Point-Centered-Quarter Analyses of Two Woodlands in East-Central Indiana

By Holly Baltzer

Point-Centered-Quarter Analyses of Two Woodlands in East-Central Indiana

An Honors Thesis (HONRS 499)

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Abstract

Point-Centered-Quarter sampling of the canopy layer (trees with a diameter at breast height of 10 cm or greater) in two forests, Frank and Phyllis Yuhas Woods and Duning Woods Nature Preserve, in East-Central Indiana was performed for this thesis. This method allows for the calculation of frequency, basal area, density and importance values of each tree species within the woods. These statistics will be reported for each study site. They will be used to determine the presence, distribution, and abundance of plant life, as well as used to place each forest within a classification system that allows for comparisons between woodlands. This study encompasses three habitats, a floodplain woods and upland woods at Yuhas, and a ravine forest at Duning. It also speculates on several possible mechanisms for, and consequences of, ecological change within the two woodlands. These studies provide baseline information of the two woods in the hopes that the data will aid future management decisions.

Acknowledgements

I would like to say a special thanks to Don Ruch, my advisor, for all of his help, for sharing his knowledge, and for teaching me so much. I would like to thank Byron Torke and Benjamin Hess for their help in the field, especially with tree identification. I also thank the Red Tail Nature Conservancy and the Whitewater Valley Land Trust for allowing me to study their woodlands. Lastly, I thank Barry Banks, Larry Gibbons, and Michael Hoff for the information on the two woods they provided.

Introduction to Studies

The two studies that comprise this thesis represent work done through out the last two years of my undergraduate degree. The Yuhas study was done mostly in my junior year. I collected and analyzed the data in the fall of 2005, and most of the following article was written by the end of spring in 2006. I presented the findings of this study at the Indiana Academy of Science Annual Conference in November, 2006. I collected the data for the Dunning study in the fall of 2006, the beginning of my senior year. The analysis and following manuscript were completed in early spring 2007. Both of these studies will appear as contributions to publications with my advisor, Dr. Donald Ruch, and many others, describing the woodlands of East-Central Indiana.

I have experienced tremendous personal growth during the course of this thesis. For this reason, I will concentrate my introduction on the development and clarification of my personal passions during my studies. Please note that my experiences have taught me a great deal of the physical mechanisms and processes of life, as well as a great deal about the methods of science that will be necessary in my career as a biologist. Also realize than I have learned more from my work in these past few years than I could ever hope to portray in this short introduction. The following are only examples of the enormous growth I have experienced.

The Yuhas study was my first introduction to field science. This was the first time I had experienced long, hard days in the field. My days at Yuhas were filled with important lessons for the development of a budding scientist. For example, one small lesson I learned began on our first day of sampling with the discovery that the distance measuring device we planned to use was not working. This meant that instead of pointing a small, hand held remote at a portable post set on our point and getting a distance measure, we had to string tape from the point to every tree we sampled. Our time per point was greatly increased. A few days later we were able to get the distance measure to work. When this happened, I realized how amazingly important having the proper equipment can be. This revelation seems like common sense, and it is in part. However, by experiencing the consequences, this lesson will forever be cemented into my methods of science, and I believe it will serve me well in the future.

I also learned a more significant lesson on the first day of sampling at Yuhas, a lesson that I hope will stick with me for the rest of my career. The terrain of the upland portion of Yuhas began flat and relatively easy to navigate. However, it was not long before we hit out first patch of stinging nettles. For those readers who do not frequently venture into woodlands without paths, stinging nettles hurt. Dr. Ruch and I had previously created a systematic sampling method for Yuhas Woods. We ran a line straight in a pre-determined direction and followed the line no matter where it took us. We followed the line through stinging nettles, skunk cabbage, multi-flora rose and numerous other obstructions. We did this because to deviate from our sampling method would introduce bias into our data, making the results of our long, hard field days garbage. The Yuhas study taught me about the problem of bias. This occurs when the method of sampling produces data that are not representative of the true nature of the subject being studied. These skewed data can then result in skewed statistical analyses that do not accurately portray the true nature of the system being studied. The statistics determine the conclusions drawn about the system. Therefore, if the data are inaccurate, the conclusions will be inaccurate and the study is worthless.

The last revelation that my time at Yuhas provided me that I wish to discuss was one that I would not fully comprehend the value of until the following year, when I returned to the forest for data collection at Duning. As I mentioned, Yuhas was the first time I had ever spent all day out in the field working for a scientific purpose. The days were long and hot (it was August, so I daresay really hot!). At times getting from point to point was painful, and at each point the work was the same; find point, make quadrants, find closest trees, collect the necessary data on trees, find the next point, over and over again. What I realized at Yuhas was that I loved what I was doing. No matter how tired I became, I wanted to wake up the next morning and go do it again. No matter how monotonous the sampling could get, I came to each point ready and excited to do the job. My time at Yuhas dispelled all doubt about the path I have chosen for my future. Biology, studying life, is what will fulfill my life and make me happy.

While my time at Yuhas helped to develop my love for studying life, my next two field experiences (the work from one does not appear in this thesis) played crucial roles in the clarification of my love for studying life. I spent the summer between data collection at Yuhas and data collection at Duning as a field research assistant to Dr. Candace Galen from the University of Missouri, working at an alpine field station in the mountains of Colorado. Working in an alpine environment is extremely different than working in a deciduous forest. To me, the beauty of alpine life is encompassed within the harsh realities of survival. Life clings to the surface of the earth, because any part that ventures to high is subject to the extreme winds and cold of the mountain air and can be destroyed. Treacherous rock beds are strewn all over the alpine, some harboring the occasional wildflower or rock covered in lichen, but many completely barren.

Conversely, the beauty of a forest is encompassed within the lushness and richness of the life it holds. Every sense in ones body is overwhelmed with life. Trees surround from above, bushes and shrubs encompass from all sides, grasses and flowers are always underfoot, the air is forever filled with the buzzing of insects and the cries of birds; life in a forest is inescapable and magnificent.

I could see the differences between these two environmental systems from the start of my summer work, but it was not until I returned to my work in a forest at Duning that I realized how differently the two environments affect me personally. Sampling in Duning was much smoother with far fewer problems than sampling in Yuhas. The woods were more open, there were no nettles, our equipment worked, and it was overall much less demanding. This gave me the opportunity to search within myself a little as I was in the woods. I realized being in a forest made me feel a totally different type of exhilaration than being on top of a mountain. The alpine is a typical, 'I'm on top of the world' sensation. In a forest, standing at the base of a tree old enough to be my great-grandfather humbles me, comforts me, and makes me feel connected to life in a way I never felt standing on top of a mountain. Kneeling down to a rock with great-grandfather old lichen is just not the same. While both environments are fantastic and awesome elements in the web of life, I have learned through the culmination of all my research experiences that I belong in a forest.

I should note that Dr. Ruch and I were not able to sample all the sections of Duning Woods that we had originally intended to sample. Please bear in mind there is much more to Duning Woods than I have reported here. I submit this thesis for review in two chapters, one for each study, because the two studies should be read as independent works. Enjoy.

POINT-CENTERED-QUARTER ANALYSIS OF THE MATURE TREES IN THE UPLAND AND FLOODPLAIN FORESTS AT FRANK AND PHYLLIS YUHAS WOODS, RANDOLPH COUNTY, INDIANA

ABSTRACT

Frank and Phyllis Yuhas Woods is a 33.6 ha (~ 83 acre) tract with forest, old field and various wetland communities in Randolph County, Indiana. It is an important natural area in East-Central Indiana due to its location on Cabin Creek and its high botanical diversity. Using a systematic Point-Centered-Quarter technique to analyze the mature tree vegetation, this study documented 29 tree species in the upland forest and 19 in the floodplain forest for a total of 35 different species. The dominant species in the upland forest was *Acer saccharum*, and in the floodplain forest was *Tilia americana*. Based on the classification use by Lindsey et. al. (1965), Yuhas Woods is best classified as a mixed woods. However, without the selective logging of *Quercus* species and the suppression of fire, it is probable that Yuhas Woods would have qualified as an oak-hickory forest. A comparison of species composition and forest structure between Yuhas Woods and other forested areas of East-Central Indiana is discussed. Lastly, the data obtained from this study will assist The Red Tail Nature Conservancy in properly managing, and even enhancing, this valuable resource.

KEY WORDS: Point-centered-quarter, Randolph County, Indiana, forest composition, floodplain forest, mixed forest, oak-hickory forest.

INTRODUCTION

Current surveys have indicated that Frank and Phyllis Yuhas Woods could be one of the most botanically rich and diverse natural area's in East-Central Indiana (Ruch, Personal Communication). It is important to inventory and classify natural lands, such as Yuhas Woods to have documentation of their structure and composition through time (Reidy, 2002). To the knowledge of this investigator, no such survey or inventory has been published on this site.

The composition of the mature trees in a forest can tell much about its overall structure and habitat. The Point-Centered-Quarter (PCQ) technique employed in this study provides basic statistics, such as frequency, basal area, density, and importance values (Cottam and Curtis, 1956), which can be used to determine the presence, distribution, and abundance of plant life. These data will provide the basis to place Yuhas Woods into a classification system that will aid in comparing Yuhas with other woods in Indiana and beyond (Reidy, 2002). This inventory will also serve to document the importance of preserving natural areas such as Yuhas Woods in Indiana.

It is intended that the results and conclusions of this research will assist The Red Tail Nature Conservancy in properly managing and conserving this valuable resource. This study will focus on the tree vegetation of Yuhas Woods and is part of a larger project examining the vegetation and community structure of the site. The goal of this study is to initiate monitoring of the upland and floodplain forests so that changes in their composition can be tracked through time. In addition, the recent disturbance history of the site will be examined to ascertain any anthropogenic effects on the woods. Finally, a comparison of Yuhas Woods to other woodland areas in East-Central Indiana will be performed.

STUDY SITE

Frank and Phyllis Yuhas Woods, located in Randolph County, Indiana, lies south of State Road W 400 S next to Vectren Energy (Figure 1). The property consists of 33.6 ha with approximately 30 ha being woodland (Banks, Director of The Red Tail Nature Conservancy, Personal Communication). The portion not covered by forest includes two old fields and a complex wetland. These non-forested areas lie to the south and to the east of the Vectren Energy complex, extending to the eastern boundary (Figure 1). The purchase of the property, by The Red Tail Nature Conservancy at auction in February of 2005, was made possible by donations provided by Mrs. Phyllis Yuhas of $200,000 and Mr. Danny Huston for the remainder of the $345,000 auction price. The land, previously owned by American Heritage Farm Inc. headed by Steve Cullison, had been in the Cullison family for at least one generation (Banks, Personal Communication).

Yuhas Woods lies in the Tipton Till Plain section of the Central Till Plain Natural Region. This region of Indiana was comprised of beech-maple forests with scattered sections of oak-hickory forests during presettlement times (Homoya et al., 1985). It is now mostly agricultural land with scattered woodlots. The soils of Yuhas Woods are silt loams to silty clay loams in the upland portions, and Sloan silt loam in the floodplains (Neely, 1987). Cabin Creek runs through the east side of the woods and occasionally overflows into the floodplain region. The upland portion is nearly flat.

Several areas of the property were not sampled (Figure 1). The area directly east of Cabin Creek was not sampled because it is a very steep incline up to a small portion of

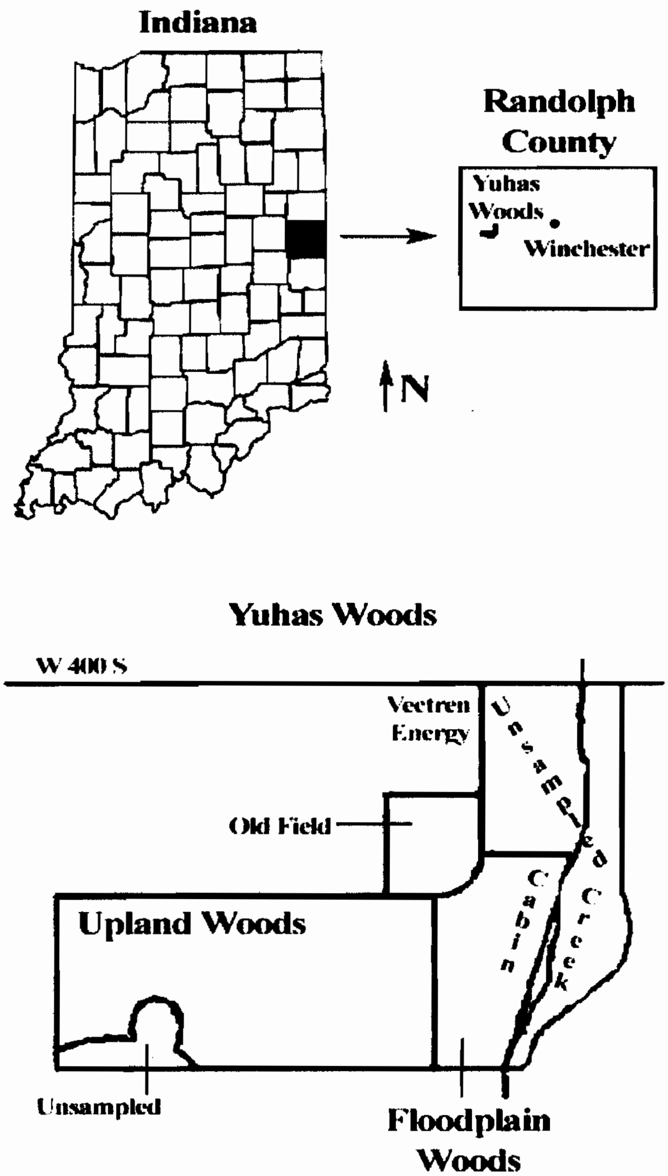

Figure 1. Map showing the location of Yuhas Woods in Indiana (top left), the location of Yuhas Woods in Randolph County (top right), and the distribution of habitats at Yuhas Woods (bottom).

woods that is no longer floodplain. The area directly north of the floodplain was not sampled because it is marshy and non-wooded, and the area directly north of that extending to the border of Yuhas Woods was not sampled because it is young successional forest and the inclusion of these areas would have skewed the remainder of the data. The area in the southwest corner of Figure 1 was not sampled because it contains a button-bush swamp, a large heron rookery that was best left undisturbed, and a sedge meadow.

