and Elders Forest (for a list of the species, see Figure 6). Alpha diversity measures diversity within a specific, particular area. In this case, alpha diversity measured the total number of species present in Children and Elders Forest, as well as the total number of species present in Maxwell Park excluding Children and Elders Forest. Alpha diversity of Children and Elders Forest was 30 species (i.e., 30 different species were present in this area), and alpha diversity excluding Children and Elders Forest was 37 species.

Size class distribution of trees in Maxwell Park
The average DBH (diameter at breast height) of trees in Maxwell Park was 7.8 inches. Figure 7 provides a graph illustrating the amount of ash, evergreen, maple, oak and hickory trees present in various size class categories. These tree groupings were chosen due to their relative abundance in Maxwell Park. The Evergreen classification included the Juniperus, Picea, and Pinus genera and excluded Bald cypress. In the smaller size classes (0-2 and 2-5 inch DBH), oaks were the most abundant genus, meaning that many oaks were recently planted in Maxwell Park. Maple and hickory trees were the second and third most abundant tree genera in the 2-5 inch DBH category. Maples dominate the 5-10 inch DBH size class, although this data may be skewed by the presence of a long line of Sugar maples lining North Parkside Road in Children and Elders Forest. Evergreen trees were typically more mature, with the majority occurring in the 10-20 and 20-30 inch DBH size class.

Children and Elders Forest versus "non"-Children and Elders Forest DBH and nativity status
Figure 8 provides a size class comparison of trees located within Children and Elders Forest compared to trees located outside Children and Elders Forest. Trees located inside the Children and Elders Forest were generally younger than trees that were located outside Children and Elders Forest. This can be observed in the much smaller average DBH of trees in Children and Elders Forest (4.7 inches) than those located outside Children and Elders Forest (12.2 inches). The largest recorded DBH in Children and Elders Forest was 16 inches, while the largest DBH located outside of Children and Elders Forest was almost double that, at 30 inches.

The amount of native trees in Children and Elders Forest (97%) was much higher than the amount of native trees planted outside Children and Elders Forest (69%) (Figure 9). Only one species (Black alder) was planted in Children and Elders Forest that was considered to be introduced by the USDA Plant Database.

Diversity in Children and Elders Forest by order, family, genus, and species
Children and Elders Forest consisted of 220 total individuals (trees), with 12 orders, 15 families, 22 genera, and 30 species. The two most abundant orders in Children and Elders Forest were Fagales (26.8%) followed closely by Sapindales (24.1%), which together represented roughly half of the trees in Children and Elders Forest. No other order had an abundance greater than 10%. The two most abundant families in Children and Elders Forest were Fagaceae (21.3%) followed closely by Aceraceae (20.5%). No other family had an abundance greater than 10%. The two most abundant genera in Children and Elders Forest were Acer (maple- 20.4%) and Quercus (oak- 20%). Similar to what was recorded with order and family diversity, no other genera had an abundance greater than 10%. The only tree species in Children and Elders Forest that comprised more than 10% of the population was the Sugar maple (14%).

Diversity outside Children and Elders Forest by order, family, genus, and species
The area of Maxwell Park that excludes Children and Elders Forest consists of 155 trees, comprising of eight orders, 11 families, 15 genera, and 37 species. The only tree species outside of Children and Elders Forest that comprised more than 10% of the population was the Green ash (11.6%). Since the Green and White ash are scheduled to be removed from Maxwell Park in the near future, the diversity of Maxwell Park excluding the Fraxinus (ash) genus was calculated. The two most abundant orders outside of Children and Elders Forest were Pinales (35%) and Fagales (33%), which together represented 68% of the trees. The two most abundant families outside of Children and Elders Forest were Fabaceae (33.8%) followed closely by Pinaceae (28.7%). The two most abundant genera excluding Children and Elders Forest were Quercus (33%) and Pinus (19.1%). No other genera had an abundance greater than 10%.

Discussion and Recommendations

In this section, information gained from the literature review, interviews with key informants, and results of the Maxwell Park tree inventory are analyzed. Topics discussed include the management implications of the Maxwell Park tree inventory, current invasive tree pest concerns for the State of Illinois, program recommendations for the Town of Normal, limitations of this study, and potential future areas of research.

This study investigated the research question *"How can tree inventories help mitigate future tree pest outbreaks?"* Through a literature review, key informant interviews, and a tree inventory of a public park in Normal, Illinois, this question was analyzed. First, the literature review revealed the importance of tree inventories in providing urban foresters with useful data, which could be used to guide planting programs. A link between high levels of tree biodiversity and a low severity of invasive tree pest outbreaks was then established. The literature review also emphasized the usefulness of tree inventories as a preliminary management tool for maximizing tree biodiversity in urban areas. As a result of the tree inventory of Maxwell Park, this study

offers specific suggestions about how the Town of Normal can further diversify their tree populations to help mitigate future invasive tree pest outbreaks. Interviews with key informants also identified several methods where tree inventories were helpful for this purpose, such as increasing the likelihood of early detection of a tree pest or providing information about the percentage of trees which may be at risk to invasive tree pest threats.

Management implications of Maxwell Park tree inventory

Order, family, genus, and species diversity of trees in Maxwell Park are assessed using the 10-20-30 species, genus, family rule, which was discussed in the literature review (Appendix A). In addition, the amount of native vs. introduced species is analyzed, and the feasibility of using students to conduct future tree inventories in the Town of Normal is evaluated.

Order diversity
Although the number of orders present in Maxwell Park was calculated, no literature could be found which recommended a specific order diversity value. Therefore, it is difficult to compare the order diversity results, since there are no recommended guidelines for the optimal amount of order diversity desired in an urban area. Nevertheless, to prepare for invasive tree pest outbreaks, it can generally be said that the Town of Normal should continue attempting to diversify their tree populations by order, since this effort will make the trees less likely to be preyed upon by a generalist pest species.

Family diversity
According to the 10-20-30 rule provided by Santamour (2004), no single family should comprise more than 30% of the total tree population. Overall, the number of families represented in Maxwell Park falls within this range, with Fagaceae (25% abundance) being the only family with an overall abundance greater than 15%. In Maxwell Park as a whole, the Town of Normal is doing a satisfactory job diversifying their tree plantings at the family level. In Children and Elders Forest, there are two families that exceed the 20% goal for family diversity: Fagaceae (21.3%) and Aceraceae (20.5%). In the area of Maxwell Park that excludes Children and Elders Forest, there are also two families that exceed the 20% goal: Fabaceae (33.8%) and Pinaceae (28.7%). Since the two areas of Maxwell Park have below the recommended level of family diversity when considered together, even though they exceed it when considered separately, the dominant families of trees in these two areas must be different. From this assessment of family diversity, it can be recommended that tree families be diversified further in the two areas of Maxwell Park.

Genera diversity
The guidelines provided by Santamour (2004) suggest that no single genus should comprise more than 20% of the trees in a particular area. Considering Maxwell Park as a whole, Quercus (oaks) had a 24% abundance in the Park, meaning this genus was 4% higher than the recommended genus diversity value. When the ash trees are removed from Maxwell Park, the percentage frequency of oaks will increase. In the future, it is recommended that either less oak trees be planted, or more different genera of trees be planted, to increase the total percentage. In Children and Elders Forest, the Acer (maple) genus was slightly above the recommended value, at 20.4%. Quercus (oak) had an abundance in Children and Elders Forest of exactly 20%.

Outside of Children and Elders Forest, the Quercus genus had an overall abundance of 33%, a full 13% above the recommended genus diversity level. It is recommended that diversity by genus be increased in all areas of the park, and that the number of maples planted in Children and Elders Forest, as well as the number of oaks planted outside of Children and Elders Forest, be decreased.

Species diversity

There were no species in Maxwell Park as a whole that had a greater than 10% species abundance, thus satisfying Santamour's species level diversity guidelines. In Children and Elder's Forest, the only tree species with a greater than 10% abundance was the Sugar maple (14%). However, the majority of the Sugar maples were planted along the road, and due to their larger diameter, it is likely that the trees were present before Children and Elders Forest was planted. If these Sugar maples along the road are not included, then the amount of Sugar maples was below 10%, thus satisfying the 10% species diversity rule. The only tree species outside of Children and Elders Forest that comprised more than 10% of the population was the Green ash (11.6%), which is scheduled to be removed from Maxwell Park in the near future. Overall, in all areas of Maxwell Park, satisfactory species level diversity was attained.

Summary of order, family, genus, and species diversity analysis

As a whole, Maxwell Park has sufficient diversity at low taxonomic levels, however in the future it is suggested that trees are diversified further among higher taxonomic levels (i.e., trees have sufficient diversity at the species level, but should be diversified further at the genus, family, and order level). In particular, the amount of oaks and maples being planted should be slightly reduced.

Discussion of native and introduced tree species in Maxwell Park

In both Children and Elders Forest and "Non" Children and Elders Forest, the majority of trees planted consist of species native to Illinois. Particularly in Children and Elders Forest, trees are almost exclusively native. This commitment to planting native species is in accordance with the mission statement of the Children and Elders Forest, which declares their dedication to planting native species. Although it is undeniably better to plant native species over non-native species due to the complex ecological interactions between native trees and their environments, the results of the literature review show that it is also important to plant a wide variety of trees in urban areas to prevent the severity of future invasive tree pest outbreaks. In addition, recent studies have suggested that the importance of planting native species in urban environments may be overrated. A recent study published in Nature by the senior research scientist at Arnold Arboretum suggests that it may be a better approach to judge plants based on their impact to human health, ecological services, economies, and biodiversity, and not simply based on the historical range of the species (Davis et. al., 2011). Therefore, it is the recommendation of this study that increasing tree biodiversity be given higher priority over increasing the number of native tree species in Maxwell Park.

Feasibility of training students to conduct a town-wide tree inventory

Although a tree inventory of Maxwell Park was successfully conducted, it would not have been possible without the assistance of a professional with an advanced level of tree identification knowledge. The main challenge with tree identification was the subtle variations between

cultivars (particularly maple), as well as species whose leaves appeared different based on the overall health and age of the tree (such as oak). Therefore, it is unlikely that training students to conduct the tree inventory for the Town would be successful. However, if the Town merely wished for students to identify the correct genus, tree identification could be possible. However, if species were not recorded, an important component of establishing biodiversity would be lost. Another possible method would be to pair a student comfortable using a GPS unit with an expert in plant identification, so they could work as a team. For the tree inventory to be conducted on a larger scale, many Trimble GPS units with the tree inventory software would need to be available for volunteers' use.

Program recommendations for the Town of Normal, Illinois

Program recommendations for this study were developed for the Town of Normal using a combination of information gained from the literature review, as well as through interviews with key informants. In addition, future steps for Normal policymakers are described below.

1. *Encourage public awareness of the dangers of transporting firewood.* While researching invasive tree pests during the literature review process, it became apparent that many insect pests, such as the Emerald ash borer, become established in new areas through the transport of wood. People often unknowingly transport firewood that has been infected with a tree pest species. Kostelnick, a key informant and expert on the spread of the Emerald ash borer, recommends educating the public about the importance of following quarantine regulations (pers. comm., 2013). In this way, communities can encourage their citizens to do their part in combating the spread of invasive tree pests.

2. *Be aware of symptoms of tree pest threats while conducting tree inventories*. When dealing with a newly established invasive species of any kind, early detection can be key to preventing its spread. After a potential threat is recognized, it is important that the threat is quickly removed.