METHODS

Data Collection.-The collection of data for the upland forest and the floodplain forest took place in August and September of 2005, respectively. The Point-Centered-Quarter (PCQ) method was used to sample stems greater than or equal to 10 cm dbh (diameter at breast height). PCQ is a plotless method in which the area around a point is divided into four quadrants and the distance measures from the central point are used to estimate density (Reidy, 2002) (Figure 2). Points were located systematically in both areas. For the upland woods, transects were oriented north-south 25 m apart, and points were taken every 25 m along each transect. Sampling began 25 m from the edges of the northeast corner. After sufficient data were collected, the last two transects were spaced 50 m apart. For the floodplain forest, transects were oriented approximately north-south parallel to Cabin Creek and were 20 m apart with points taken every 20 m along each transect. Sampling began from a permanent metal pole in the northwest corner of the woods just west of Cabin Creek.

At each sample point four quadrants were defined using the tape as the north-south boundary and imposing an imaginary line perpendicular to the tape for the

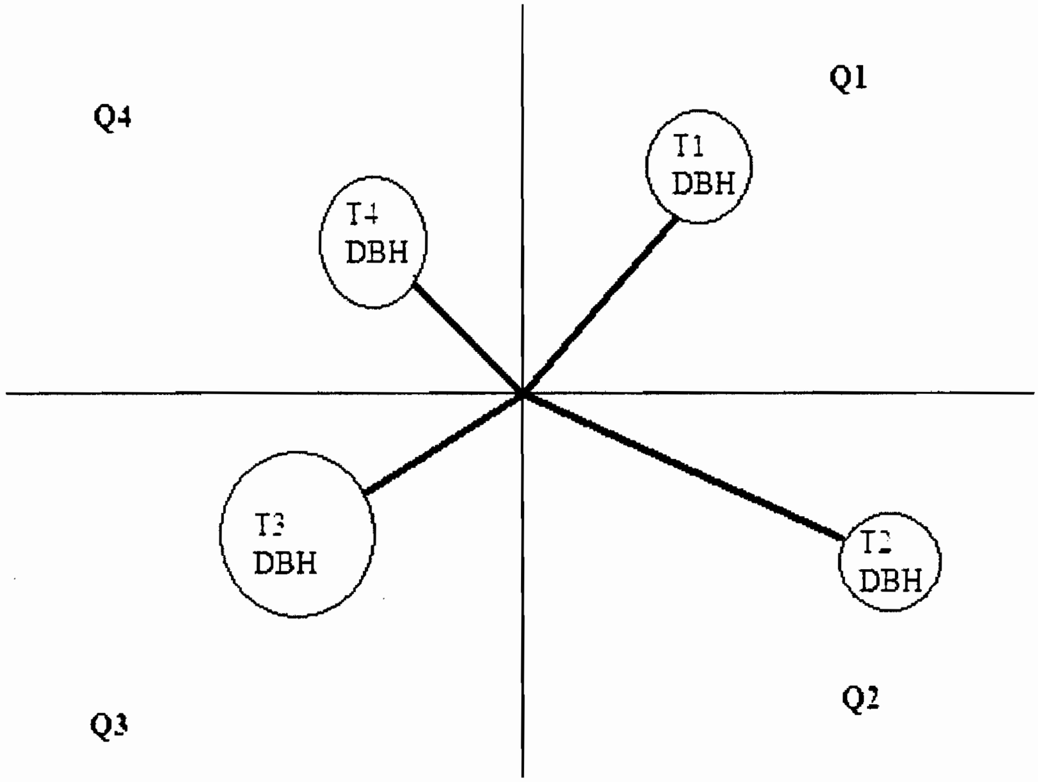

Figure 2. Diagram of PCQ sampling method. Area around each point was divided into four quadrants, the nearest tree with a dbh greater than or equal to ten cm was found. dbh, species name and distance from point were recorded. Adapted from figure in Reidy, 2002.

east-west boundary. Quadrants were then numbered from one to four with quadrant one being the first clockwise quadrant from north (Reidy, 2002). The nearest tree to the point in each quadrant with a dbh greater than or equal to 10 cm was selected. For each tree selected, the dbh (to the nearest 0.1 cm), the distance from the middle of the stem to the point (to the nearest 0.1 m), the species, and any pertinent observations concerning the site were recorded. Distance measurements were made using a Haglof Forestor DME 201 Distance Measuring Kit

Analyses of Data.-Data were analyzed to obtain information on the structure and composition of both woodland types. Stem density, in stems per ha for each species, was determined. To do this, the relative density, RDEN (the percent density of one species compared to all species per ha) was computed by dividing the number of individual trees per species by the total number of trees sampled and multiplying by 100. The average density (AVGDEN) was computed by dividing 10,000 (the factor to convert meters into hectares) by the square of the mean distance for all trees in meters. Lastly, Density (DEN) was determined using the following equation:

$$DEN = (RDEN / 100) \times AVGDEN$$

Next, the relative basal area, RBA (the percent basal area for one species compared to the total basal area for all species), was calculated. First, the dbh in centimeters for each tree was converted to a basal area in m^2 using the following equation:

$$\text{Basal area per tree} = \pi\,(dbh / 2)^2 / 10{,}000$$

The average basal area (AVGBA) for each species was then determined by summing the basal areas of all the trees of a species and dividing by the total number of trees for that species. The basal area per species (BA), in m^2, was then calculated by multiplying the AVGBA by the DEN for each species. Finally, the relative basal area (RBA) for each species was determined by dividing the BA per species by the total BA for all species and multiplying by 100.

Next, relative frequency, RFREQ (the percent frequency of one species per ha compared to all species), was determined. To do this, the frequency (FREQ) for each species was computed by dividing the total number of points at which a species occurred by the total number of points sampled, 105 for the upland woods and 32 for the floodplain woods. RFREQ was then calculated using the following equation:

RFREQ = (FREQ per species / total FREQ of all species) x 100

Lastly, the importance value (IV) for each species was calculated by summing the RDEN, RFREQ and RBA; and the relative importance value (RIV) for each species was calculated by dividing the IV for each species by three.

Size class distributions for the six most dominant species, based on RIV, in the upland woods were delineated, and the densities for each size class of each species were calculated. Nomenclature follows Gleason and Cronquist (1991).

RESULTS

From the upland woods, a total of 29 species with a dbh greater than or equal to 10 cm were documented in this study (Table 1). *Acer saccharum* was found to rank highest in relative importance (RIV = 25.5), and was by far the most dominant species in this portion of the woods. This was due to its high frequency of smaller sized trees (Table 1 & 2). *Quercus alba* (RIV = 12.5) and *Ulmus rubra* (RIV = 9.3) were the next important and the only other species with relative importance values above 9.0. The high RIV of *Q.*

Table 1. Data for upland area of Yuhas Woods; species are listed by the relative importance values. Density (DEN) is the number of stems per hectare. Relative density (RDEN) is the number of individuals of a species relative to the total number of trees expressed as a percent. Basal area (BA) is the meters squared per hectare of each species. Relative basal area (RBA) is the total basal area of a species relative to the total basal area of all species express as a percent. Frequency (FREQ) is the proportion of plots in which a species occurred relative to the total number of plot. Relative frequency (RFREQ) is the frequency of each species relative to all species expressed as a percent. Importance value (IV) is the sum of RDEN, RBA and RFREQ. Relative importance value (RIV) is the average of RDEN, RBA, and RFREQ expressed as a percent.

Species	**DEN**	**RDEN**	**BA**	**RBA**	**FREQ**	**RFREQ**	**IV**	**RIV**
Acer saccharum Marsh.	137.5	31.7	6.3	21.1	0.7	23.7	76.5	25.5
Quercus alba L.	39.3	9.0	5.4	18.2	0.3	10.1	37.4	12.5
Ulmus rubra Muhl.	42.4	9.8	2.0	6.9	0.3	11.2	27.8	9.3
Carya ovata (Mill.) Koch	32.0	7.4	1.7	5.9	0.2	7.8	21.0	7.0
Prunus serotina Ehrh.	32.0	7.4	0.9	3.2	0.2	7.1	17.6	5.9
Carya cordiformis (Wang.) Koch	25.8	6.0	1.7	5.9	0.2	5.4	17.2	5.7
Aesculus glabra Willd.	21.7	5.0	0.6	2.1	0.1	4.7	11.8	3.9
Fraxinus pennsylvanica Marsh.	12.4	2.9	1.5	5.0	0.1	3.0	10.9	3.6
Juglans nigra L.	8.3	1.9	1.4	4.7	0.1	2.7	9.3	3.1
Liriodendron tulipifera L.	9.3	2.1	1.1	3.6	0.1	2.4	8.1	2.7
Quercus rubra L.	8.3	1.9	1.1	3.7	0.1	2.4	8.0	2.7
Quercus muhlenbergii Engelm.	6.2	1.4	0.8	2.8	0.1	2.0	6.3	2.1
Celtis occidentalis L.	10.3	2.4	0.3	0.9	0.1	2.7	6.0	2.0
Acer saccharinum L.	5.2	1.2	1.2	4.1	0.02	0.7	6.0	2.0
Ulmus americana L.	9.3	2.1	0.2	0.5	0.1	3.0	5.7	1.9
Fraxinus americana L.	8.3	1.9	0.3	1.0	0.1	2.7	5.6	1.9
Carya glabra (Mill.) Sweet	6.2	1.4	0.5	1.9	0.1	2.0	5.3	1.8
Quercus palustris Munchh.	1.0	0.2	0.9	3.1	0.01	0.3	3.7	1.2
Ostrya virginiana (Mill.) Koch	5.2	1.2	0.1	0.3	0.05	1.7	3.1	1.0
Fagus grandifolia Ehrh.	2.1	0.5	0.4	1.4	0.02	0.7	2.5	0.8
Quercus velutina Lam.	2.1	0.5	0.2	0.7	0.02	0.7	1.9	0.6
Tilia americana L.	2.1	0.5	0.1	0.4	0.02	0.7	1.5	0.5
Gymnocladus dioica (L.) Koch	1.0	0.2	0.3	0.9	0.01	0.3	1.5	0.5
Nyssa sylvatica Marsh.	1.0	0.2	0.2	0.6	0.01	0.3	1.2	0.4
Acer rubrum L.	1.0	0.2	0.1	0.5	0.01	0.3	1.1	0.4
Populus deltoides Marsh.	1.0	0.2	0.1	0.4	0.01	0.3	1.0	0.3
Carya laciniosa (Michx.) Loudon	1.0	0.2	0.1	0.2	0.01	0.3	0.8	0.3
Cercis canadensis L.	1.0	0.2	0.03	0.1	0.01	0.3	0.7	0.2
Carpinus caroliniana Walter	1.0	0.2	0.01	0.04	0.01	0.3	0.6	0.2

Table 2. Data for floodplains of Yuhas Woods; species are listed by the relative importance values. See Table 1 for an explanation of terms.

Species	DEN	RDEN	BA	RBA	FREQ	RFREQ	IV	RIV
Tilia americana L.	45.8	13.3	2.6	11.2	0.4	12.7	37.2	12.4
Aesculus glabra Willd.	51.2	14.8	1.4	6.3	0.4	12.7	33.9	11.3
Acer negundo L.	48.5	14.1	1.5	6.5	0.4	12.7	33.3	11.1
Acer saccharum Marsh.	26.9	7.8	3.7	16.4	0.2	6.9	31.1	10.4
Fraxinus nigra Marsh.	32.3	9.4	2.7	11.7	0.3	9.8	30.9	10.3
Quercus macrocarpa Michx.	18.9	5.5	4.2	18.7	0.2	5.9	30.0	10.0
Fraxinus pennsylvanica Marsh.	29.6	8.6	1.2	5.1	0.3	8.8	22.5	7.5
Carpinus caroliniana Walter	24.3	7.0	0.4	1.9	0.3	7.8	16.7	5.6
Juglans nigra L.	10.8	3.1	1.0	4.2	0.1	3.9	11.2	3.7
Ulmus rubra Muhl.	16.2	4.7	0.4	1.6	0.2	4.9	11.2	3.7
Platanus occidentalis L.	2.7	0.8	1.8	7.7	0.03	1.0	9.5	3.2
Liriodendron tulipifera L.	5.4	1.6	0.9	4.0	0.03	1.0	6.5	2.2
Ostrya virginiana (Mill.) Koch	8.1	2.3	0.1	0.4	0.1	2.9	5.7	1.9
Cercis canadensis L.	8.1	2.3	0.1	0.3	0.1	2.9	5.6	1.9
Quercus bicolor Willd.	2.7	0.8	0.6	2.4	0.03	1.0	4.2	1.4
Crataegus punctata Jacq.	5.4	1.6	0.1	0.5	0.1	2.0	4.0	1.3
Quercus muhlenbergii Engelm.	2.7	0.8	0.1	0.6	0.03	1.0	2.4	0.8
Fraxinus americana L.	2.7	0.8	0.1	0.3	0.03	1.0	2.0	0.7
Ulmus americana L.	2.7	0.8	0.05	0.2	0.03	1.0	2.0	0.7

alba was due primarily to one very large stem (Figure 3), since its frequency was much less than *A. saccharum*. Like *A. saccharum*, the RIV of *U. rubra* was due to a high frequency of small stems. *Carya ovata* ranked fourth with a RIV of 7.0 and was followed by a steady decline in RIV by *Prunus serotina* (5.9) and *Carya cordiformis* (5.7). No other species in the upland woods had a RIV above 5.0 (Table 1). The RIV for all *Quercus* species (e.g., *Q. alba, Q. muehlenbergii, Q. palustris, Q. rubra,* and *Q. velutina*) was 19.1, for all *Carya* species (e.g., *C. cordiformis, C. glabra,* and *C. ovata*) was 14.5, and for all *Fraxinus* species (e.g., *F. americana* and *F. pennsylvania*) was 5.5.

The densities of the top six important species in the upland forest were broken into size classes (Figure 3 & Table 3). *Acer saccharum* had the highest density in size classes of 49.9 cm dbh and lower, and in the 60-69.9 cm dbh class. *Quercus alba* had a higher density in classes 50-59.9 cm and 70-79.9 cm dbh, but was not found in class 60-69.9 cm dbh. None of the other top four species, based on RIV, were found in a class higher than 40-49.9 cm dbh. The density of *A. saccharum* peaks in the lowest size class and progressively declines in the larger classes. Only one stem was found in its highest size class, whereas 91 stems were found in its smallest size class. *Ulmus rubra*, *Prunus serotina*, and *Carya ovata* also have their greatest densities in the lower size classes (Table 3). High numbers in the lower size classes suggests that these species are replacing themselves. *Carya cordiformis* and *Q. alba* had their highest densities in about the middle of their size class ranges. The absence of *Q. alba* stems in the larger size classes is probably due to the logging that occurred before the land was acquired by The Red Tail Nature Conservancy (Gibbons, land owner neighboring Yuhas Woods, Personal Communication). The lower density of stems of *Q. alba* in the smallest size class may

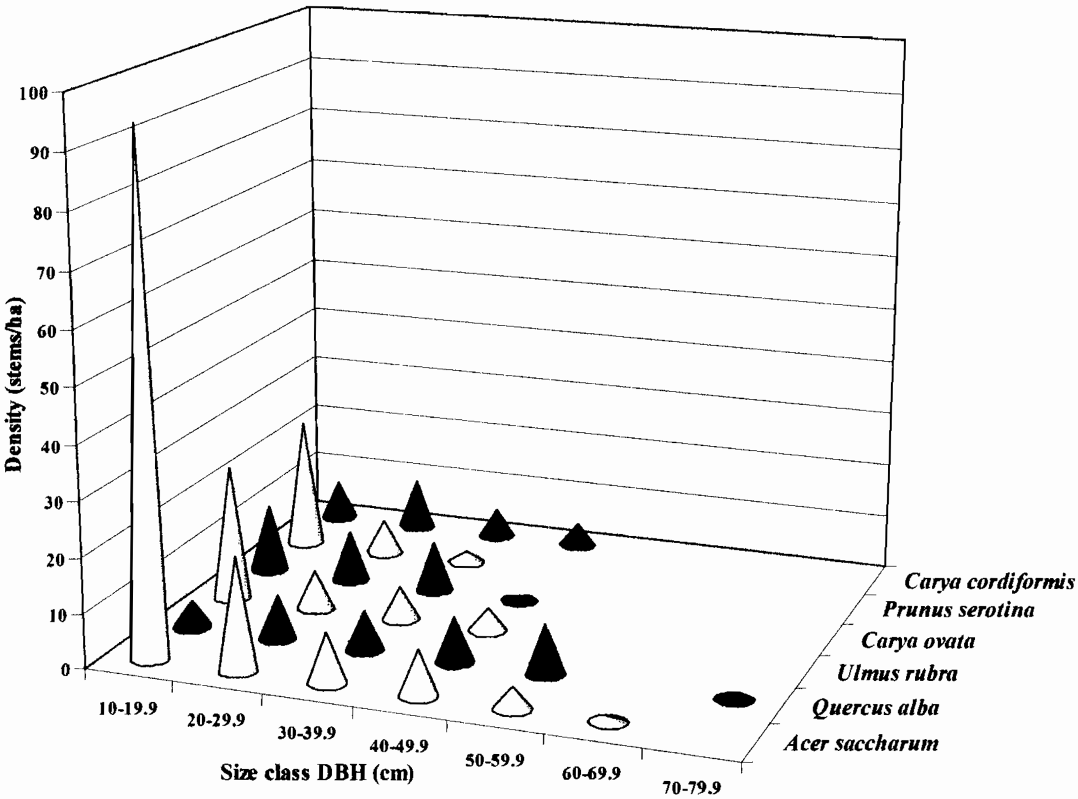

Figure 3. Shown here is the density distribution of size classes for the top six important species of the upland woods.

Table 3. Size class data for the top six most important species in the upland woods.

Species	10-19.9	20-29.9	30-39.9	40-49.9	50-59.9	60-69.9	70-79.9
Acer saccharum Marsh.	94.08	20.67	9.30	8.27	4.13	1.03	----
Quercus alba L.	5.17	8.27	7.24	8.27	9.30	----	1.03
Ulmus rubra Muhl.	24.80	7.24	6.20	4.13	----	----	----
Carya ovata (Mill.) Koch	12.40	9.30	9.30	1.03	----	----	----
Prunus serotina Ehrh.	23.74	6.20	2.07	----	----	----	----
Carya cordiformis (Wang.) Koch	7.23	9.30	5.17	4.13	----	----	----

indicate it is not replacing itself well.

From the floodplain woods, a total of 19 species with a dbh greater than or equal to 10 cm were documented in this study (Table 2). *Tilia americana* ranked highest in relative importance (12.4) in this portion of Yuhas Woods. Its high RIV resulted from its high frequency of moderate sized stems (Table 2). The distribution of RIV's for species of the floodplain woods was more uniform than in the upland woods. The next five species, *Aesculus glabra, Acer negundo, Acer saccharum, Fraxinus nigra*, and *Quercus macrocarpa*, all had RIV's between 11.3 and 10.0 (Table 2). *Aesculus glabra* and *A. negundo* were important because they had a high frequency of stems with small overall basal areas. *Acer saccharum* and *Q. macrocarpa* had the highest relative basal areas for the floodplain species, 16.4 and 18.7 respectively, but had the lowest frequencies of the top six species (Table 2). The importance of *F. nigra* was due to its modest frequency and overall basal area.

DISCUSSION

According to Lindsey et. al. (1965), for a wooded area to be classified as oak-hickory the total IV of *Quercus spp.* and *Carya spp.* must be double that of *Acer saccharum* plus *Fagus grandifolia*. Respectively, their IV's are 101.6 and 79.0 (Table 1). These IV's do not meet the requirements set down by Lindsey et. al. in order for Yuhas Woods to be classified as oak-hickory. Based on the results of this study, Yuhas Woods is best classified according to Lindsey et. al. requirements as a mixed woods. However, *Quercus* spp. and *Carya* spp. make up 33.6% of the overall RIV, overtopping the combined RIV of *A. saccharum* and *F. grandifolia* by almost 10.0% (Table 1). Despite the data indicating a comparative IV not high enough to classify the woods as oak-hickory, the data does indicate that the oaks and hickories are of major importance in Yuhas Woods.

A similar trend has been documented in the upland mesic woods of Mounds State Park in Madison County, Indiana (Rothrock et. al., 1993). *Acer saccharum* seems to be overtaking both of these oak dominated woodlands and out competing *F. grandifolia*. In Yuhas Woods this trend could be the result of the past logging regime. Yuhas Woods has been selectively logged through out its recent history, with the last logging approximately twenty years ago (Gibbons, Personal Communication). It is probable that the lack of large oak trees is due to logging, and had oaks been found in higher size classes, the total IV for *Quercus* spp. and *Carya* spp. probably would have doubled the total for *A. saccharum* and *F. grandifolia*. Furthermore, it was shown by Lorimer (1983) that selective harvesting of oak forests, does not always promote oak re-establishment and it may hasten the conversion of the land to another type of woods. Additionally, Parker and Sherwood (1986) demonstrated that *A. saccharum* out competes *Quercus* spp. in small canopy gaps. The results of these studies reflect what was found in Yuhas Woods, that is, a small number of large oaks due to logging and a large number of small sugar maples filling the gaps, but that do not have the canopy room to maintain their high densities as the trees grow (Table 3 & Figure 3).

These observations could also be partly due to the suppression of fire in this region, and many other regions of the United States, since European settlement (McMclain, 1993; Abrams, 1992). Oak forests are considered to be an early to mid stage of succession, with the next stage composed of more shade tolerant trees such as *Acer saccharum*. However, *A. saccharum* is very intolerant to fire, and it is thought that the frequent fires in the Great Lakes Region, probably due to the activities of the Native Americans, kept many forests from reaching a climax community. When the Europeans colonized this area, they suppressed wildfires to protect their towns and agriculture (Abrams, 1992). This would have freed the forest from its stasis in succession, and allowed *A. saccharum* and other shade tolerant, but fire sensitive, trees to begin replacing the oaks. Yuhas Woods is surrounded by agriculture and has certainly not been allowed to burn for some time. Without fire to kill *A. saccharum* seedlings, it is not surprising to find them as the dominant species in the woods.

The floodplain region of Yuhas Woods fits the general description of a floodplain by Lindsey and Schmelz (1970). As far as is known, the course of Cabin Creek has not been altered in Yuhas Woods (Banks, Personal Communication), creating the potential that this section is relatively undisturbed. The species reported here are consistent with those that would be expected in frequently flooded woodlands with a constant and high availability of moisture. However, when compared to other floodplain woods in East-Central Indiana, Yuhas Woods, based on RIV, has a unique community composition. The floodplain woods at Yuhas differ from other sites in Indiana in that *Tilia americana* dominates. In Mounds State Park, Madison County, and Wilbur Wright Fish and Wildlife Area, Henry County, the floodplain forests are dominated by *Acer negudo*, while *T. americana* was not listed as an important tree in either area. In addition, *Ulmus americana* was of high importance in both these areas, but last in importance in Yuhas (Rothrock et. al., 1993; Ruch et. al., 2002). The floodplain forest of Botany Glen, Grant County, was also different in composition than the floodplain woods at Yuhas. *Platanus occidentalis* and *U. americana* dominated the floodplain of Botany Glen (Stonehouse et.

al. 2003), while neither had high importance in the floodplain at Yuhas. However, the two sites did share *Aesculus glabra* as a sub-dominant species. It should be noted, that an apparent component of the Yuhas' previous logging practices was to girdle trees considered undesirable. Except for the northern end of the floodplain, all *P. occidentalis* trees had been killed by this practice. This accounts for the low importance of this species in the floodplain woods at Yuhas.

Cooper-Ellis et al. (1999) stressed the importance of adding corridors in Indiana in order to increase and maintain Indiana's biodiversity. The woods at Yuhas are home to a great amount of diversity. Approximately 450 species of plants were documented during the 2005 and 2006 growing seasons (Ruch, Personal Communication). The location of Yuhas Woods on Cabin Creek makes it an excellent addition to the preserved land of Indiana for the purpose of increasing Indiana's corridors.

CONCLUSIONS

The upland portion of Yuhas Woods is best classified by Lindsey et. al. (1965) as a mixed woods. However, there is evidence that it was once an oak-hickory forest, and had selective logging for oaks not occurred it may still have met the requirements for oak-hickory classification. The floodplain portion of Yuhas contains the typical floodplain species, but with very different species composition, based on RIV, than other floodplains in East-Central Indiana, making this an interesting site for further study. Yuhas' location on Cabin Creek and its potential to become an old growth forest make it highly important to preserve this land and protect the life it harbors. Lastly, it is the intention of The Red Tail Nature Conservancy to manage Yuhas Woods, or ensure it is managed by another agency, as a nature preserve with the primary goal of maintaining species diversity.

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POINT-CENTERED-QUARTER ANALYSIS OF THE MATURE TREES IN DUNING WOODS NATURE PRESERVE, WAYNE COUNTY, INDIANA

ABSTRACT

Duning Woods Nature Preserve (DWNP) is a 48.6 ha (120 acre) tract containing ravine forest, a tree farm and a pine plantation in Wayne County, Indiana. It is an important nature preserve in East-Central Indiana due to its location on Lick Creek and its unique ravine habitat. Using the Point-Centered-Quarter technique to analyze the mature tree vegetation, this study documented 31 trees species with a dbh (diameter at breast height) greater than or equal to 10 cm. The dominant species was *Quercus rubra,* followed closely by *Acer saccharum.* These results show DWNP has changed since a previous study conducted at the site when it was reported that *Quercus rubra* and *Quercus alba* dominated (Lindsey et. al., 1969). Based on the results from this study using the classification system devised by Lindsey et. al. (1965), today DWNP is best classified as a mixed woods. However, the suppression of wildfire, coupled with some selective logging at the site, may have caused a decrease in *Q. alba* and/or an increase in *A. saccharum* since the 1969 study done by Lindsey et. al. These factors could plausibly have changed the importance values computed for the woodland species such that the forest no longer meets the criteria as oak-hickory, even though it once did. Lastly, a comparison of forest structure between DWNP and other forested areas of the Midwest is discussed.

KEY WORDS: Point-centered-quarter, Wayne County, Indiana, red oak, ravine forest, mixed forest, oak-hickory forest.

INTRODUCTION

Current surveys have indicated that Duning Woods Nature Preserve (DWNP) is a unique and botanically diverse area in East-Central Indiana (Ruch, Personal Communication). This study will focus on the tree vegetation of DWNP and is part of a larger project examining the vegetation and community structure of the site. A long term study of this site, including permanent plot analysis is currently underway (Ruch, Personal Communication). It is important to inventory and classify natural lands, such as DWNP to have documentation of their structure and composition through time (Reidy, 2002).

The composition of the mature trees in a forest tells much about its overall structure and habitat. The Point-Centered-Quarter (PCQ) technique employed in this study provides basic statistics, such as frequency, basal area, density, and importance values (Cottam and Curtis, 1956), which can be used to determine the presence, distribution, and abundance of plant life. Additionally, these statistical matrices can be used to predict future changes in the woodlands. The data collected in this study will provide the basis to rank DWNP in a classification system that will aid in comparing DWNP with other forested areas in the Midwest (Reidy, 2002). Further, it will also be used to compare the current composition of DWNP to a previous study done at the site by Lindsey et al. (1969).

The goals of this study are (1) to classify the forest and compare this classification to past conclusions on the woods; (2) to examine the history and disturbance effects of oak dominated forests in the Midwest in relation to the changes seen at DWNP since the

1969 study (Lindsey et al., 1969); and (3) to compare this site to similar sites in the Midwest.

STUDY SITE

Duning Woods Nature Preserve is located southeast of Centerville, Indiana in Wayne County (Figure 1). It lies along Airport Road, between Shoemaker Road to the north and Study Road to the south. The forest is part of a larger plot of land that has been owned by the Hoff family since 1906 (Hoff, personal communication). It became a State Nature Preserve in 2001 when the last member of the Hoff family to own the land, Nancy Hoff, sold the property for its timber value of $180,000 and donated the underlying land for preservation (Unanimous, 2001). Funds for the sale were provided by a variety of sources, most notably from the Indiana Heritage Trust, Fort Wayne's Ropchan Foundation, and the Whitewater Valley Land Trust. It is currently managed by the Whitewater Valley Land Trust (Unanimous, 2001).