3. *Consult the Illinois Forest Health Highlights brochure to remain updated on current threats to Illinois trees.* The Illinois Forest Health Highlights brochure is published by the Illinois Department of Natural Resources once a year, and provides an informative yet concise summary of the most important threats to forests in Illinois (Miller, 2012). Much of the information given in the yearly publication is highly relevant and useful information to those involved in the tree selection process. By viewing this brochure once a year, urban foresters can stay updated on current and future tree pest outbreaks in Illinois.

4. *Consider taking part in professional training workshops offered by the Illinois Department of Natural Resources.* Topics for the three workshops offered in 2012 included classroom and field training in tree pest identification, diagnosis, and sampling techniques.

5. *Develop landscape design standards for public parks.* Based on the interviews conducted for this project, it appears that all parties are in agreement about the importance of biodiversity in preventing the severity of future tree pest outbreaks. However, to gauge the Town's progress in

meeting these goals, first specific goals and a plan should be developed. It is recommended that the Town of Normal develop benchmarks stating desired tree biodiversity in public parks.

6. *Consider conducting an inventory of all trees located in the Town of Normal public parks.* Although it is not feasible to have students who are inexperienced in tree identification conduct the tree inventory on their own, students could potentially be trained to operate the GPS device, and then be placed with an expert in tree identification. Though it would take a considerable amount of time to conduct a tree inventory of the public parks in Normal, the benefits of obtaining the data provided by a tree inventory are numerous.

Limitations of study and future areas of research

Although many community members outside of the Bloomington-Normal area were contacted for interviews, there was a very low response rate. To learn from the experiences of other cities that have conducted large scale-tree inventories, these communities must continue to be sought out. If the Town of Normal Parks and Recreation Department chooses to conduct its own tree inventory of public parks, it is imperative that outside communities are contacted. In addition to attempting to contact key officials in these communities, it is also possible for the Town of Normal to view details of many tree inventories online. For example, there is a large amount of information regarding the methodology employed during tree inventories conducted by the cities of Portland, Oregon, Ann Arbor, Michigan, and Cambridge, Massachusetts, all of which is available to the public.

In addition, the 375 trees inventoried in Maxwell Park comprises a very small amount of the total number of trees that are likely present in all 13 of the public parks in Normal. Thus, due to the relatively small sample size used for this tree inventory, it is possible that the trees located in Maxwell Park are not representative of the rest of the trees present in other public parks in Normal. If time were not a factor, this limitation could be easily improved by increasing the number of parks that are inventoried.

Through interviews with Davison and Little, it was apparent that invasive species outbreaks can place a financial burden on citizens, as well as local governments. A potential question for future research would be: How should private landowners and/or local governments help to mitigate the cost of removing ash tree species? In addition, further research could examine the merits and weaknesses of tree inventories, and invasive tree pest controls. Thus, tree removal could be investigated from an economic standpoint, as opposed to the largely ecological perspective represented in this paper.

Future research

In summary, the findings from this research suggest that *increasing biodiversity* is the most important approach for minimizing the effects of invasive tree pest outbreaks. Tree inventories are used as a tool to calculate levels of tree biodiversity that are present in a particular area. Once the relative abundance of each species is known, park planners have obtained the information

necessary to make informed decisions regarding future tree plantings, thus undertaking the preliminary steps towards ensuring a healthy tree profile for many future generations.

Conclusion

Invasive tree pest outbreaks pose a significant management concern to urban foresters. It is important to manage urban parks using a tree planting policy that minimizes the susceptibility of these areas to pest species. The biodiversity of trees in Maxwell Park (located in the Town of Normal, Illinois) was evaluated assuming that the greater the tree biodiversity in a park, the more resilient the park would be to future invasive pest outbreaks. Through a literature review, key informant interviews, and a tree inventory of a public park in Normal, Illinois, the research question of how tree inventories can help mitigate future invasive tree pest outbreaks was analyzed.

The literature review provided in Appendix A showed that, by researching how invasive tree pests have impacted North American trees historically, one can better understand best practices in avoiding insect outbreaks. In addition, considering published guidelines proposed for reasonable levels for diversity provides an established recommendation for communities to follow. The 10-20-30 species-genus-family rule suggested by Santamour (2004) for measuring biodiversity and resistance to invasive tree pest outbreaks was applied to tree inventory data collected from Maxwell Park.

As a result of the Maxwell Park tree inventory conducted in fall 2013, the Town of Normal appears to be applying an acceptable approach for planting diverse types of trees in their parks at the species level. However, diversity at a higher taxonomic level is needed to ensure that parks are not susceptible to non-specific invasive tree pests that can feed on a variety of host plants. It is important to note that, when it comes to mitigating invasive species outbreaks, there is no magic 'fix-it' button which will completely eliminate the pest problem (John Kostelnick, pers. comm., 2013). However, if any tree pest outbreaks do occur in the future, the effects of the outbreaks may be minimized due to the Town's dedication to planting many diverse tree types.

After analyzing information gained from the literature review and key informant interviews, six program recommendations for the Town of Normal were identified. 1) Encourage public awareness of the dangers of transporting firewood. 2) Be aware of symptoms of tree pest threats whilst conducting tree inventories. 3) Consult the Illinois Forest Health Highlights brochure to stay updated on current threats to Illinois trees. 4) Consider taking part in professional training workshops offered by the Illinois Department of Natural Resources. 5) Develop landscape design standards for public parks. 6) Consider conducting an inventory of all trees located in the Town of Normal public parks.

An important limitation of the study was the small number of key informants that were interviewed from areas outside of the Bloomington-Normal community. Future studies could continue to locate other cities that had used tree inventories successfully in the past. In addition, a future study could look at the problem of invasive tree pest outbreaks from an economic perspective.

Urban trees provide communities with a multitude of social, economic, and environmental benefits. A tree inventory is an essential first step in the effective management of urban parks. Increasing tree biodiversity is the most important approach to minimize the potential for invasive tree pest outbreaks. The results of this study can be used to improve the Town of Normal's tree management policy by assessing the strengths and weaknesses of the current tree composition of Maxwell Park. The results also provide justification for future investment in replanting programs. This study reinforces the importance of the Town of Normal's commitment towards funding urban forestry programs to prevent costly, deleterious future invasive tree pest outbreaks.

Works Cited

Convention on Biological Diversity, Rio de Janeiro (1992). Article 2: Use of Terms.

Davey Resource Group. Summary Report: Calculated Public Tree Values and Benefits for The City of Ann Arbor (2009). City of Ann Arbor Forestry Department, Ann Arbor, Michigan.

David Pimentel, Rodolfo Zuniga, Doug Morrison. Update on the Environmental and Economic Costs Associated with Alien-Invasive Species in the United States. Ecological Economics. 52 (2005) 273-288.

Davis, Mark A., et al. Don't judge species on their origins. Nature 474.7350 (2011): 153-154.

Miller, Fredrick. 2012 Illinois Forest Health Highlights (2012). Illinois Department of Natural Resources.

National Invasive Species Information Center (2006). Executive Order 13112.

Santamour, F.S. Trees for urban planting: Biodiversity, uniformity, and common sense (1990). Proceedings of the 7th Conference of the Metropolitan Tree Improvement Alliance. 7:57–65.

Appendix A: Literature Review: Using Tree Inventories to Mitigate Future Tree Pest Outbreaks.

Introduction

The Emerald ash borer is one of several well known invasive tree pests that have decimated Eastern and Midwestern forests in the United States during the past century. As globalization continues, potentially deadly pests are constantly being introduced to the detriment of many native tree populations. Historically, the planting of urban trees has played a significant role in controlling, or, more commonly, failing to control, the spread of invasive tree pests that prey on native trees. When a large proportion of a community's tree population consists of a single species, the detrimental effects of an introduced pest are intensified. In the first section of this literature review, three of the most devastating exotic species to impact Midwestern forests will be examined. Special emphasis will be placed on lessons learned by urban planners, as well as repeated mistakes made in the replanting of municipal trees following these devastating outbreaks. Next, best management practices for preserving urban tree species biodiversity will be discussed. Finally, the usefulness of tree inventories as a method for determining biodiversity as well as resistance toward future insect and pathogen outbreaks will be described.

History of selected invasive tree pest outbreaks in Central and Eastern forests

The Chestnut blight, Dutch elm disease, and the Emerald ash borer are three of the most infamous invasive tree pest outbreaks in the history of the United States. These three pests have each decimated tree populations across the country and have shaped urban tree policy for many subsequent decades. Although the following section will focus on these three invasive tree pests, it is important to note that these outbreaks are not unique. Instead, they represent a small fraction of the many invasive tree pests that are present in areas throughout the United States. Some additional examples of invasive tree pests which prey on U.S. trees include the Asian longhorned beetle, Hemlock woolly adelgid, Thousand cankers disease, and the Gypsy moth.

Chestnut tree blight fungus and the American chestnut

The American chestnut (*Castanea dentata*) is native to the Eastern United States, historically occupying over 200 million acres. It is estimated that over four billion trees grew in this range, many of which were planted in urban environments (American Chestnut Foundation). The chestnut tree blight fungus (*Cryphonectria parasitica*) was first discovered in the United States during the early 1900s. The fungus was thought to have been introduced unintentionally through the importation of Asian chestnut trees (*Castanea crenata* and *C. mollissima*). The hypovirulent fungus killed an estimated 3.6 million hectares of American chestnut trees, resulting in a near extinction of the species (Anagnostakis 1987). The chestnut blight was the first example of a widespread exotic pest invasion to trees in North America, and community guidelines outlining replanting techniques had not yet come into existence. The American elm was widely used as a replacement species for the American chestnut, with little thought given to increasing tree biodiversity.

Dutch elm disease and the American elm
Historically, the American elm (*Ulmus americana*) served as a highly beloved icon of Eastern American forests, with Thomas Jefferson once declaring the elm to be "Nature's noblest vegetable" (Santamour 2004). Before the outbreak of Dutch elm disease (DED) in the 1930s, American elm was one of the most commonly used street trees in the United States. One study estimated that up to 45 percent of all street trees in Chicago in 1971 consisted of elms (Dreistadt 1990). During the course of 40 years following the introduction of DED, American elms were virtually wiped out across the US.

As a consequence of the destruction of millions of elm trees, for the first time, public interest became focused on the subject of urban forest planning. Before the advent of DED, trees were selected for planting based on aesthetic features, such as their form, habit, color, temperature and soil tolerance, and moisture regime (Raupp et al. 2006). After the DED outbreak, city officials began to consider the biodiversity of trees as a selection factor. Horticulturalists began to notice that monocultures were highly susceptible to pest species, and many arborists attempted to avoid this weakness by planting different cultivars and varieties of ashes (Marche and Jordan, 2013).

In many other areas; however, city planners continued searching for the elusive 'perfect urban tree' to replace the American elm. Oaks, maples, and ashes were still commonly overplanted. A study conducted by Miller and Miller (1991) found that the Norway maple had been overplanted as a replacement species for elms in Wisconsin. The failure to plant a diverse tree population following the DED outbreak led to the continued susceptibility of urban trees to future invasive tree pests.

The Emerald ash borer and the ash tree
Today, ash (*Fraxinus* spp) is one of the most widely planted tree species in urban Midwestern areas (Smitley et al. 2009). It is native to North America: specifically, to hardwood forests occurring in the Midwestern and Eastern United States. Up to 20 percent of cataloged street trees in the Chicago region were ashes in the early 1990s (Chicago Bureau of Forestry 1995), where it was used as a replacement for elm trees. The popularity of the ash may be partly due to its resistance to the invasive gypsy moth (*Lymantria dispar*) (Smitley et al. 2009). In addition, the ash is considered a hardy, valuable lumber species, with a rapid growth rate (Marche and Jordan, 2013). The ash also provides important cover and habitat functions to a variety of wildlife.

The Emerald ash borer (*Agrilus planipennis*) was discovered in Michigan in June 2002, although it may have been present in Michigan as early as 1999 (Smitley et al. 2009). Introduced from Asia, the insect was likely brought to the United States through the transport of lumber aboard cargo ships. As of February 1, 2013, the Emerald ash borer has resulted in the death of 20 million ash trees in 18 states and two Canadian provinces (Marche and Jordan, 2013). All native and cultivated ash trees in North American are currently considered at risk. This includes 16 North American ash trees (Raupp et al. 2006, McCullough and Siegert 2007).

To slow the spread of the Emerald ash borer, several preventative measures have been taken. As part of an informative guide to the public about Emerald ash borer treatment options, the Illinois Arborist Association advised that "the only poor choice is doing nothing" (2012). In Illinois, 41 counties with confirmed Emerald ash borer sightings are currently under quarantine, which

prohibits the transport of firewood. In addition, there is currently a ban on the sale of ash trees in plant nurseries (Smitley et al. 2009). At sites where the Emerald ash borer has been detected outside its current range, all ash trees within a 200 to 800 meter radius of the infected tree have been felled, removed, and subsequently destroyed. Following this, three year detection surveys have been implemented (McCullough and Siegert 2007). In Illinois, the Illinois Emerald Ash Borer Reforestation Committee has created a list of candidate ash replacement species, to ensure that planters have a wide variety of tree species to choose from (see Appendix F).

Best practices for managing urban trees

The notion of managing urban trees using an ecological perspective is a relatively new concept that has only recently been investigated. Using an 'ecological perspective' means studying the interactions among organisms and their environment. The following section will address some of the studies to date which discuss the important ways that enhancing biodiversity can work to alleviate invasive tree pest problems. General rules that ecologists have postulated from the 1970s to today regarding the preservation of urban tree species biodiversity will be examined.

A history of tree biodiversity guidelines
One of the first guidelines for species biodiversity was given in 1975 by Barker, who advised that street trees be composed of no more than five to 10 percent of a single species. Moll (1989) expanded this rule to include a maximum of no more than five percent of any one species and no more than 10 percent of any one genus.

The five percent species limit rule suggested by Barker has been criticized, however, by Miller and Miller (1991) who argue that this number is not realistic, given the small number of tree species available, the need for aesthetic unity, and the restricted suitability of a particular taxon to specific ecological areas. Miller and Miller found a 10% species limit to be sufficient, since in the event of a catastrophic taxon-specific invasion event, 90% of the tree population would be still be safe.

A more recent study opposed the 10% species rule suggested by Miller and Miller, stating that this rule does not adequately address the realities of host-pest interactions. Santamour (2004) notes that, if a city with 100,000 trees were to follow this 10% guideline, it is possible that only 10 individual species with 10,000 individual trees each would be present. In addition, if a community planted three species of ash following the suggested 10% rule, they may now face a 30% loss of trees due to the Emerald ash borer. Instead, Santamour proposes that pest outbreaks can be avoided if a 10-20-30 rule is followed: no more than 10% of one species, 20% of one genus, and 30% of one family of trees should be planted (1990).

All guidelines that recommend species-level tree diversity provide protection against exotic specifist pests such as the chestnut blight and DED; however, these rules become less successful when implemented against introduced pests that are less host-specific. Even the 10-20-30 rule, which incorporates some diversity guidelines above the species level, would fail to protect a tree community from invasive tree pests, such as the Emerald ash borer and the hemlock woolly adelgid (*Adelges tsugae*) (Raupp et al. 2006). The gypsy moth (*Lymantria dispar dispar*), an invasive generalist insect species, is known to feed on over 500 plant species native to North

America. In order to combat invasive generalist pests, it is necessary to diversify at higher taxonomic levels.

Alternative viewpoints to increasing biodiversity

Although planting schemes that use ecological guidelines can be important in avoiding the spread of an invasive tree pest species, not everyone is in agreement over the benefits of increasing biodiversity. Richards (1983) examined the relationship between species biodiversity and the stability of a street tree population in Syracuse, New York, and found that relatively few tree species were well-suited to the urban environment. The study found that older, well-adapted trees contributed more to ecosystem stability than the younger, more diverse populations. However, it must be noted that population stability measures the adaptability of tree species, rather than simply a large amount of tree biodiversity, so a diverse population does not necessarily equal a well-adapted population. Instead of species biodiversity, Richards places emphasis on diversifying the age structure of tree populations. In fact, Richards argues that planters are worrying about biodiversity at the expense of replacing older, more common, well-adapted tree species. Therefore, this study is saying that *less* emphasis should be placed on tree biodiversity.

There are several limitations to the concept that planting well-adapted tree species should be prioritized over maximizing biodiversity, although both criteria are undoubtedly important. First, chestnut, elm and ash trees are all considered to be highly adapted tree species. Using Richards (1983) criteria, where the importance of biodiversity is lessened, the same devastation of urban tree populations could reoccur. In addition, Richard's rule seeks to increase the "stability" of urban tree populations, which the study defines as "resistance to internal or external events causing extreme fluctuation in numbers, mass or other qualities of the population". Therefore, *an increase in population stability does not necessarily mean that resistance to invasive tree pests is also high.*

Despite these critiques, Richard's population stability model contains an important takeaway message. Namely, the adaptability of species to a particular area must be considered *in addition* to biodiversity. It is advisable to plant trees using recommended species for the given area. Appendix F provides a list of selected candidate species selected by the Illinois Emerald Ash Borer Reforestation Committee to replace the ash tree in Central Illinois. Additional studies have supported the rule that site assessment should precede plant selection for urban areas (Bassuk 1990).

Other strategies to fight pest invasions

According to Campanella, "the mantra of urban forestry today is sustainability and species biodiversity" (2003). There are many ways to increase tree biodiversity that should ideally be considered along with implementation of sustainable practices. It is the role of the urban forester to balance the needs of all parties involved in the selection of plants: experts, elected officials and citizens desires should all be taken into account. In addition, the constraints of local economies, liability issues, the physical growth of trees, and severe weather events also play a role in determining candidate species.

Tree families that are currently underrepresented in populations should be planted whenever possible. In addition, native species should be selected. In cases where nonnative tree species are introduced, these plants can become invasive. The exotic Chinese 'Tree of Heaven' (*Ailanthus altissima*) has been nicknamed by some people as the "Tree of Hell" due to its allelopathic and invasive tendencies (Burch and Zedaker 2003). Exotic plant species can actually decrease biodiversity by outcompeting many other types of trees. Since there are many definitions as to whether a species is considered 'native' (i.e., a species may be considered 'native' to a particular ecoregion, state, or even continent), Wade suggests limiting the title of 'native' to those trees that are present in the city area (2010).

Another way to minimize invasive tree pests is through the development of tree breeding programs with an emphasis on pest resistance. The benefits of this are twofold. First, cultivars can be created which are directly resistant to certain insects, funguses, and blights. Second, the creation of new cultivars will provide more stock for selection by urban planners; thus increasing biodiversity. Currently, very few trees are being grown and sold that have resistance to pests (Santamour 2004).

In the future, climate change will likely stress urban tree populations even further. The frequency of drought is expected to increase, resulting in weakened trees and an increased vulnerability to pests. Increasing temperatures may also increase the range and density of insect pests. One such example of this is the mountain pine beetle in British Columbia. This beetle is native to North America, however due to changes in climate it has become invasive, far exceeding its previous range in many cities and forests (Carroll et al. 2006). It is likely that climate change will exacerbate the problems of invasive insect pests, as trees are weakened and insect range and numbers are strengthened.

Finally, municipalities should consider tree biodiversity as a means to help alleviate the threats of invasive tree pest outbreaks as the first stage of management. This step involves the implementation of a continued maintenance cycle to evaluate tree populations. The next section of this paper will discuss in detail why the use of tree inventories is so essential to this process.

The importance and use of tree inventories for urban tree management

Trees in urban settings are different than trees in forests, because the progeny (the next generation of trees) is almost entirely human-determined (i.e., the seeds of the current generation rarely produce a new generation). The species biodiversity of a younger generation is *independent* of the older generation, which is unlike a forest, where the biodiversity of the younger generation is *dependent* on the older generation. Therefore, tree biodiversity in an urban setting is largely reliant on human management efforts. If left unattended, the potential benefits provided by urban trees cannot be fully achieved.

It is important to understand the current composition of an urban tree population to make informed decisions regarding future tree placements. If the tree composition is not known beforehand, urban planners run several risks:

1. There is no background information on which tree species were successful in the past. Trees planted in urban areas are often grown under highly stressful environments, facing problems

such as soil compaction, poor drainage and aeration, high soil pH levels, restricted root space, and excess salt concentrations from the salting of road (Bassuk 1990). Because of these factors, the urban forester has a high risk of continuing to plant ill-adapted species with a high early mortality rate.

2. Tree species biodiversity of a park could be decreased if the urban forester does not know the types of species that are already in existence in an area; thus, the urban forester has the risk of overplanting certain tree species.
3. Similarly, age structure biodiversity of trees could be lowered.
4. Planting new trees could negatively influence older trees. For example, planting shade tolerant trees next to shade-intolerant trees could result in all species that were shade-intolerant being incapable of growth and continued survival. The urban forester could also mistakenly select trees that have allelopathic properties or attempt to plant young trees near older generations with these chemical compounds.

All of these factors (health, biodiversity, age structure, etc.) can result in a tree population becoming more or less vulnerable to invasive tree pests. Therefore, it is important to continually monitor tree populations. Through the use of a tree inventory, many indicators of urban forest health can be determined.

Example urban tree inventories

In the wake of the Emerald ash borer incident along with other invasive species that urban forests are currently experiencing, many towns and cities have taken it upon themselves to conduct tree inventories to better prepare themselves for future outbreaks. Using tree inventories, Raupp et al. found that 36 percent of trees in Lincolnshire, Illinois were at risk to the Emerald Ash Borer and the Asian Longhorned Beetle (2006). In Chicago, the study determined that 59 percent of urban trees were considered at risk for these two pests.

A study of ecological change in six Midwestern cities from the periods of 1980 to 2005 revealed a surprising decrease in tree biodiversity on public and private lands. The study was first conducted in 1980 to determine the effects of Dutch elm disease. The study was renewed in 2003 and 2005 in an effort to document changes in urban forest structure. The study found that in 1980, 27 percent of the tree taxon were considered overplanted, while in 2003 and 2005, 42 percent of the tree taxa were considered overplanted (Wade 2010). In particular, the study found that maple (*Acer* spp) trees were drastically overplanted, with maples representing nearly 40 percent of public trees during the 25 year time period.