Duning Woods Nature Preserve is a ravine forest consisting of 120 acres, or 48.6 hectares (Hoff, Personal Communication). Included at the site, but not included in this study, is a relatively flat 21 acre tree farm in the northeast corner, as well as a small pine plantation in the southwest corner. Lick Creek runs though the entire length of DWNP, from north to south (Figure 1). A previous study conducted on a 90 acre section of DWNP reported that it is ravine forest with mostly northeast facing slopes, dominated by *Quercus rubra* and *Quercus alba* (Lindsey et al, 1969). Lindsey et al. (1969) classified the woodlands as an oak-hickory forest.

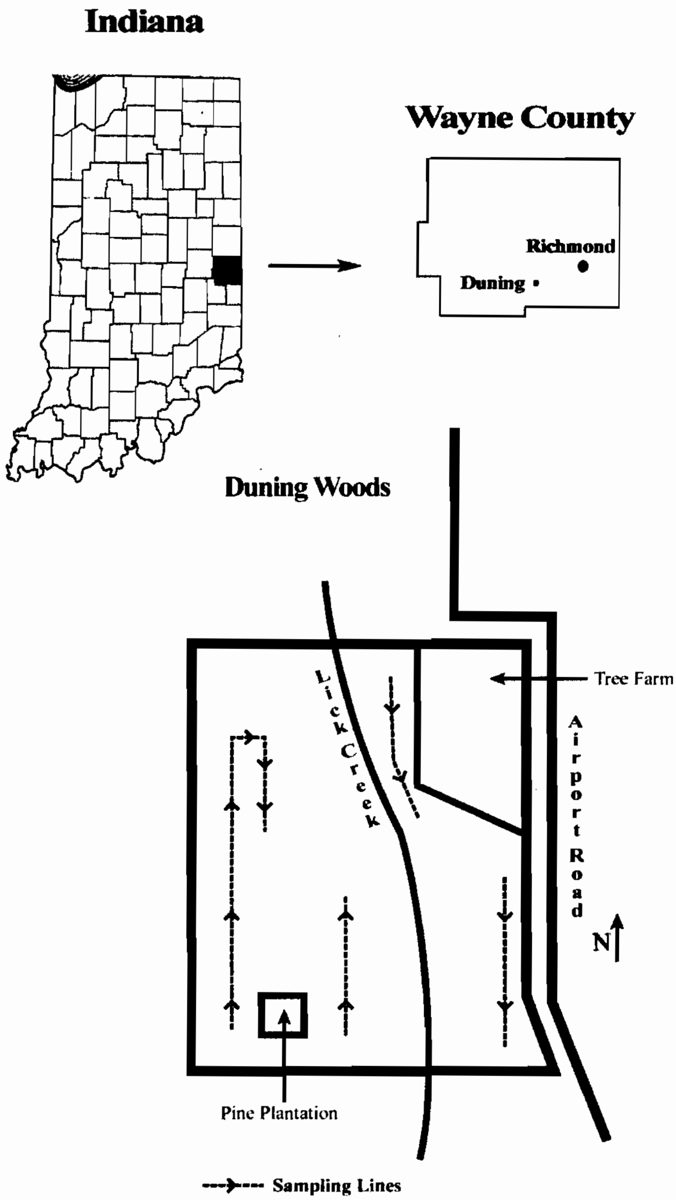

Figure 1. Map showing the location of Duning Woods Nature Preserve in Indiana (top left), the location of Duning Woods in Wayne County (top right), and the distribution of habitats and sampling lines at Duning Woods (bottom).

Duning Woods Nature Preserve lies on the border between the Tipton Till Plain and the Dearborn Upland physiographic regions of Indiana (Hill, 2007). The gorge system running through the woods is continuous with the Whitewater River Gorges along the east fork of the Whitewater River. These ravines were created at the end of the last ice age, about 18 to 20 thousand years ago, when the Wisconsinan Glaciers melted creating floods of water that carved away at the bedrock (WayneNet, 2007). The elevation with the woods ranges from a low of 940 feet to a high of 1,040 feet.

The forest contains three main soil types. The tree farm is on Strawn clay loam soil, a deep, well drained soil with slopes increasing from 2%-6% in the far northeast to 6%-12% in the south and west portions of the farm. The majority of the woodlands consist of Miami silt loam soils, a deep, well drained soil with slopes ranging between 2%-50%. Finally, the area surrounding Lick Creek is occasionally flooded and consists of Shoals silt loam soil, a deep, somewhat poorly drained soil common to floodplains (Blank, 1987) (Figure 1).

METHODS

Data Collection – The collection of data for DWNP took place in the fall of 2006. The Point-Centered-Quarter (PCQ) method was used to sample stems greater than or equal to 10 cm dbh (diameter at breast height). PCQ is a plotless method in which the area around a point is divided into four quadrants and the distance measures from the central point are used to estimate density (Reidy, 2002) (Figure 2). Lines were located randomly and a point was taken every 25 m along each line. One line ran parallel to the creek on the east side. One line started in the southwest corner and ran north, then turned east for 50 m, then went back south again until the line was disrupted by impassable

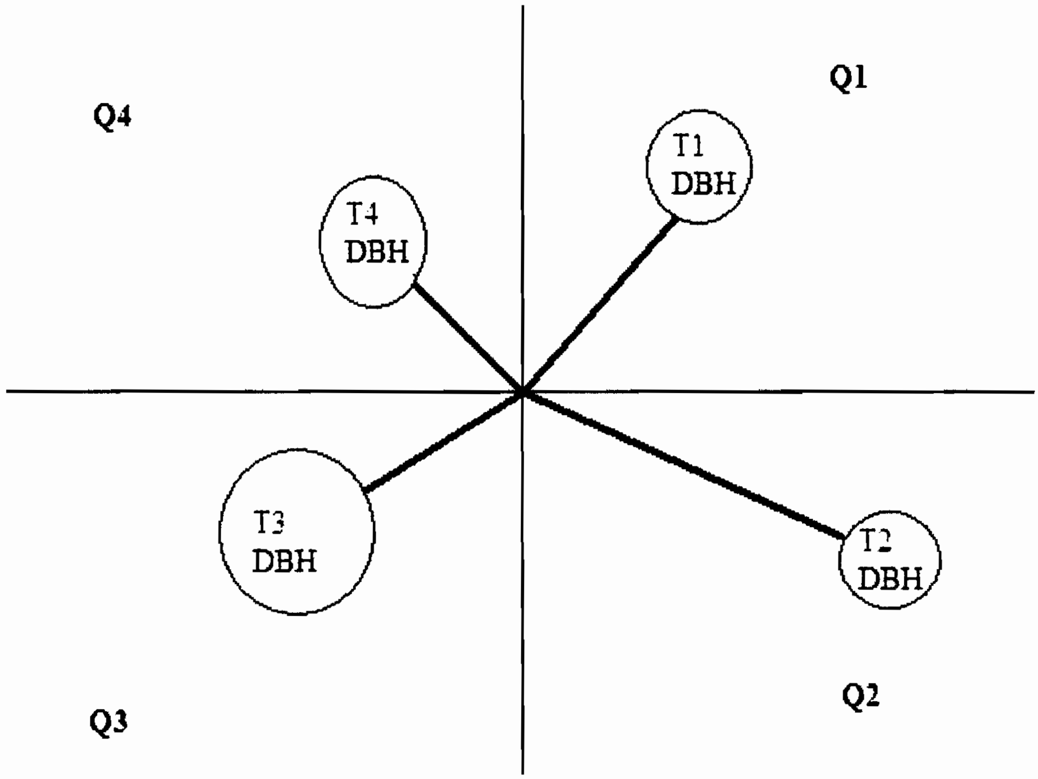

Figure 2. Diagram of PCQ sampling method. Area around each point was divided into four quadrants, the nearest tree with a DBH greater than or equal to 10 cm was found. DBH, species name and distance from point were recorded. Q1 was always the northeast quadrant. Adapted from figure in Reidy, 2002.

ravines. The last line began in the south on the west side of the creek and ran north to the first impassable ravine (Figure 1).

At each sample point four quadrants were defined using the tape as either the north-south or east-west boundary and imposing an imaginary line perpendicular to the tape for the other boundary. Quadrants were then numbered from one to four with quadrant one being the first clockwise quadrant from north. The nearest tree to the point in each quadrant with a dbh greater than or equal to 10 cm was selected. For each tree selected, the dbh (to the nearest 0.1 cm), the distance from the middle of the stem to the point (to the nearest 0.1 m), the species, and any pertinent observations concerning the site were recorded. Distance measurements were made using a Haglof Forestor DME 201 Distance Measuring Kit.

Analyses of Data.-Data were analyzed to obtain information on the structure and composition of the woods. Stem density, in stems per ha for each species, was determined. To do this, the relative density, RDEN (the percent density of one species compared to all species per ha) was computed by dividing the number of individual trees per species by the total number of trees sampled and multiplying by 100. The average density (AVGDEN) was computed by dividing 10,000 (the factor to convert meters into hectares) by the square of the mean distance for all trees in meters. Lastly, density (DEN) was determined using the following equation:

$$DEN = (RDEN / 100) \times AVGDEN$$

Next, the relative basal area, RBA (the percent basal area for one species compared to the total basal area for all species), was calculated. First, the dbh in centimeters for each tree was converted to a basal area in m^2 using the following equation:

Basal area per tree = π (dbh / 2)^2 / 10,000

The average basal area (AVGBA) for each species was then determined by summing the basal areas of all the trees of a species and dividing by the total number of trees for that species. The basal area per species (BA), in m^2, was then calculated by multiplying the AVGBA by the DEN for each species. Finally, the relative basal area (RBA) for each species was determined by dividing the BA per species by the total BA for all species and multiplying by 100.

Next, relative frequency, RFREQ (the percent frequency of one species per ha compared to all species), was determined. To do this, the frequency (FREQ) for each species was computed by dividing the total number of points at which a species occurred by the total number of points sampled, 100. RFREQ was then calculated using the following equation:

RFREQ = (FREQ per species / total FREQ of all species) x 100

Lastly, the importance value (IV) for each species was calculated by summing the RDEN, RFREQ and RBA; and the relative importance value (RIV) for each species was calculated by dividing the IV for each species by three.

Size class distributions for the six dominant species, based on RIV, were delineated, and the densities for each size class of each species were calculated. Nomenclature follows Gleason and Cronquist (1991).

RESULTS

A total of 31 tree species with a dbh of 10 cm or greater were documented in this study (Table 1). *Quercus rubra* was found to rank highest in RIV with a value of 20.58%. This was followed closely by *Acer saccharum* at 18.43%. These two species were by far the most dominant in the woods. The high RIV of *Q. rubra* was due mainly to a moderate density and frequency of high basal area stems. The high RIV of *A. saccharum* was due mainly to a high density and frequency of small basal area stems (Tables 1 & 2). These were followed next by *Carya ovata* (RIV = 8.83) with a moderate density of less frequent, smaller basal area stems. Fourth, was *Liriodendron tulipifera* (RIV = 7.87), its RIV was due in part to one very large tree found (Figure 3). Next, was *Fagus grandifolia* which had a RIV of 6.23%, and *Quercus alba*, which had a RIV of 5.02%. No other species had a RIV above 3.6%.

The densities of these top six important species were broken into size classes (Figure 3 & Table 2). *Quercus rubra* had its highest densities within the 10-19.99 cm dbh class and the 30-39.99 cm dbh class, producing a bimodal curve that steadily declined after the 30-39.99 cm dbh range. This may indicate that *Q. rubra* is replacing itself within the woods. *Acer saccharum* had its highest density in the 10-19.99 cm dbh range and then declined drastically. There was only one tree in its highest size class, 60-69.99 cm dbh and no trees in one class lower, 50-59.99 cm dbh, whereas there were 45 trees in its lowest size class. This may indicate that although *A. saccharum* produces many seedlings, few survive to become dominant canopy trees. *Carya ovata* peaked in the 20-29.99 cm dbh range then declined, with a highest size class of 50-59.99 cm dbh (only one tree). *Liriodendron tulipifera* and *Quercus alba* also exhibit bimodal curves.

Table 1. Data for Duning Woods species are arranged by the relative importance values. Density (DEN) is the number of stems per hectare. Relative density (RDEN) is the number of individuals of a species relative to the total number of trees expressed as a percent. Basal area (BA) is the meters squared per hectare of each species. Relative basal area (RBA) is the total basal area of a species relative to the total basal area of all species express as a percent. Frequency (FREQ) is the proportion of plots in which a species occurred relative to the total number of plots. Relative frequency (RFREQ) is the frequency of each species relative to all species expressed as a percent. Importance value (IV) is the sum of RDEN, RBA and RFREQ. Relative importance value (RIV) is the average of RDEN, RBA, and RFREQ expressed as a percent.

Species	BA	RBA	RDEN	DEN	FREQ	RFREQ	IV	RIV
Quercus rubra L.	12.35	30.92	16.00	79.72	0.43	14.83	61.75	20.58
Acer saccharum Marsh.	5.70	14.28	22.75	113.35	0.53	18.28	55.30	18.43
Carya ovata (Mill.) Koch	3.24	8.11	9.75	48.58	0.25	8.62	26.48	8.83
Liriodendron tulipifera L.	4.79	12.00	5.75	28.65	0.17	5.86	23.61	7.87
Fagus grandifolia Ehrh.	1.44	3.59	7.50	37.37	0.22	7.59	18.68	6.23
Quercus alba L.	2.63	6.58	4.00	19.93	0.13	4.48	15.06	5.02
Ulmus americana L.	0.43	1.07	4.50	22.42	0.15	5.17	10.74	3.58
Carya cordiformis (Wang.) Koch	1.04	2.61	2.75	13.70	0.09	3.10	8.46	2.82
Fraxinus pennsylvanica Marsh.	1.39	3.49	2.00	9.97	0.08	2.76	8.25	2.75
Fraxinus americana L.	1.11	2.78	1.75	8.72	0.07	2.41	6.94	2.31
Prunus serotina Ehrh.	0.22	0.56	2.50	12.46	0.10	3.45	6.51	2.17
Juniperus virginiana L.	0.94	2.35	2.00	9.97	0.06	2.07	6.42	2.14
Fraxinus quadrangulata Michx.	0.79	1.99	2.25	11.21	0.06	2.07	6.30	2.10
Morus rubra L.	0.26	0.66	2.25	11.21	0.07	2.41	5.33	1.78
Cornus florida L.	0.12	0.31	2.50	12.46	0.06	2.07	4.88	1.63
Carya glabra (Mill.) Sweet	0.47	1.17	1.50	7.47	0.06	2.07	4.74	1.58
Quercus muhlenbergii Engelm.	0.68	1.71	1.00	4.98	0.04	1.38	4.09	1.36
Ostrya virginiana (Mill.) Koch	0.11	0.27	1.50	7.47	0.06	2.07	3.84	1.28
Maclura pomifera (Raf.) Schneid	0.22	0.55	1.00	4.98	0.03	1.03	2.58	0.86
Nyssa sylvatica Marsh	0.32	0.80	0.75	3.74	0.03	1.03	2.58	0.86
Ulmus rubra Muhl.	0.08	0.20	1.00	4.98	0.03	1.03	2.24	0.75
Tilia americana L.	0.31	0.78	0.75	3.74	0.02	0.69	2.22	0.74
Cercis Canadensis L.	0.06	0.16	1.00	4.98	0.03	1.03	2.19	0.73
Pinus sylvestris L.	0.30	0.76	0.50	2.49	0.02	0.69	1.95	0.65
Populus grandidentata Michx.	0.29	0.73	0.50	2.49	0.02	0.69	1.92	0.64
Carpinus caroliniana Walter	0.03	0.08	0.75	3.74	0.03	1.03	1.87	0.62
Quercus velutina Lam.	0.25	0.62	0.50	2.49	0.02	0.69	1.81	0.60
Gleditsia triacanthos L.	0.13	0.32	0.25	1.25	0.01	0.35	0.91	0.30
Platanus occidentalis L.	0.12	0.31	0.25	1.25	0.01	0.35	0.90	0.30
Sassafras albidum (Nutt.) Nees	0.07	0.18	0.25	1.25	0.01	0.35	0.78	0.26
Celtis occidentalis L.	0.02	0.05	0.25	1.25	0.01	0.35	0.64	0.21

Table 2. Size class data for the top six important species.

Species	**10-19.99**	**20-29.99**	**30-39.99**	**40-49.99**	**50-59.99**	**60-69.99**	**70-79.99**	**80-89.99**	**90-99.99**
Quercus alba L.	4.98	4.98	2.49	1.25	2.49	3.74	—	—	—
Fagus grandifolia Ehrh.	21.28	9.97	6.23	—	—	—	—	—	—
Liriodendron tulipifera L.	2.49	8.72	2.49	6.23	3.74	2.49	1.25	—	1.25
Carya ovata (Mil.) Koch	13.7	16.19	11.21	6.23	1.25	—	—	—	—
Acer saccharum Marsh.	56.05	29.9	14.95	11.21	—	1.25	—	—	—
Quercus rubra L.	18.68	8.72	17.44	11.21	9.97	6.23	4.98	1.25	1.25

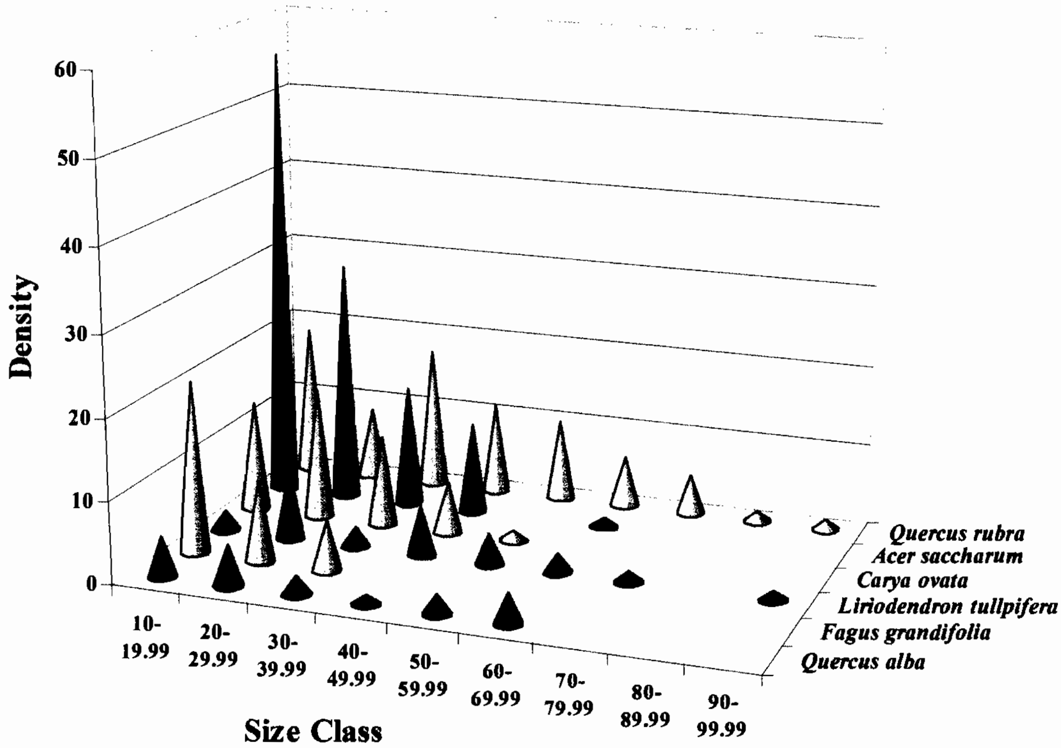

Figure 3. Illustrated here is the density distribution by size classes for the top six important species.

Liriodendron tulipifera peaked in the 20-29.99 cm dbh class and 40-49.99 cm dbh class, and *Q. alba* peaked evenly in the 10-19.99 and 20-29.99 cm dbh ranges and then again in the 60-69.99 cm dbh range. Lastly, *Fagus grandifolia* showed the same pattern as *A. saccharum,* having the highest density in the 10-19.99 cm dbh size class and then drastically declining, having no stems larger than 39.99 cm dbh.

DISCUSSION

Analysis of the data collected for Duning Woods Nature Preserve for this study does not lead to the same conclusions drawn by Lindsey et. al. (1969). First, Lindsey et. al. reported that Duning was dominated by *Quercus rubra* and *Quercus alba.* This study found *Q. rubra* as dominant with *Acer saccharum* as second dominant. Second, DWNP was reported as an oak-hickory forest. By the classification system devised by Lindsey et. al. (1965) for a forest to be classified as oak-hickory the total importance value (IV) of all *Quercus* spp. plus all *Carya* spp. must be double the IV of *A. saccharum* plus *Fagus grandifolia.* The importance values found in this study are 122.62 and 74.04, respectively. Thus, the current forest at DWNP does not meet the criteria specified by Lindsey et. al. (1965) for oak-hickory classification. Based on their classification system, DWNP is best classified as a mixed forest.

There are three possible reasons why there seems to have been a decrease in the number of *Q. alba* and an increase in the number of *A. saccharum* since 1969. First, the presettlement Midwest contained many oak dominated forests and savannas (McClain 1993; McCone & Cottam 1985). Oak forests are considered a mid to early stage of succession, and it is believed that the frequent fire regime of the Native Americans provided adequate disturbance to maintain oak dominance. With European settlement, that fire regime ended in order to protect towns and crops (Abrams 1992; Cottam 1949; Rentch & Hicks 2005). This allowed more fire-intolerant, but shade-tolerant species such as *A. saccharum* to increase in abundance within fire suppressed areas (Abrams 1992; Feist et. al. 2004). Second, it has been demonstrated that *A. saccharum* tends to out-compete *Quercus* spp. in small canopy gaps (Parker & Sherwood 1986). Over time as wind and other forces caused tree falls within a forest, it is more likely that sugar maple will fill the canopy gap than any type of oak. Third, during the 1970's, many white oaks were harvested to secure funds for the purchase of Lick Creek Summit Nature Preserve, another property owned by the Whitewater Valley Land Trust. While neither of the first two factors seem like fast acting agents of change within a forest, the third could, and possibly did, change the composition of the forest at DWNP. It should be noted that DWNP is just under the double requirement for oak-hickory classification. Thus, even a slight decrease in *Q. alba* and/or increase in *A. saccharum* since the 1969 study could plausibly have changed the importance values such that the forest now does not classify as oak-hickory, even though it once did.

As mentioned, much of the presettlement Midwest was dominated by oak forest. However, this domination was mostly *Quercus alba,* with woodlands dominant by *Quercus rubra* being relatively uncommon. A study of presettlement mixed mesophytic forest composition in eastern Ohio found *Q. alba* averaged number one in dominance, whereas *Q. rubra* average only eleventh at all study sites (Rentch & Hicks 2005). Many of these same areas were surveyed again by Rentch & Hicks and they found *Q. rubra* had declined to twelfth and *Q. alba* had declined to fifth. This study shows the rarity of red oak dominated forests within the Midwest, and adds further evidence to the idea that oak dominated forests have been diminishing over time.

This rarity of red oak dominated forests, combined with DWNP's ravine topography, makes comparing DWNP's forest to other forests difficult. One area of similar ravine topography and community composition is the upland mesic forest at Dean Hills Nature Preserve in central Illinois (Feist et. al. 2004). This area of Dean Hills is also mostly north facing slopes. It is dominated by *A. saccharum*, *Q. rubra*, and *Q. alba*. However, sugar maples are by far dominant over oaks in Dean Hills, whereas in DWNP's forest red oaks dominant over sugar maples, and dominance is more evenly shared. Additionally, *Q. alba* is a much larger portion of the forest at Dean Hills than it is in the forest at DWNP (which might be attributed to the selective logging during the 1970's). Feist et. al. (2004) conclude that this area has seen the trend of replacement of oaks by sugar maples just as this study found in DWNP, and probably for the same reasons of fire suppression and oaks failing to compete for the forest canopy.

CONCLUSIONS

Duning Woods Nature Preserve is best classified by Lindsey et. al. (1965) as a mixed woods. However, evidence from Lindsey et. al (1969) show that it was once an oak-hickory forest. Had selective logging for *Quercus alba* not occurred at this site it may still have met the requirements for oak-hickory classification today. DWNP is a unique site in the Midwest because of its ravine topography and its domination by *Quercus rubra*. However, the data reported show the same trend of oak replacement by sugar maple that many sites in Indiana and the Midwest are also undergoing.

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Point	Species	DBH (cm)	Distance (m)
1	*Carya ovata*	30.10	5.37
1	*Carya ovata*	35.10	7.73
1	*Carya ovata*	28.50	4.26
1	*Carya ovata*	25.00	3.67
2	*Carya ovata*	23.40	11.24
2	*Fraxinus pennsylvanica*	37.10	4.83
2	*Fraxinus pennsylvanica*	42.70	3.25
2	*Ulmus americana*	11.50	5.93
3	*Acer saccharum*	14.90	6.06
3	*Aesculus glabra*	10.80	3.79
3	*Aesculus glabra*	13.10	0.82
3	*Aesculus glabra*	15.20	6.48
4	*Carya ovata*	16.50	2.75
4	*Carya ovata*	30.75	4.56
4	*Juglans nigra*	46.70	4.81
4	*Ostrya virginiana*	13.50	5.68
5	*Carya ovata*	33.50	7.29
5	*Fraxinus americana*	15.40	5.72
5	*Prunus serotina*	18.25	3.95
5	*Quercus alba*	38.20	1.74
6	*Aesculus glabra*	12.50	5.27
6	*Carya ovata*	27.00	4.77
6	*Ulmus americana*	13.80	6.97
6	*Ulmus rubra*	19.00	5.58
7	*Carya ovata*	19.00	6.92
7	*Quercus alba*	38.50	4.82
7	*Ulmus rubra*	46.70	3.58
7	*Ulmus rubra*	14.10	5.03
8	*Fraxinus americana*	14.20	3.48
8	*Quercus rubra*	20.80	1.76
8	*Ulmus americana*	11.80	3.98
8	*Ulmus rubra*	10.00	3.76
9	*Prunus serotina*	11.40	5.39
9	*Quercus alba*	29.50	5.69
9	*Quercus alba*	23.40	2.74
9	*Quercus alba*	44.50	1.92
10	*Prunus serotina*	11.20	4.61
10	*Quercus alba*	19.40	3.80
10	*Ulmus rubra*	17.90	1.44
10	*Ulmus rubra*	35.90	6.11
11	*Acer saccharum*	15.70	5.35
11	*Fraxinus pennsylvanica*	21.80	1.39
11	*Prunus serotina*	29.90	2.92
11	*Ulmus rubra*	14.50	4.24
12	*Acer saccharum*	12.00	2.83
12	*Acer saccharum*	17.60	4.53
12	*Carya glabra*	22.90	4.79
12	*Quercus alba*	18.60	3.35
13	*Acer saccharum*	10.70	3.03