The City of Ann Arbor, Michigan used a tree inventory of all public trees located on streets and in parks. As part of their inventory, they reviewed species, size, diameter, geo-coded location, condition and maintenance needs of all the city trees. The information was then added as a layer on the city's GIS database and integrated with the Cityworks software (Davey Resource Group 2009). From this inventory, it was discovered that maples comprised 40 percent of all city trees. As a result, the city has decided to broaden its tree biodiversity, and have begun replanting with the goal of increasing biodiversity against future pests which could have effects similar to the Emerald ash borer.

Literature Review Conclusion

Through an examination of the history of invasive tree pest outbreaks on trees in the United States, it is easy to recognize that exotic tree pests create a significant problem for urban foresters. The many different theories discussing maximizing resistance to insect outbreaks illustrate that there is no easy solution to eliminate this problem. The 10-20-30 species-genus-family rule suggested by Santamour (2004) provides a concrete method of measuring tree biodiversity and resistance to invasive tree pest species in an urban area. This rule can be applied to tree inventory data collected from municipalities.

The most effective management of urban tree populations, however, begins with implementing solutions far in advance. By assuming a proactive stance towards the eradication of invasive tree pest species, and by following the examples set by other cities who conducted exhaustive tree inventories to document their city's biodiversity, city planners can better help their own communities achieve sustainable urban tree management. As shown by the tree inventory conducted in Ann Arbor, Michigan, tree inventories can have an important influence on the diversification and the planning of future generations of urban trees.

Literature Review Works Cited

American Chestnut Fountation. "History of the American Chestnut Foundation." 2013. The American Chestnut Foundation.

Anagnostakis, Sandra L. "Chestnut blight: the classical problem of an introduced pathogen." Mycologia 79.1 (1987): 23-37.

Barker, P.A. 1975. Ordinance control of street trees. Journal of Arboriculture. 1(11):212-215.

Bassuk, Nina L. "Street tree biodiversity: Making better choices for the urban landscape." Proceedings of the 7th METRIA Conference. 1990.

Campanella, Thomas J. "Republic of Shade: New England and the American Elm". 2003. New Haven: Yale University Press, 2003.

Carroll, A. L., et al. "Impacts of Climate Change on Range Expansion by the Mountain Pine Beetle." *Mountain Pine Beetle Initiative Working Paper* (2006).

Chicago Bureau of Forestry, 1995. The State of Chicago's Street Trees: A Random Sample Inventory. City of Chicago Department of Streets and Sanitation, Bureau of Forestry, Chicago, Illinois

Davey Resource Group, 2009. Summary Report: Calculated Public Tree Values and Benefits for The City of Ann Arbor. City of Ann Arbor Forestry Department, Ann Arbor, Michigan.

Dreistadt, Steve H., Donald L. Dahlsten, and Gordon W. Frankie. "Urban forests and insect ecology." BioScience 40.3 (1990): 192-198.

Illinois Arborist Association, 2012. Strategic Management of Emerald ash borer in Illinois. Urban Forestry Management Series.

Marche II, Jordan D. "Fool Me Twice, Shame on Me: The Emerald ash borer in Southeastern Michigan." *FOREST* (2013): 5.

Miller, Randall H., and Robert W. Miller. "Planting survival of selected street tree taxa." Journal of Arboriculture 17.7 (1991): 185-191.

McCullough, Deborah G., and Nathan W. Siegert. "Estimating potential Emerald ash borer (Coleoptera: Buprestidae) populations using ash inventory data."*Journal of Economic Entomology* 100.5 (2007): 1577-1586.

Raupp, Michael J., A. Buckelew Cumming, and Erin C. Raupp. "Street tree biodiversity in eastern North America and its potential for tree loss to exotic borers." *Arboriculture and Urban Forestry* 32.6 (2006): 297.

Santamour, F.S. 1990. Trees for urban planting: Biodiversity, uniformity, and common sense. Proceedings of the 7th Conference of the Metropolitan Tree Improvement Alliance. 7:57–65.

Santamour Jr, Frank S. "Trees for urban planting: Biodiversity, uniformity, and common sense." The Overstory Book: Cultivating Connections with Trees. Permanent Agriculture Resources, Holualoa, Hawaii (2004): 396-399.

Smitley, David, et al. "Biology and Management of the Emerald ash borer." *Biology of Annual Bluegrass*: 138. 25 Feb 2009.

State of Illinois Emerald ash borer Reforestation Committee, 2007. Increasing Tree Biodiversity in the Urban Landscape- Central Illinois. Governor's Emerald ash borer Management & Science Advisory Panel.

Wade, C. A. (2010). Ecological change in the urban forest of six Midwest, USA cities over twenty-five years. (Order No. 3435152, Michigan State University). ProQuest Dissertations and Theses, 22

Appendix B: Map of Maxwell Park in Normal, Illinois. This map was created by using the GPS locations of trees that were collected during the tree inventory process.

Map of Maxwell Park

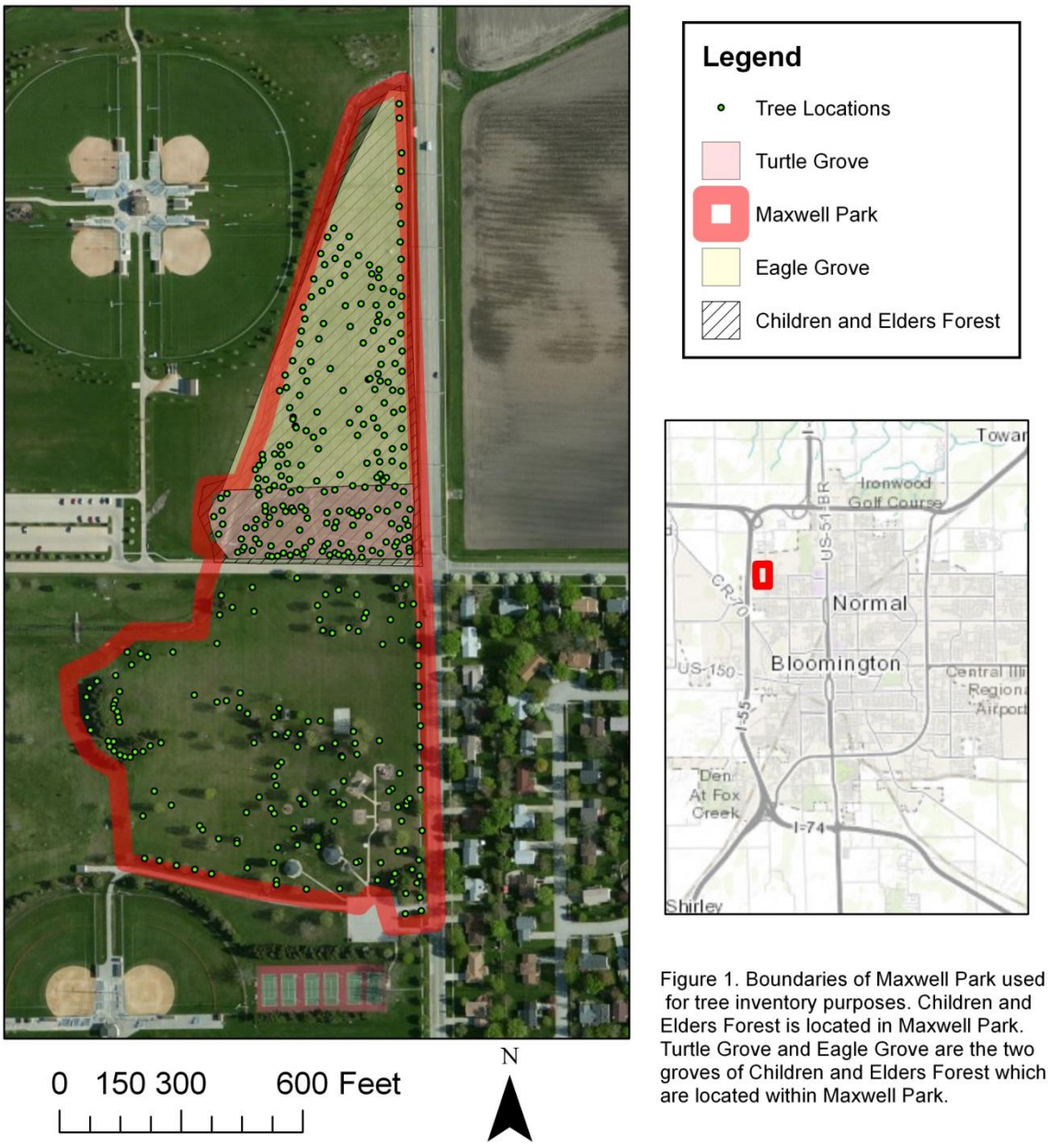

Figure 1. Boundaries of Maxwell Park used for tree inventory purposes. Children and Elders Forest is located in Maxwell Park. Turtle Grove and Eagle Grove are the two groves of Children and Elders Forest which are located within Maxwell Park.

Appendix C: *Interview questions for key informants*

Garry Little, *Director of the Town of Normal Parks and Recreation Department, IL*

1. From the data that I collected from my tree inventory, what would the Parks Department be interested in? How can I use it to help you?
2. Does the Parks and Recreation Department have a specific or general goal about the percentage of species they want to be native, or about the number of species they want to see represented?
3. Has a complete inventory of Normal been done before?
4. Has a complete inventory of Bloomington been done before?
5. If the Parks and Recreation Department decided to conduct a complete tree inventory over all publicly-owned trees in Normal, how would/could it be funded?
6. Do you have any other comments or questions for me?

Mercy Davison, *City Planner for the Town of Normal, IL*

1. What are the benefits of having urban trees in Normal?
2. Are there any disadvantages?
3. As a city planner, do you have any say in the decision of where to plant trees, how many, and what type?
4. As a city planner, what type of criteria do you consider when selecting what type of trees to plant?
5. What criteria do you think townspeople use?
6. From the data that I collected from my tree inventory, what would the Parks Department be interested in? How can I use it to help you?
7. Does the Town have a specific or general goal about the percentage of species they want to be native, or about the number of species they want to see represented?
8. Do you know any city planners or officials involved in tree planting in other cities/towns that I could contact?
9. Do you have any other comments or questions for me?

Jonathan Thayn and John Kostelnick, *Illinois State University professors researching spatial distributions of gypsy moth outbreaks, Normal, IL*

***Note: interviews were conducted separately on two different occasions*

1. What are your research interests? Are you doing any research currently?
2. Do you know anything about the Asian Longhorned Beetle? Could this be a potential threat to our community in the future? If so, what species of trees will be impacted and how severe is the outbreak likely to be?
3. How will climate change effect the rate and severity of future invasive species outbreaks?
4. What are the biggest non-insect invasive species problems you have seen in our community (such as DED, chestnut blight)?
5. Have you noticed that the types of invasive species problems that urban trees experience are different than those experienced by trees located in forests? If so, why do you think that is?
6. Do you think that planting native vs. nonnative trees influences their susceptibility to invasive species? (i.e., are native tree species more, less, or equally likely to be attacked by invasive species?) If native and nonnative trees are equally likely to be preyed upon by

invasive species, what are the benefits of planting mostly native species? Specifically, how does planting native trees contribute to the overall health of urban forests?
7. What are the ways to minimize the severity of invasive species outbreaks?
8. What aspects do you think would be important to record during a city-wide inventory? (such as species, DBH, location, etc)
9. After a tree inventory is completed, how would you like to see the data used? What kinds of information do you think is important for planting officials to learn from a tree inventory?