13	*Acer saccharum*	16.70	0.44
13	*Carya ovata*	17.90	2.44
13	*Quercus alba*	25.70	4.30
14	*Fraxinus pennsylvanica*	10.70	3.66
14	*Quercus alba*	25.40	1.25
14	*Quercus alba*	50.20	5.65
14	*Quercus alba*	37.30	4.63
15	*Aesculus glabra*	12.90	1.41
15	*Aesculus glabra*	18.40	2.57
15	*Quercus alba*	57.70	8.06
15	*Ulmus rubra*	33.50	2.12
16	*Aesculus glabra*	12.30	2.35
16	*Carya glabra*	24.70	5.56
16	*Carya ovata*	14.60	3.55
16	*Quercus alba*	40.60	3.00
17	*Carya ovata*	18.55	3.55
17	*Carya ovata*	34.20	1.80
17	*Ulmus americana*	12.60	2.29
17	*Ulmus rubra*	12.70	4.36
18	*Aesculus glabra*	15.20	2.53
18	*Carya ovata*	32.00	3.59
18	*Quercus alba*	32.50	3.62
18	*Quercus alba*	37.50	8.63
19	*Aesculus glabra*	12.40	5.54
19	*Carya ovata*	26.60	4.32
19	*Quercus alba*	77.70	8.93
19	*Ulmus rubra*	13.80	2.25
20	*Carya cordiformis*	21.20	8.79
20	*Celtis occidentalis*	10.50	3.15
20	*Fraxinus americana*	11.00	5.57
20	*Juglans nigra*	41.00	6.27
21	*Aesculus glabra*	14.10	2.12
21	*Carya ovata*	35.50	4.48
21	*Carya ovata*	20.30	5.67
21	*Prunus serotina*	14.90	3.69
22	*Carya cordiformis*	26.60	2.11
22	*Celtis occidentalis*	13.00	4.44
22	*Prunus serotina*	31.90	3.04
22	*Quercus alba*	50.40	3.29
23	*Acer saccharum*	17.20	6.80
23	*Acer saccharum*	15.70	10.28
23	*Quercus alba*	19.20	1.65
23	*Quercus velutina*	34.00	3.98
24	*Acer saccharum*	11.80	4.64
24	*Acer saccharum*	13.80	11.88
24	*Quercus alba*	17.60	1.92
24	*Quercus velutina*	39.00	2.52
25	*Acer saccharum*	39.00	8.45
25	*Carya ovata*	17.80	6.21
25	*Quercus alba*	48.60	5.21

25	*Ulmus rubra*	27.10	6.82
26	*Aesculus glabra*	13.50	4.40
26	*Quercus alba*	52.00	6.61
26	*Ulmus rubra*	24.80	7.13
26	*Ulmus rubra*	27.30	5.23
27	*Celtis occidentalis*	19.10	2.07
27	*Celtis occidentalis*	16.70	4.31
27	*Juglans nigra*	28.40	3.53
27	*Ulmus rubra*	33.60	4.88
28	*Carya ovata*	25.00	1.21
28	*Carya ovata*	10.90	0.49
28	*Juglans nigra*	64.40	6.36
28	*Ulmus rubra*	20.50	2.23
29	*Aesculus glabra*	10.30	8.00
29	*Aesculus glabra*	15.80	1.99
29	*Carya ovata*	21.00	1.74
29	*Carya ovata*	29.40	1.90
30	*Aesculus glabra*	11.20	4.39
30	*Fraxinus pennsylvanica*	15.90	2.77
30	*Quercus alba*	38.20	5.72
30	*Ulmus americana*	18.60	4.68
31	*Acer saccharum*	15.10	8.22
31	*Celtis occidentalis*	13.80	1.40
31	*Celtis occidentalis*	17.80	1.83
31	*Ulmus rubra*	38.10	0.75
32	*Acer saccharum*	15.60	2.98
32	*Acer saccharum*	12.60	3.22
32	*Juglans nigra*	46.60	1.70
32	*Prunus serotina*	11.20	4.87
33	*Prunus serotina*	23.70	4.29
33	*Prunus serotina*	18.00	5.78
33	*Ulmus americana*	19.00	5.92
33	*Ulmus rubra*	13.80	3.18
34	*Acer saccharinum*	53.00	3.25
34	*Acer saccharinum*	52.80	7.35
34	*Acer saccharinum*	25.20	6.42
34	*Acer saccharinum*	17.50	7.92
35	*Acer saccharinum*	91.70	11.52
35	*Fraxinus pennsylvanica*	49.50	7.58
35	*Fraxinus pennsylvanica*	61.60	8.53
35	*Fraxinus pennsylvanica*	59.60	2.74
36	*Acer saccharum*	18.30	3.74
36	*Prunus serotina*	13.70	3.29
36	*Prunus serotina*	27.80	4.56
36	*Prunus serotina*	13.80	5.73
37	*Acer rubra*	41.80	4.13
37	*Fraxinus americana*	41.00	4.71
37	*Quercus palustris*	106.80	7.29
37	*Ulmus americana*	17.00	2.77
38	*Acer saccharum*	21.50	2.05

38	*Fraxinus pennsylvanica*	11.30	3.65
38	*Quercus muehlenbergii*	38.20	14.57
38	*Ulmus rubra*	13.80	2.25
39	*Aesculus glabra*	63.00	5.00
39	*Quercus alba*	15.80	4.10
39	*Quercus alba*	55.80	5.05
39	*Quercus alba*	26.90	5.00
40	*Acer saccharum*	46.30	6.43
40	*Fraxinus americana*	14.00	3.01
40	*Fraxinus pennsylvanica*	18.00	5.71
40	*Quercus muehlenbergii*	52.90	2.12
41	*Acer saccharum*	13.70	4.97
41	*Acer saccharum*	47.80	6.00
41	*Acer saccharum*	27.80	4.81
41	*Carya cordiformis*	31.20	1.68
42	*Acer saccharum*	56.20	2.49
42	*Celtis occidentalis*	12.40	6.27
42	*Fagus grandifolia*	50.20	13.09
42	*Ulmus rubra*	15.50	1.07
43	*Acer saccharum*	10.90	6.21
43	*Prunus serotina*	10.00	4.82
43	*Ulmus rubra*	37.50	4.78
43	*Ulmus rubra*	22.80	2.86
44	*Acer saccharum*	26.70	1.59
44	*Acer saccharum*	29.40	5.42
44	*Acer saccharum*	12.40	5.26
44	*Fraxinus americana*	11.30	5.98
45	*Acer saccharum*	11.90	7.21
45	*Acer saccharum*	19.90	1.16
45	*Acer saccharum*	11.30	4.78
45	*Carya ovata*	15.30	7.37
46	*Acer saccharum*	34.40	9.60
46	*Acer saccharum*	36.00	3.75
46	*Ostrya virginiana*	16.30	1.56
46	*Quercus rubra*	45.80	3.73
47	*Acer saccharum*	12.70	5.27
47	*Acer saccharum*	11.60	6.54
47	*Juglans nigra*	48.20	2.15
47	*Quercus alba*	20.90	7.96
48	*Carya cordiformis*	29.30	4.68
48	*Liriodendron tulipifera*	34.10	3.62
48	*Quercus rubra*	39.50	5.62
48	*Ulmus americana*	16.50	8.09
49	*Acer saccharum*	27.90	3.89
49	*Carya cordiformis*	41.30	8.65
49	*Fraxinus pennsylvanica*	45.90	5.06
49	*Ulmus americana*	10.90	4.79
50	*Acer saccharum*	17.30	4.42
50	*Carya cordiformis*	25.90	0.41
50	*Carya ovata*	12.50	7.23

50	*Quercus rubra*	18.90	7.29
51	*Aesculus glabra*	15.40	1.85
51	*Carya cordiformis*	17.00	5.54
51	*Carya cordiformis*	22.40	8.12
51	*Juglans nigra*	49.60	2.11
52	*Acer saccharum*	22.30	5.98
52	*Carpinus caroliniana*	12.80	3.81
52	*Carya cordiformis*	16.60	6.80
52	*Carya cordiformis*	14.90	6.69
53	*Acer saccharum*	19.50	1.72
53	*Acer saccharum*	15.10	6.92
53	*Acer saccharum*	12.70	3.83
53	*Carya ovata*	12.80	5.58
54	*Acer saccharum*	15.10	3.70
54	*Acer saccharum*	17.80	3.70
54	*Ostrya virginiana*	12.40	5.93
54	*Quercus alba*	51.00	4.09
55	*Carya cordiformis*	24.60	5.73
55	*Carya cordiformis*	35.10	1.80
55	*Carya ovata*	19.60	7.30
55	*Quercus alba*	29.10	0.80
56	*Acer saccharum*	27.20	6.51
56	*Carya glabra*	22.00	0.73
56	*Quercus rubra*	56.20	5.33
56	*Quercus rubra*	43.90	12.62
57	*Acer saccharum*	11.90	6.87
57	*Acer saccharum*	47.90	3.89
57	*Prunus serotina*	13.60	5.65
57	*Quercus rubra*	32.50	3.92
58	*Acer saccharum*	14.20	7.22
58	*Prunus serotina*	18.50	8.70
58	*Prunus serotina*	26.10	1.49
58	*Ulmus rubra*	10.70	4.04
59	*Acer saccharum*	12.10	2.06
59	*Acer saccharum*	12.30	5.19
59	*Fagus grandifolia*	49.50	6.69
59	*Ulmus rubra*	15.50	10.68
60	*Acer saccharum*	11.40	6.12
60	*Acer saccharum*	14.90	5.41
60	*Ulmus rubra*	11.90	3.05
60	*Ulmus rubra*	18.10	2.20
61	*Acer saccharum*	39.60	4.29
61	*Acer saccharum*	46.70	6.91
61	*Fraxinus americana*	29.00	5.14
61	*Liriodendron tulipifera*	31.40	6.95
62	*Acer saccharum*	10.20	4.33
62	*Acer saccharum*	15.50	5.90
62	*Carya ovata*	48.40	2.52
62	*Quercus muehlenbergii*	37.50	6.13
63	*Acer saccharum*	15.90	6.62

63	*Acer saccharum*	16.50	5.96
63	*Acer saccharum*	13.00	4.87
63	*Ulmus rubra*	14.70	2.31
64	*Acer saccharum*	11.20	3.85
64	*Liriodendron tulipifera*	26.70	3.36
64	*Liriodendron tulipifera*	16.80	5.12
64	*Prunus serotina*	28.30	7.23
65	*Prunus serotina*	12.80	2.51
65	*Prunus serotina*	16.10	1.10
65	*Prunus serotina*	13.20	4.07
65	*Prunus serotina*	27.30	4.21
66	*Acer saccharum*	11.70	2.68
66	*Acer saccharum*	16.80	4.96
66	*Prunus serotina*	13.50	1.43
66	*Quercus alba*	57.80	4.01
67	*Acer saccharum*	21.80	4.16
67	*Carya ovata*	11.70	2.87
67	*Nyssa sylvatica*	48.60	5.32
67	*Quercus rubra*	55.40	8.98
68	*Acer saccharum*	14.20	8.26
68	*Carya cordiformis*	42.80	3.60
68	*Carya glabra*	38.00	2.52
68	*Ulmus rubra*	32.40	5.07
69	*Acer saccharum*	12.40	6.28
69	*Acer saccharum*	10.60	6.47
69	*Carya ovata*	35.10	4.12
69	*Quercus muehlenbergii*	28.50	4.53
70	*Acer saccharum*	12.10	3.45
70	*Acer saccharum*	16.50	2.92
70	*Acer saccharum*	11.10	4.05
70	*Liriodendron tulipifera*	21.00	3.11
71	*Aesculus glabra*	10.90	2.21
71	*Aesculus glabra*	15.50	4.44
71	*Aesculus glabra*	13.50	4.21
71	*Carya cordiformis*	22.80	9.45
72	*Acer saccharum*	14.00	4.43
72	*Celtis occidentalis*	15.00	4.87
72	*Quercus alba*	59.60	2.73
72	*Ulmus rubra*	15.80	7.82
73	*Acer saccharum*	12.40	1.76
73	*Ulmus rubra*	41.70	6.45
73	*Ulmus rubra*	11.60	0.74
73	*Ulmus rubra*	17.60	3.07
74	*Acer saccharum*	18.90	8.97
74	*Carya cordiformis*	28.10	2.25
74	*Carya cordiformis*	17.00	6.27
74	*Ulmus rubra*	46.10	2.83
75	*Acer saccharum*	16.20	7.94
75	*Acer saccharum*	22.30	6.07
75	*Liriodendron tulipifera*	49.00	8.36

75	*Ulmus rubra*	21.00	2.51
76	*Acer saccharum*	24.40	6.68
76	*Acer saccharum*	18.20	8.82
76	*Liriodendron tulipifera*	47.20	2.77
76	*Liriodendron tulipifera*	52.50	4.21
77	*Acer saccharum*	12.10	8.10
77	*Fraxinus americana*	16.10	0.68
77	*Liriodendron tulipifera*	46.20	4.22
77	*Populus deltoides*	38.80	8.06
78	*Acer saccharum*	13.60	4.55
78	*Prunus serotina*	17.20	4.99
78	*Prunus serotina*	16.80	2.17
78	*Ulmus rubra*	16.10	6.51
79	*Acer saccharum*	14.90	5.10
79	*Acer saccharum*	49.90	5.27
79	*Ostrya virginiana*	11.00	2.06
79	*Quercus alba*	47.20	6.15
80	*Acer saccharum*	14.40	2.08
80	*Acer saccharum*	10.80	4.46
80	*Quercus alba*	46.30	4.19
80	*Quercus alba*	26.60	4.37
81	*Acer saccharum*	11.40	4.04
81	*Acer saccharum*	19.50	4.55
81	*Carya cordiformis*	36.10	1.90
81	*Quercus alba*	42.30	5.42
82	*Acer saccharum*	21.40	2.90
82	*Acer saccharum*	15.10	5.75
82	*Acer saccharum*	53.70	5.11
82	*Acer saccharum*	17.30	8.64
83	*Aesculus glabra*	10.70	4.37
83	*Aesculus glabra*	11.80	5.16
83	*Carya laciniosa*	26.20	6.02
83	*Quercus alba*	31.80	4.87
84	*Acer saccharum*	10.50	10.14
84	*Fraxinus pennsylvanica*	43.80	9.91
84	*Prunus serotina*	11.80	2.17
84	*Quercus muehlenbergii*	52.40	7.71
85	*Acer saccharum*	16.20	6.63
85	*Acer saccharum*	20.30	7.64
85	*Acer saccharum*	27.90	6.72
85	*Quercus alba*	55.90	6.69
86	*Acer saccharum*	10.80	3.50
86	*Acer saccharum*	18.10	4.94
86	*Acer saccharum*	27.20	8.33
86	*Prunus serotina*	11.00	2.92
87	*Acer saccharum*	15.70	2.16
87	*Acer saccharum*	11.40	2.48
87	*Acer saccharum*	21.70	2.64
87	*Ulmus rubra*	19.80	3.26
88	*Acer saccharum*	13.80	2.77