Mark Stahl, *Garden Center Manager for Owen Nursery in Bloomington, IL*
1. How have invasive species outbreaks impacted the trees at Owen Nursery?
2. What are the criteria Owen Nursery uses when selecting trees?
3. What are the criteria that nurseries use when deciding how to price trees?
4. In your opinion, what are the top three threats to Illinois trees in the upcoming years?
5. How has the ban on the sale of Ash trees in Illinois affected Owen Nursery?
6. Have you noticed that, since the ban of Ashes, a different type of tree has become more popular?
7. Are there any other invasive species that have affected the trees in Owen Nursery in the past?
8. Do you have any other comments or questions for me?

Randy Thorndyke, *Certified Arborist for the Town of Normal, IL*
1. How long have you been involved with managing trees?
2. How has the summer drought impacted the ash trees in Normal?
3. How will the removal of ash trees affect Maxwell Park?
4. Is doing a tree inventory of Maxwell Park helpful to the Parks and Recreation Department? In what way?
5. What are the biggest invasive species concerns to trees in Normal currently?
6. Are there any invasive tree species that the Parks Department is currently dealing with?
7. What invasive species do you think will become problems in the future?
8. Do you think that the gypsy moth presents a threat to Normal trees?

Kerry Gray, *Urban Forestry & Natural Resources Planning Coordinator for Ann Arbor, MI*
1. What variables (such as species, DBH, location, etc.) did you record as part of your inventory?
2. What type of GPS did you use to conduct the inventory?
3. What were some of the problems you encountered when conducting an inventory at such a large scale?
4. How did you overcome these problems?
5. If you could give any advice to towns who wish to conduct their own tree inventories, what would it be?

Appendix D: *Figures*

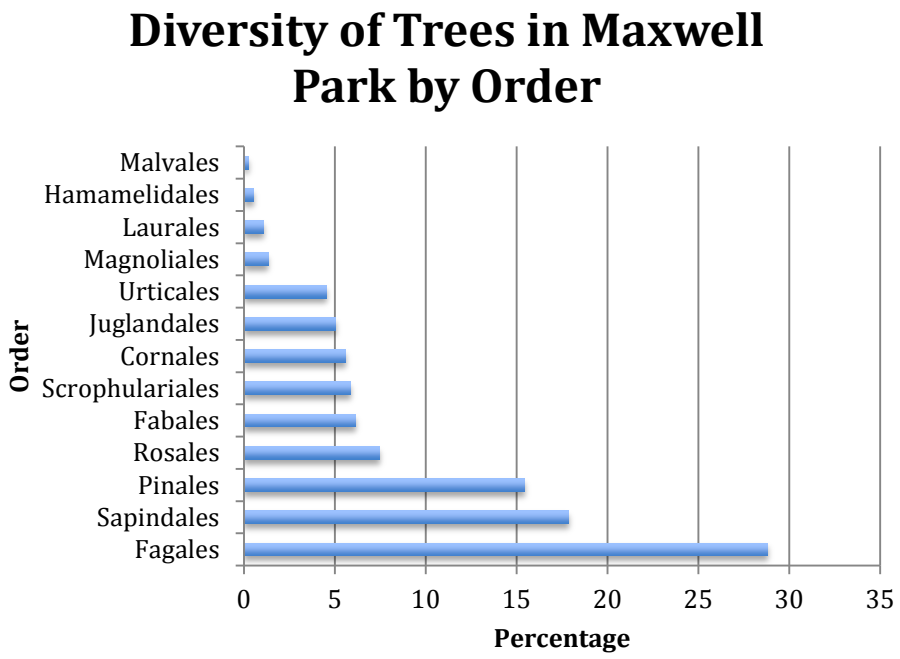

Figure 1. Diversity of trees in Maxwell Park, Normal,Illinoisby order Current as of November 2013.

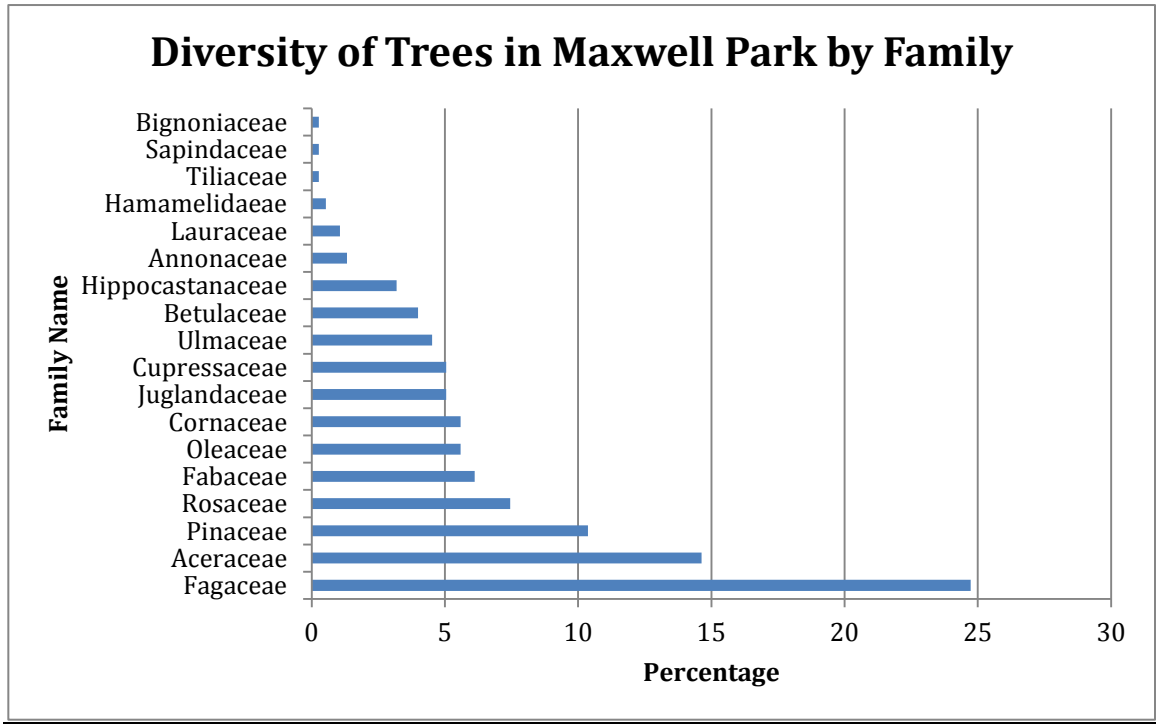

Figure 2. Diversity of trees in Maxwell Park, Normal,Illinoisby family. Current as of November 2013.

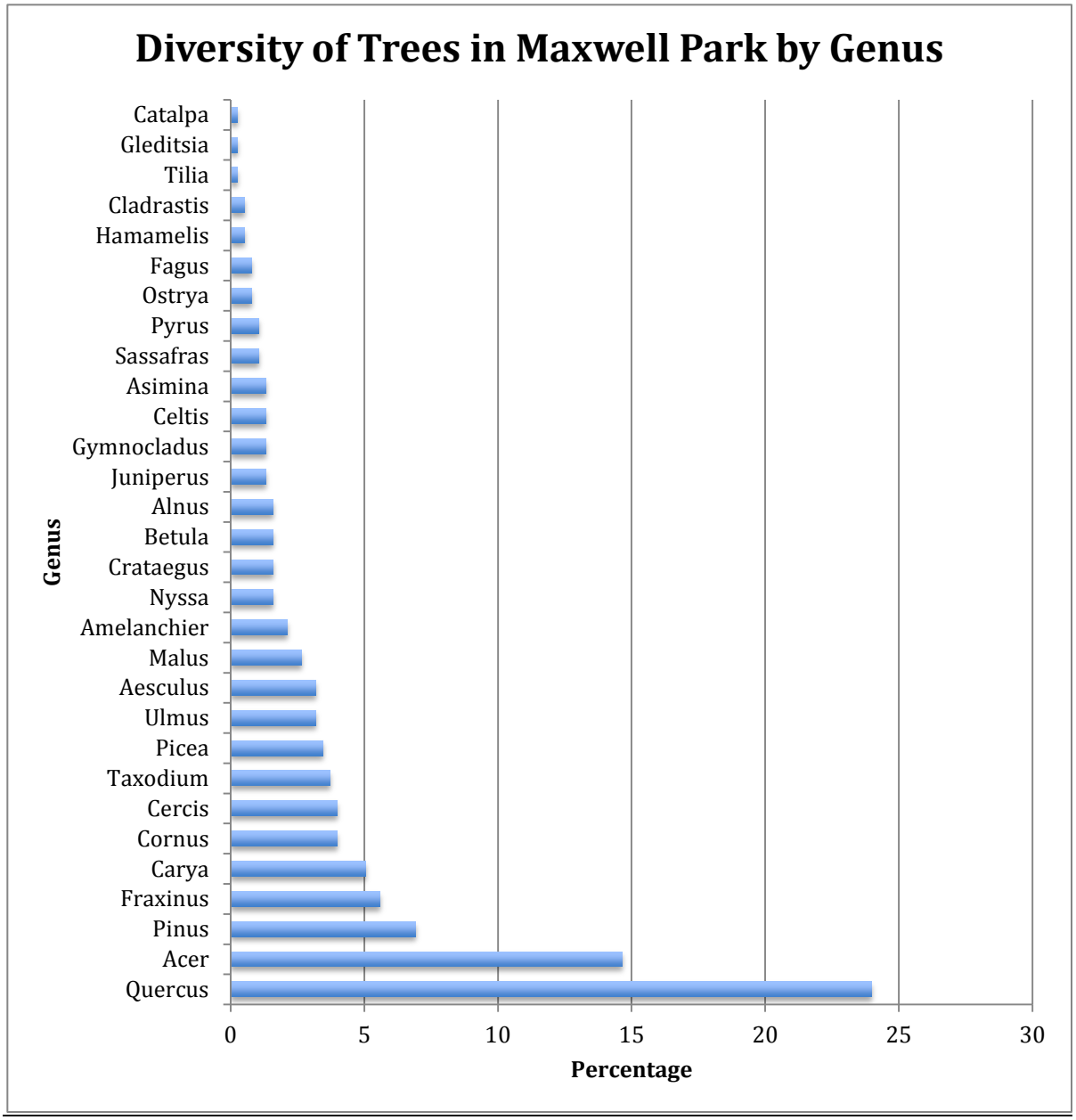

Figure 3. Diversity of trees in Maxwell Park, Normal,Illinoisby genus. Current as of November 2013.

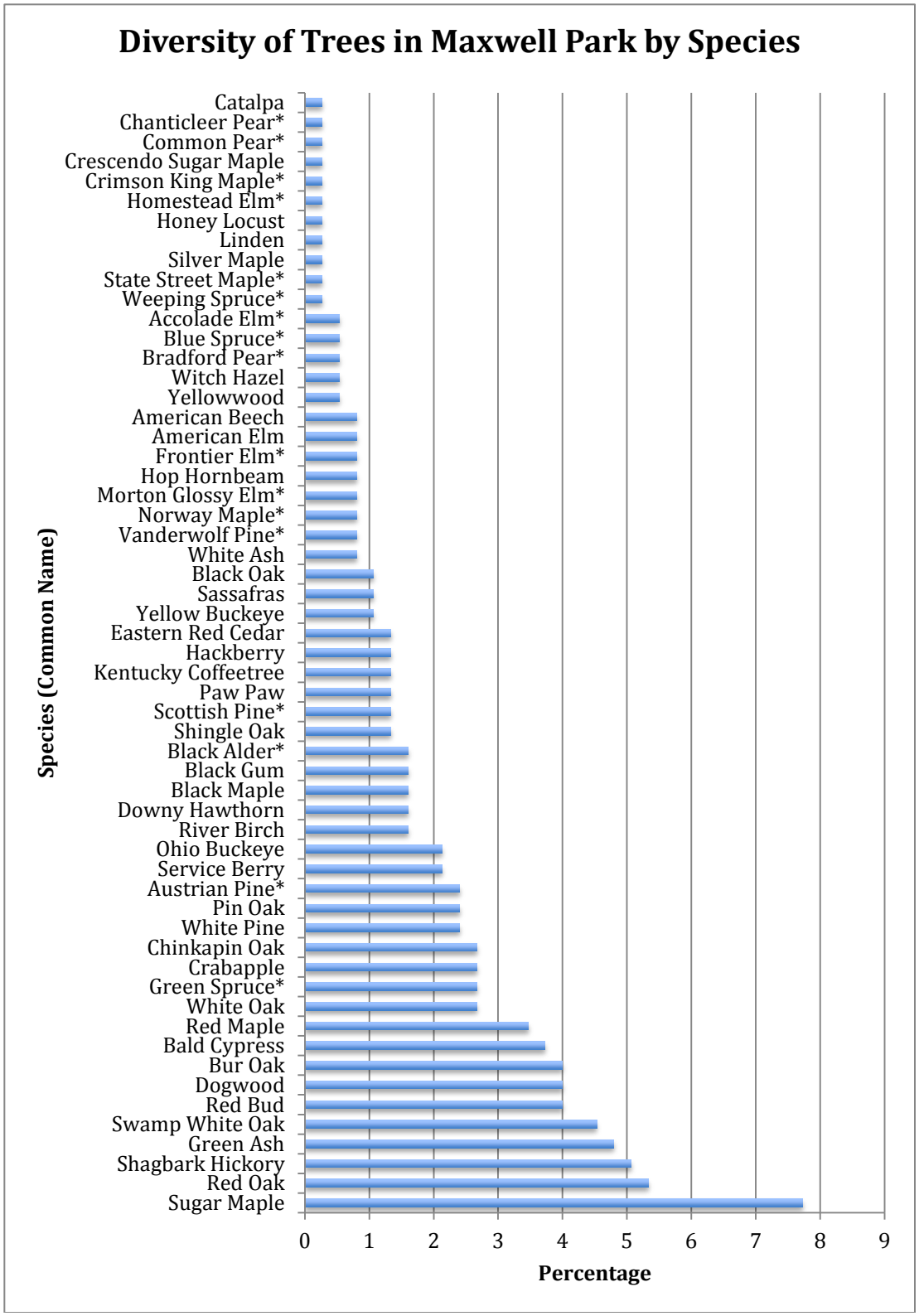

Figure 4. Diversity in Maxwell Park, Normal,Illinoisby tree species. Current as of November 2013. Species are listed using their common name for easy reference. Species denoted with an asterisk (*) are considered "introduced" to Illinois according to the USDA plant database.

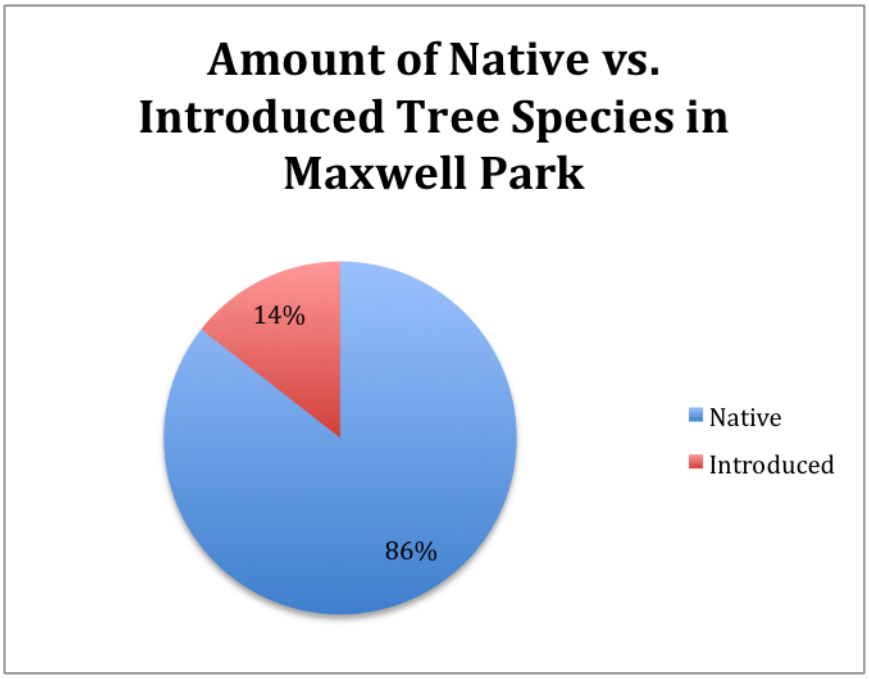

Figure 5. Amount of native versus introduced tree species in Maxwell Park, Normal, IL. Nativity status was determined using the three categories as defined by the USDA Plant Database: native, introduced, and absent/unreported. In order to be considered "native", trees must have been classified as native to the State of Illinois by the USDA Plant Database (i.e., it was not enough that a species was classified as native to the U.S.) The introduced and absent/unreported categories were combined, since presence in Maxwell Park indicated that the species were present in Illinois. Current as of November 2013. n=375.

Species Present in Children and Elders Forest	Species Present Excluding Children and Elders Forest
American Beech	Accolade elm
American Elm	Austrian Pine
Bald Cypress	Bald Cypress
Black Alder	Black Gum
Black Gum	Black Maple
Black Maple	Blue Spruce
Black Oak	Bradford Pear
Bur Oak	Bur Oak
Chinkapin Oak	Catalpa
Dogwood	Chanticlear Pear
Downy Hawthorn	Chinkapin Oak
Hackberry	Common Pear
Hop Hornbeam	Crabapple
Kentucky Coffeetree	Crescendo Sugar Maple
Linden	Crimson King Maple
Ohio Buckeye	Eastern Red Cedar
Paw Paw	Frontier Elm
Red Bud	Green Ash
Red Maple	Green Spruce
Red Oak	Homestead Elm
River Birch	Honey Locust
Sassafrass	Morton Glossy Elm
Service Berry	Norway Maple
Shagbark Hickory	Pin Oak
Shingle Oak	Red Oak
Swamp White Oak	Scottish Pine
White Ash	Service Berry
White Oak	Shingle Oak
Witch Hazel	State Street Maple
Yellowwood	Sugar Maple
	Swamp White Oak
	Vanderwolf Pine
	Weeping Spruce
	White Ash
	White Oak
	White Pine
	Yellow Buckeye

Figure 6. Comparison of species present in Children and Elders Forest versus excluding Children and Elders Forest in Normal, IL. Species that were present in only one of the two areas are highlighted in yellow. Current as of November 2013.

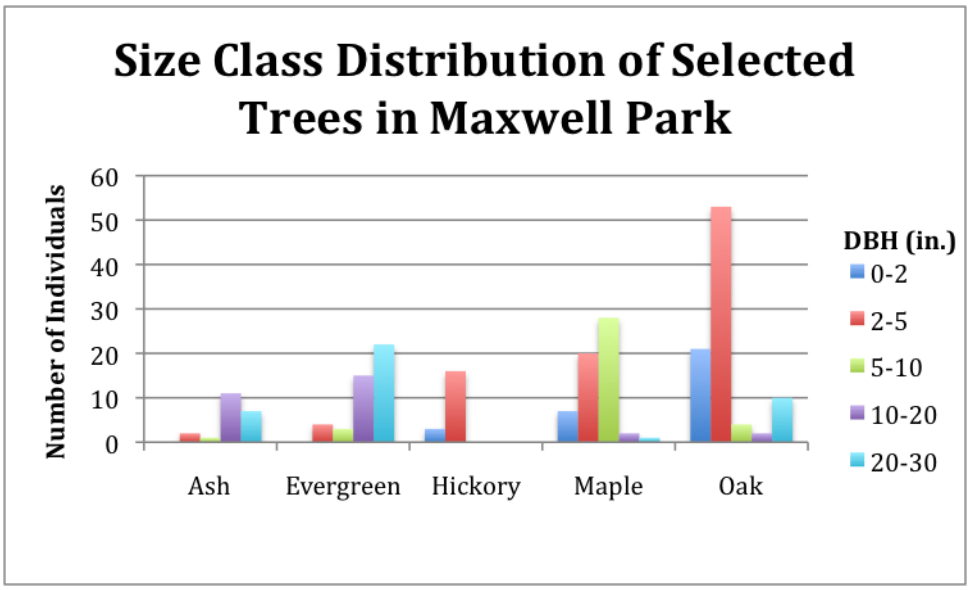

Figure 7. Size class distribution of selected trees in Maxwell Park, Normal, IL. The DBH (diameter at breast height) of trees was divided into five categories: 0-2 inches, 2-5 inches, 5-10 inches, 10-20 inches, and 20-30 inches. The evergreen category included the Juniperus, Picea, and Pinus genera. Current as of November 2013.

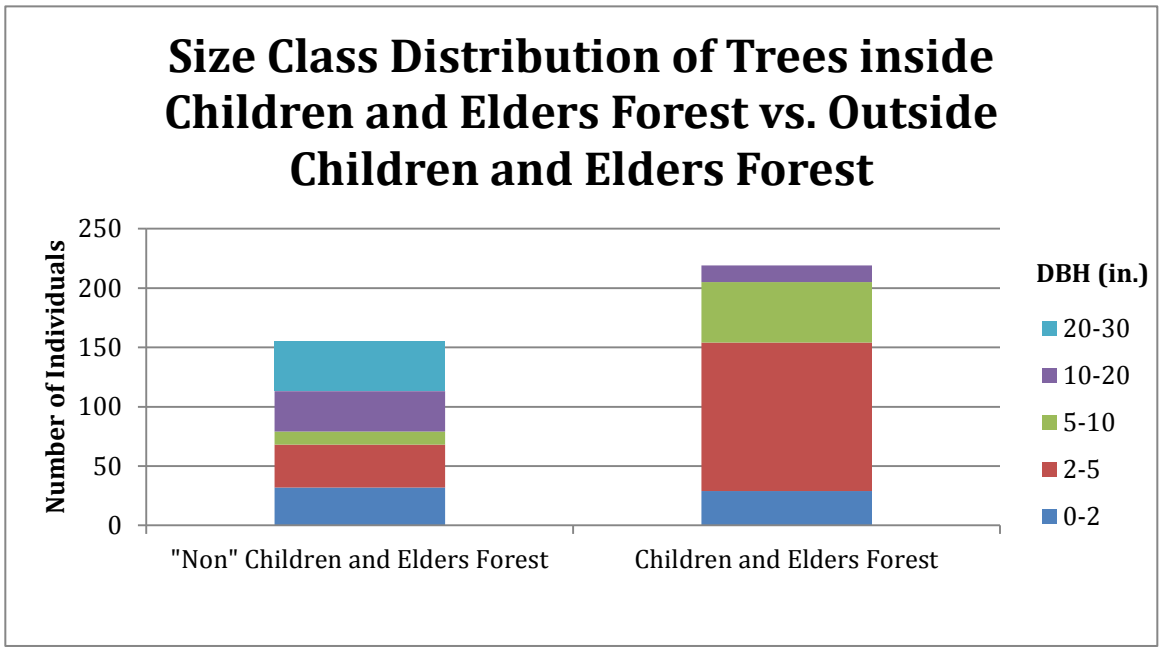

Figure 8. Size class distribution of trees inside Children and Elders Forest versus outside Children and Elders Forest, Normal, IL. Current as of November 2013.