88	*Acer saccharum*	14.90	5.63
88	*Acer saccharum*	15.70	2.47
88	*Carya glabra*	31.70	5.93
89	*Acer saccharum*	13.60	3.80
89	*Acer saccharum*	15.60	2.22
89	*Cercis canadensis*	17.70	3.70
89	*Juglans nigra*	39.00	4.39
90	*Acer saccharum*	12.70	2.59
90	*Acer saccharum*	11.90	4.72
90	*Acer saccharum*	52.10	3.24
90	*Ulmus rubra*	14.80	10.17
91	*Acer saccharum*	11.10	6.37
91	*Acer saccharum*	13.30	7.92
91	*Carya cordiformis*	46.10	5.45
91	*Ostrya virginiana*	16.00	7.16
92	*Acer saccharum*	18.60	4.37
92	*Celtis occidentalis*	34.60	6.34
92	*Prunus serotina*	15.00	6.83
92	*Ulmus rubra*	13.10	1.59
93	*Acer saccharum*	12.60	2.93
93	*Acer saccharum*	15.90	6.08
93	*Celtis occidentalis*	13.80	3.97
93	*Ulmus rubra*	24.70	4.36
94	*Carya cordiformis*	14.00	6.91
94	*Carya cordiformis*	19.40	3.96
94	*Carya cordiformis*	46.90	6.81
94	*Carya cordiformis*	34.20	1.80
95	*Acer saccharum*	27.60	10.20
95	*Carya cordiformis*	31.90	1.59
95	*Carya cordiformis*	28.20	3.16
95	*Carya cordiformis*	18.00	4.31
96	*Acer saccharum*	33.50	9.22
96	*Acer saccharum*	67.30	1.35
96	*Ulmus rubra*	11.70	3.63
96	*Ulmus rubra*	47.10	11.22
97	*Acer saccharum*	47.70	4.02
97	*Acer saccharum*	20.80	6.79
97	*Acer saccharum*	30.40	6.07
97	*Gymnocladus dioica*	56.70	5.97
98	*Acer saccharum*	38.80	6.65
98	*Acer saccharum*	20.00	7.11
98	*Acer saccharum*	36.80	8.13
98	*Tilia americana*	25.40	10.75
99	*Acer saccharum*	18.90	1.63
99	*Acer saccharum*	11.50	5.23
99	*Acer saccharum*	23.90	2.33
99	*Quercus muehlenbergii*	31.80	7.73
100	*Acer saccharum*	59.10	7.69
100	*Acer saccharum*	19.50	5.35
100	*Acer saccharum*	18.50	5.94

100	*Acer saccharum*	40.20	4.17
101	*Acer saccharum*	20.80	5.27
101	*Acer saccharum*	12.40	6.01
101	***Carya glabra***	**52.00**	**7.15**
101	*Carya ovata*	37.50	3.46
102	***Acer saccharum***	**16.30**	**4.83**
102	*Acer saccharum*	15.50	2.40
102	***Acer saccharum***	**38.50**	**4.46**
102	*Quercus alba*	49.00	4.21
103	***Acer saccharum***	**18.90**	**0.25**
103	*Acer saccharum*	12.50	5.41
103	***Acer saccharum***	**17.30**	**7.59**
103	*Ulmus rubra*	19.30	1.48
104	***Acer saccharum***	**12.20**	**5.28**
104	*Prunus serotina*	10.90	5.15
104	***Prunus serotina***	**36.00**	**10.52**
104	*Tilia americana*	25.40	3.06
105	***Acer saccharum***	**42.60**	**0.70**
105	*Prunus serotina*	19.90	7.37
105	***Prunus serotina***	**13.80**	**9.40**
105	*Quercus alba*	49.80	7.52

Point	Species	DBH (cm)	Distance (m)
1	Acer saccharum	26.20	9.90
1	Acer saccharum	19.60	9.22
1	Fraxinus nigra	20.90	2.78
1	Tilia americana	15.60	5.67
2	Fraxinus pennsylvanica	15.40	2.68
2	Juglans nigra	45.40	7.02
2	Liriodendron tulipifera	60.40	8.92
2	Liriodendron tulipifera	25.10	5.22
3	Acer negundo	12.70	6.39
3	Acer negundo	21.90	2.58
3	Juglans nigra	27.80	4.21
3	Tilia americana	31.70	4.27
4	Aesculus glabra	22.50	3.62
4	Aesculus glabra	16.90	3.77
4	Aesculus glabra	14.80	2.70
4	Carpinus caroliniana	12.10	9.93
5	Acer saccharum	69.80	7.82
5	Acer saccharum	25.40	1.31
5	Aesculus glabra	12.90	5.43
5	Fraxinus nigra	22.80	4.07
6	Carpinus caroliniana	11.60	4.70
6	Crataegus punctata	16.40	4.36
6	Tilia americana	32.80	6.47
6	Ulmus rubra	12.20	2.17
7	Aesculus glabra	10.60	2.35
7	Carpinus caroliniana	13.80	5.26
7	Tilia americana	10.70	5.74
7	Tilia americana	27.20	9.09
8	Acer negundo	28.00	6.69
8	Quercus bicolor	51.30	3.48
8	Quercus macrocarpa	59.30	5.86
8	Tilia americana	41.50	6.18
9	Acer saccharum	20.00	5.38
9	Carpinus caroliniana	15.60	2.76
9	Fraxinus nigra	28.60	8.62
9	Tilia americana	13.40	4.01
10	Acer negundo	13.20	10.46
10	Aesculus glabra	40.50	2.84
10	Fraxinus pennsylvanica	24.20	4.03
10	Ostrya virginiana	11.70	5.88
11	Acer negundo	11.30	1.54
11	Ostrya virginiana	11.90	7.44
11	Tilia americana	29.30	4.37
11	Tilia americana	11.80	4.83
12	Carpinus caroliniana	23.20	6.93
12	Tilia americana	11.30	1.22
12	Tilia americana	23.70	0.22
12	Ulmus rubra	20.00	2.50
13	Aesculus glabra	21.60	5.09

13	Cercis canadensis	10.60	4.35
13	Fraxinus nigra	38.00	9.86
13	Fraxinus pennsylvanica	20.70	2.06
14	Carpinus caroliniana	10.20	2.04
14	Quercus macrocarpa	34.20	2.17
14	Quercus macrocarpa	50.10	3.56
14	Ulmus rubra	15.10	4.62
15	Acer negundo	14.60	7.46
15	Fraxinus pennsylvanica	20.60	6.86
15	Tilia americana	31.30	1.16
15	Tilia americana	29.30	4.12
16	Acer negundo	25.70	4.54
16	Acer negundo	12.90	4.91
16	Ulmus rubra	11.60	2.70
16	Ulmus rubra	20.20	4.16
17	Carpinus caroliniana	10.80	4.34
17	Carpinus caroliniana	18.60	4.96
17	Fraxinus nigra	42.40	8.09
17	Fraxinus nigra	40.00	10.07
18	Cercis canadensis	11.40	6.33
18	Fraxinus nigra	10.80	1.98
18	Fraxinus pennsylvanica	11.30	5.26
18	Tilia americana	12.30	4.96
19	Aesculus glabra	13.60	7.38
19	Fraxinus pennsylvanica	23.20	7.46
19	Quercus macrocarpa	31.60	4.34
19	Quercus muehlenbergii	25.90	7.40
20	Acer saccharum	48.90	5.44
20	Aesculus glabra	21.60	6.28
20	Carpinus caroliniana	13.80	3.95
20	Tilia americana	24.70	4.56
21	Cercis canadensis	10.50	3.32
21	Crataegus punctata	16.60	5.18
21	Fraxinus pennsylvanica	15.10	6.33
21	Fraxinus pennsylvanica	37.30	6.63
22	Acer saccharum	70.20	3.34
22	Aesculus glabra	19.20	12.22
22	Fraxinus nigra	27.40	8.41
22	Fraxinus nigra	24.00	9.89
23	Acer negundo	12.40	7.66
23	Fraxinus pennsylvanica	19.00	10.10
23	Fraxinus pennsylvanica	10.00	3.38
23	Tilia americana	31.50	1.53
24	Acer negundo	10.10	6.41
24	Acer negundo	11.10	4.84
24	Aesculus glabra	10.50	5.44
24	Fraxinus nigra	45.30	4.92
25	Aesculus glabra	13.70	4.18
25	Aesculus glabra	15.80	8.39
25	Fraxinus pennsylvanica	32.20	3.12

25	Juglans nigra	32.00	5.21
26	Acer negundo	20.20	2.30
26	Platanus occidentalis	91.10	5.15
26	Quercus macrocarpa	25.30	5.06
26	Tilia americana	41.20	4.48
27	Acer negundo	17.60	2.32
27	Fraxinus americana	16.80	6.70
27	Fraxinus nigra	29.60	11.12
27	Quercus macrocarpa	56.00	2.41
28	Acer negundo	31.40	6.73
28	Acer negundo	18.80	4.83
28	Acer negundo	21.80	8.31
28	Ulmus americana	14.60	5.78
29	Acer negundo	13.60	2.02
29	Acer saccharum	38.60	7.07
29	Aesculus glabra	13.10	7.58
29	Ulmus rubra	19.80	2.82
30	Aesculus glabra	11.80	8.79
30	Aesculus glabra	14.00	4.44
30	Aesculus glabra	23.10	9.39
30	Fraxinus nigra	43.10	8.52
31	Acer negundo	37.00	9.53
31	Acer saccharum	28.90	1.67
31	Acer saccharum	29.90	6.77
31	Quercus macrocarpa	89.90	1.45
32	Aesculus glabra	24.50	4.54
32	Aesculus glabra	12.80	6.21
32	Juglans nigra	25.40	4.13
32	Ostrya virginiana	12.60	11.37

Point	Species	DBH (cm)	Distance (m)
1	Fraxinus pennsylvanica	32.70	6.48
1	Platanus occidentalis	35.50	1.71
1	Ulmus americana	10.40	2.84
1	Ulmus americana	13.60	1.94
2	Prunus serotina	20.80	4.40
2	Quercus alba	21.10	5.41
2	Quercus alba	10.30	1.23
2	Quercus rubra	52.30	1.92
3	Acer saccharum	13.20	7.80
3	Acer saccharum	11.90	6.29
3	Cornus florida	10.10	5.87
3	Prunus serotina	11.10	1.13
4	Morus rubra	11.80	2.33
4	Morus rubra	11.00	1.09
4	Morus rubra	10.20	0.98
4	Nyssa sylvatica	39.10	6.68
5	Acer saccharum	40.90	3.15
5	Acer saccharum	48.40	1.90
5	Cornus florida	11.60	6.63
5	Prunus serotina	13.70	8.89
6	Fagus grandifolia	14.50	7.10
6	Quercus rubra	59.00	4.73
6	Quercus rubra	76.00	2.71
6	Quercus rubra	59.40	4.10
7	Carya ovata	30.60	9.86
7	Prunus serotina	16.40	3.70
7	Quercus rubra	28.20	2.06
7	Quercus rubra	13.30	2.25
8	Carya ovata	11.50	1.64
8	Quercus rubra	27.90	6.05
8	Quercus rubra	21.40	4.12
8	Quercus velutina	36.00	2.07
9	Acer saccharum	20.70	9.38
9	Carya ovata	37.90	4.21
9	Nyssa sylvatica	16.10	9.56
9	Quercus alba	56.20	5.72
10	Maclura pomifera	20.10	5.13
10	Ostrya virginiana	19.20	3.67
10	Ulmus americana	20.70	2.12
10	Ulmus americana	24.10	3.21
11	Acer saccharum	21.50	3.09
11	Acer saccharum	23.30	2.57
11	Acer saccharum	22.30	3.20
11	Ulmus americana	14.10	8.06
12	Acer saccharum	25.30	3.39
12	Carya ovata	43.10	2.14
12	Quercus rubra	57.60	2.77
12	Quercus rubra	44.00	6.66
13	Acer saccharum	14.10	3.71

13	Acer saccharum	10.20	6.58
13	Carya ovata	30.50	3.21
13	Carya ovata	20.40	3.12
14	Acer saccharum	31.50	1.41
14	Acer saccharum	18.10	4.85
14	Acer saccharum	11.60	1.68
14	Acer saccharum	35.50	7.33
15	Acer saccharum	21.70	6.02
15	Acer saccharum	37.80	8.32
15	Acer saccharum	43.90	1.13
15	Quercus alba	29.00	2.96
16	Acer saccharum	10.00	3.89
16	Juniperus virginiana	28.60	3.76
16	Morus rubra	13.10	0.99
16	Ulmus americana	14.80	5.64
17	Fagus grandifolia	11.70	2.22
17	Liriodendron tulipifera	54.10	3.93
17	Quercus muhlenbergii	10.70	3.49
17	Quercus rubra	36.20	2.60
18	Fagus grandifolia	21.70	3.98
18	Quercus rubra	31.40	4.17
18	Quercus rubra	34.00	2.13
18	Quercus rubra	19.50	2.60
19	Acer saccharum	12.00	4.39
19	Acer saccharum	11.10	1.14
19	Quercus rubra	36.20	3.47
19	Quercus rubra	35.60	2.66
20	Cornus florida	11.40	6.58
20	Fagus grandifolia	14.10	2.93
20	Fraxinus pennsylvanica	46.30	3.69
20	Quercus alba	13.40	5.92
21	Acer saccharum	26.50	5.33
21	Carya cordiformis	20.80	4.93
21	Cornus florida	12.30	4.61
21	Cornus florida	11.70	4.02
22	Acer saccharum	15.50	3.54
22	Carpinus caroliniana	11.00	5.08
22	Carya cordiformis	20.20	4.65
22	Fagus grandifolia	37.80	6.34
23	Cornus florida	10.00	0.25
23	Cornus florida	11.70	4.88
23	Cornus florida	10.80	4.73
23	Cornus florida	11.40	1.80
24	Acer saccharum	19.30	5.63
24	Acer saccharum	17.20	3.25
24	Fagus grandifolia	24.80	3.24
24	Liriodendron tulipifera	21.60	6.63
25	Acer saccharum	39.00	4.93
25	Acer saccharum	31.90	5.26
25	Celtis occidentalis	14.00	4.73