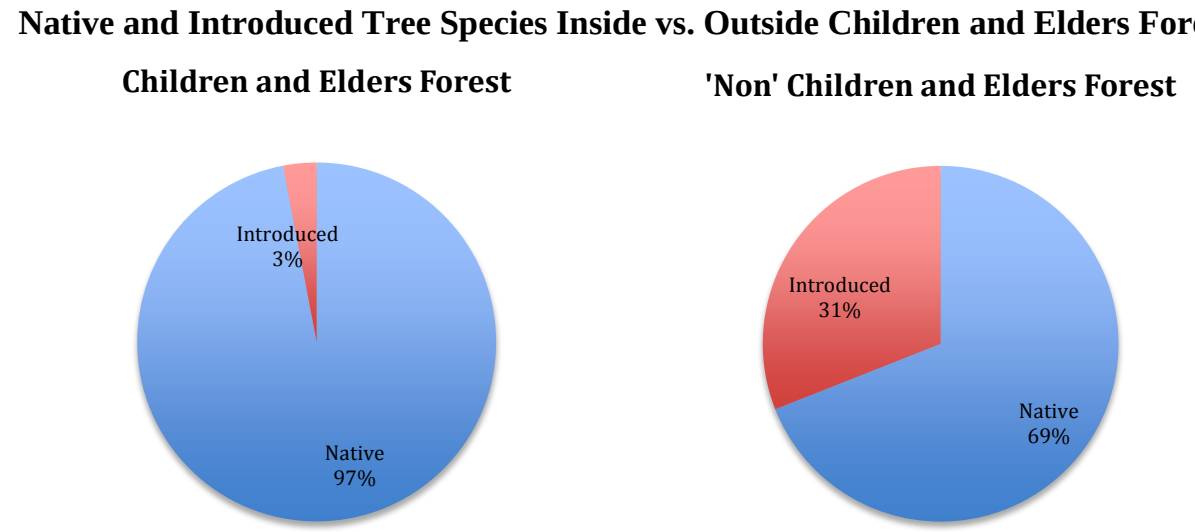

Figure 9. Comparison of native versus introduced species of trees located within and outside Children and Elders Forest, Normal, IL. Current as of November 2013.

Appendix E: *Timeline*
Assessing the Biodiversity and Susceptibility of Trees in Maxwell Park to Future Tree Pest and Disease Outbreaks Through the Use of a Tree Inventory

August 2013
- Contacted experts on the Emerald Ash Borer to assess the progress of Illinois in minimizing the impact of the EAB, as well as gaining advice for potential projects and contacts
- August 1: Research project description due
- August 8: Phone meeting with Mercy Davison, Town Planner for Normal
- August 23: Meeting with Garry Little, Director of Normal Parks & Recreation Department

September 2013
- Worked on memorizing tree species
- Conducted tree inventory for Maxwell Park with Randy Thorndyke and Bobby Jones
- September 3: Meeting with Randy Thorndyke, certified arborist for the Town of Normal
- Conducted tree inventory for Maxwell Park with Randy Thorndyke and Bobby Jones
- September 8: Revised research project description and timeline due
- September 19: IRB research project application
- September 22: Detailed literature review outline due

October 2013
- Conducted tree inventory for Maxwell Park with Randy Thorndyke and Bobby Jones
- October 3: Research project proposal due
- October 7: Written peer response #1 due
- October 25: Meeting with Julie from Normal Engineering Department
- October 25-November 2: Analyzed data from Maxwell Park inventory
- October 28: Worked with Carolyn Ashley (IWU student) to map Maxwell Park using GIS
- October 31: Interview with Jonathan Thayn, ISU professor
- October 31: Interview with Garry Little, Director of Normal Parks & Recreation Department

November 2013
- November 1: Interview with Mercy Davison, Town Planner for Normal
- November 1: Email interview with Mark Stahl, Garden Center Manager of Owen Nursery
- November 3: First draft of research project report due
- November 5: Interview with John Kostelnick, ISU professor
- November 8: Meeting with Joe Grabill, Director of Children and Elders Forest
- November 11: Written peer response #2 due
- November 14: Powerpoint presentation due
- November 18: Email interview with Kerry Grey, Urban Forestry & Natural Resources Planning Coordinator for Ann Arbor, MI
- November 24: Revised powerpoint presentation due
- November 26: Final research project report due

December 2013
- December 3: 15 minute community debriefing presentation
- December 5: Longer presentation to Garry Little, Mercy Davison, Bobby Jones, and Randy Thorndyke
- December 10: Research diary and consent forms due

Appendix F: List of candidate trees for planting in Central Illinois.
Adapted from the State of Illinois Emerald Ash Borer Reforestation Committee: "Increasing Tree Diversity in the Urban Landscape - Central Illinois"
(http://www.agr.state.il.us/eab/PDFs_for_web/Reforestation/Central_IL.pdf

- **For the purposes of overall diversity some commonly used trees have been omitted from this list of recomendations (ie. Honeylocust, Autumn Blaze Maple). This does not mean that they cannot be used, rather that the committee felt that their inclusion may have influenced reforestation efforts in such a manner as to create future pest and diversity problems due to current high populations.**
- When the species only is listed, then all cultivars and the species are recommended.
- When the species and cultivars are listed, then only the species and the selected cultivars are recommended.
- Northern Illinois is the region north of I-80. USDA Plant hardiness zones 4b(northwestern Illinois), 5a , and 5b(northeastern Illionis).
- Central Illinois is from I-80 on the north to I-70 on the south. USDA Plant hardiness zones 5a-5b.
- Southern Illinois the region south of I-70. USDA Plant hardiness zones 5b-6b.
- It is the recommendation of this committee that those trees provided to private property owners match the size being planted by the local government.
- The committee recommends that trees be purchased within 200 miles radius of their planting location.
- Trees may be purchased as bare-root, balled & burlapped (B&B), grow bag or container grown. Size requirements, availability and planting time restraints may be used to determine what harvesting method is acceptable for individual planting projects.
- Private Property designation includes residential, corporate, parks, golf courses, cemeteries or any other planting site other than the public right-of-way between the street curb and the adjacent private property line.
- City Parkway designation refers to the public right-of-way. The public right of way is measured from private property line to private property line and includes but is not limited to street surface, sidewalks, medians, plaza's, traffic circles, curbs and parkways or boulevards.
- All trees listed under the City Parkway designation are to be single stem (tree form).

Tree Species for Central Illinois				Planting Site				Other				
Common Name	Scientific Name			City parkway	Sidewalk cut out	Private property	Under wires	Salt tolerant	Spring planting best	Availability	Hardiness	Ease of Transplant
	Genus	Species	Cultivar									
White Fir	*Abies*	*concolor*				●				AV	GD	GD
Hedge Maple	*Acer*	*campestre*		●		●	●	●	●	AV	GD	GD
Miyabe Maple	*Acer*	*miyabei*		●		●	●			GD	GD	GD
State Street® Miyabe Maple	*Acer*	*miyabei*	Morton'	●		●	●			GD	GD	GD
Black Maple	*Acer*	*nigrum*		●		●				LTD	AV	AV
Sycamore Maple	*Acer*	*pseudoplatanus*		●	●	●		●	●	VLTD	AV-PR	AV
Fall Fiesta Sugar Maple	*Acer*	*saccharum*				●				AV	GD	AV
Green Mountain® Sugar Maple	*Acer*	*saccharum*	'PNI 0285'	●		●				AV	AV-PR	AV
Silver Queen Silver Maple	*Acer*	*saccharinum*	Silver Queen	●		●				NA	GD	GD
Skinner's Cut-leaved Silver Maple	*Acer*	*saccharinum*	Skinneri'	●		●				LTD	GD	GD
Norwegian Sunset® Maple	*Acer*		Norwegian Sunset®	●		●	●			LTD	GD	GD
Pacific Sunset® Maple	*Acer*		Pacific Sunset®	●		●	●			AV	GD	GD
Autumn Fantasy Maple	*Acer*	*x freemanii*	Autumn Fantasy'	●		●				GD	GD	GD
Marmo Maple	*Acer*	*x freemanii*	Marmo'	●		●				GD	GD	GD
Sienna Maple	*Acer*	*x freemanii*	Sienna'	●		●	●			LTD	GD	GD
Ohio Buckeye	*Aesculus*	*glabra*		●	●	●				AV	GD	AV
Baumann Horsechestnut	*Aesculus*	*hippocastanum*	'Baumannii'	●	●	●		●		LTD	GD	AV
Yellow Buckeye	*Aesculus*	*flava*		●		●			●	LTD	AV	AV
White Alder **	*Alnus*	*incana*				●				LTD	GD	GD
European Black Alder **	*Alnus*	*glutinosa*				●				GD	GD	GD
Apple Serviceberry	*Amelanchier*	*× grandiflora*		●		●	●			LTD	GD	GD
Allegheny serviceberry	*Amelanchier*	*laevis*		●		●	●			LTD	GD	GD
River Birch	*Betula*	*nigra*		●		●			●	GD	GD	AV
European Hornbeam	*Carpinus*	*betulus*		●		●			●	AV	GD	DIF
American Hornbeam	*Carpinus*	*caroliniana*		●		●	●		●	AV	GD	DIF
Bitternut Hickory	*Carya*	*cordiformis*				●			●	NA	GD	DIF
Shellbark Hickory	*Carya*	*laciniosa*				●			●	NA	GD	DIF
Pignut Hickory	*Carya*	*glabra*				●			●	NA	GD	DIF
Mockernut Hickory	*Carya*	*tomentosa*				●			●	NA	GD	DIF
Shagbark Hickory	*Carya*	*ovata*				●			●	VLTD	GD	DIF