25	Fagus grandifolia	19.90	4.65
26	Acer saccharum	16.70	2.07
26	Carya ovata	17.00	5.33
26	Fraxinus americana	39.30	3.34
26	Ulmus americana	18.10	4.19
27	Acer saccharum	13.50	1.63
27	Carya ovata	23.00	5.36
27	Fraxinus pennsylvanica	68.70	2.66
27	Quercus rubra	98.50	2.37
28	Acer saccharum	10.20	4.60
28	Morus rubra	26.00	6.69
28	Quercus rubra	54.90	3.30
28	Quercus rubra	63.10	1.53
29	Acer saccharum	27.50	3.87
29	Fraxinus quadrangulata	46.00	2.51
29	Quercus alba	60.80	6.25
29	Quercus rubra	47.60	5.19
30	Acer saccharum	10.20	8.47
30	Carpinus caroliniana	11.00	8.23
30	Quercus rubra	25.70	10.75
30	Quercus rubra	59.20	5.46
31	Acer saccharum	13.70	1.67
31	Cercis canadensis	13.10	5.29
31	Fraxinus quadrangulata	47.00	2.74
31	Morus rubra	20.80	1.78
32	Fraxinus pennsylvanica	13.30	3.42
32	Quercus rubra	10.40	0.82
32	Quercus rubra	11.20	5.95
32	Ulmus americana	17.10	3.31
33	Morus rubra	13.10	3.06
33	Pinus sylvestris	37.70	1.01
33	Pinus sylvestris	40.90	2.19
33	Prunus serotina	12.20	5.10
34	Fagus grandifolia	14.10	4.49
34	Fagus grandifolia	15.80	1.24
34	Fraxinus pennsylvanica	67.50	3.41
34	Ulmus americana	15.50	6.99
35	Gleditsia triacanthos	36.10	6.12
35	Morus rubra	10.50	4.00
35	Ulmus americana	16.60	5.84
35	Ulmus americana	10.00	1.17
36	Acer saccharum	21.30	2.29
36	Fraxinus americana	32.50	4.28
36	Fraxinus pennsylvanica	12.00	2.04
36	Ulmus americana	17.60	8.47
37	Juniperus virginiana	12.20	0.43
37	Quercus rubra	18.90	5.80
37	Ulmus rubra	15.60	6.98
37	Ulmus rubra	14.80	8.57
38	Liriodendron tulipifera	35.80	4.33

38	Quercus alba	13.40	3.43
38	Quercus rubra	14.80	2.80
38	Ulmus americana	15.00	3.13
39	Maclura pomifera	22.30	3.95
39	Maclura pomifera	24.10	2.30
39	Quercus rubra	10.80	6.30
39	Ulmus americana	13.50	9.51
40	Acer saccharum	25.20	5.95
40	Fraxinus pennsylvanica	30.90	9.93
40	Juniperus virginiana	40.70	5.27
40	Quercus rubra	17.40	5.97
41	Carya cordiformis	21.10	1.50
41	Carya ovata	23.30	7.06
41	Ostrya virginiana	12.40	3.02
41	Quercus rubra	41.50	10.65
42	Cercis canadensis	12.20	1.17
42	Nyssa sylvatica	38.40	12.58
42	Quercus alba	14.70	7.65
42	Quercus rubra	12.70	12.32
43	Fraxinus quadrangulata	27.60	2.76
43	Fraxinus quadrangulata	17.60	4.17
43	Quercus rubra	47.50	1.38
43	Quercus rubra	14.40	5.60
44	Carya ovata	25.60	2.79
44	Carya ovata	14.10	1.61
44	Carya ovata	17.10	7.03
44	Ulmus americana	12.30	2.87
45	Carya cordiformis	14.70	5.37
45	Fraxinus americana	13.60	1.78
45	Quercus alba	28.20	1.67
45	Quercus velutina	35.20	3.90
46	Carya cordiformis	26.20	1.27
46	Carya ovata	20.00	3.98
46	Quercus muhlenbergii	33.70	1.79
46	Quercus rubra	44.30	4.92
47	Carya cordiformis	14.50	3.54
47	Carya cordiformis	26.50	3.53
47	Carya cordiformis	31.50	5.19
47	Fraxinus quadrangulata	19.00	2.36
48	Carya ovata	21.00	4.40
48	Carya ovata	20.80	4.31
48	Fraxinus quadrangulata	24.00	1.54
48	Fraxinus quadrangulata	35.40	2.27
49	Fraxinus quadrangulata	12.00	6.06
49	Fraxinus quadrangulata	19.20	5.52
49	Juniperus virginiana	27.40	3.33
49	Sassafras albidum	27.20	1.09
50	Juniperus virginiana	32.10	7.39
50	Juniperus virginiana	20.20	8.58
50	Juniperus virginiana	18.10	2.10

50	Liriodendron tulipifera	40.80	5.65
51	Cercis canadensis	14.60	7.36
51	Cercis canadensis	10.70	2.63
51	Liriodendron tulipifera	50.50	6.05
51	Ulmus americana	17.40	2.55
52	Acer saccharum	20.20	8.55
52	Carya ovata	23.20	3.35
52	Carya ovata	27.10	1.25
52	Carya ovata	17.30	1.24
53	Carya ovata	12.60	1.87
53	Morus rubra	28.00	1.88
53	Quercus rubra	14.80	3.13
53	Ulmus americana	11.20	4.63
54	Acer saccharum	10.20	1.80
54	Fraxinus americana	35.20	4.10
54	Fraxinus pennsylvanica	21.70	2.16
54	Quercus rubra	20.10	2.72
55	Acer saccharum	30.90	8.86
55	Acer saccharum	23.70	9.42
55	Carya glabra	36.00	8.69
55	Carya ovata	27.30	3.58
56	Acer saccharum	38.40	7.88
56	Acer saccharum	17.30	1.49
56	Fagus grandifolia	15.90	4.84
56	Quercus rubra	29.70	5.75
57	Acer saccharum	27.60	5.47
57	Acer saccharum	19.50	0.51
57	Acer saccharum	13.50	6.18
57	Quercus rubra	71.80	1.44
58	Acer saccharum	15.60	3.35
58	Carya ovata	38.00	1.64
58	Carya ovata	45.20	5.45
58	Carya ovata	23.70	2.54
59	Acer saccharum	14.00	2.13
59	Acer saccharum	23.30	4.12
59	Carya glabra	37.60	1.39
59	Carya ovata	38.30	6.36
60	Acer saccharum	30.20	1.46
60	Carya cordiformis	63.30	3.98
60	Fagus grandifolia	16.40	1.76
60	Tilia americana	49.80	5.83
61	Fagus grandifolia	20.50	3.70
61	Fagus grandifolia	21.60	3.02
61	Quercus rubra	51.50	2.52
61	Quercus rubra	74.50	3.08
62	Acer saccharum	41.50	7.11
62	Acer saccharum	20.80	9.43
62	Quercus muhlenbergii	51.00	2.95
62	Quercus rubra	64.80	4.27
63	Acer saccharum	10.10	2.71

63	Acer saccharum	32.10	5.78
63	Carya ovata	26.30	2.41
63	Quercus rubra	55.90	8.49
64	**Acer saccharum**	**17.50**	**5.83**
64	Carya ovata	30.30	4.59
64	**Carya ovata**	**19.90**	**6.99**
64	Quercus alba	66.40	1.39
65	**Carya cordiformis**	**42.90**	**6.13**
65	Fraxinus americana	66.50	4.67
65	**Ostrya virginiana**	**11.70**	**1.22**
65	Quercus rubra	40.60	4.79
66	**Acer saccharum**	**28.30**	**9.75**
66	Quercus rubra	30.50	4.10
66	**Quercus rubra**	**37.40**	**4.24**
66	Quercus rubra	34.20	9.75
67	**Carya ovata**	**54.60**	**3.66**
67	Carya ovata	14.00	6.98
67	**Prunus serotina**	**10.50**	**4.76**
67	Quercus rubra	36.10	1.50
68	**Acer saccharum**	**14.00**	**7.64**
68	Carya ovata	16.00	1.59
68	**Carya ovata**	**34.70**	**8.84**
68	Quercus rubra	41.20	1.39
69	**Acer saccharum**	**17.30**	**2.81**
69	Acer saccharum	24.90	4.36
69	**Quercus rubra**	**72.50**	**2.66**
69	Quercus rubra	62.80	2.52
70	**Carya cordiformis**	**27.50**	**2.52**
70	Quercus rubra	65.10	7.55
70	**Ulmus americana**	**10.90**	**4.03**
70	Ulmus rubra	13.40	2.72
71	**Carpinus caroliniana**	**10.20**	**2.53**
71	Carya glabra	13.00	4.01
71	**Fagus grandifolia**	**11.50**	**5.21**
71	Ostrya virginiana	12.90	2.69
72	**Acer saccharum**	**10.00**	**0.79**
72	Ostrya virginiana	10.20	2.28
72	**Populus grandidentata**	**37.70**	**3.77**
72	Quercus rubra	16.10	3.56
73	**Carya ovata**	**13.70**	**5.60**
73	Quercus rubra	48.70	5.27
73	**Quercus rubra**	**32.80**	**3.82**
73	Quercus rubra	12.70	2.45
74	**Liriodendron tulipifera**	**37.00**	**3.46**
74	Maclura pomifera	27.60	3.97
74	**Populus grandidentata**	**39.60**	**7.63**
74	Quercus rubra	39.30	7.91
75	**Liriodendron tulipifera**	**25.50**	**5.42**
75	Quercus rubra	15.70	6.26
75	**Quercus rubra**	**38.00**	**4.03**

75	Quercus rubra	39.30	6.50
76	Acer saccharum	14.00	1.07
76	Quercus alba	34.80	2.84
76	Quercus rubra	42.90	2.32
76	Quercus rubra	21.70	5.29
77	Fagus grandifolia	28.70	2.90
77	Quercus alba	43.60	4.09
77	Quercus alba	28.30	7.53
77	Quercus alba	66.70	3.02
78	Acer saccharum	14.00	5.68
78	Acer saccharum	14.80	3.75
78	Carya glabra	32.90	4.20
78	Carya ovata	45.80	3.61
79	Carya ovata	47.20	6.52
79	Carya ovata	24.90	8.01
79	Carya ovata	30.90	2.43
79	Carya ovata	31.00	7.52
80	Acer saccharum	10.20	2.73
80	Acer saccharum	15.40	8.38
80	Quercus alba	34.00	2.08
80	Quercus rubra	60.80	9.63
81	Acer saccharum	12.60	2.83
81	Carya glabra	23.90	4.33
81	Liriodendron tulipifera	98.40	5.96
81	Ulmus rubra	13.50	8.03
82	Acer saccharum	12.80	5.49
82	Carya ovata	16.40	4.89
82	Fagus grandifolia	24.80	2.37
82	Fagus grandifolia	13.50	7.40
83	Fagus grandifolia	13.20	3.08
83	Liriodendron tulipifera	63.10	2.96
83	Liriodendron tulipifera	13.50	2.95
83	Liriodendron tulipifera	44.40	4.44
84	Fraxinus americana	26.00	6.90
84	Liriodendron tulipifera	45.50	1.04
84	Liriodendron tulipifera	18.10	2.08
84	Liriodendron tulipifera	26.40	14.87
85	Fagus grandifolia	15.80	2.83
85	Fagus grandifolia	36.30	7.39
85	Fagus grandifolia	36.80	12.10
85	Liriodendron tulipifera	24.10	4.24
86	Cornus florida	11.70	4.35
86	Fagus grandifolia	12.60	3.69
86	Liriodendron tulipifera	65.20	3.21
86	Liriodendron tulipifera	20.40	1.67
87	Fagus grandifolia	12.50	4.59
87	Fagus grandifolia	11.40	4.45
87	Liriodendron tulipifera	70.40	8.23
87	Liriodendron tulipifera	40.80	4.14
88	Acer saccharum	11.10	9.13

88	Fagus grandifolia	20.60	5.79
88	Liriodendron tulipifera	28.80	5.38
88	Quercus rubra	35.20	3.25
89	Acer saccharum	10.00	1.18
89	Acer saccharum	13.30	7.74
89	Acer saccharum	60.10	7.21
89	Liriodendron tulipifera	57.00	7.57
90	Acer saccharum	25.10	4.78
90	Acer saccharum	27.60	4.39
90	Acer saccharum	17.40	7.25
90	Liriodendron tulipifera	49.50	5.81
91	Acer saccharum	22.50	4.22
91	Fagus grandifolia	18.50	3.79
91	Fagus grandifolia	28.40	8.91
91	Liriodendron tulipifera	28.80	3.73
92	Juniperus virginiana	66.70	2.74
92	Quercus rubra	15.00	7.15
92	Tilia americana	24.50	2.40
92	Tilia americana	10.70	7.50
93	Acer saccharum	19.90	9.34
93	Carya glabra	15.90	5.05
93	Carya ovata	40.60	2.81
93	Prunus serotina	14.80	1.39
94	Acer saccharum	17.30	10.79
94	Acer saccharum	20.50	3.12
94	Acer saccharum	12.40	6.91
94	Prunus serotina	21.30	3.76
95	Fagus grandifolia	17.00	2.39
95	Fraxinus americana	47.10	3.66
95	Ostrya virginiana	13.60	4.38
95	Quercus alba	57.70	8.24
96	Acer saccharum	20.80	1.21
96	Acer saccharum	38.00	1.10
96	Acer saccharum	34.50	6.51
96	Quercus rubra	80.00	3.56
97	Acer saccharum	18.30	4.71
97	Acer saccharum	16.50	8.81
97	Prunus serotina	12.20	4.33
97	Quercus muhlenbergii	56.10	2.79
98	Acer saccharum	18.40	2.39
98	Fagus grandifolia	33.00	6.61
98	Fagus grandifolia	33.70	9.65
98	Prunus serotina	13.60	7.31
99	Acer saccharum	24.70	2.51
99	Acer saccharum	40.80	1.98
99	Acer saccharum	48.60	9.37
99	Acer saccharum	41.00	7.60
100	Acer saccharum	43.10	6.61
100	Acer saccharum	45.50	5.15
100	Acer saccharum	30.60	5.21

100	Acer saccharum	28.70	6.50