Tree Species for Central Illinois				Planting Site				Other				
Common Name	Scientific Name			City parkway	Sidewalk cut out	Private property	Under wires	Salt tolerant	Spring planting best	Availability	Hardiness	Ease of Transplant
	Genus	Species	Cultivar									
Chinese Catalpa	*Catalpa*	*ovata*		●		●				LTD	GD	GD
Northern Catalpa	*Catalpa*	*speciosa*		●	●	●		●		GD	GD	GD
Sugarberry	*Celtis*	*laevigata*		●		●				LTD	GD	GD
Chicagoland Hackberry	*Celtis*	*occidentalis*	'Chicagoland'	●	●	●				LTD	GD	GD
Hackberry	*Celtis*	*occidentalis*		●	●	●				GD	GD	GD
Windy City Hackberry	*Celtis*	*occidentalis*	'Windy City'	●	●	●				LTD	GD	GD
Katsuratree	*Cercidiphyllum*	*japonicum*		●		●			●	GD	AV	AV
Eastern Redbud	*Cercis*	*canadensis*		●		●	●		●	GD	AV	GD
Whitebud	*Cercis*	*canadensis*	'Alba'	●		●	●		●	AV	GD	AV
American Yellowwood	*Cladrastis*	*kentukea*		●		●				LTD	GD	AV
Pagoda Dogwood	*Cornus*	*alternifolia*				●	●		●	AV	GD	GD
Flowering Dogwood	*Cornus*	*florida*				●	●		●	AV	GD	AV
Corneliancherry Dogwood	*Cornus*	*mas*		●		●	●		●	GD	GD	GD
Turkish Hazelnut	*Coryfus*	*columa*		●		●			●	AV	AV	AV
Thornless Cockspur Hawthorn	*Crataegus*	*crus-galli*	var. inermis	●		●	●		●	GD	GD	GD
Washington Hawthorn	*Crataegus*	*phaenopyrum*				●	●		●	GD	GD	GD
Winter King Green Hawthorn	*Crataegus*	*viridis*	Winter King'			●	●		●	GD	GD	GD
Persimmon	*Diospyros*	*virginiana*				●				LTD	GD	AV
Hardy Rubber Tree	*Eucommia*	*ulmoides*				●				VLTD	GD	AV
American Beech	*Fagus*	*grandifolia*				●			●	LTD	GD	DIF
Copper Beech	*Fagus*	*sylvatica*	(syn.'Cuprea')			●			●	GD	GD	DIF
Fern-leaved European Beech	*Fagus*	*sylvatica*	Asplenifolia'			●			●	AV	GD	DIF
Ginkgo, Male only	*Ginkgo*	*biloba*		●	●	●				AV	GD	GD
Magyar Ginkgo	*Ginkgo*	*biloba*	Magyar'	●	●	●				LTD	GD	GD
Princeton Sentry Ginkgo	*Ginkgo*	*biloba*	Princeton Sentry'	●	●	●				LTD	GD	GD
Kentucky Coffeetree	*Gymnocladus*	*dioicus*		●	●	●		●		GD	GD	GD
Silverbell	*Halesia*	*tetraptera*				●	●		●	LTD	GD	AV
Buttemut	*Junglens*	*cinerea*				●			●	LTD	GD	DIF
Black Walnut	*Juglans*	*nigra*				●		●	●	LTD	GD	DIF
Canaert Eastern Redcedar	*Juniperus*	*virginiana*	'Canaertii'			●		●	●	AV	GD	GD
Eastern Redcedar	*Juniperus*	*virginiana*				●		●	●	AV	GD	GD
Chinese Juniper	*Juniperus*	*chinensis*	Upright cultivers			●		●	●	AV	GD	AV
Moraine Sweetgum	*Liquidambar*	*styraciflua*	Moraine'	●	●	●			●	AV	GD	AV
Tuliptree	*Liriodendron*	*tulipifera*				●			●	AV	AV	AV
Cucumbertree magnolia	*Magnolia*	*acuminata*				●			●	AV	GD	AV
Korean Crabapple	*Malus*	*baccata*	var. *jackii*			●	●		●	GD	GD	GD
Beverly Crabapple	*Malus*		'Beverly'			●	●		●	GD	GD	GD
Cardinal Crabapple	*Malus*		'Cardinal'			●	●		●	GD	GD	GD
Purple Prince Crabapple	*Malus*		Purple Prince			●	●			GD	GD	GD
Red Jewel Crabapple	*Malus*		'Jewelcole'			●	●		●	GD	GD	GD
Red Peacock Crabapple	*Malus*		Red Peacock'			●	●		●	GD	GD	GD
Sargent's Crabapple	*Malus*	*sargentii*				●	●		●	GD	GD	GD
Golden Raindrops® Crabapple	*Malus*	*transitoria*	Schmidtcutleaf'			●	●		●	GD	GD	GD
Zumi Crabapple	*Malus*	*x zumi*				●	●		●	GD	GD	GD
Dawn Redwood	*Metasequoia*	*glyptostroboides*		●	●	●			●	VLTD	AV	AV
Black Gum, Tupelo	*Nyssa*	*sylvatica*				●			●	LTD	AV	AV
Ironwood	*Ostrya*	*virigniana*		●		●	●		●	AV	GD	GD
Black Hills Spruce	*Picea*	*glauca*	'Densata'			●		●		GD	GD	GD
Serbian Spruce	*Picea*	*omorika*				●		●		GD	GD	GD
Blue Spruce	*Picea*	*pungens*				●				GD	GD	GD
London Plane Tree	*Platanus*	*x acerifolia*	Exclamation	●	●	●		●	●	LTD	AV	GD
Robusta Poplar	*Populus*	*x euramerica*	'Robusta'	●		●		●	●	LTD	AV	GD
Siouxland Poplar	*Populus*	*deltoides*	'Siouxland'	●		●		●	●	LTD	AV	GD
Quaking Aspen	*Populus*	*tremuloides*				●		●	●	AV	AV	GD
Sargent Cherry	*Prunus*	*sargentii*		●	●	●			●	LTD	AV	GD
Japanese Flowering Cherry	*Prunus*	*serrulata*				●			●	LTD	AV	GD
Canada Red Choke Cherry	*Prunus*	*virginiana*	'Canada Red'	●	●	●				AV	AV	GD
Amur cherry	*Prunus*	*maackii*				●			●	LTD	AV	GD
Callery Pear **	*Pyrus*	*calleryana*	Cultivars	●	●	●			●	GD	GD	GD
Sawtooth Oak **	*Quercus*	*acutissima*		●		●			●	VLTD	GD	AV
White Oak	*Quercus*	*alba*				●			●	LTD	GD	DIF
Crimson Spire™ Oak	*Quercus*	*alba x robur*	Crimschmidt'	●	●	●			●	VLTD	GD	AV
Swamp White Oak	*Quercus*	*bicolor*		●	●	●			●	GD	GD	GD

Tree Species for Central Illinois				Planting Site				Other				
Common Name	Scientific Name			City parkway	Sidewalk cut out	Private property	Under wires	Salt tolerant	Spring planting best	Availability	Hardiness	Ease of Transplant
	Genus	Species	Cultivar									
Hill's Oak	*Quercus*	*ellipsoidalis*		●		●			●	AV	GD	GD
Shingle Oak	*Quercus*	*imbricaria*		●		●			●	AV	GD	AV
Bur Oak	*Quercus*	*macrocarpa*		●		●			●	GD	GD	DIF
Chinkapin Oak	*Quercus*	*muehlenbergii*		●		●			●	AV	GD	AV
Chestnut Oak	*Quercus*	*prinus*		●		●			●	VLTD	GD	AV
English Oak	*Quercus*	*robur*		●	●	●		●	●	LTD	GD	AV
Regal Prince English Oak	*Quercus*	*robur*	Regal Prince	●	●	●			●	GD	GD	AV
Skymaster® English Oak	*Quercus*	*robur*	Pyramich'	●	●	●			●	LTD	GD	AV
Heritage® Macdaniel's Oak	*Quercus*	*x macdanielii*	Clemons'	●	●	●		●	●	VLTD	GD	AV
Red Oak	*Quercus*	*rubra*		●		●			●	AV	GD	AV
Shumard's Oak	*Quercus*	*shumardii*		●		●			●	LTD	GD	AV
Chicago Blues Black Locust	*Robinia*	*pseudoacacia*	Chicago Blues'	●	●	●		●	●	LTD	AV	AV
Scholar tree	*Sophora*	*japonica*		●		●				VLTD	GD	AV
China Snow® Peking Lilac	*Syringa*	*pekinensis*	Morton'	●		●	●		●	GD	GD	GD
Ivory Silk Japanese Tree Lilac	*Syringa*	*reticulata ssp. reticulata*	'Ivory Silk'	●	●	●	●	●		GD	GD	GD
Summer Snow Japanese Tree lilac	*Syringa*	*reticulata ssp. reticulata*	'Summer Snow'	●	●	●	●	●		LTD	GD	GD
Pondcypress	*Taxodium*	*ascendens*		●	●	●			●	VLTD	PR	AV
Baldcypress	*Taxodium*	*distichum*		●	●	●		●	●	GD	GD	GD
Shawnee Brave	*Taxodium*	*distichum*	Shawnee Brave	●	●	●		●	●	GD	GD	GD
American Linden	*Tilia*	*americana*		●		●				AV	GD	GD
Boulevard Linden	*Tilia*	*americana*	'Boulevard'	●		●				LTD	GD	GD
Legend™ Linden	*Tilia*	*americana*	Wandell'	●		●				LTD	GD	GD
Redmond Linden	*Tilia*	*americana*	Redmond	●		●				GD	GD	GD
American Sentry Linden	*Tilia*	*americana*	American Sentry	●		●				GD	GD	GD
Bigleaf Linden	*Tilia*	*platyphyllos*		●		●				LTD	GD	GD
Green Mountain® Silver Linden	*Tilia*	*tomentosa*	PNI 6051	●		●				VLTD	GD	GD
Sterling Silver™ Silver Linden	*Tilia*	*tomentosa*	Sterling'	●		●				LTD	GD	GD
Prospector Wilson's Elm	*Ulmus*	*wilsoniana*	Prospector'	●	●	●				AV	GD	GD
Regal Elm	*Ulmus*	*carpinifolia*	Regal'	●	●	●				AV	GD	GD
Commendation Elm	*Ulmus*	*carpinifolia*	Commendation	●	●	●				AV	GD	GD
Triumph™ Elm	*Ulmus*		Morton Glossy'	●	●	●				GD	GD	GD
Lacebark Elm	*Ulmus*	*parvifolia*				●			●	AV	AV	GD
Village Green Japanese Zelkova	*Zelkova*	*serrata*	'Village Green'	●	●	●		●	●	LTD	AV	AV

**** These species may be invasive and should not be planted in or adjacent to natural areas.**

List Key:

City Parkway	The city parkway refers to a predominantly, continuous soil planting area within the public right-of-way, typically adjacent to the curb line of a street.
Sidewalk Cut-out	A sidewalk cut-out refers to an opening in a sidewalk completely surrounded by concrete, asphalt, or pavers.
Private Property	Private property includes residential, corporate, parks, golf courses, cemeteries, or any other landscaped planting site not within the public right-of-way.
Under Wires	Smaller trees better suited for planting under utility wires.
Salt Tolerant	Salt tolerant trees are recommended for use in areas which are subject to road salt.
Spring Planting Best	Trees which may require spring planting or at least to be nursery dug in the spring to improve establishment and survivability rates.
Availability	
GD =	Good: commonly available in most nurseries
AV =	Average: available in many nurseries
LTD =	Limited: available in some nurseries in limited quantities
VLTD =	Very Limited: somewhat difficult to find in nurseries
NA =	Not Available: currently no known growers
Hardiness	
EX =	Excellent: good overall survivability
GD =	Good: performs well
AV =	Average: grows within the area
AV-PR=	Average to Poor: may grow within protected sites but otherwise not survive in exposed sites.
Ease of Transplant	
GD =	Good: Easily transplantable
AV =	Average: Transplants reasonably well
DIF=	Difficult: Requires special consideration for successful transplant

The document was developed by the State of Illinois Emerald Ash Borer Reforestation Committee, a sub-committee of the Governor's Emerald Ash Borer Management & Science Advisory Panel .